International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jfav.htm
2016 Vol. 6 (3) September-December, pp. 1-15/Amara Denis et al.

Research Article

ASSESSMENT OF SOIL FERTILITY STATUS USING NUTRIENT INDEX APPROACH

***Amara Denis M. K.[1], Patil, P. L.[2], Kamara, A. M.[3] and Saidu, D. H.[4]**

[1]*Department of Soil Science, School of Agriculture, Njala University, Njala Campus, Sierra Leone*
[2]*Department of Soil Science & Agricultural Chemistry, College of Agriculture, University of Agricultural Sciences, Dharwad, 580005, Karnataka, India*
[3]*Department of Extension & Rural Sociology, School of Agriculture, Njala University, Njala Campus, Sierra Leone*
[4]*Welthungerhilfe DiPAT Project Bo, 137 Bo-Kenema Highway, Bo, Sierra Leone*
** Author for Correspondence*

ABSTRACT

A detailed soil survey was undertaken in Bogur microwatershed in Karnataka state of India with the aim of evaluating the fertility status of soils using nutrient index approach. A total of 118 surface samples were collected on grid basis with an auger from a depth of 0-20 cm and analyzed for pH, electrical conductivity, organic carbon, available nitrogen, P_2O_5 and K_2O, available sulphur and available micronutrients (Zn, Mn, Fe & Cu) using standard analytical methods. Based of fertility ratings, pH of soils was acidic to alkaline. Electrical conductivity was normal (<1.0 dS/m). Soil organic carbon was low to high, with more than 70% of study area falling in the high category. Exchangeable Ca and Mg contents were low to high. Available macronutrient status (N, P, K, & S) were low to high. The availability of micronutrients was highly variable. Zinc (Zn) was low to medium, iron (Fe) was low, while manganese (Mn) and copper (Cu) were low to high. Based on the nutrient indices, the study that the pH is low to medium, electrical conductivity is high, nitrogen is low to medium, phosphorus is medium to high, potassium is high, available sulphur is low, exchangeable Ca is medium to high, exchangeable Mn is high, Zn is deficient, Mn is deficient to high, Fe is deficient and Cu is sufficient to excess. Soil reaction, available N, K, S, Zn and Fe were observed as the most important soil fertility constraints that could affect sustainable crop production in the study area. The situation therefore demands the adoption of appropriate management practices in order to boost the fertility status. These practices may include such practices as site specific nutrient management, increased use of organic nutrient sources, sustainable land use and cropping systems and appropriate agronomic practices.

Keywords: *Nutrient Index, Fertility Status, Macronutrients, Micronutrients, Sierra Leone, Denis*

INTRODUCTION

Soil fertility is a dynamic natural property which can change under the influence of natural and human induced factors. In agriculture, depletion can be due to excessively intense cultivation and inadequate soil management. Top soil depletion occurs when the nutrient-rich organic topsoil, which takes hundreds to thousands of years to build up under natural conditions, is eroded or depleted of its organic material (Bjonnes, 1997).

As human population continues to increase, human disturbance on the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe *et al.*, 2012).

In India, low fertility of soils is the major constraint to achieving high productivity goals (SLUSI, 2010). In many parts of the country, soil fertility fluctuates throughout the growing season each year due to alteration in the quantity and availability of mineral nutrients through the addition of fertilizers, manure, compost, mulch, and lime in addition to leaching. Intensively cultivated soils are being depleted with available nutrients especially secondary and micronutrients. In both agriculturally advanced irrigated ecosystems and less-endowed rainfed regions, nutrient replenishment through fertilizers and manures remain far below crop removal, thus causing the mining of nutrient reserves over years. Widespread deficiencies of N, P, K, S, Zn, Fe, B etc have emerged and significant crop responses to application of these nutrients have been reported.

The deficiencies are so intense and severe that visual symptoms are very often observed in major crops. Hence, evaluation of fertility status of the soils of an area or a region is an important aspect in the context of sustainable agriculture (Singh and Misra, 2012).

Soil fertility decline is naturally more alarming in intensively cultivated regions wherein nutrient withdrawals by crops are high and replenishment is inadequate, and this has grave implications in term of (i) more acute and wide spread deficiencies, (ii) declining nutrient use efficiency and returns from money spent on nutrient and other inputs, (iii) a weakened foundation for high yielding sustainable farming and (iv) escalating remedial costs for rebuilding depleted soils.

Therefore, for maintaining soil health and sustainable agricultural production, replenishment of macro and micronutrients and addition of soil amendments is a must in the soil to obtain good crop yields. If their status in the soil is known before the crop is sown, it provides a sound basis for determining the nutrient requirements for the desired production.

The fertility status of soils can be evaluated using nutrient index methods and fertility indicators. RaviKumar and Somashekar (2013) evaluated the nutrient index of soils using organic carbon, available P and available K concentrations as a measure of soil fertility in Varahi River basin, India. Similarly, fertility status of soils of several microwatersheds in Karnataka has been mapped and the nutrient status of these areas is well documented (Vishwanath Shetty, 2008; Pulakeshi *et al.*, 2012; Vidyavathi, 2012). However, the fertility status of soils in Bogur microwatershed has not been studied to ascertain their present fertility conditions for proper management and efficient crop productivity.

A study conducted by Amara *et al.*, (2015a) to assess the soil productivity constraints revealed that rapid development and population growth in the study area has led to increasing human demands for land as well as food crops like rice, maize and vegetables among others. In response to this, soils of the study area have been subjected to different land uses, most of which are not environmentally friendly. Keeping this in view, the study therefore, aimed at evaluating the fertility status of soils in five villages located within the study area using fertility ratings and nutrient index in order to determine the variability existing among soil physicochemical properties.

MATERIALS AND METHODS

Study Area

Bogur micro-watershed (Figure 1), is located in the hot semi-arid agro-ecological region of India between latitude 15.60º to 15.70º N and longitude 74.97º to 74.98º E in the Dharwad taluk of Dharwad district in the northern transition zone of Karnataka state. It has an area of 760.6 ha, with a medium to high available water content and a length of growing period of 150-180 days. The climate is characterized by hot and humid summer and mild and dry winter.

The average annual rainfall is 755.2 mm, which is distributed over May to October and annual temperature ranges from 24-28 °C with an Ustic soil moisture and Isohyperthermic soil temperature regimes (Amara *et al.*, 2013). The highest elevation in this area is 754 m above mean sea level while the relief is very gently to strongly sloping.

The general slope is towards the northeast, southeast and southwest but it is more in the southwest direction. The drainage pattern is parallel. The soils are derived from chlorite schist with shale as dominant parent material containing banded iron oxide quartzite concretions. This characteristic feature makes the soils coarse textured and shallow at the higher elevations but gradually, fineness and depth of soil increases towards the lower elevations.

Black and red soils are the main soil types but the red soils are in much higher proportion than the black soils. The natural vegetation mainly comprised of trees and shrubs including Acacia (*Acacia auruculiformis*), Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus sideroxylon* and *Eucalyptus regnana*).

Research Article

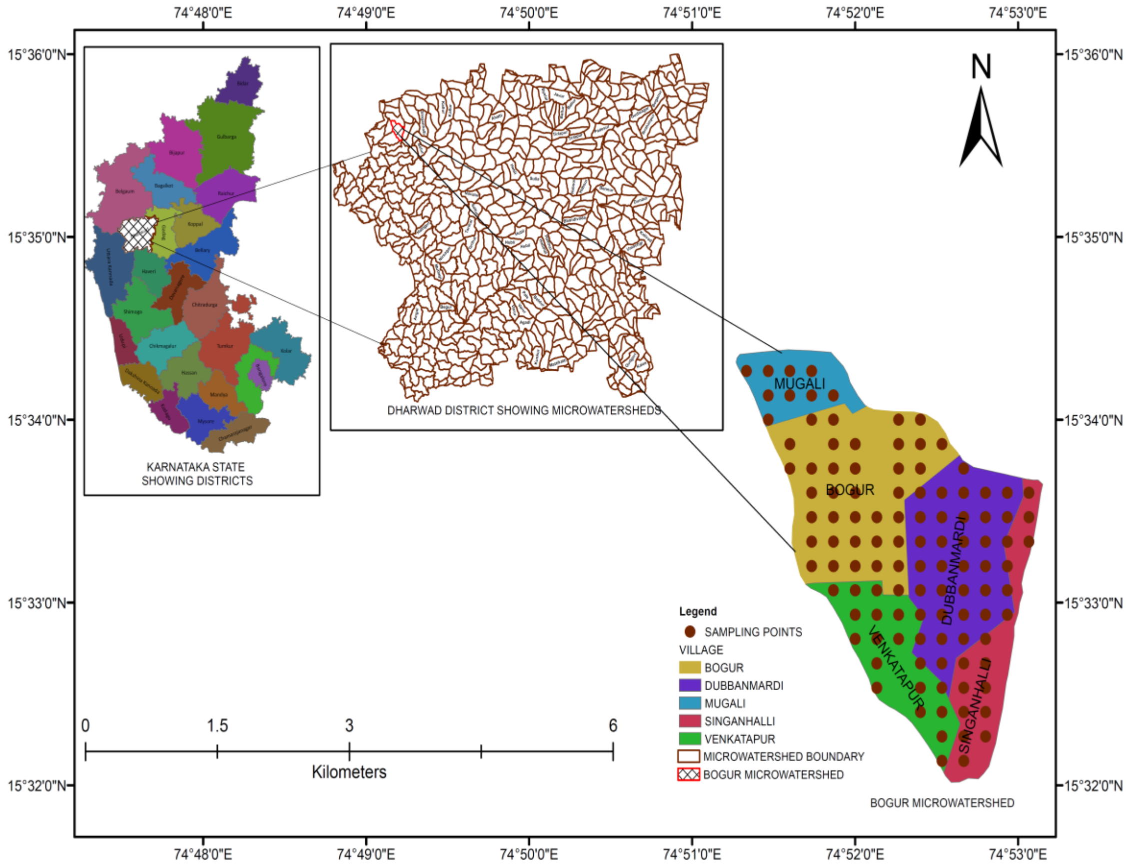

Figure 1: Location Map of Study Area

Soil Sampling and Analysis

A detailed soil survey of the study area was carried out on a grid map prepared using ArcGIS software. A total of 118 soil samples were collected with soil auger from a depth of 0-20 cm in five villages that make up Bogur microwatershed. The exact sample locations (latitude and longitude) were recorded with the help of a hand held GPS device. The collected soil samples were processed and stored at suitable room temperature in the Soil Science & Agricultural Chemistry laboratory of the University of Agricultural Sciences Dharwad. The stored samples were then analyzed for pH, electrical conductivity, organic carbon, available nitrogen, P_2O_5 and K_2O, available sulphur and available micronutrients (Zn, Mn, Fe & Cu) using standard analytical methods. Soil reaction (pH) was determined by using 1:2.5 soils: water suspension with the calibrated pH meter by following the method given by Jackson (1973). Electrical conductivity was determined by using 1:2.5 soils: water suspension with the calibrated conductivity meter by following the method given by Jackson (1973). Organic carbon was determined by following modified Walkley and Black (1934) method. Available nitrogen was determined by modified alkaline permanganate method as described by Sharawat and Burford (1982). Available phosphorous was determined by spectrophotometer by following Bray and Kurtz (1945) and Olsen *et al.*, (1954) methods and available phosphorous was expressed in P_2O_5 by using conversion factor. Available potassium was determined by Flame Photometer with neutral ammonium acetate as an extractant by following Hanway and Heidel (1952) method. Available sulphur was determined by following Turbidimetric Chesin and Yien (1950) method. Exchangeable calcium and magnesium were determined in neutral normal ammonium acetate extract by Versanate Titration as described by Black (1965). Available micronutrient cations (Zn, Fe, Cu & Mn) were determined by following Lindsay and Norvell (1978) method using Atomic Absorption Spectrophotometer.

Nutrient Availability Index (NAI) Determination

To evaluate the fertility status of soils in the study area, different soil physico-chemical properties that affect nutrient availability including pH, electrical conductivity, available N, P, K and S, exchangeable Ca and Mg, and available micronutrients (Zn, Mn, Fe and Cu) were calculated based on the specific rating chart (Table 1) modified from Brajendra *et al.,* (2014).

Table 1: Rating Chart for Soil Test Values and their Nutrient Indices

Soil Property	Unit	Range		
Soil pH	pH unit	< 6.0 (Acidic)	6.1-8.0 (Neutral)	>8.0 (Alkaline)
Electrical conductivity	dS/m	<1.0 (Normal)	1.0-2.0 (Critical)	>2.0 (Injurious)
Organic Carbon	%	<0.5 (Low)	0.5-0.75 (Medium)	>0.75 (High)
Available Nitrogen (N)	kg/ha	<280 (Low)	280-560 (Medium)	>560 (High)
Available Phosphorus (P_2O_5)	kg/ha	<10 (Low)	10-25 (Medium)	>25 (High)
Available Potassium (K_2O)	kg/ha	<110 (Low)	110-280 (Medium)	>280 (High)
Available Sulphur (S)	ppm	<10 (Low)	10-30 (Medium)	>30 (High)
Exchangeable Calcium (Ca)	meq/100g	<1.5 (Low)	1.5-4.5 (Medium)	>4.5 (High)
Exchangeable Mg	meq/100g	<1.5 (Low)	1.5-4.5 (Medium)	>4.5 (High)
Available Zinc (Zn)	ppm	<0.6 (Low)	0.6-1.0 (Medium)	>1.0 (High)
Available Manganese (Mn)	ppm	<2.0 (Low)	2-3 (Medium)	>3.0 (High)
Available Iron (Fe)	ppm	<0.2 (Low)	0.2-0.6 (Medium)	>0.6 (High)
Available Copper (Cu)	ppm	<4.5 (Low)	4.5-5.5 (Medium)	>5.5 (High)
Nutrient Index	**Index**	**I**	**II**	**III**

In order to compare the levels of soil fertility of one area with those of another it was necessary to obtain a single value for each nutrient. Here the nutrient index introduced by Parker *et al.*, (1951) and modified by Shetty *et al.*, (2008); Pathak (2010); Kumar *et al.*, (2013) and RaviKumar and Somashekar (2013) was employed. Parker's nutrient index is a three tier system used to evaluate the fertility status of soils based on the percentage of samples in each of the three classes, i.e., low, medium and high and multiplied by 1, 2 and 3 respectively. The sum of the figures thus obtained is divided by 100 to give the index or weighted average as given in the equation below:

Nutrient Index = {(1 x A) + (2 X B) + (3 X C)}/ TNS

where A = Number of samples in low category; B = Number of samples in medium category; C = Number of samples in high category, TNS = Total number of samples. The nutrient index with respect to soil pH, organic carbon, available P, and exchangeable K were used to evaluate the fertility status of soils in the five villages. The rating chart is given in Table 2.

Table 2: Nutrient Index with Range and Remarks

Nutrient Index	Range	Remarks
I	Below 1.67	Low
II	1.67-2.33	Medium
III	Above 2.33	High

RESULTS AND DISCUSSION

Soil Fertility Status of Study Area

The analytical results of physico-chemical parameters analyzed in the soil samples from the study area are presented in Tables 3, 4 & 5.

Soil Reaction (Soil pH)

Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The measure of soil pH is an important parameter which helps in identification of the chemical nature of the soil (Shalini *et al.,* 2003) as it measures the hydrogen ion concentration in the soil to indicate the acidic and alkaline nature of the soil. The supply of plant nutrients and thus, the fertility of the soil are affected by pH. The solubility of most nutrients varies in response to pH. The study revealed that the pH values of soils in all the villages varied from moderately acidic to moderately alkaline (5.24─8.36). According to the results (Table 3), the pH of soils in Mugali, Venkatapur and Singhanhalli villages are moderately acidic to neutral in nature (5.3─7.57), whereas soils in Bogur and Durbanmardi villages are moderately acidic to moderately alkaline (5.24─8.36). In soils of Mugali and Singhanhalli villages, high per cent of samples (60─67%) were acidic, however, the highest mean pH value was from Bogur village where 15, 57.5 and 27.5 per cent of the soil samples were found to be acidic, neutral and alkaline, respectively.

Soils of Bogur village show high pH values (more alkaline) than soils of other villages. These high pH values are possibly due to presence of soluble and exchangeable sodium along with HCO_3^- ions, which precipitates calcium and magnesium carbonates during evaporation (Singh *et al.*, 2016). According to Brady and Weil (2005), alkalinity problem in soils is due to the indigenous calcareous parent material with typical low organic matter content.

Therefore, in such areas where the potential of salinity has started showing up, it is of the view that the retention of crop residues on soil surface along with fertilization with organic manure and involvement of legumes in crop rotation coupled with minimum/no-tillage practices play an important role to sustain soil fertility, improving fertilizer/water use efficiency, physical conditions of soils and enhance crop productivity (Sainju *et al*., 2008). High pH values are thus, indicative of development of salinity in soils of Bogur.

The pH values of soils in Venkatapur range from 5.49─7.01 (i.e., acidic to alkaline) with about 85.7 per cent of samples being of alkaline reaction. The availability of some plant nutrients is greatly affected by soil pH.

The "ideal" soil pH is close to neutral, and neutral soils are considered to fall within a range from a slightly acidic pH of 6.5 to slightly alkaline pH of 7.5. It has been determined that most plant nutrients are optimally available to plants within this pH range, since this pH range is generally very compatible to plant root growth. Nitrogen (N), Potassium (K), and Sulfur (S) are major plant nutrients that appear to be less affected directly by soil pH than many others, but still are to some extent. Phosphorus (P), however, is directly affected.

At alkaline pH values greater than pH 7.5 for example, phosphate ions tend to react quickly with calcium (Ca) and magnesium (Mg) to form less soluble compounds. At acidic pH values, phosphate ions react with aluminum (Al) and iron (Fe) to form less soluble compounds. Most of the other nutrients (especially micronutrients) tend to be less available when soil pH is above 7.5, and in fact are optimally available at a slightly acidic pH, e.g. 6.5 to 6.8.

The exception is molybdenum (Mo), which appears to be less available under acidic pH and more available at moderately alkaline pH values. On this note, it is observed that soils of Venkatapur show potential for high nutrient availability.

Electrical Conductivity (EC)

The electrical conductivity (EC) is the measure of the soluble salts present in the soil and is affected by cropping sequence, irrigation, land use and application of fertilizers, manure, and compost (Singh *et al*., 2016). High value of electrical conductivity represents higher degree of salinity. Excessive amount of dissolved salts in soil solutions causes hindrance in normal nutrient uptake process either by imbalance of ions uptake, antagonistic effect between nutrients or excessive osmotic potentials of soil solution or a combination of the three effects (Rahman *et al*., 2010).

The results presented in Table 3 indicate that salinity hazard does not presently exist in the study area. The mean value of EC is 0.1 dS/m with a range varying from 0.0 to 0.27 dS/m. The variations in the EC could be due to the inherent drainage system of the soils in these villages.

According to Roy *et al*., (1962), low EC of soils is indicative that the prevailing conditions are not favorable for accumulation of salts. The EC results of the study area are therefore in conformity with the results obtained by Roy *et al*., in 1962.

Table 3: Descriptive Statistics of Measured Soil Properties in Bogur Microwatershed

Soil Reaction (pH)

Location	**Percent of Samples Falling within Range**			**Range**	**Mean ± SD**
	<6.0 (Acidic)	**6.0 - 8.0 (Neutral)**	**>8.0 (Alkaline)**		
Mugali	60	40	0	5.3-6.7	6.1 ± 0.5
Bogur	15	57.5	27.5	5.5-8.27	7.1 ± 0.9
Venkatapur	14.3	85.7	0	5.49-7.01	6.3 ± 0.4
Durbanmardi	43.8	50	6.2	5.24-8.36	6.4 ±0.9
Singhanhalli	66.7	33.3	0	5.4-7.57	6.1 ± 0.5

Electrical Conductivity

Location	**<1.0 dS/m (Normal)**	**1.0-2.0 dS/m (Medium)**	**>2.0 dS/m (High)**	**Range**	**Mean ± SD**
Mugali	100	0	0	0.0-0.2	0.1 ± 0.0
Bogur	100	0	0	0.02-0.27	0.1 ± 0.1
Venkatapur	100	0	0	0.03-0.09	0.1 ± 0.2
Durbanmardi	100	0	0	0.03-0.27	0.1 ± 0.1
Singhanhalli	100	0	0	0.04-0.18	0.1 ± 0.0

Organic Carbon

Location	**<0.5% (Low)**	**0.5-0.75% (Medium)**	**>0.75% (High)**	**Range**	**Mean ± SD**
Mugali	0	10	90	0.7-2.5	1.3 ± 0.5
Bogur	12.5	15	72.5	0.16-2.26	1.3 ± 0.7
Venkatapur	0	0	100	0.09-3.55	2.3 ± 0.7
Durbanmardi	9.4	12.5	78.1	0.31-5.15	1.6 ± 1.1
Singhanhalli	0	6.7	93.3	1.05-4.45	2.1 ± 1.3

Exchangeable Ca

Location	**<1.5 meq/100g)**	**1.5-4.5 meq/100g (Medium)**	**>4.5 meq/100g (High)**	**Range**	**Mean ± SD**
Mugali	0	0	100	4.6 - 14.2	8.7 ± 3.1
Bogur	97.5	2.5	0	3.2 - 33.6	16.1 ± 9.3
Venkatapur	0	4.8	95.2	4.4 - 13.8	8.4 ± 2.7
Durbanmardi	0	6.2	93.8	3.6 - 32.4	10.9 ± 7.8
Singhanhalli	0	20	80	3.3 - 23.0	8.6 ± 5.0

Exchangeable Mg

Location	**<1.5 meq/100g)**	**1.5-4.5 meq/100g (Medium)**	**>4.5 meq/100g (High)**	**Range**	**Mean ± SD**
Mugali	0	50	50	2.8 - 7.4	4.8 ± 1.6
Bogur	2.5	17.5	80	1.9 - 18.2	9.2 ± 5.2
Venkatapur	0	38.1	61.9	2.4 - 8.8	5.1 ± 1.4
Durbanmardi	0	56.3	43.7	2.2 - 23.2	6.5 ± 5.2
Singhanhalli	0	60	40	2.2 - 19.6	5.4 ± 4.1

Organic Carbon

Organic matter has a vital role in agricultural soils. It supplies plant nutrients, improves oil structure, improve water infiltration and retention, feeds soil micro flora and fauna, and enhance the retention and cycling of applied fertilizer (Johnston, 2007).

The organic carbon content of the soils in the study area varied from 0.09 to 5.15%. The mean value was significantly high in Venkatapur (2.3%) and Singhanhalli (2.1%) and low in Mugali and Bogur (1.3%)

(Table 3). The study revealed that the organic carbon content of soils in the study area is significantly high with more than 70% of soil samples falling in the high (i.e., >0.75%) category. According to Kavitha and Sujatha (2015), high levels of organic matter not only provides part of the N requirement of crop plants, but also enhance nutrient and water retention capacity of soils and create favourable physical, chemical and biological environment.

The results (Table 3) show that only 12.5% and 9.4% of soil samples in Bogur and Durbanmardi, respectively fall in the low (<0.5%) category. Continuous and intensive cultivation leading to high crop removal might be responsible for the low organic carbon content indicative of samples from these villages.

In addition, low input of FYM and crop residues as well as rapid rate of decomposition due to high temperature, organic matter degradation and removal taken place at faster rate coupled with low vegetation cover, thereby leaving less chances of accumulation of organic matter in the soil which could further exacerbate the situation.

Exchangeable Calcium and Magnesium

Major portion of the study area was sufficient (i.e., high) in exchangeable Ca and Mg status with the exception of Bogur village where deficiency of exchangeable Ca contents (Ca <1.5 meq/100g) was found in 97.5% of soil samples, which may be due to easy leaching of bases and low organic carbon values. The content of calcium in the soils varied from 3.2 to 33.6 meq/100g, while the magnesium content varied from 1.9 to 23.2 meq/100g (Table 3).

The calcium content was significantly high (>4.5 meq/100g) in soils of Mugali, Venkatapur, Durbanmardi and Singhanhalli but significantly low (<1.5 meq/100g) in soils of Bogur. According to Kavitha and Sujatha (2015), calcium content in soils is usually affected by drainage, soil type, pH and liming practices.

Therefore, the low levels of Ca might be attributed to the continuous addition of acidifying chemical fertilizers. According to Amara *et al.*, (2015b), soil characterization and classification revealed that soils of Bogur are red soils while soils of Mugali, Venkatapur, Durbanmardi and Singhanhalli are black and mixed red and black soils.

Anantharayana *et al.*, (1986) reported higher exchangeable Ca and Mg contents in black soils than red soils. Availability of calcium and magnesium to crops do not generally pose problems in black soils, as these soils are calcareous in nature.

The exchangeable Ca and Mg are attributed to the type and amount of clay, present in these soils (Alur, 1994). Soil of Mugali, Venkatapur and Singhanhalli villages recorded high clay content. As reported by Nandi and Dasog (1992), high value of exchangeable Ca and Mg is an indication of dominance of smectite type of clay mineral.

Available Nitrogen

The available nitrogen content was low in major portion of Venkatapur, Durbanmardi and Singhanhalli villages as 74.5%, 84.4%, and 100%, respectively of soil samples analyzed showed nitrogen content below 280kg/ha (Table 4), which might be due to low organic matter content in these soils. In soils of Mugali and Bogur, 50.0% and 82.5%, of samples respectively analyzed recorded nitrogen content that was in the medium category (280-560kg/ha). In the entire study area, only 2.5% of soil samples from Bogur village showed nitrogen status that was in the high category (>560kg/ha). According to Ashok Kumar (2000), such variation in N content may be related to soil management, application of FYM and fertilizer to previous crop. The nitrogen content in soils is dependent on temperature, rainfall and altitude. In addition, continuous and intensive cultivation leading to high crop removal together with insufficient replenishment might be the reason for the high degree of nitrogen deficiency in these soils. The medium nitrogen status recorded in some portion of the study area may be due to application of N fertilizer recommended for the crops.

Available Phosphorus

Phosphorus has been called the "Master key to agriculture" because low crop production is attributed mainly to the deficiency of phosphorus, except nitrogen, than the deficiency of other elements (Singh *et* *al.*, 2016). Phosphorus is essential for growth, cell division, root growth, fruit development and early ripening of the crop. It is also required for energy storage and transfer being a constituent of several organic compounds including oils and amino acids. Phosphate ion enters the soil solution either as a result of mineralization of organophosphates or the application of fertilizers. The plants take available P mostly in the form of $H_2PO_4^-$ from soil solution.

Chemisorptions of P occur due to interaction of phosphate ions with the atoms like aluminium (Al), iron (Fe) or calcium (Ca) depending upon soil pH. The level of phosphorous in soils of the study area varied from 5.0 to 30.7kg/ha. Its mean content was significantly high in soils of Bogur and Venkatapur and low in soils of Singhanhalli (16.0 kg/ha) (Table 4).

A high proportion of soil samples (60-90%) were medium in available phosphorus (P_2O_5), within the range of 10-25kg/ha, which may be due to the high input of phosphate fertilizers over a period of time. As reported by Anon (2003), high level of P in soil not only impairs the availability and uptake of essential nutrients by plants but also leads to soil and water pollution.

Available Potassium

Potassium exists in K^+ form and its function appears to be catalytic in nature (Singh *et al.*, 2016). Potassium is important for plant because it participates in the activation of large number of enzymes which are involved in the physiological processes of plants. It controls the water economy and provides the resistance against a number of pests, diseases and environmental stresses. The content of potassium in soils of the study area varied from low to medium (20–587kg/ha). Its mean content was significantly high in soils of Bogur (244.7kg/ha) and low in soils of Venkatapur (163.2kg/ha) (Table 4).

The low content of available phosphorus in Venkatapur soils might be due to the low use of potassium fertilizers. Phosphorus deficiency (low P content) was moderately high in soils of Venkatapur and Durbanmardi villages. These are villages where small-scale irrigation is practiced by a fairly large number of farmers.

Hence, the leaching condition brought in by irrigation coupled with strong acidity which does not permit retention of potassium on the soil exchangeable complex might be the probable reason for the low phosphorus status of these soils.

Black soils were higher in available potassium status than red soils which might be due to the predominance of K rich micaceous and feldspars minerals in parent material. In addition, Kaolinite type of clay mineralogy may be the cause for their medium and low rating for available potassium (Pulakeshi *et al.*, 2012).

Available Sulphur

The sulphur content of the soils varied from low to high (0.6–35.6ppm). The mean was significantly high in soils of Venkatapur (12.3ppm) and Singhanhalli (12.1ppm) but significantly low in soils of Mugali (7.5ppm) (Table 4). The deficiency of sulphur was well observed in all villages. This deficiency signifies the portion of study area falling in the critical limit (8-10 ppm) as reported by DAC (2011). However, the deficiency followed a sequence; being significantly high in Mugali (90%), followed by Durbanmardi (65.6%), Bogur (62.5%), Venkatapur (57.1%) and Singhanhalli (46.6%). Overall, major portion of study area was medium to low in available sulphur. The low and medium levels of available sulphur in soils of the study area might be due to lack of sulphur addition and continuous removal of S by crops (Balanagoudar, 1989).

Similar results were observed by Pulakeshi *et al.*, (2012) in Mantagani village under northern transition zone of Karnataka where 181 and 126 ha of study area were observed to be medium and low respectively, in available sulphur.

Available Micronutrients

The status of micronutrients is given in Table 5. The content of zinc in the soils varied from low to medium (0.0–1.0ppm). Deficiency of available Zn was well observed among villages in the study area. However, the deficiency followed a sequence; being significantly high in Venkatapur (85.7%), followed by Mugali and Singhanhalli (80% each), Bogur (77.5%) and Durbanmardi (59.4%) (Table 5). The high deficiency status of Zn might be due to the formation of Zn-phosphates following large applications of P fertilizer as well as the formation of complexes between Zn and organic matter in soils with high pH and high organic matter content or because of large applications of organic manures and crop residues (Kavitha and Sujatha, 2015). Hence, their solubility and mobility may decrease resulting in reduced availability. According to Singh *et al*., (2016), zinc uptake by plants decreases with increased soil pH. Uptake of zinc also is adversely affected by high levels of available phosphorus in soils (Pulakeshi *et al.*, 2012).

The manganese content of soils varied from 0.2–40.3ppm. It was significantly high in soils of Venkatapur, Durbanmardi and Singhanhalli (100% each) and Bogur (92.5%) but significantly low in soils of Mugali (100%) (Table 5). Deficiency levels of manganese were prominently high in Mugali while sufficiency levels were evident in soils of Venkatapur, Durbanmardi and Singhanhalli. The sufficiency levels indicative of these soils might be due to the neutral to low pH and nature of the parent material as reported by Prasad and Sahi (1989).

According to Arora and Shekon (1981), high pH coupled with semi-arid conditions decrease the availability of Mn by converting it into unavailable forms (Mn^{++} converted Mn^{+++}). In a study conducted by Vijayshekar *et al.*, (2000), sufficient content of manganese due to high organic matter content was observed in Upper Krishna Command Area.

The entire study area was under deficient iron status as all samples analyzed showed that the iron content was in the low category (<4.5ppm) (Table 5). The low Fe content of these soils might be due to precipitation of Fe^{2+} and decrease in its availability. Similar results were also observed by RaviKumar *et al.*, (2007).

According to Patil and Dasog (1999), poorly aerated or compacted soils also reduce iron uptake by plants. In addition, uptake of iron decreases with increased soil pH, and is adversely affected by high levels of available phosphorus, manganese and zinc in soils (RaviKumar *et al.*, 2007).

The copper content of the soils varied from low to high (0–0.93ppm) (Table 5). Raghupathi (1989) reported that available copper content in North Karnataka soils ranged from 0.4─1.2ppm. There was no significant variation in the mean content of Cu. The deficiency level of this nutrient was less prominent in soils of Venkatapur, Durbanmardi and Singhanhalli. Soils of Mugali and Bogur did not show any deficiency symptoms. Overall, based on the results of this study, it is revealed that the severity of macronutrient deficiency in the study area occur in the order N > S > K > P > Ca > Mg and micronutrient deficiency in the order Fe > Zn > Mn > Cu.

Soil Nutrient Indices

Nutrient index value (NIV) is the measure of nutrient supplying capacity of soil to plants (Singh *et al.*, 2016). The soil nutrient index of the study area (Tables 6, 7 & 8) was calculated from low, medium and high ratings of soil nutrients. If the index value was less than 1.67, the fertility status was low and the value between 1.67-2.33 then the status was medium. If the value greater than 2.33, the fertility status was high. Nutrient index analysis for the study area revealed that soil reaction was low to medium. Among the five villages in the study area, the pH status was low in Mugali, Durbanmardi and Singhanhalli villages and medium in Bogur and Venkatapur villages. Electrical conductivity was low (i.e., normal) in all villages.

Organic carbon was high in all villages. Exchangeable Ca was medium in Bogur and high in the other villages, while exchangeable Mg was high in all villages. Available N was medium in Bogur and low in the other villages. Available phosphorus was high in Bogur and medium in the other villages whereas available potassium and sulphur were medium and low respectively in all villages. The nutrient indices of micronutrients revealed high variability in the study area. Available Zn and Fe were low (i.e., deficient) in all villages. Available Mn was in the range of L-M-H (i.e., Low-Medium-High), which is otherwise referred to as deficient-sufficient-excess. Mugali village was deficient (i.e., low) in available Mn, Bogur was sufficient (i.e., medium), while Venkatapur, Durbanmardi and Singhanhalli villages recorded excess (i.e., high) Mn content. For available Cu, its nutrient index ranged from sufficient to excess. It was sufficient in Venkatapur, Durbanmardi and Singhanhalli villages and excess in Mugali and Bogur villages.

International Journal of Food, Agriculture and Veterinary Sciences ISSN: 2277-209X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jfav.htm
2016 Vol. 6 (3) September-December, pp. 1-15/Amara Denis et al.

Research Article

Table 4: Status of Available Macronutrients in Bogur Microwatershed

Nitrogen (N)					
Location	**Percent of Samples Falling within Range**			**Range**	**Mean ± SD**
	<280 Kg/Ha (Low)	**280-560 Kg/Ha(Medium)**	**>560 Kg/Ha (High)**		
Mugali	50	50	0	119.1-354.9	280.3 ± 41.9
Bogur	15	82.5	2.5	67.1-309.4	243.0 ± 67.1
Venkatapur	71.4	28.6	0	218.4-345.8	267.4 ± 39.4
Durbanmardi	84.4	15.6	0	127.4-318.5	240.3 ± 42.1
Singhanhalli	100	0	0	209.3-273.0	247.5 ± 22.1
Phosphorus (P_2O_5)					
Location	**<10 Kg/Ha (Low)**	**10-25 Kg (Medium)**	**>25 Kg/Ha (High)**	**Range**	**Mean ± SD**
Mugali	0	90	10	14.4-27.0	21.0 ± 3.1
Bogur	0	65	35	5.0-28.0	22.3 ± 5.0
Venkatapur	4.8	61.9	33.3	10.1-30.5	22.2 ± 6.4
Durbanmardi	9.4	62.5	28.1	7.0-30.7	21.3 ± 6.4
Singhanhalli	26.7	66.6	6.7	7.7-26.8	16.0 ± 5.6
Potassium (K_2O)					
Location	**<110 Kg/Ha (Low)**	**110-280 Kg/Ha (Medium)**	**>280 Kg/Ha (High)**	**Range**	**Mean ± SD**
Mugali	10	90	0	100.0-250.0	171.5 ± 38.7
Bogur	12.5	60	27.5	60.8-587.8	244.7 ± 160.1
Venkatapur	33.3	57.2	9.5	60.8-425.7	163.2 ± 91.0
Durbanmardi	34.4	43.8	21.8	20.3-506.8	188.1 ± 124.5
Singhanhalli	20	60	20	60.8-344.6	180.4 ± 81.3
Available Sulphur (S)					
Location	**<10 ppm (Low)**	**10-30 ppm (Medium)**	**>30 ppm (High)**	**Range**	**Mean ± SD**
Mugali	90	10	0	3.8 - 12.9	7.5 ± 2.8
Bogur	62.5	35	2.5	0.6 - 24.9	9.7 ± 7.7
Venkatapur	57.1	33.3	9.6	1.1 - 34.1	12.3 ± 9.7
Durbanmardi	65.6	34.4	0	1.5 - 29.0	8.3 ± 5.8
Singhanhalli	46.7	46.6	6.7	2.8 - 35.6	12.1 ± 8.8

Table 5: Status of Available Micronutrients in Bogur Microwatershed

Zinc (Zn)					
Location	**Percent of Samples Falling within Range**			**Range**	**Mean ± SD**
	<0.6 ppm (Low)	**0.6-1.0 ppm (Medium)**	**>1.0 ppm (High)**		
Mugali	80	20	0	0.1 - 0.9	0.5 ± 0.3
Bogur	77.5	22.5	0	0.0 - 0.9	0.4 ± 0.2
Venkatapur	85.7	14.3	0	0.14 - 0.98	0.4 ± 0.2
Durbanmardi	59.4	40.6	0	0.1 - 1.0	0.5 ± 0.3
Singhanhalli	80	20	0	0.1 - 0.8	0.4 ± 0.2
Manganese (Mn)					
Location	**<2 ppm (Low)**	**2-3 ppm (Medium)**	**>3 ppm (High)**	**Range**	**Mean ± SD**
Mugali	100	0	0	14.3 - 21.9	20.7 ± 2.2
Bogur	5	2.5	92.5	0.2 - 33.4	18.6 ± 13.7
Venkatapur	0	0	100	9.46 - 22.21	19.9 ± 3.1
Durbanmardi	0	0	100	4.5 - 40.3	22.0 ± 3.7
Singhanhalli	0	0	100	5.5 - 36.1	20.0 ± 6.7
Iron (Fe)					
Location	**<4.5 ppm (Low)**	**4.5-5.5 ppm (Medium)**	**>5.5 ppm (High)**	**Range**	**Mean ± SD**
Mugali	100	0	0	0.3 - 1.6	0.9 ± 0.4
Bogur	100	0	0	0.2 - 1.5	0.6 ± 0.4
Venkatapur	100	0	0	0.39 - 1.65	0.9 ± 0.3
Durbanmardi	100	0	0	0.2 - 1.8	0.8 ± 0.4
Singhanhalli	100	0	0	0.4 - 1.6	0.9 ± 0.3
Copper (Cu)					
Location	**<0.2 ppm (Low)**	**0.2-0.6 ppm (Medium)**	**>0.6 ppm (High)**	**Range**	**Mean ± SD**
Mugali	0	30	70	0.1 - 0.9	0.6 ± 0.2
Bogur	0	57.5	42.5	0.2 - 0.9	0.6 ± 0.2
Venkatapur	28.6	38.1	33.3	0.0 - 0.93	0.4 ± 0.3
Durbanmardi	15.6	37.5	46.9	0.1 - 0.9	0.5 ± 0.3
Singhanhalli	20	53.3	26.7	0.1 - 0.8	0.5 ± 0.2

Table 6: pH, Salt and Organic Carbon Indices of Soils of Bogur Microwatershed

Location	Soil Reaction (pH)		Electrical Conductivity		Organic Carbon	
	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating
Mugali	1.40	Low	1.00	Normal	2.90	High
Bogur	2.13	Medium	1.00	Normal	2.60	High
Venkatapur	1.86	Medium	1.00	Normal	3.00	High
Durbanmardi	1.62	Low	1.00	Normal	2.69	High
Singhanhalli	1.33	Low	1.00	Normal	2.93	High

Table 7: Nutrient Indices of Major Macronutrients in Soils of Bogur Microwatershed

Location	Available N		Available P_2O_5		Available K_2O		Available S		Exchangeable Ca		Exchangeable Mg	
	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating
Mugali	1.50	Low	2.10	Medium	1.90	Medium	1.10	Low	3.00	High	2.50	High
Bogur	1.88	Medium	2.35	High	2.15	Medium	1.40	Low	1.03	Medium	2.78	High
Venkatapur	1.29	Low	2.29	Medium	1.76	Medium	1.53	Low	2.95	High	2.62	High
Durbanmardi	1.16	Low	2.19	Medium	1.87	Medium	1.34	Low	2.94	High	2.44	High
Singhanhalli	1.00	Low	1.80	Medium	2.00	Medium	1.60	Low	2.80	High	2.40	High

Table 8: Nutrient Indices of Major Micronutrients in Soils of Bogur Microwatershed

Location	Available Zn		Available Mn		Available Fe		Available Cu	
	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating	Nutrient Index	Fertility Rating
Mugali	1.20	Deficient	1.00	Deficient	1.00	Deficient	2.70	Excess
Bogur	1.23	Deficient	2.88	Sufficient	1.00	Deficient	2.43	Excess
Venkatapur	1.14	Deficient	3.00	Excess	1.00	Deficient	2.05	Sufficient
Durbanmardi	1.41	Deficient	3.00	Excess	1.00	Deficient	2.31	Sufficient
Singhanhalli	1.20	Deficient	3.00	Excess	1.00	Deficient	2.07	Sufficient

Conclusion

The study has revealed that the pH of soils in the five villages were acidic to alkaline. Electrical conductivity was normal (<1.0 dS/m). Soil organic carbon was low to high, with more than 70% of study area falling in the high category. Exchangeable Ca and Mg contents were low to high. Available macronutrient status (N, P, K, & S) were low to high. The availability of micronutrients was highly variable. Zinc (Zn) was low to medium, iron (Fe) was low, while manganese (Mn) and copper (Cu) were low to high. Based on the nutrient indices of Parker *et al*., (1951), Shetty *et al*., (2008); Pathak (2010) and Kumar *et al.*, (2013) and RaviKumar and Somashekar (2013), the fertility status of the study area showed that the pH is low to medium, electrical conductivity is high, nitrogen is low to medium, phosphorus is medium to high, potassium is high, available sulphur is low, exchangeable Ca is medium to high, exchangeable Mn is high, Zn is deficient, Mn is deficient to high, Fe is deficient and Cu is sufficient to excess. Soil reaction, available N, K, S, Zn and Fe were observed as the most important soil fertility constraints that could affect sustainable crop production. The situation therefore demands the adoption of appropriate management practices in order to boost the fertility status. These practices may include such practices as site specific nutrient management, increased use of organic nutrient sources, sustainable land use and cropping systems, and appropriate agronomic practices.

REFERENCES

Alur AS (1994). Properties of red soils of Agro-climatic zone-3 (Region-2) of Northern Karnataka. M.Sc. (Agri.) Thesis, University of Agricultural Sciences, Bangalore (India).

Amara Denis MK, Massaquoi SDA and Patil PL (2015b). Characterization of soils in hot semi-arid agro-ecological region of India: A case study of Singhanhalli-Bogur microwatershed in northern transition zone of Karnataka. *AshEse Journal of Agricultural Sci*ences **1**(8) 54-70.

Amara Denis MK, Patil PL, Dasog GS and Manjunath MV (2013). Rainfall Erosivity (R-Factor) Estimation for Singhanhalli-Bogur Microwatershed in Northern Transition Zone of Karnataka. *Research Journal of Agricultural Sci*ences **4**(5/6) 644-647.

Amara Denis MK, Sawyerr PA, Mansaray SD and Kamanda PJ (2015b). Assessment of Soil Productivity Potentials in Hot Semi-Arid Northern Transition Zone of India using Riquier Index and GIS Techniques. *Asian Journal of Agriculture and Food Sci*ences **4**(1) 1-17.

Anathanarayana R, Reddy MN, Mithyantha MS and Perur NG (1986). Status of available secondary nutrients in acid soils of Karnataka. *Journal of Indian Society of Soil Science* **34** 614-616.

Anonymous (2003). Malaprabha Command Area: Annual Progress report of AICRP on Water Management, Belvatagi, University of Agricultural Sciences, Dharwad (India).

Arora CL and Sekhon GS (1981). Influence of soil characters on DTPA extractable micronutrients cations in some soil series of Punjab. *Journal of Indian Society of Soil Sci*ence **29** 453-462.

Ashok Kumar S (2000). Studies on soil aggregation in Vertisols of North Karnataka. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad (India).

Balanagoudar AB (1989). Investigation on status and forms of sulphur in soils of North Karnataka. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad (India).

Bjonnes R (1997). *Food vs Feed*, (People's News Agency; Frederiksberg C, Denmark).

Black CA (1965). *Method of Soil Analysis* **II**, 573-590, (American Society of Agronomy, Madison, USA).

Brady NC and Weil RR (2005). The Nature and properties of soil (thirteenth edition), (Macmillan Publishing Co, New York, USA).

Brajendra, Latha PC, Surekha K, Prasad Babu MBB, Ghosh TJ and Bhadana VB (2014). *Soil Health Testing Manual*, (Parmar Publishers and Distributors, India).

Bray RH and Kurtz IT (1945). Determination of total organic carbon and available forms of phosphorous in soils. *Soil Science* **59** 39-45.

Chesin L and Yien CH (1950). Turbidimetric determination of available sulphate. *Proceedings of Soil Science Society of America* **14** 149-151.

DAC (2011). *Methods Manual-Soil Testing in India,* (Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi, India).

Hanway JJ and Heidel H (1952). Soil analysis methods as used in Iowa State College. *Soil Testing Laboratory, Iowa State Collage Bulletin* **57** 1-131.

Jackson ML (1973). *Soil Chemical Analysis,* (Prentice Hall of India Pvt. Ltd., New Delhi, India) 498.

Johnston AE (2007). Soil organic matter, effects on soil and crop. *Soil Use and Management* **2**(3) 97-105.

Kavitha C and Sujatha MP (2015). Evaluation of soil fertility status in various agro ecosystems of Thrissur District, Kerala, India. *International Journal of Agriculture and Crop Sciences* **8**(3) 328-338.

Kulshrestha S, 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 Environmental Sciences* **7**(1) 47-52

Kumar P, Kumar A, Dyani BP, Kumar P, Shahi U P, Singh SP, Kumar R, Kumar Y and Sumith R (2013). Soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. *African Journal of Agricultural Research* **8**(14) 1209-1217.

Lindsay WL and Norwell A (1978). Development of DTPA soil test for Zn, Fe, Mn and Cu. *Society of American Journal* **42** 421-428.

Medhe SR, Tankankhar VG and Salve AN (2012). Correlation of chemical properties, secondary nutrients and micronutrient anions from the soils of Chakur Tahsil of Latur district, Maharashtra. *Journal of Trends in Life Sciences* **1**(2).

Nandi S and Dasog GS (1992). Properties, origin and distribution of carbonate nodules in some Vertisols. *Journal of Indian Society of Soil Sci*ence **40** 329-334.

Olsen SR, Cole CV, Watanabe FS and Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium carbonate. *USDA Circular* **939** 1–19.

Parker FW, Nelson WL, Winters E and Miles JE (1951). The broad interpretation and application of soil test summaries. *Agronomy Journal* **43**(3) 103–112.

Pathak H (2010). Trends of fertility status of Indian soil. *Current Advances in Agricultural Sci*ences **2**(1) 10-12.

Patil PL and Dasog GS (1999). Pedogenesis and classification of lateritic soils of North Karnataka I. Characterization and classification. *Agropedology* **9** 1-15.

Prasad SN and Sahi BP (1989). Distribution of manganese in relation to soil properties in some typical soil profiles. *Journal of Indian Society of Soil Sci*ence **37**(3) 567-570.

Pulakeshi HBP, Patil PL, Dasog GS, Radder BM and Mansur CP (2012). Mapping nutrients status by geographic information system (GIS) in Mantagani village under northern transition zone of Karnataka. *Karnataka Journal Agricultural Sciences* **25**(3) 232-235.

Raghupathi HB (1989). Investigation on soil copper and crop response in selected soils of Karnataka. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad (India).

Rahman O, Ahmad B and Afzal S (2010). Soil fertility and salinity status of Attock district. *Journal of Agricultural Research* **48**(4) 505-516.

RaviKumar MA, Patil PL and Dasog GS (2007). Mapping of Nutrients Status of 48A Distributary of Malaprabha Right Bank Command of Karnataka by GIS Technique. I- Major Nutrients. *Karnataka Journal of Agricultural Sciences* **20**(4) 735-737.

RaviKumar P and Somashekar KR (2013). Evaluation of nutrient index using organic carbon, available P and available K concentrations as a measure of soil fertility in Varahi River basin, India. *Proceedings of the International Academy of Ecology and Environmental Sciences* **3**(4) 330-343.

Roy BB and Landey RI (1962). Studies on red and lateritic soils of Mond watershed area of Raigarh district. *Indian Journal of Agricultural Sci*ences **32**(6) 294-302.

Sainju UM, Senwo ZN, Nyakatawa EZ, Tazisong IA and Reddy KC (2008). Tillage, cropping systems and nitrogen fertilizer source effects on soil carbon sequestration and fractions. *Journal of Environmental Quality* **37** 880–888.

Sharawat KL and Burford JR (1982). Modification of alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. *Soil Sci*ence **133** 53-57.

Singh G, Sharma M, Manan J and Singh G (2016). Assessment of Soil Fertility Status under Different Cropping Sequences in District Kapurthala. *Journal of Krishi Vigyan* **5**(1) 1-9.

Singh RP and Mishra SK (2012). Available macronutrients (N,P,K and S) in the soils of chiraigaon block of district Varansi (U.P.) in relation to soil Characteristics. *Indian Journal of Scientific Research* **3**(1) 97-100.

SLUSi (2010). Annual Report 2009-2010. Soil and Land Use Survey of India, Kodigehalli Road, Bangalore, India.

Vidyavathi V, Dasog GS, Babalad HB, Hebsur NS, Gali SK, Patil SG and Alagawadi AR (2012). Nutrient status of soil under different nutrient and crop management practices. *Karnataka Journal of Agricultural Sciences* **25**(2) (193-198).

Vijaya Sekhar R, Kuligod V, Basavaraj B, Dasog GS and Salimath SB (2000). Studies on micronutrient status in important black soil series of UKP command, Karnataka. *Andhra Agricultural Journal* **47** 141-143.

Vishwanath Shetty Y, Nagamma MS, Dinesh Kumar M and Jayaprakash SM (2008). Fertility Status of Arecanut Garden Soils of Karnataka. *Karnataka Journal of Agricultural Sciences* **21**(4) 503-506.

Wackley A and Black IA (1934). Estimation of soil organic carbon by chromic acid titration method. *Soil Sci*ence **37** 29-38.