CORE
Metadata, citation and similar papers at core.ac.uk
Provided by ePrints@Bangalore University

Proceedings of the International Academy of Ecology and Environmental Sciences, 2013, 3(4): 330-343

Article

Evaluation of nutrient index using organic carbon, available P and available K concentrations as a measure of soil fertility in Varahi River basin, India

P. Ravikumar, **R. K. Somashekar**
Department of Environmental Science, Bangalore University, Bangalore 560056, India
E-mail: prakruthiravi@gmail.com, nisargaravi@gmail.com

Received 8 June 2013; Accepted 15 July 2013; Published online 1 December 2013

(cc) BY

Abstract

Varahi River basin is in the midst of Udupi district in the western part of Karnataka state, covering parts of Kundapura and Udupi taluks in Udupi District, Karnataka, India. Spatial distributions for twenty physical and chemical properties were examined in the soil samples of selected agricultural fields in 28 different locations in Varahi River basin. The present study revealed that there is not much variation in soil fertility status of soils developed on various landforms in the area as the soils were having low to medium in organic carbon (0.06 to 1.20 %) and available nitrogen (6.27 to 25.09 Kg/ha) content; low to medium in available P (2.24 to 94.08 Kg/ha) and deficient to doubtful in available K (20.10 - 412.3 Kg/ha) contents. The soils of Varahi River basin were characterized as low-medium-low (LML) category based on the nutrient index calculated w.r.t. available organic carbon, available P and available K. Further, Sodium Absorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) indicated that the soils were excellent for irrigation.

Keywords Varahi River basin; nutrient index; salt index; soil reaction index; organic carbon.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

From the advent of agriculture, there has been an innate interest in soil and land quality (Carter et al., 2004) and understanding changes in soil fertility resulting from agricultural intensification before they severely limit crop yields. Historically, few farmers used chemicals, but maintained soil fertility by allowing long fallow periods. Today, farmers have increased the use of chemical fertilizers and herbicides, and fallow cycles have decreased or disappeared, with the continuous use of the land becoming more frequent (Zhang and Zhang, 2007). Frequently, loss of productivity has been related to the loss of soil organic matter (SOM) and stored nutrients that result from cultivation (Juo et al., 1996). Hence, an understanding of the distributions of soil properties at the field scale is important for refining agricultural management practices and assessing the effects of agriculture on environmental quality (Cambardella et al., 1994). Evaluating agricultural land management practices requires knowledge of soil spatial variability and understanding their relationships because of the fact that (a) spatial variability in soils occurs naturally from pedogenic factors, (b) natural variability of soil results from complex interactions between geology, topography, climate as well as soil use (Jenny, 1980; Quine and Zahng, 2002). In addition, variability can also occur as a result of land use and management strategies, making the soil to exhibit marked spatial variability at the macro– and micro– scale (Brejda et al., 2000; Vieira and Paz-Gonzalez, 2003).

Karlen et al. (1997) proposed a complete definition for soil quality as ‘‘the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain biological productivity, maintain or enhance water and air quality, and promote human heath’’. But, the general consensus is that the soil quality concept should not be limited to soil productivity, but should encompass environmental quality (Karlen et al., 2003). Large quantities of mineral nutrients are removed from soils due to growth and development of plant and harvesting of crops. Hence, maintaining or improving soil quality can provide economic benefits in the form of increased productivity, more efficient use of nutrients and pesticides, improvements in water and air quality, and lessening of greenhouse gas emissions (USDA-ERS, 1997). Thus, assessment of soil quality involves measuring physical, chemical, and biological soil properties and using these measured values to detect changes in soil as a result of land use change or management practices (Adolfo et al., 2007). Though the soil fertility, compactability and erodibility are the elements of soil quality, the problem of decline in soil fertility endangers the maximum the growth in productivity (Katyal, 2003). Even Warren and Agnew (1988) opined that of all the threats to sustainability, the threat due to soil fertility depletion is the most serious. Depending upon the cropping pattern, leaching, erosion, etc., soil looses a considerable amount of nutrients every year. If cropping is continued over a period of time without nutrients being restored to the soil, its fertility will be reduced and crop yields will decline. Poor soil fertility conceives sparse plant cover, which promote erosion vulnerability. This happens because 90% of plant available N and S, 50-60% K, 25-30% P and almost 70% of micronutrients reside in organic matter (Stevenson, 1982).

Soil fertility fluctuates throughout the growing season each year due to alteration in the quantity and availability of mineral nutrients by the addition of fertilizers, manure, compost, mulch, and lime or sulfur, in addition to leaching. Hence, soil testing will determine the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and further to maintain the optimum fertility in soil year after year.

2 Materials and Methodology

2.1 Study area

River Varahi is a major west flowing River in the west coast in Udupi district, which originates from the high peaks of the Western Ghats near Guddakoppa village in Hosanagar taluk, Shimoga district at an altitude of about 761 m above mean sea level (MSL) and flows for a length of 88 km. A dam (13^0 39’ 15” N latitude and 74^0 57’ 0” E longitude) has been constructed across the River Varahi at Hole Shankaranarayana village, which is approximately 6 km from Siddapura village, Kundapura taluk, Udupi district. The stream collects heavy rainfall in the hilly region around Agumbe and Hulikal. Tributaries like Hungedhole, Kabbenahole, Dasnakatte, Chakranadi etc., join Varahi before emptying into the Arabian Sea. Varahi River basin stretches geographically from 13^0 26’ 34.8” N to 13^0 39’ 32.4” N latitude and 74^0 40’ 33.6” to 74^0 56’ 34.8” E longitude, positioned in the midst of Udupi district in the western part of Karnataka state (Fig. 1). The River Varahi has been one of the major sources of water for Mani Dam near Mani village, with diversion weir and Forebay Dam for generation of electricity at the Varahi Hydroelectricity Power Station. The study area is having a catchment area of 293.0 Km^2 (29300 ha). The gross command area of 362.41 Km^2 covers parts of Kundapura (209.73

Km^2) and Udupi (152.68 Km^2) taluks of Udupi District, which is the area around the dam, where the benefits of the dam, such as irrigation water reach. The reservoir water has been directed to various villages in the study area by via Varahi Left Bank Canal (VLBC, 33 Km) and Varahi Right Bank Canal (VRBC, 44.70 Km). The net irrigable command area is around 157.02 Km^2 (15702 ha) covering part of Kundapura (83.24 Km^2) and Udupi (73.78 Km^2) taluks of Udupi District, area under flow irrigation accounts to 129.79 Km^2 (12979 ha) and 27.23 Km^2 (2723 ha) comes under lift irrigation. The Varahi Irrigation Project aimed at providing enhanced irrigation facilities and an improved drinking water facility to the villages of two taluks of Udupi district by means of canal system in addition to hydroelectric power generation. The climate of the study area is moderately hot and enjoys a pleasant temperature range from the highest mean maximum of 35^{0}C to lowest mean maximum of 23^{0}C with a mean temperature of 27^{0}C. South Canara is a thickly populated area in general and Udupi district in particular which receives plenty of rainfall during South West Monsoon. The mean annual rainfall is 539.97 cm (5399.68 mm) with a maximum of 632 cm (6320 mm) and a minimum of 318 cm (3180 mm), while the mean relative humidity is 76%. Varahi River basin comprises of varying slopes such as gentle, moderate, moderately steep, nearly level, strong slope, very gentle and very steep, with slope value varying from 0-35 %. Topology of the region is generally flat with nearly level slope (0-1%) and the area lies between 25 to 40 m above mean sea level. Udupi district is characterized by various geological formations belonging mainly to Archean and Upper proteozoic to recent periods**.** The metamorphic and plutonic rock types covers major portion of the district followed by plutonic rocks, volcanics / meta volcanics with patches of residual capping and unconsolidated sediments. The geomorphology of region is generally plains and piedmont zone with patches of hills, plateaus here and there. The major soil types in the Varahi River basin are Clayey skeletal followed by patches of sandy loamy and loamy sandy.

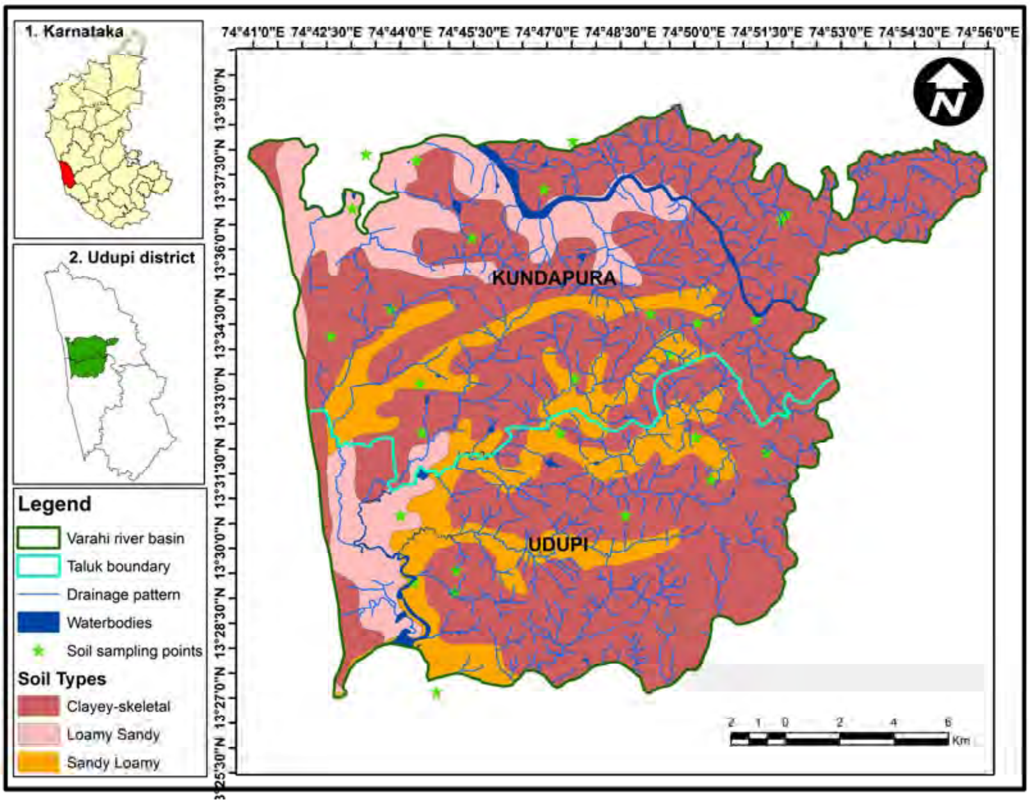

Fig. 1 Location map of Varahi River basin showing sampling points and major soil types.

2.2 Soil sample collection and analysis

In total 28 representative surface soil samples from agricultural lands spread over different villages in the Varahi River basin were collected at a depth of 15-30 cm using a hand auger / soil auger during November 2008 (post-monsoon). The soil samples collected were air-dried in shade, gently crushed to powder in a ceramic mortar using wooden mallet and sieved through a 2mm sieve to remove stones, roots, and large organic residues, passed through a 20 mesh sieve to obtain very fine particles which is then stored in clean polyethylene containers before conducting analyses for chemical and physical characteristics, with the samples being numbered from RVS1 to RVS28. The following physical and chemical analyses in the processed soils were conducted in accordance with the Standard techniques of soil survey (Jackson and Black, 1965, 1968, 1982) were followed to obtain qualitative and quantitative data of the soils.

1) pH and electrical conductivity (EC, dS/m) were determined in the supernatant solution of 1:5 soil/water ratio (w/v) using a pH meter and conductivity bridge / meter (Jackson, 1973) respectively

2) Exchangeable base cations (viz., Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) in soil were extracted by leaching the soil with 1N ammonium acetate at pH 7.0 (w/v), kept for overnight and then filtered using Whatman filter paper No. 42 and final volume was made up to 100 ml using distilled water. The ammonium acetate leachate (viz., filtrate) is used to estimate calcium (Ca^{2+}) and magnesium (Mg^{2+}) by EDTA titrimetric method (Jackson, 1973). The potassium (K^{+}) and sodium (Na^{+}) in the filtrate was determined using flame photometer (Chapman, 1965).

3) Organic carbon and Soil Organic matter (SOM) were determined following the wet digestion method of Walkley and Black (1934a).

4) Total nitrogen was determined by Kjeldahl digestion, distillation and titration procedures as described by Jackson (1958) and Bremner et al. (1982).

5) Available Phosphorus in the soil samples was determined by leaching the soil with 0.002N H_2SO_4 (1 soil : 200 H_2SO_4 suspension, w/v) and shaken for at least 30 minutes and filtered through Whatman filter paper No. 42 to get a clear solution. the amount of phosphorus in the extract was estimated by chlorostannous reduced phosphomolybdate blue colour method using spectrophotometer at wavelength of 690 nm (Jackson, 1973),

6) Moisture content in soil is measured by placing 10 g of raw soil in a dry beaker in a hot air oven for 1 hour at 105^{0}C. The weight of beaker with dried soil and weight of beaker with raw soil was recorded. Moisture content of the soil is measured using the formula

$$\mathbf{\%\ of\ Moisture} = \frac{\mathbf{(W2 - W3)}}{\mathbf{(W2 - W1)}}\ \mathbf{X\ 100}$$

where W1 = Weight of beaker, W2 = Weight of beaker + wet sample, and W3 = Weight of beaker + dry sample.

7) Water holding capacity of soil is the amount of maximum water, which can be held in the saturated soil. It is measured as the amount of water taken up by unit weight of dry soil when immersed in water under standardized conditions. Take a filter paper in a funnel and weigh it. Pour 10ml of water with a pipette wetting the entire filter paper and collect excess of water until the last drop falls. Add 5g of soil in the funnel and find the weight of the soil with wet filter paper. Pipette out 25ml of water and add gradually until the last drop of water drips out of the funnel. Note the final weight.

$$\mathbf{\%WHC} = \frac{\mathbf{(W4 - W3) - (W2 - W1)}}{\mathbf{(W3 - W2)}}\ \mathbf{X\ 100}$$

where W1 = Weight of funnel + dry filter paper, W2 = Weight of funnel + wet filter paper, W3 = Weight of funnel + wet filter paper + 5g dry soil, and W4 = Weight of funnel + wet filter paper + wet soil.

8) Exchangeable Sodium Percentage (ESP) and Sodium Absorption Ratio (SAR) - Exchangeable sodium percentage (ESP) and Sodium Absorption Ratio (SAR) is estimated by calculation, by considering the values of exchangeable Na, exchangeable Ca, exchangeable K and exchangeable Mg.

$$\mathbf{ESP} = \mathbf{Exchangeable}\ \frac{\mathbf{Na}}{\mathbf{Ca} + \mathbf{Mg} + \mathbf{K} + \mathbf{Na}}\ \mathbf{X\ 100}$$

$$\mathbf{SAR} = \mathbf{Exchangeable}\ \frac{\mathbf{Na}}{\sqrt{\frac{\left(\mathbf{Ca}/\mathbf{Mg}\right)}{\mathbf{2}}}}$$

where the ionic concentrations of Ca, Mg, K and Na are expressed in meq/100g.

2.3 Nutrient index

To evaluate the soil fertility status in Varahi River basin, different indices like soil reaction index, salt index and nutrient index with respect to organic carbon, available phosphorus and available K were calculated based on the specific rating chart (Table 1). Table 1 and 2 represent the rating chart followed to rate the soil analysis results and criteria to calculate nutrient index respectively.

Table 1 Rating chart for soil test values and their nutrient indices.

1. Soil pH			
	Acidity	Neutral	Alkaline
Range	Below 6.0	6.0-8.0	Above 8.0
Soil Reaction Index	I	II	III
2. Electrical Conductivity			
	Normal	Critical	Injurious
Range(µS/cm)	Below 1000	1000-2000	Above 2000
Salt Index	I	II	III
3. Organic Carbon (OC)			
	Low	Medium	High
Range (%)	Below 0.5	0.5-0.75	Above 0.75
Nutrient index	I	II	III
4. Available Phosphorus (P)			
	Low	Medium	High
Range (kg/ha)	Below 22	22 -54	Above 54
Nutrient index	I	II	III
5. Available Potash (K)			
	Low	Medium	High
Range (kg/ha)	Below 123	123-293	Above 296
Nutrient index	I	II	III

The nutrient index in soil was evaluated for the soil samples analyzed using the following formula:

$$\mathbf{Nutrient\ Index} = \frac{\begin{array}{c}(\mathbf{1\ X\ no.\ of\ samples\ in\ low\ category}) + \\ (\mathbf{2\ X\ no.\ of\ samples\ in\ medium\ category}) + \\ (\mathbf{3\ X\ no.\ of\ samples\ in\ high\ category})\end{array}}{\mathbf{Total\ number\ of\ samples}}$$

Table 2 Nutrient index with range and remarks.

Nutrient index	Range	Remarks (OC, P, K)
I	Below 1.67	Low
II	1.67 – 2.33	Medium
III	Above 2.33	High

3 Results and Discussion

The analytical results of physical and chemical parameters analyzed in the soil samples from the study area are presented in Table 3.

Table 3 Descriptive statistics of analytical results of soil samples.

Parameter	Descriptive Statistics (n=28)		
	Mean ± SD	Minimum	Maximum
pH	7.44 ± 0.24	7.04	7.99
EC dS/cm	0.07 ± 0.04(73.63 ± 43.29 µS/cm)	0.03(30.7 µS/cm)	0.23(234 µS/cm)
Na meq/100g	0.15 ± 0.24	0.04	1.33
K meq/100g	0.12 ± 0.08	0.02	0.47
% K_2O	0.01 ± 0.00	0.00	0.02
P mg/100 g	0.03 ± 0.02	0.00	0.08
% P_2O_5	0.00 ± 0.00	0.00	0.01
Ca meq/100g	2.08 ± 1.14	0.80	4.60
Mg meq/100g	0.85 ± 0.49	0.20	1.80
% OC	0.42 ± 0.25	0.06	1.20
% OM	0.72 ± 0.44	0.10	2.07
% moisture	1.18 ± 0.51	0.31	2.51
WHC	32.22 ± 11.76	5.90	54.43
Avail. P (Kg/ha)	36.11 ± 26.84	2.24	94.08
Avail. N2 (Kg/ha)	16.35 ± 5.22	6.27	25.09
Avail. K (Kg/ha)	108.32 ± 73.52	20.10	412.30
SAR	0.09 ± 0.11	0.03	0.57
ESP	4.35± 3.89	1.07	19.27

EC – Electrical Conductivity, OC- Organic Carbon; OM- Organic Matter; WHC – Water holding capacity; ESP- Exchangeable Sodium Percentage; SAR – Sodium Absorption Ratio

3.1 Soil pH

The measure of soil pH is an important parameter which helps in identification of chemical nature of the soil (Shalini et al., 2003) as it measures hydrogen ion concentration in the soil to indicate its acidic and alkaline nature of the soil. In Varahi River basin, the pH of the soil samples ranged from 7.04 to 7.99, indicating the existence of a variety of soils that are neutral to slightly alkaline nature (Table 4). Sample no. RVS4 and RVS5 had the highest pH value of 7.99 and sample RVS27 has the lowest being 7.04 (Table 4).

Table 4 Measured pH of soil samples.

Sl. No	pH values	Range (No. of samples; %)
1	6.5 to 7.00	-----
2	7.00 to 7.5	7.04-7.5 (19; 67.86%)
3	7.5 to 8.0	7.51-7.99 (9; 32.14%)
4	8.0 to 8.5	----

3.2 Electrical conductivity

Conductivity, as the measure of current carrying capacity, gives a clear idea of the soluble salts present in the soil. It plays a major role in the salinity of soils. Lesser the EC value, low will be the salinity value of soil and vice versa. Even though, soil conductivity is influenced by many factors, high conductivities are usually associated with clay-rich soil and low conductivities are associated with sandy and gravelly soils. This is a result of the shape and physical properties of the particles which make up the soil. In the Varahi River basin, the EC values varied from 30.7 to 234 µS/cm, with an highest EC value of 234µS/cm in sample no. RVS3 and the lowest value of 30.7µS/cm in sample no.RVS8.

3.3 Water holding capacity

Water holding capacity is the amount of water that can be retained / held by the soil when all the pores in the soil have been filled with water. Under this condition, soil is saturated with water, accompanied by very poor or no drainage. In the Varahi River basin, the WHC of the soil samples ranged from 5.9 to 54.43 against the standard value for WHC of 5%. WHC was more in the surface soil layer which had greater accumulation of organic matter, litter, root mass, etc., thereby indicating relatively stronger influence of soil organic matter on water holding capacity as observed by Woomer and Swift (1994). Most locations in the study area had clayey type soil, which could hold more amount of water.

3.4 Soil moisture / Moisture content / Soil water

It is the water contained in the soil and is a great regulator of physical, chemical and biological activities in the soil. It dissolves salts and make up the soil solution, which is important as a medium for supplying different essential nutrients between the soil solids and the soil solution and, then between soil solution and the plants. The percentage of soil moisture in the soil samples from Varahi River basin varied from 0.31 to 2.51.

3.5 Exchangeable calcium

There was a wide variation in the distribution of exchangeable calcium in the Varahi River basin, as it ranged from 0.8 to 4.6 (expressed as Ca, meq/100g). The minimum value of 0.8 meq/100g was noticed in samples RVS18, RVS20, RVS21 and RVS22 and the maximum value is 4.6 meq/100g in samples RVS5 and RVS27**.**

3.6 Exchangeable magnesium

In the Varahi River basin, the exchangeable magnesium concentration varied from 0.2 to 1.8 (expressed as Mg, meq/100g) with a minimum value of 0.2 meq/100g in samples RVS8, RVS9 and RVS10 and a maximum value of 1.8 meq/100g in samples RVS21 and RVS28.

3.7 Exchangeable sodium

In the Varahi River basin, the exchangeable sodium concentration varied from 0.043 to 1.33 (expressed as Na, meq/100g) with a minimum and maximum value of 0.043 meq/100g (samples RVS19 and RVS22) and 1.33 meq/100g (sample RVS5) respectively.

3.8 Exchangeable potassium

Potassium (K) is the third most required element by the plants, which plays a key role in water balance in plants or regulation of osmosis (Singh and Tripathi, 1993). It is the most abundant metal cation in plant cell (2 to 3 % by dry weight). In the Varahi River basin, the exchangeable potassium values were in a narrow range, varying between 0.023 to 0.472 (expressed as K, meq/100g), with a minimum value of 0.023 meq/100g in the sample RVS24 and a maximum value of 0.472 meq/100g in the sample RVS17. Under ordinary field condition, with an adequate nutrient supply, K^+ removal by crops is high, often being three to four times that of phosphorus and equal to that of nitrogen. This tendency is termed as 'luxury consumption' because the excess K^+ adsorbed apparently does not increase crop yield to any extent. A certain amount of this element is needed for optimum yields and this is termed as 'required potassium'. All K^+ above this critical level is considered as luxury; the removal of which is ultimately wasteful. The various forms of potassium in the soil can be classified on the basis of their availability (a) Relatively unavailable form (90-98%), (b) Relatively available form (1-2% of the total amount of these elements in an average mineral soil) and (c) Slowly available form (It is fixed form of K^+, which cannot be replaced by ordinary exchange method and is referred to as non-exchangeable K^+).

3.9 Available potash (K)

The available Potash (K) values varied from 20.1 to 412.3 kg/ha in the Varahi River basin **(**Fig. 2A**)**. Majority of the soil samples in the Varahi River basin had deficient (60.72 %) and doubtful (35.71 %) supply of potassium (Table 5**)**. Soil samples with deficient and doubtful supply of potassium can be enriched with garden compost containing 0.48% K_2O or vermicompost containing about 0.7% K_2O.

Table 5 Measured concentration of available potash in soil (Muhr et al., 1965).

Sl. No	**Supply of Available Potash (K)**	**Quantity (Kg/ha)**	**Range (No. of samples; %)**
1	Deficient supply of (K)	< 113	20.1-103.1 (17; 60.72)
2	Doubtful supply of (K)	113 to 280	114.4-207.9 (10; 35.71)
3	Adequate supply of (K)	> 280	412.3 (1; 3.57)

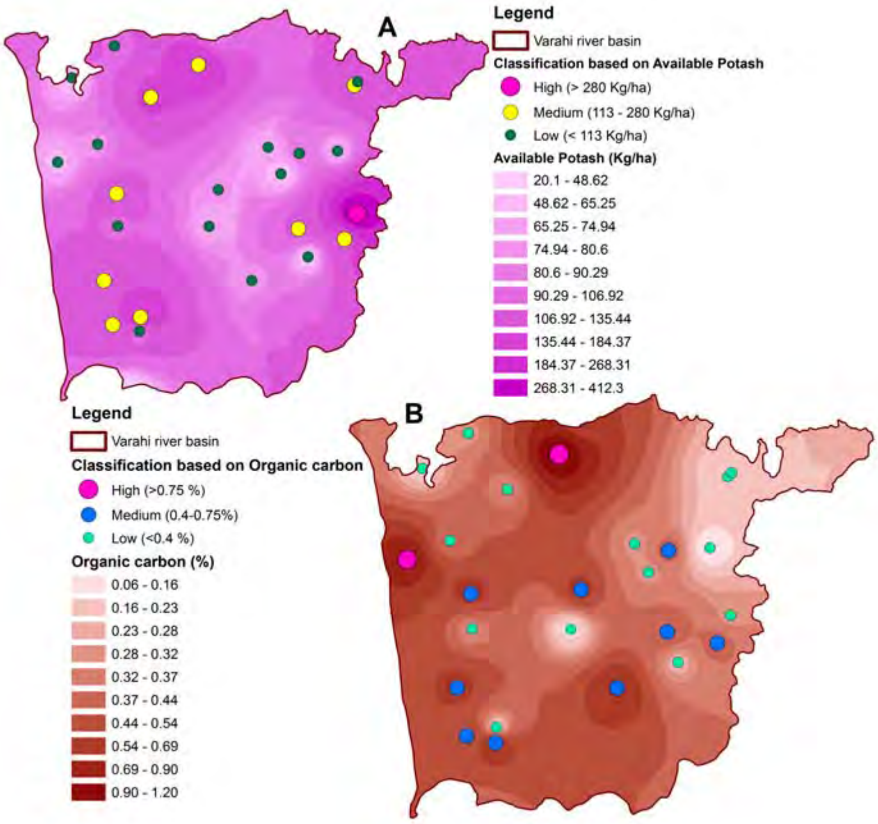

Fig. 2 Spatial distribution of (A) available potash and (B) organic carbon in the study area.

3.10 Percent Organic carbon (OC) and Percent Organic Matter (OM)

The importance of organic matter in the soil is implied in the definition of soil, which recognizes fertility status of the soil, as a unique feature distinguishing soil from the parent rock / other non-fertile soils. It increases the soil fertility / nutrient status and controls erosion and runoff of the soil and water, besides it is a major determinant of improved soil structure, moisture content and general nutrient status of the soil. The percentage of organic carbon ranged from 0.06 to 1.2 in the study area (Fig. 2B), indicating variable organic matter content and decomposition rates and the organic matter content varied from 0.1 to 2.07 %. Depending upon the organic carbon content (%), the quality of soil may be graded as low, medium and high. In the Varahi River basin, around 60.72 % of the samples showed low percent organic carbon (i.e., < 0.40). Majority of the soil samples (i.e., 92.86 %) appear to possess low to medium percent organic carbon content (Table 6) and it is necessary to apply organic wastes as an important source of nutrient to these agricultural fields.

Table 6 Classification of soil quality based on organic carbon content

Sl. No	Percent of organic carbon	Rating	Range (No. of samples; %)
1	< 0.40	Low	0.06-0.40 (17; 60.72)
2	0.4 to 0.75	Medium	0.42-0.73 (9; 32.14
3	> 0.75	High	0.9-1.2 (2; 7.14)

3.11 Available nitrogen

Plants take up nitrogen generally as nitrates under aerobic conditions and as ammonium ions during anaerobic conditions. Nitrogen is most often the limiting nutrient for the plant growth. The nitrogen content is very low (< 272 Kg/ha) in all the soil samples in the study area (Table 7). Excess soil moisture content is one of the important factors affecting nitrification in water logged soils and is having a major contribution to vary the process. Since excess water is found in water logged areas, soil suppresses the process of nitrification because of deficient oxygen. Unlike in dry soils as in case of our study area soils however, do have enough moisture for the bacterial metabolism and the moistening of such soils rapidly increases the rate of biosynthesis of nitrogen. All the soil samples were having low available nitrogen content, ranging from 6.27 to 25.09 kg/ha (Fig. 3A) and it is essential to apply organic wastes as an important source of nutrient to the agricultural fields.

Table 7 Concentration of Available Nitrogen in the soil (Muhr et al., 1965).

Sl. No.	Quantity of nitrogen (Kg/ha)	Rating	Range (No. of samples; %)
1	Less than 272	Low	6.27-25.09 (28;100)
2	Between 272 to 554	Medium	----
3	More than 554	High	----

3.12 Available phosphorus

Phosphorus is the second most important macronutrient available in the biological systems, which constitutes more than 1% of the dry organic weight. It is also a second most limiting factor often affecting plant growth, which exists in the soil in both organic and inorganic forms. In the Varahi River basin, the available phosphorus content ranged between 2.24 and 94.08 kg/ha (Fig. 3B) and 39.29 % of the soil samples showed low to medium quantity of available phosphorus, while remaining (60.71 %) had adequate to abundant quantity of available phosphorus (Table 8). Soils from Agricultural fields with low to medium phosphorus content in the study area can be supplemented by applying phosphorous rich fertilizers as required by a specific crop.

Table 8 Measured concentration of available phosphorus (Muhr et al., 1965)

Sl. No	Grade	Concentration (Kg/ha)	Range (No. of samples; %)
1	Low phosphorus	Less than 12.4	2.24-12.32 (6; 21.43)
2	Medium phosphorus	12.4 to 22.4	12.77-21.28 (5; 17.86)
3	Adequate phosphorus	More than 22.4	24.64-32.37 (4;14.29)
4	Abundant phosphorus	Still higher	34.83-94.08 (13;46.42)

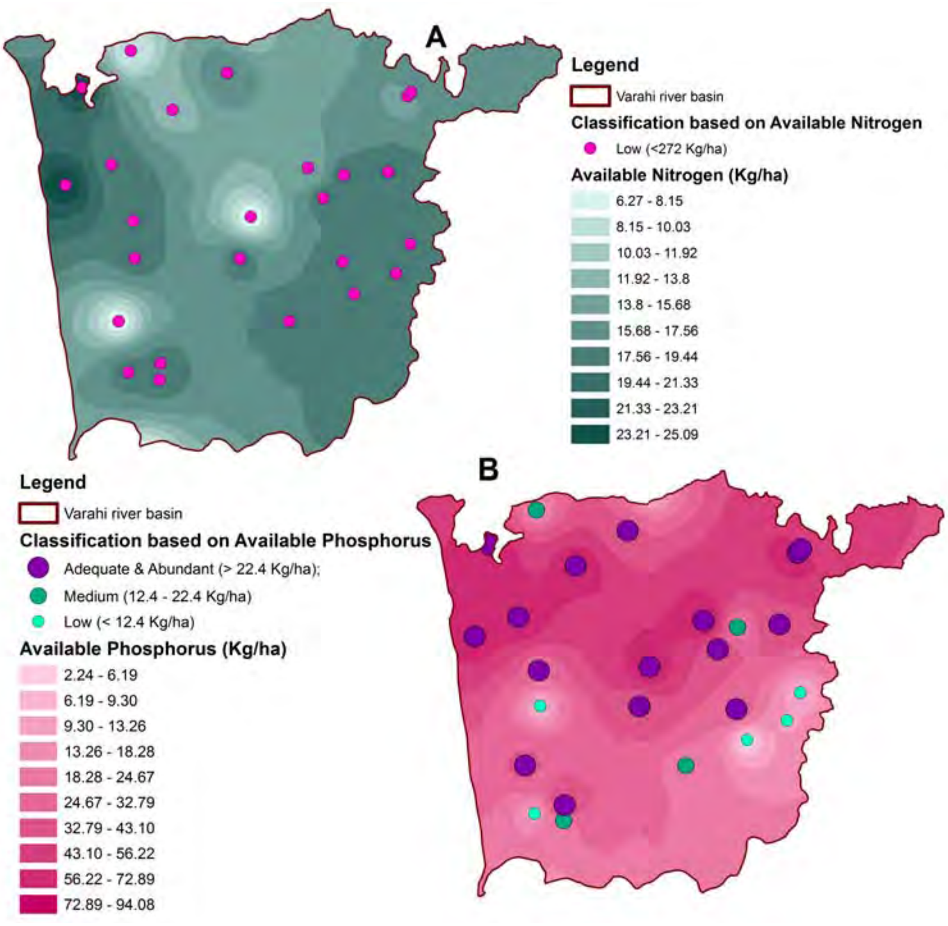

Fig. 3 Spatial distribution of (A) available nitrogen and (B) available phosphorus in the study area.

3.13 Irrigational quality parameters

3.13.1 Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage (ESP) identifies the degree to which the adsorption / exchange complex of soil is saturated with sodium. The ESP levels of 15 yield pH values of 8.5 and above. Higher levels may bring the pH to at least 10. It is important to note that sodium has been found partially to take the place of potassium in the nutrition of certain plants. Exchangeable Sodium percentage values for all the soil samples in the Varahi River basin varied between 1.07 to 19.27 (Table 9) and thus fall under excellent category, which is a good indication of a fertile soil status.

Table 9 Classification of soil samples based on ESP values.

Sl. No.	ESP	Category	Range (No. of samples; %)
1	< 20	Excellent	1.07-19.27 (28; 100)
2	20 to 40	Good	-----
3	40 to 60	Permissible	-----
4	60 to 80	doubtful	-----

3.13.2 Sodium Absorption Ratio (SAR)

Sodium Absorption Ratio is considered as a better measure of sodium hazard in irrigation as SAR of water is directly related to the absorption of sodium by soil and is a valuable criterion for determining the suitability of water for irrigation. When the concentration of sodium ion is high in irrigation water, Na^+ tends to be absorbed by clay particles, displacing magnesium and calcium ions. This exchange process of sodium in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage. In agricultural practice, sodium concentration is expressed in terms of percent sodium, which can be defined as the percentage of the sodium concentration of water to the total cationic concentration. SAR values in all the soil samples analyzed from Varahi River basin ranged from 0.026 to 0.572, belonging to excellent category for the purpose of irrigation (Table 10).

Table 10 SAR based classification of soil samples (TODD, 1959).

Sl. No.	SAR	Category	Range (No. of samples; %)
1	Less than 10	Excellent	0.026-0.572 (28; 100)
2	10 to 18	Good	-----
3	18 to 26	Fair	-----
4	More than 26	Poor	-----

3.13.3 Salinity

A salt affected soil is defined as soil that has been adversely affected the growth of most crops by the presence anion or cation of soluble salts. This type of soil is commonly seen in arid and semi-arid regions; in irrigation River basin; in regions with poor drainage and in areas where poor quality water is used for irrigation, because there is insufficient rainfall to flush them from the upper soil layers. They include both sodic and saline soils. Salinity is usually measured in terms of electrical conductivity and expressed in dS/m at 25˚C. Depending upon the electrical conductivity of the soil, soil salinity can be classified into five classes. From the results (Table 11), it is clear that the salinity problem is not critical in the Varahi River basin as the saline criterion is < 0.7, indicating the good quality of soil (Fig. 4). Because, the soluble salts concentration above 4 dS/m in soil moisture inhibits the seed germination and growth of most commercial crops, which adversely affects the biomass production and economic yield.

Table 11 Saline conditions and categories of crop tolerance in Varahi River basin.

EC (dS/m)	Category	Range (No. of samples; %)
< 0.7	All crops	0.031-0.234 (28;100)
0.7 – 2.0	Most crops	----
2.0 – 10.0	Salt tolerant crops	----
10.0 – 32.0	Most halophytes	----
33.0 >	No crops (sea water)	----

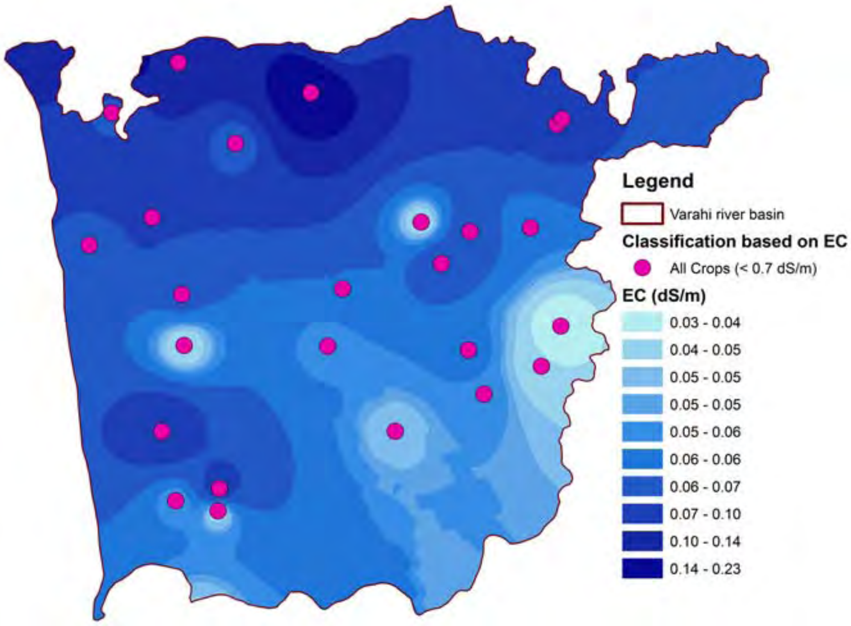

Fig. 4 Spatial distribution of electrical conductivity in the soil samples from the study.

3.14 Fertility status of soils

In the Varahi River basin, the overall quality of soil in the study area appears to be very fertile except for certain parameters. It is observed that soil pH range between 7.04 and 7.99 and all the samplers belong to soil reaction index II, which indicate the neutral range. The electrical conductivity of the soil samples in the range of 30.7 and 234 µS/cm in Varahi River basin and all the soil samples belong to normal (i.e., salt index-I) category. The percent organic carbon content of soil samples was in the range of 0.06 to 1.2 and majority of the samples belongs to low level as per the nutrient index, while the available phosphorus values (2.24 - 94.08 kg/ha) are in low to high range and the available nitrogen values (6.27-25.09 kg/ha) belong to low range. It is possible to classify nutrient status of the particular area and classify each nutrient level (i.e., low, medium or high) based on a rating chart using the results and nutrient indices. Based on the criteria given in Table 2, the soils of Varahi River basin were categorized into low-medium-low (LML) category based on OC, available P and available K concentrations (Table 12). Compared to the results obtained for soil fertility categories by Verma et al., (2005), there is no wide variation in soil fertility status in the Varahi River basin.

Table 12 Nutrient Index values for the soil samples of Varahi River basin.

Characteristics	Nutrient index values	Remarks
Organic carbon (OC)	1.393	low
Available phosphorus (P)	1.857	Medium
Available potash (K)	1.321	Low

4 Conclusion

Based on the criteria for calculating nutrient index, the soils of Varahi River basin are characterized as low-medium-low (LML) category. Majority of the soil samples were having low to medium percent organic carbon and available nitrogen and it is useful to apply organic wastes as an important source of nutrient to the agricultural fields. Soils from Agricultural fields with low to medium phosphorus content could be supplemented by applying phosphorous rich fertilizers as required by a specific crop. Soil samples with deficient and doubtful supply of potassium can be enriched with garden compost that contains 0.48% K_2O or vermicompost containing around 0.7% K_2O. Further, irrigational quality parameters such as sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP) also indicated that the soils were excellent for irrigation.

References

Adolfo CC, Klaudia OL, Jorge EB, et al. 2007. Exploring the effect of changes in land use on soil quality on the eastern slope of the Cofre de Perote Volcano (Mexico). Forest Ecology and Management, 248: 174-182

Barber SA. 1960. Trans. Seventh International Congress on Soil Science, 3: 435

Black CA. 1965a. Methods of Soil Analysis Part II- Chemical and Micro-Biological Properties. No. 9 Series Agronomy. American Society of Agronomy Inc Publishers, Medison, Wisconsin, USA

Black, CA. 1965b. Method of Soil Analysis Vol. II. 573-590, American Society of Agronomy, Madison, USA

Black CA. 1968. Soil-plant Relationships. John Wiley and Sons, New York, USA

Black CA. 1982. Method of Soil Analysis Part I and II. American Society of Agronomy, Madison, Wisconsin, USA

Brejda JJ, Moorman TB, Karlen DL, et al. 2000. Identification of regional soil quality factors and indicators: I. Central and southern high plains. Soil Science Society of America Journal, 64: 2115-2124

Bremner JM. 1982. Nitrogen-Urea. In: Methods of Soil Analysis Part 2 (2nd ed). 699-709

Cambardella CA, Moorman TB, Novak JM, et al. 1994. Field-scale variability of soil properties in central Iowa soils. Soil Science Society of America Journal, 58; 1501-1511

Carter MR, Andrews SS, Drinkwater LE 2004. Systems approaches for improving soil quality. In: Managing Soil Quality: Challenges in Modern Agriculture (Schjonning P, Elmholt S, Christensen BT, eds). 261-281, CABI International, Wallingford, UK

Chapman HD. 1965. Cation exchange capacity. In: Methods of Soil Analysis (Black CA, et al. ed). Agronomy 9: 891-901, American Society of Agronomy Inc Publishers, Medison, Wisconsin, USA

Jackson ML. 1958. Soil Chemical Analysis. 183-204, Prentice Hall Inc., USA

Jackson ML. 1965. Soil Chemical Analysis - Advanced Course. Department of Soils, University of Wisconsion, Wisconsin, USA

Jackson ML. 1968. Weathering of primary and secondary minerals in soils. In: Transaction of International Congress of Soil Science 9th Congress. 281-292, Adelaide, Australia

Jackson ML. 1973. Soil Chemical Analysis (II Edition). Prentice Hall of India Private Limited, New Delhi, India

Jackson ML. 1982. Análisis químico de suelos. 282-309, Ediciones Omega, Barcelona, Spain

Jenny H. 1980. The Soil Resource: Origin and Behavior. Ecological Studies Vol.37. Springer-Verlag, New York, USA

Juo ASR, Manu A. 1996. Chemical dynamics in slash-and-burn agriculture. Agriculture, Ecosystems and Environment, 58: 49–60

Karlen DL, Mausbach MJ, Doran JW, et al. 1997. Soil quality: A concept, definition, and framework for evaluation. Soil Science Society of America Journal, 61: 4-10

Karlen DL, Ditzler CA, Andrews AS. 2003. Soil quality: Why and how? Geoderma, 114: 145-156

Katyal JC. 2003. Soil fertility management– A key to prevent desertification. Journal of the Indian Society of Soil Science, 51: 378-387

Muhr GR, Dutta NP, Sankara Subramanoey. 1965. Soil Testing in India. USAID, New Delhi, India

Quine TA, Zhang Y. 2002. An investigation of spatial variation in soil erosion, soil properties and crop production within an agricultural field in Devon. U.K. Journal of Soil and Water Conservation, 57: 50-60

Shalini Kulshrestha, Devenda HS, Dhindsa SS, et al. 2003. Studies on causes and possible remedies of water and soil pollution in Sanganer town of Pink City. Indian Journal of of Environmental Sciences, 7(1): 47-52

Singh K, Tripathi D. 1993. Different forms of Potassium and their distribution in some representative soil groups of Himachal Pradesh. Journal of Potassium Research, 9: 196-205

Stevenson FS. 1982. Organic matter and nutrient availability. In: Non–symbiotic Nitrogen Fixation and Organic Matter in the Tropics. Trans. 12th Int. Cong. Soil Sci. 137-151, New Delhi, India

USDA-ERS. 1997. Agricultural Resources and Environmental Indicators 1996–1997. Agricultural Handbook, 712. U.S. Gov. Print. Office, Washington DC, USA

Verma VK, Patel LB, Toor GS, et al. 2005. Spatial distribution of macronutrients in soils of arid tract of Punjab, India. International Journal of Agriculture and Biology, 7(2): 295-297

Vieira SR, Paz Gonzalez A. 2003. Analysis of the spatial variability of crop yield and soil properties in small agricultural plots. Bragantia (Campinas), 62: 127-138

Walkely A, Black IA. 1934. An examination of Degtjareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-38

Warren A, Agnew C, 1988. An Assessment of Desertification and Land Degradation in Arid and Semi Arid Areas. Drylands Farming, Ecology and Conservation Unit, University College, London, UK

Woomer PL, Swift MJ. 1994. The Biological Management of Tropical Soil Fertility. Wiley, Chichester, UK

Zhang WJ, Zhang XY. 2007. A forecast analysis on fertilizers consumption worldwide. Environmentla Monitoring and Assessment, 133: 427-434