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Monitoring soil quality changes in relation to land use and management in a watershed, Karnataka

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Abstract: The study carried out in Rajankunte watershed between 1980 and 2002 indicated that the total cultivable land area reduced at the rate of 4.1 ha annually. The reduction in area under food crops, agro-forestry and grazing lands has been diverted to horticulture. Nitrogen and phosphorus application in the watershed increased by 67 and 32 per cent over 22 years and, in general, nutrient application increased by 35 per cent. The change in land use and nutrient use pattern resulted in increase in area under acid soils, decline in base saturation and soil organic carbon (SOC) in 0-30 cm layer at a faster rate. The change in land use and management greatly affects the soil quality and require immediate correction measures like lime application and soil and water conservation measures including proper crop rotations to arrest the further degradation. The total cost of correcting soil acidity using lime worked out to be of Rs 218802/- for the entire watershed and an average cost of Rs 761/- ha for improving soil quality in Rajanukunte Watershed.

Additional key words: *Land use change, soil quality, soil organic carbon, soil reaction, base saturation, liming*

Introduction

The soil quality is the capacity of soil to nurture and sustain plant and animal productivity (Carter *et al.* 1997; Soil Science Society of America 1995). Some authors widen its horizon to include environmental regulatory capacity (Lal 1997). It is a measure of the condition of soil in relation to the requirement of one or more species and/or to any human need or purpose (Johnson *et al.* 1977). There are indicators of soil quality which are used to determine the quality of soil. Such indicators/properties can be used to assess the fitness of soil for production of food or other crops. The soil productivity is influenced by (1) extrinsic factors (e.g., climate), (2) intrinsic characteristics of soil (*i.e.*, inherent soil quality) and (3) those processes or properties that are affected by its use and management (*i.e.*, dynamic soil quality). The sustainable production depends on selecting land uses that are well suited to the capacity of the soil and maintaining soil conditions that minimize the risk of productivity decline (Larson and Pierce 1994).

The soil is the ultimate source for most of the essential plant nutrients and it varies in nutrient content because of wide variation in nature of the parent material and weathering conditions as well as land management and anthropogenic activities. In agricultural systems, soil fertility is maintained through application of manures, other organic materials, inorganic fertilizers, amendments such as lime or tank silt and inclusion of legumes in the cropping system. The fertility of soils has to be enhanced to match changes in land use from low value cereal crops to high value horticultural and commercial crops (Ramesh Kumar *et al.* 2005).

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Lack of adequate knowledge of the required amount and kind of fertilizer and method of application to a crop results in nutrient deficiency in soils (Malewar 2005). As a result, declining fertilizer use efficiency and increasing multi - nutrient deficiency have been observed after the green revolution leading to decline in land productivity (Swarup and Ganeshmurthy 1998; Sankaram and Prakash Rao 2002). Generally, intensive crop production and faulty land management aggravate decline in soil quality. Understanding these changes in soil quality needs temporal quantification of various physical and chemical properties (Karlen *et al.* 1997).

The aim of this paper is to analyze the changes in land use and management practices and their effect on soil quality in Rajanukunte watershed near Bangalore over the 22 years (1980 to 2002).

Materials and Methods

Location and Extent

Rajanukunte watershed falls in three villages namely Shanuboganahalli, Chokkanahalli and Adde Viswanathapura in Bangalore North taluk, Bangalore Rural District, Karnataka. It covers about 570 ha and lies between 13°10 ' to 13°11' N latitude and 77°32'to 77°33' E longitudes at 860 to 915 m above MSL.

Climate

The climate of the area is semi-arid tropical with mean annual rainfall of 870 mm in 42 rainy days, 476 mm from the southwest monsoon (June to September), 225 mm from the northeast monsoon (October to December), 169 mm in January to May. The mean annual temperature is 23.6^0 C and mean maximum and mean minimum temperatures are 33.4^{0}C and 15.0^0 C, respectively.

Monitoring soil quality parameters

The soil quality is measured as a baseline value or set of values against which future changes in the soil can be analysed and compared. The selection and quantification of properties used to assess soil quality is often based on their spatial and temporal variability, on their relevance to crop production, and on whether they can be controlled or managed in an appropriate time frame for annual crop production or long term sustainability (Gregorich 2006). A set of basic soil properties and characteristics (Table 1) has been proposed as indicators of soil quality. The advantage of a chronosequential approach is that we can compare measurable changes in soil physical and chemical properties (Webb *et al.* 2000; Hartemink 2006).

Land use and management practices

The land use pattern in the watershed was mapped in the years 1980 and 2002. Farm household survey was also undertaken for assessing land management, cropping pattern and crop rotation, and level of input use and yield.

Detailed soil survey

The detailed survey of soils in Rajanukunte watershed was taken up in the year 1980 and 2002. The watershed was traversed to confirm the location of the fields as shown on the cadastral map and to identify the physiographic units such as mounds, undulating pediment, uplands and valleys by means of visible breaks in slope and other topo-

Table 1. Some chemical properties of soils used as indicators of soil quality

Soil properties	Method	Information
Soil reaction	pH meter	Acidity or alkalinity of soil, nutrient availability
Organic carbon	Wet or dry combustion	Organic matter reserves, nutrient cycling, soil structure
Cation exchange capacity	Ammonium acetate method	Nutrient availability and clay type
Base saturation	Ammonium acetate extraction	Availability of nutrients

Table 2. Trends in the changes in land use in Rajanukunte watershed

Land use / land cover	1980 Area (ha)	2002 Area (ha)	Change (in ha)	
			Total	Annual change
Ragi	354.63	169.04	-185.59	-8.44
Paddy	1.6	5.56	3.96	0.18
Total food crops	356.23	174.6	-181.63	-8.26
Vegetables	37.16	12.19	-24.97	-1.14
Flowers	0	6.28	6.28	0.29
Guava	4.31	36.25	31.94	1.45
Grapes	4.42	73.68	69.26	3.15
Mango	1.46	0.11	-1.35	-0.06
Coconut	0	34.9	34.9	1.59
Banana	0	18.03	18.03	0.82
Total horticultural crops	47.35	181.44	134.09	6.1
Eucalyptus	63.08	51.33	-11.75	-0.53
Casurina	12.95	0	-12.95	-0.59
Total agro-forestry	76.03	51.33	-24.7	-2.37
Fallow land	28.51	10.85	-17.66	-0.8
Total cultivable land	508.12	418.21	-89.91	-4.09

graphic features. The soil profiles dug along the transects to a depth of 1.5 m or to the parent material were examined for morphological characteristics (AISLUS 1970). Soil samples were collected from the typifying pedon of soil series and analyzed for physical and chemical characteristics following standard procedures (Sarma *et al.* 1987). The soils were classified according to Soil Taxonomy (Soil Survey Staff 1999). The soil map was prepared by delineating the phases of soil series on a cadastral base of 1:8000 scale.

Results and Discussion

Land use changes in the watershed

In 22 years, significant changes in land use occurred. The total cultivated area in 1980 was 508 ha and in 2002 it has reduced to 418 ha (Table 2) and the rate of decline was 4.1 ha per annum. Among the crops, maximum decline was observed in food crops by 181. 6 ha followed by agroforestry (24.7 ha) and fallow-land (17. 7 ha). Among the food crops, the area under finger-millets has reduced from 354.6 ha to 169 ha at the rate of 8.44 ha annually. Similarly, casurina and eucalyptus area has reduced annually at the rate of 0.59 and 0.53 ha, respectively. The area under horticultural crops increased from 47.3 in 1980 to 181.4 in 2002 and net gain of 134 ha was recorded and annual increase was at the rate of 6.1 ha. Among the horticultural crops, grapes recorded the largest annual rate of increase (3.15 ha), followed by coconut (1.59 ha), guava (1.45 ha), banana (0.82 ha) and flowers (0.29 ha). However, the area under vegetables reduced from 37.2 to 12.2 ha. The decrease in area under food crops, agroforestry and common grazing land has been diverted to fruit crops and non-agricultural use.

Change in nutrient use pattern

In the Rajanukunte watershed, the nutrient application showed farmers preference for nitrogen over phospho-

Table 3. Changes in fertilizer consumption in Rajanukunte watershed

Crops	Average fertilizer consumption (kg ha^{-1})							
	1980				2002			
	Nitrogen	Phosphorous	Potash	NPK	Nitrogen	Phosphorous	Potash	NPK
Cereals	41.58	48.06	42.00	131.64	80.00	40.16	35.55	155.71
Fruits	193.74	175.25	164.16	533.15	378.95	270.08	200.96	849.99
Vegetables	59.65	75.58	54.82	190.06	84.41	84.62	40.03	209.05
Average	46.55	53.36	45.84	145.75	199.23	134.35	101.74	435.32

rous and potash. In 1980, the mean consumption of nitrogen, phosphorous and potash fertilizers was 47, 53 and 46 kg ha^{-1} and in 2002, it has increased to 199, 134 and 102 kg ha^{-1} with an increase of 328, 152 and 128 per cent respectively over 22 years (Table 3). In fruit crops, consumption of nitrogen, phosphorous and potash increased to 97, 54 and 22 per cent in 22 years besides increase in area. The higher use of nitrogen than recommended dose was observed and it may be due to its lower price and a general misconception among farmers that application of N fertilizer will result in immediate improvement in health of the crop. In 1980, the total consumption of nitrogen, phosphorous and potash fertilizer was 18.72, 21.46 and 18.43 tonnes and in 2002 it has increased to 64, 43 and 33 tonnes with an increase of 242, 101 and 77 per cent, respectively over 22 years. The total fertilizer (NPK) consumption in the watershed was 58 tonnes in 1980 and it increased to 140 tonnes in 2002 indicating an increase of 138 per cent.

Changes in soil quality

The significant changes were observed in soil pH, base saturation and organic carbon content. The details of decline in soil quality are as follows:

Soil pH

In majority of the soils, the pH has been reduced except in soil-4 and 10 over the period of 22 years (Table 4). During 1980, the soils of major area (290.10 ha) were neu-

Table 4. Spatial and temporal change (0-20 cm depth) in pH and BS in Rajanukunte watershed

Soils	**pH**			**BS**		
	1980	**2002**	**% Change**	**1980**	**2002**	**% Change**
Soil-1	5.80	5.10	-12.07	74	65	-12.50
Soil -2	6.20	5.10	-17.74	78	28	-64.16
Soil -3	7.1	6.00	-15.49	88	63	-28.57
Soil -4	6.50	7.10	9.23	107	61	-42.49
Soil -5	7.00	6.80	-2.86	107	86	-19.58
Soil -6	6.50	5.30	-18.46	89	73	-18.04
Soil -7	6.70	7.70	14.93	95	139	45.75
Soil -8	7.00	5.50	-21.43	98	87	-11.34
Soil -9	6.90	5.70	-17.39	97	77	-20.71
Soil -10	6.40	6.50	1.56	62	53	-13.56
Soil -11	7.60	7.20	-5.26	104	97	-6.52
Soil -12	7.30	6.10	-16.44	75	86	14.13

Table 5. Change in soil pH in Rajanukunte watershed

pH class	1980	Per cent	2002	Per cent
Strongly. acid (5.1 - 5.5)	0.00	0.0	160.24	38.3
Moderately acid (5.6-6.0)	35.96	7.1	47.68	11.4
Slightly acid(6.1-6.5)	88.95	17.5	79.64	19.0
Neutral (6.6-7.3)	290.10	57.0	99.63	23.8
Mildly alkaline (7.4-7.8)	3.21	0.6	31.03	7.4
Total area	418.22	82.2	418.22	100.0
Soil Organic Carbon				
Low(< 1 kg m^{-2})	43.75	10.5	56.53	13.5
Medium (1-2 kg m^{-2})	133.37	31.9	126.98	30.4
High (> 2 kg m^{-2})	241.10	57.7	234.71	56.1
Total area	418.22	100.0	418.22	100.0

tral, followed by slightly acid (88.95 ha), moderately acid (35.96 ha) and 3.21 ha was mildly alkaline. In 2002, strongly acid soils occupied largest area (160.24 ha), followed by neutral soils (99.63 ha), slightly acid (79.64 ha), moderately acid (47.68 ha) (Fig. 1a). The increase in area under strongly acid soils is because of change in land use from cereal to horticultural crops and high use of acid forming fertilizers like urea and diammonoium phosphate. The area under mildly alkaline soils increased from 3.21 ha in 1980 to 31 ha in 2002 (Fig 1b) in narrow valleys where the lands were intensively cultivated for vegetables and flowers under irrigated conditions. Basic cations from upper reach, leaches and deposit in the valleys, which in turn increased the pH. Similar finding were reported that soil pH increased over period of time due to change in management (Maity *et al.* 2006)

Soil base saturation

The data (Table 4) indicates that base saturation decreased in 2002 as compared to 1980 in majority of the soils. The per cent change was variable in different depths. However, greater reduction in base saturation was observed in surface layers.

Soil organic carbon

The soil organic carbon in 0-30 cm depth were grouped in to low (< 1 kg m^{-2}), medium (1-2 kg m^{-2}) and high (> 2 kg m^{-2}) classes. The organic carbon of the soils of the watershed did not show much change over the years (Table 5). The increase in area under low organic carbon might be due to intensive cultivation.

Crop production constraints

The nutritional constraints in soils of the watershed are low availability of Ca, Mg and P where as the availability of Fe, Mn, Cu and Zn is high. Out of the total geographical area of 562 ha in Rajanukunte watershed, 51 per cent (287 ha) is affected by soil acidity. Out of the area under acid soils, 56 per cent of the area is under strongly acid soils and requires urgent attention. The other constraints in the upland acid soils are coarse texture, surface crusting and low organic matter contents. The low water holding capacity is also a common feature of these soils. Further, depletion in seed germination and crop establishment are of concern due to crust formation. The other chemical constraints include nutrient depletion, CEC and low base saturation. These problems may be managed by liming (Panda *et al.* 1982; Mishra *et al.* 1989; Sahu *et al.* 1990 ; Mishra 2004)

Cost of correcting soil acidity

The usually adopted means of amelioration of soils

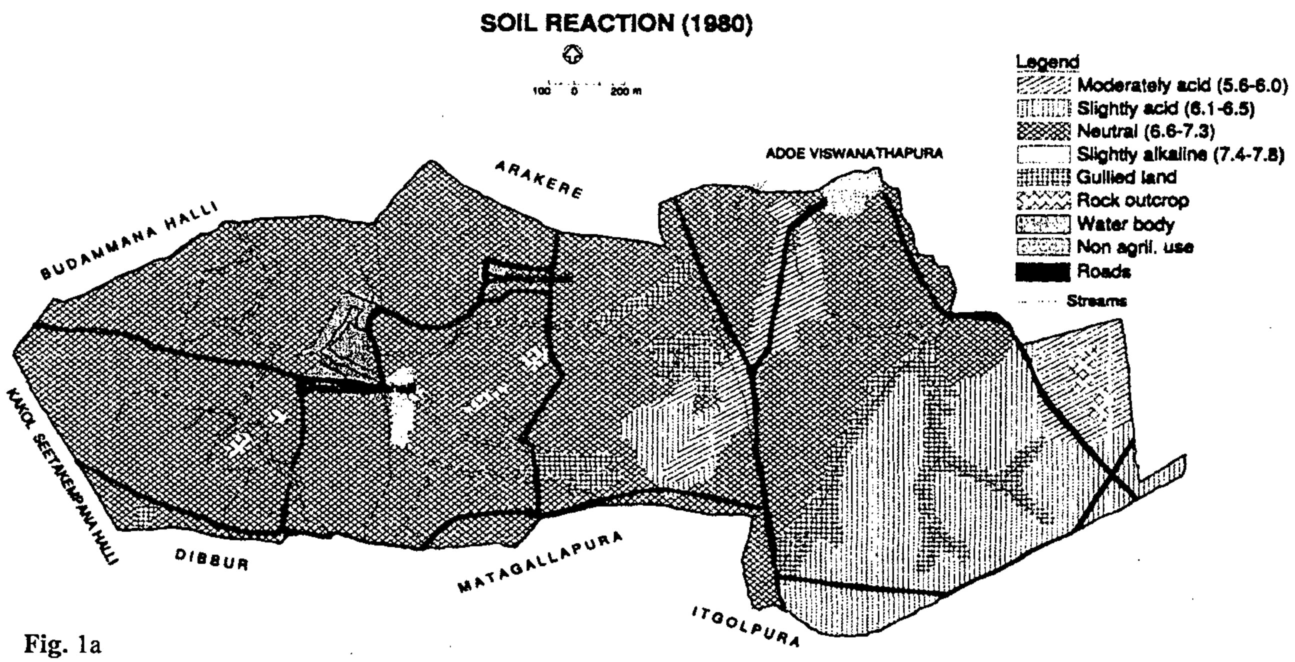

Fig. 1a

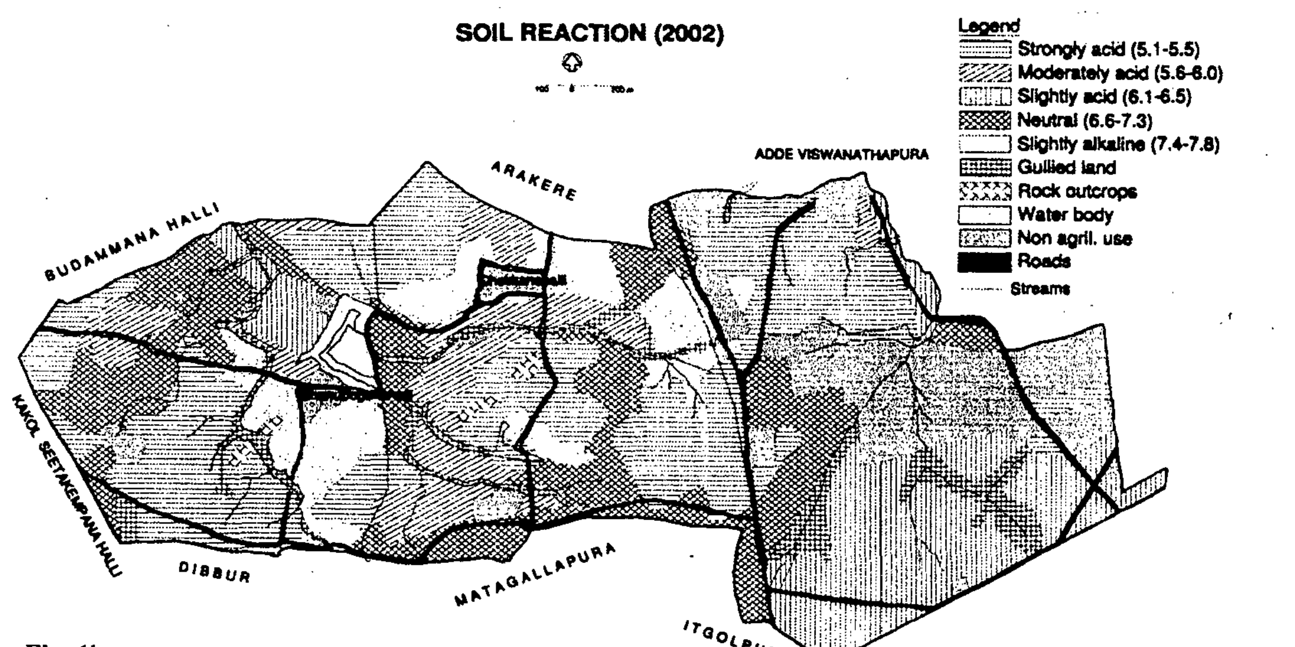

Fig. 1b

Fig. 1 (a & b) Change in Soil Reaction in Rajanukunte Watershed

Table 6. Estimated cost for lime amendment for acid soils in Rajanukunte watershed

pH class	Area (ha)	(Total lime requirement)	Total Cost (Rs.)	Cost Per ha
Strongly acid (5.1 - 5.5)	160.24	84927	161362	1007
Medium acid (5.6-6.0)	47.68	14304	27178	570
Slightly acid (6.1-6.5)	79.64	15928	30263	380
Total	288	115159	218802	761

acidity is through liming. Among the naturally occurring lime sources, calcite, dolomite and stromatolitic limestones are important. In Rajanukunte watershed, about 160 ha is under strongly acid, 48 ha under moderately acidic and 80 ha is under slightly acid soils. The per ha recommended dose of lime for different acidity level and total requirement for correcting soil acidity was estimated based on recommendation made by University of Agricultural Sciences, Bangalore.

The recommended lime requirement for strongly acid, moderately acid and slightly acid soils was 530, 300 and 200 kg ha^{-1}, respectively. The cost of soil amendment per ha ranged from a maximum of Rs 1007 ha^{-1} for strongly acid soil to a minimum of Rs. 380 ha^{-1} for slightly acid soils. For Rajanukunte watershed, about 1,15,159 kg of agricultural grade lime is required which costs about Rs. 2,18,802. However, the average soil amendment cost worked out to Rs 761/- ha^{-1} (Table 6).

The change in land use and management greatly affects the soil quality. The present study indicated that the area under cereals, agroforestry have been shifted to perennial horticultural fruit crop like grape, guava and banana. With increased application of fertilzer lead to acidification of soils, decrease in base saturation and organic carbon over 22 years. Thus, it is concluded that due to change in land use and management the soil quality declined significantly and require immediate correction measures like lime application and soil and water conservation measures including proper crop rotations to arrest the further degradation.

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