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Assessment of Soil Fertility Status of Appanahalli Sub Watershed of Gubbi Taluk, Karnataka

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Authors Contribution

Sayantika Bhattacharya : Carried out the experiment, drafted the manuscript and performed the statistical analysis;
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Abstract

A study was conducted to assess the fertility status of soils in Appanahalli sub water shed of Gubbi taluk, Karnataka. A total of six micro watersheds under Appnahalli sub watershed with three major landforms *viz*., undulating upland or Ridge, Midland and Valley under Ragi cropping system were selected. At 300 m grid interval, 180 representative soil samples were collected at 0-20 cm and 20-40 cm depth during the year 2020. Results of study indicated that soil reaction of Appanahalli sub watershed was very acidic to moderately alkaline in nature (4.99 to 8.13) with the mean value of 6.50. The highest mean pH value was observed in Singadahalli micro watershed (6.86). Among the three major landforms studied, pH values in lowland were better than midland and upland physiography. The soils of sub-watershed were non saline and ranged from 0.02 dSm^{-1} to 0.48 dSm^{-1} in all the micro watersheds. Soil pH and EC were increased with depth. Soil Organic carbon (SOC) content was ranged from 0.13 to 0.78 per cent with a mean value of 0.50 per cent. Haradagere micro watershed recorded highest organic carbon with a mean value 0.58 per cent. However, the values of available N ranged from 123.15 kg ha^{-1} to 345.61 kg ha^{-1}. The highest average (46.04 and 279.44 kg ha^{-1}) available P_2O_5 and K_2O was recorded in Singadahalli and Galigkere-3 micro watershed, respectively. Available Fe, Mn, Cu, Zn and microbial biomass carbon and nitrogen contents were found in sufficiency range in surface soils of all micro watersheds. Soil organic carbon, available N, P, K, Fe, Mn, Cu and Zn contents were higher in surface soils and valley portion of watershed. Nutrient availability in a soil is governed by its pH and better nutrient availability can be expected only at neutral soil reaction. Hence, proper and adequate measures like amelioration of soil acidity/alkalinity need to be adopted for bringing the soils to favourable soil reactions to a better fertility and productivity conditions.

Keywords : Watersheds, Soil fertility status, Available nutrients

Land resources of the country are its most precious and sacred endowment. Land and water are the most important natural resources which play a vital role in agricultural development. But the land is continuously under threat of degradation through various erosional activities. As per the desertification and land degradation atlas of India (2015-2018), 96.4 million hectares *i.e.,* 29.32 per cent of the total geographical area of the country and approximately 6.35 per cent of land in Karnataka is undergoing the process of desertification / land degradation. As per the special report on climate change and land of Intergovernmental panel for climate change released during August, 2019, land use change, land-use intensification and climate change have contributed to desertification and land degradation. The soil productivity and sustainability of soil depends on dynamic equilibrium among its physical, chemical and

biological properties (Ahmed *et al.,* 2012).

Therefore, an imperative stage has come where suitable soil and water conservation measures on watershed basis are immediately warranted to reduce soil erosion, restore land productivity and improve the socio-economic status of the area. With the general acceptance of watershed as the principal unit of planning, many developmental activities based on suitable utilization of locally available natural resources need to be taken which requires detailed characterization of natural resources (Manchanda *et al.,* 2002). Soil resource mapping by using geos patial techniques, identification of constraints/ potentials, delineation of erosion-prone areas is pre-requisite for suggesting conservation measures (Surya *et al.,* 2008) and several studies reported potential use of remote sensing for characterization and management of land resources at watershed level (Srinivasa *et al.,* 2008).

Intensive cultivation practices without giving adequate consideration to quality of land resources are noted with ending up in numerous problems like yield stagnation, nutrient mining/depletion and soil degradation. Majumdar *et al.* (2016) quoting evidences from experiments opined that it is a much costlier affair to restore fertility status of a soil denuded of its native fertility through external fertilizer application. Maintenance of food security in a sustainable manner strongly demands management and conservation of land / soil resources by up keeping its quality in a fertile state. In this context, a study namely 'Assessment of soil fertility status of Appanahalli sub watershed of Gubbi taluk, Karnataka' was conducted to know the fertility status of soils of Appanahalli sub watershed.

Material and Methods

Study Area

Appanahalli sub-watershed is located in central Karnataka plateau with hot, moist, semi-arid eco sub region, Southern plateau and hill region which belongs to the sub region 8.2 of Karnataka. The sub-watershed (Gubbi taluk, Tumkuru district) is located in between $13^0$29' 36.94" and $13^0$25'48.015" North latitude and $76^0$43'27.767" and $76^0$48'58.762" East longitudes covering an area of 3484 ha bounded by Anantapur on the north, Kolar and Bangalore on the east, Mandya on south, Hassan and Chitradurga on west. This sub watershed consists of 6 micro watersheds- a) Singadahalli, b) Galigerkere-1, c) Galigerkere-2, d) Galigerkere-3, e) Haradagere-2 and f) Appanahalli-1. The area receives an average annual rainfall of 679.1-888.9 mm, 50 per cent of which is received mainly during kharif season. The elevation of the sub-watershed is 800-900 m above mean sea level. The relief of the study area is very gently sloping to gently sloping, where very gently sloping land covers an area of 1956 ha (56.2%) and gently sloping land occupy 820 ha (23.5%) area. The major crop cultivated in the watershed is Ragi.

Soil Sampling and Analysis

Considering the uniformity of soil sample distribution in the study area, soil samples were collected from 6 micro watersheds under 3 major landforms (ridge, midland and valley) having ragi based cropping system from 5 farmers plot after harvest. The soil samples were collected at a depth of 0-20 cm and 20-40 cm having approximate grid interval of 300 meters. A total of 180 samples (90 surface and 90 subsurface) were collected from all three major land forms. In the laboratory, the soil samples were air dried under shade and were grounded with a wooden pestle and mortar and passed through 2 mm sieve to separate coarse fragments (> 2 mm). For estimation of chemical properties, a small quantity of 2 mm sieved soil sample was passed through 80 mesh sieves after fine grinding the sample in agate pestle and mortar. The processed soil samples were stored in plastic bags and used for various analysis.

Chemical Analysis of the Soils

Soil samples collected were analysed for its chemical properties using standard procedures. Soil pH was measured in water at 1:2.5 soil : water ratio as per the method outlined by Jackson (1973). Electrical conductivity (EC) was measured in 1:2.5 soil : water ratio. Soil organic carbon (OC) was determined by

wet digestion method as described by Walkley and Black (1934). Available N, P, K were determined by alkaline potassium permanganate (Subbiah and Asija, 1956), Bray's-1 extraction (Bray and Kurtz, 1945) and Olsen method, neutral ammonium acetate (Jackson, 1973) method respectively. Soil micronutrients were extracted by DTPA at pH 7.3 using 1 : 2 soil : solution ratio as outlined by Lindsay and Norvell (1978). The extractable Fe, Mn, Cu and Zn were estimated by atomic absorption spectrometer.

Results and Discussion

Chemical Properties of Soils under different Landforms

Soil Reaction and Electrical Conductivity

Analytical results revealed that pH of Appanahalli sub watershed is very acidic to moderately alkaline in nature (4.99 to 8.13) with a mean value of 6.50. The highest mean value of pH was observed in Singadahalli micro watershed (6.86) followed by Galigkere-3 (6.47) and the lowest mean value was observed in Haradagere micro watershed (6.21) (Table 1). Among the three major landforms studied, pH values in lowland were better than midland and upland physiography. The soils of sub-watershed were non saline and ranged from 0.02 dSm^{-1} to 0.48 dSm^{-1} with a mean value of 0.16 dSm^{-1} (Table 1). In all the micro watersheds, Soil pH and EC of soil increased with depth. This might be due to accumulation of leached bases in the lower horizons. The surface soil accumulated more bases and salts due to their fineness and associated poor drainage conditions owing to low rainfall received in these areas. Thangasamy *et al.* (2005) reported that the variation in soil pH is associated with parent material, rainfall and topography. Pillai and Natarajan (2004) also reported similar low EC values indicating the non-saline nature of soils of Garakahalli watershed.

Organic Carbon

Organic carbon (OC) content of Appanahlli sub watershed ranged from 0.13 to 0.78 per cent with a mean value of 0.50 per cent. In Haradagere micro watershed highest OC was recorded with a mean value 0.58 per cent (Table 1). Organic carbon content was noticed higher in the surface soils compared to that of sub-surface soils for all the studied watersheds. Rajeshwar *et al.* (2009) in a similar study reported that higher values of organic carbon on the surface can be attributed to the addition of farmyard manure and plant residues to surface horizons. This finding is in agreement with findings of Chibsa and Taa (2009), in which they reported that the SOC decrease with increasing soil depth, with more accumulation on the upper surface soil layer. The surface samples of the study area ranged from low to high but most of the samples recorded medium organic carbon content and this may be due to the favourable arid / semi-arid climatic conditions prevailing in these sites for a higher decomposition of the organic matter.

Available Nitrogen

The available nitrogen (N) content of soils of Appanahalli sub watershed varied from low to medium (123.15 to 345.61 kg ha^{-1}) with a mean value of 228.00 kg ha^{-1} (Table 2). In accordance with studies conducted by Chikkaramappa *et al.* (2021) and Sathish *et al.* (2018), low organic matter content in these areas could be due to low rainfall and high temperature which facilitate faster degradation and removal of organic matter led to nitrogen deficiency. Similar nitrogen status was observed by Krishna *et al.* (2017) in Arjunagi sub-watershed under northern dry zone of Karnataka. Their concentration was high on the surface layers compared to sub-surface for all the micro watersheds. Among the three different landforms, available nitrogen content was highest in lowland or valley and least amount was recorded in ridges. This is related to loss of nutrients due to erosion and runoff from upper land of watershed and their deposition in the lowland of watershed. Higher nitrogen value on the surface soils might be due to the high organic carbon content and also external application of fertilizers (Satish Kumar and Naidu, 2012).

Available Phosphorous

The available phosphorous content in the soils of sub watershed ranged from 10.12 to 78.34 kg ha^{-1} with a mean value of 33.81 kg ha^{-1} (Table 2). Available

TABLE 1

Chemical properties of soils under different landforms of Appanahalli sub watershed of Tumkur district

Watershed	Depth (Cm)	Sample no	pH			EC (dS m^{-1})			OC (g/kg)		
			V	M	R	V	M	R	V	M	R
Appanahalli	0-20	1	6.59	6.63	5.87	0.15	0.16	0.17	3.00	4.20	3.50
		2	7.65	6.29	7.97	0.18	0.10	0.10	6.60	7.70	3.70
		3	7.79	6.33	6.44	0.16	0.13	0.17	2.70	6.60	6.70
		4	7.22	6.14	6.31	0.15	0.09	0.16	3.30	5.10	2.90
		5	6.49	6.38	6.26	0.15	0.14	0.09	6.40	2.30	7.00
	20-40	1	6.73	6.65	5.93	0.17	0.18	0.19	2.70	4.00	3.10
		2	7.80	6.33	7.41	0.23	0.12	0.11	6.10	7.50	3.60
		3	7.82	6.37	6.50	0.18	0.15	0.19	2.50	6.40	6.10
		4	7.23	6.30	6.36	0.20	0.10	0.20	3.10	4.40	2.40
		5	6.53	6.42	6.30	0.17	0.16	0.11	5.90	2.10	6.50
	Range			5.87-7.97			0.09-0.23			2.10-7.70	
	Mean			6.70			0.15			4.60	
Galigkere-1	0-20	1	7.08	5.34	6.04	0.12	0.07	0.07	6.00	7.10	2.80
		2	7.13	6.58	6.11	0.04	0.17	0.05	6.40	3.70	6.20
		3	6.85	6.03	5.52	0.09	0.14	0.11	7.80	6.30	4.90
		4	6.72	6.22	6.16	0.12	0.12	0.04	6.80	5.60	2.40
		5	7.23	6.35	5.77	0.11	0.05	0.09	6.70	4.10	3.30
	20-40	1	7.13	5.42	6.11	0.15	0.11	0.11	4.60	6.80	2.10
		2	7.20	6.65	6.14	0.07	0.19	0.08	5.90	3.30	5.60
		3	7.02	6.16	5.71	0.12	0.16	0.13	7.50	5.80	4.40
		4	6.84	6.29	6.19	0.14	0.15	0.06	6.30	5.20	2.10
		5	7.50	6.42	5.85	0.15	0.09	0.12	6.20	3.30	2.60
	Range			5.34-7.50			0.04-0.19			2.10-7.80	
	Mean			6.39			0.11			5.10	
Galigkere-2	0-20	1	7.18	5.55	6.12	0.15	0.07	0.10	3.90	6.90	2.70
		2	7.37	6.33	6.33	0.10	0.15	0.09	7.20	3.80	4.90
		3	5.42	5.87	6.18	0.11	0.17	0.13	7.10	5.70	5.00
		4	6.39	6.18	6.06	0.14	0.11	0.15	6.30	5.10	4.60
		5	7.41	5.90	6.98	0.13	0.05	0.03	7.00	3.30	3.10
	20-40	1	7.18	5.55	6.12	0.15	0.07	0.10	3.30	6.10	1.90
		2	7.37	6.33	6.33	0.10	0.15	0.09	6.50	3.40	4.40
		3	5.42	5.87	6.18	0.11	0.17	0.13	5.80	4.90	4.30
		4	6.39	6.18	6.06	0.14	0.11	0.15	5.70	4.30	4.10
		5	7.41	5.90	6.98	0.13	0.05	0.03	6.40	2.60	1.90
	Range			5.42-7.41			0.03-0.17			1.90-7.20	
	Mean			6.35			0.11			4.70	
Galigkere-3	0-20	1	6.72	7.43	5.59	0.19	0.31	0.07	5.50	4.20	2.80
		2	7.33	6.41	6.11	0.18	0.26	0.10	6.10	3.80	3.30
		3	7.13	6.02	5.18	0.28	0.08	0.038	4.90	3.10	1.90
		4	8.02	6.19	5.83	0.43	0.17	0.12	7.60	4.40	2.40
		5	7.16	6.31	4.99	0.26	0.12	0.07	6.80	4.00	1.60

Watershed	Depth (Cm)	Sample no	pH			EC (dS m^{-1})			OC (g/kg)		
			V	M	R	V	M	R	V	M	R
	20-40	1	6.90	7.68	5.63	0.21	0.32	0.09	5.20	4.10	2.60
		2	7.41	6.45	6.14	0.19	0.28	0.12	5.70	3.60	3.10
		3	7.19	6.19	5.21	0.31	0.11	0.05	4.80	2.70	1.80
		4	8.13	6.27	5.87	0.45	0.21	0.16	7.10	4.10	2.20
		5	7.21	6.35	5.04	0.28	0.14	0.11	6.60	3.90	1.30
	Range			4.99-8.13			0.038-0.45			1.30-7.60	
	Mean			6.47			0.19			4.00	
Haradagere	0-20	1	6.87	6.06	5.31	0.09	0.09	0.08	4.60	6.80	7.10
		2	7.13	6.08	5.23	0.21	0.02	0.04	7.00	6.70	1.80
		3	7.29	6.15	5.14	0.36	0.13	0.10	6.90	7.00	6.60
		4	7.13	6.22	5.05	0.11	0.04	0.07	4.05	7.40	5.80
		5	7.10	5.81	5.11	0.22	0.05	0.12	6.60	6.60	6.60
	20-40	1	7.02	6.29	5.44	0.11	0.17	0.11	4.30	6.50	6.80
		2	7.39	6.30	5.32	0.27	0.09	0.07	4.000	6.60	1.60
		3	7.45	6.39	5.29	0.48	0.16	0.10	6.20	5.00	6.50
		4	7.26	6.35	5.26	0.17	0.07	0.11	3.80	7.10	5.50
		5	7.70	5.98	5.17	0.27	0.09	0.16	6.40	6.40	6.30
	Range			5.05-7.7			0.02-0.48			1.60-7.40	
	Mean			6.21			0.14			5.80	
Singadahalli	0-20	1	7.83	6.21	5.53	0.34	0.33	0.13	3.40	7.00	5.70
		2	7.89	7.39	7.57	0.27	0.28	0.25	7.00	5.10	3.10
		3	6.78	6.33	5.87	0.36	0.14	0.17	7.70	6.50	6.60
		4	6.88	6.41	5.91	0.31	0.19	0.07	6.20	5.70	6.90
		5	7.54	7.79	6.01	0.26	0.26	0.09	5.40	6.60	4.00
	20-40	1	7.91	6.26	5.80	0.37	0.37	0.15	2.80	4.00	5.20
		2	7.95	7.65	7.65	0.30	0.32	0.28	6.50	4.50	2.60
		3	7.01	6.51	5.97	0.37	0.16	0.19	7.20	6.30	6.20
		4	6.98	6.45	6.01	0.35	0.21	0.10	5.80	5.50	6.30
		5	7.65	7.95	6.08	0.30	0.30	0.11	5.10	5.90	3.20
	Range			5.53-7.95			0.07-0.37			2.60-7.70	
	Mean			6.86			0.24			5.50	
APPANAHALLI	Range			4.99-8.13			0.02-0.48			1.30-7.80	
	Mean			6.50			0.16			5.00	

V=Valley, M=Midland, R=Ridge

phosphorus status of Appanahalli, Galigkere-1, Galigkere-2 and Galigkere-3 micro watershed areas was low to medium. This might be due to variation in soil properties like clay content, CEC and P fixation capacity. In addition to this, it was observed that the farmers were using only DAP as the source of nutrients in adequate quantity. Haradagere and Singadahalli watershed recorded exceptionally high amount of available phosphorus due to heavy use of complex fertilizers. Application of excess dosage without having knowledge of the crop requirement and soil fertility status might have led to slight increase in the availability of phosphorous and also variations in available P_2O_5 content in soils were related with the intensity of soil weathering or soil disturbance, the degree of P-fixation and continuous application of mineral Phosphorous fertilizer sources as indicated by Satish *et al.* (2018). Available phosphorus content was higher in surface soil than subsurface soils and their content were more in valley of watershed when

TABLE 2

Available macro nutrient status of soils under different landforms of Appanhalli sub watershed of Tumkur district

Watershed	Depth (Cm)	Sample no	Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})			Available K_2O (kg ha^{-1})		
			V	M	R	V	M	R	V	M	R
Appanahalli	0-20	1	282	205.23	249	19.12	15.89	14.24	153.7	148.5	183.43
		2	193.23	260.1	161.17	11.78	19.12	13.77	330.19	234.1	143.12
		3	260.7	230.87	196.1	11.66	17.1	14.26	179.98	155.64	197.23
		4	171.09	220.19	134.1	18.02	14.98	27.12	160.02	140.12	177.16
		5	206.76	247.17	271.66	16.09	13	55.98	145.76	171.98	168.54
	20-40	1	280.09	201.12	243.5	17.86	13.45	13.65	151.76	141.76	181.13
		2	185.77	249.87	150.19	10.12	18.87	11.34	325.67	230.12	140.65
		3	245.12	222.98	192.45	11.43	15.65	12.76	177.12	148.98	195.78
		4	166.23	213.56	127.56	17.79	13.29	26.98	154.52	136.15	170.12
		5	200.78	241.54	255.19	14.99	12.13	50.16	140.98	166.18	166.23
	Range		127.56-282.12			10.12-55.98			136.15-330.19		
	Mean		215.51			18.09			177.22		
Galigkere-1	0-20	1	213.43	231.12	185.67	12.34	51.67	49.18	185.12	202.43	140.09
		2	132.87	265.76	323.97	43.97	12.65	19.77	201.32	185.23	142.33
		3	150.32	176.34	224.5	32.88	20.77	29.02	110.86	189.12	127.88
		4	156.13	185.76	178.96	47.01	18.02	35.91	281.12	151.12	133.45
		5	156.78	151.43	145.67	15.98	20.88	43.12	156.98	143.87	157.81
	20-40	1	209.87	229.98	179.86	12.19	51.19	49.07	176.65	193.4	131.6
		2	125.76	261.99	318.23	42.19	12.34	19.68	191.23	168.9	135.2
		3	141.23	169.87	221.34	32.65	20.68	28.83	100.04	174.65	116.8
		4	153.42	175.99	172.65	46.92	18.01	35.67	272.43	145.9	128.41
		5	151.88	143.21	138.23	15.53	20.76	43.02	151.6	133.5	154.21
	Range		125.76-323.97			12.19-51.67			100.04-281.12		
	Mean		189.07			30.06			162.77		
Galigkere-2	0-20	1	205.76	250.2	181.9	11.89	55.87	51.12	189.5	211.3	150.12
		2	131.6	267.8	323.4	45.71	12.08	19.89	212.43	182.3	142.32
		3	155.12	171.56	212.16	34.67	22.09	30.12	119.12	193.32	129.65
		4	155.87	181.23	220.52	48.02	19.12	28.92	285.65	155.76	147.46
		5	150.88	156.12	145.6	17.54	20.98	45.65	167.2	145.6	361.43
	20-40	1	198.16	246.87	176.98	11.76	55.14	50.02	177.98	201.32	145.98
		2	123.43	260.09	318.98	44.65	11.78	19.21	210.12	176.98	139.12
		3	149.32	165.43	217.98	33.98	21.9	30.09	111.34	186.78	120.09
		4	151.77	178.65	213.94	47.09	18.85	28.44	282.73	151.43	139.92
		5	145.67	151.18	141.54	17.21	20.33	45.12	164.14	139.23	356.99
	Range		123.43-323.40			11.76-55.87			111.34-361.43		
	Mean		191.65			30.64			183.24		
Galigkere-3	0-20	1	345.6	231.19	189.5	45.57	44.93	25.53	367.2	350	195.6
		2	342.15	241.87	231	57.19	50.04	24.65	394.8	320.4	169.6
		3	265.3	234.66	212.98	45.95	42.89	17.87	347.6	357.6	153.36
		4	285.6	271.14	224.17	58.21	40.12	18.38	386.4	291.6	100.8
		5	278.5	285.65	204.65	41.39	43.29	14.3	357.6	278.4	163.41

Watershed	Depth (Cm)	Sample no	pH			EC (dS m^{-1})			OC (g/kg)		
			V	M	R	V	M	R	V	M	R
	20-40	1	341.65	224.98	182.43	45.21	44.78	25.31	361.23	344.23	191.32
		2	335.78	235.15	224.13	57.02	49.97	24.19	390.18	313.98	164.89
		3	260.23	227.32	216.24	45.48	42.75	17.78	342.78	352.97	147.12
		4	279.87	264.18	220.13	58.12	40.03	18.32	381.12	276.96	97.65
		5	272.31	280.19	193.24	41.23	43.16	14.12	352.64	272.9	158.74
	Range		182.43-345.60			14.12-58.21			97.65-394.8		
	Mean		253.39			37.93			279.44		
Haradagere	0-20	1	282.34	161.78	345.61	65.01	26.89	31.14	265.78	211.14	230.9
		2	290.12	314.65	320.98	73.99	29.15	29.01	191.17	229.87	213.4
		3	256.17	245.65	275.67	64.86	38.41	20.43	350.98	145.6	119.87
		4	265.78	224.32	140.12	69.12	40.02	26.18	275.68	167.8	295.7
		5	284.6	193.6	211.34	27.72	29.12	33.41	367.87	312.43	181.3
	20-40	1	275.43	156.98	340.04	64.87	26.16	30.98	262.43	201.65	222.65
		2	284.5	208.87	325.76	73.32	28.83	28.65	187.65	224.14	211.2
		3	253.87	241.7	271.8	64.16	38.04	20.14	343.7	141.98	109.8
		4	261.43	219.67	123.15	69.03	39.93	25.77	270.13	160.5	291.13
		5	280.09	187.56	201.87	27.22	27.86	33.05	263.8	301.07	176.87
	Range		123.15-345.61			20.14-73.99			109.8-367.87		
	Mean		248.18			40.08			230.94		
Singadahalli	0-20	1	225.12	280.01	220.09	36.65	17.36	38.21	237.12	330.4	161.87
		2	340.09	221.32	225.43	51.98	39.04	38.78	290.02	241.56	177.87
		3	319.12	281.76	281.3	42.65	78.34	33.12	275.43	231.43	181.98
		4	298.87	272.54	265.76	51.87	74.23	20.01	370.4	225.77	185.01
		5	321.77	323.14	215.98	59.02	77.06	39.43	321.5	240.98	121.32
	20-40	1	218.9	276.18	215.43	36.14	16.88	37.97	265.42	323.5	156.78
		2	331.23	215.98	220.12	49.83	38.54	38.18	287.13	235.17	170.16
		3	312.98	275.67	275.54	40.12	78.01	32.76	270.09	227.98	176.98
		4	294.56	268.43	260.13	48.98	74.02	19.12	265.43	221.32	181.13
		5	317.34	319.23	211.76	58.24	76.66	38.01	319.23	232.19	115.98
	Range		211.76-340.09			16.88-78.34			115.98-370.4		
	Mean		270.19			46.04			234.71		
APPANAHALLI	Range		123.15-345.61			10.12-78.34			97.65-394.8		
	Mean		228.00			33.81			211.39		

V = ValleyM= MidlandR = Ridge

compared to upland.

Available Potassium

Available potassium content of Appanahalli sub-watershed varied from 97.65 to 394.8 kg ha^{-1} with a mean value of 211.39 kg ha^{-1} (Table 2). In all the six micro watersheds low to medium status of available potassium was recorded with the highest average value of 279.43 kg ha^{-1} in Galigkere-3 micro-watershed. Red soils have lesser fine fractions, in addition, kaolinite types of clay minerals are the causes for medium and low rating of available K_2O. Application of organic manures to soil which contains various organic acids might have aided in release of non-exchangeable K to water soluble forms and the results were in accordance with Chitra and Janaki (1999). available potassium content was higher in surface soil than subsurface soils and their content were more in

TABLE 3

Available micro nutrient status in soils of Appanahalli sub watershed of Tumkur district

Watershed	Depth (Cm)	Sample no	Fe (mg kg^{-1})			Mn (mg kg^{-1})			Cu (mg kg^{-1})			Zn (mg kg^{-1})		
			V	M	R	V	M	R	V	M	R	V	M	R
Appanahalli	0-20	1	17.54	7.65	8.98	9.37	10.6	12.33	1.1	1.6	1.18	3.06	1.6	0.66
		2	20.76	10.43	5.22	10.67	20.18	9.5	1.22	1.9	1.38	0.5	1.65	0.85
		3	21.33	17.23	10.75	11.64	12.33	14.5	1.15	0.78	0.61	0.63	0.48	0.76
		4	7	14.45	14.79	11.3	6.5	12.76	1.1	0.7	1.03	1.1	0.5	0.8
		5	5.72	11.32	6.93	9.66	11.49	6.99	1.29	1.32	2.56	0.82	0.56	1.12
	20-40	1	16.89	7.45	8.77	9.35	10.4	12.31	0.98	1.41	1.15	2.96	1.34	0.63
		2	20.73	10.38	5.12	10.54	20.14	9.2	1.16	1.65	1.31	0.32	1.59	0.81
		3	21.13	17.14	10.56	11.56	12.28	13.98	1.1	0.71	0.57	0.49	0.44	0.72
		4	5.98	14.38	14.67	11.19	6.21	11.78	0.77	0.67	1.01	1.05	0.41	0.77
		5	5.66	10.79	6.85	9.63	11.42	6.85	1.15	1.27	2.48	0.76	0.52	1.11
	Range			5.12-21.33			6.21-20.18			0.57-2.56			0.32-3.06	
	Mean			11.89			11.22			1.21			0.97	
Galigkere-1	0-20	1	1.78	10.03	12.21	3.41	3.04	5.21	0.31	0.14	0.28	0.15	0.21	0.28
		2	11.72	2.12	11.84	11.82	1.95	6.93	0.55	0.54	0.51	1.47	0.19	0.61
		3	13.52	4.17	2.55	11.85	3.49	2.11	0.38	0.11	0.39	0.41	0.16	0.72
		4	6.18	13.12	2.98	15.39	2.63	4.85	0.26	0.18	0.43	0.23	0.24	0.56
		5	12.86	4.55	4.74	15.89	9.36	5.26	0.55	0.44	0.15	0.36	0.14	0.22
	20-40	1	1.76	10.01	12.18	3.39	3.01	5.19	0.29	0.11	0.26	0.12	0.18	0.25
		2	11.69	2.02	11.81	11.81	1.92	6.91	0.51	0.52	0.49	1.45	0.17	0.58
		3	13.51	3.99	2.49	11.82	3.47	2.02	0.33	0.08	0.35	0.38	0.12	0.7
		4	6.13	13.05	2.94	15.36	2.62	4.81	0.19	0.15	0.39	0.22	0.21	0.54
		5	12.84	4.51	4.72	15.86	9.33	5.18	0.51	0.41	0.12	0.31	0.13	0.17
	Range			1.76-13.52			1.92-15.89			0.08-0.55			0.12-1.47	
	Mean			7.60			6.86			0.33			0.38	
Galigkere-2	0-20	1	1.75	10.09	13.41	3.32	3.01	5.23	0.32	0.18	0.29	0.16	0.23	0.32
		2	11.65	2.07	11.87	11.89	1.97	6.89	0.55	0.55	0.55	1.5	0.24	0.8
		3	13.66	4.12	2.52	11.85	3.49	2.06	0.4	0.12	0.48	0.43	0.14	0.81
		4	6.23	13.25	10.23	16.02	2.6	3.14	0.23	0.18	0.39	0.31	0.27	0.78
		5	13.17	4.68	4.68	16.89	9.31	5.23	0.42	0.3	0.18	0.38	0.21	0.36
	20-40	1	1.71	9.98	13.35	3.28	3	5.21	0.28	0.14	0.25	0.15	0.21	0.26
		2	11.52	2.02	11.81	11.85	1.92	6.83	0.51	0.51	0.51	0.13	0.22	0.5
		3	13.47	4.05	2.46	11.81	3.47	2.01	0.38	0.11	0.44	0.38	0.11	0.79
		4	6.21	13.19	10.19	15.93	2.43	3.05	0.21	0.15	0.37	0.26	0.23	0.74
		5	13.12	4.66	4.62	16.78	9.14	5.13	0.38	0.26	0.15	0.31	0.17	0.33
	Range			1.71-13.66			1.92-16.89			0.11-0.55			0.11-1.5	
	Mean			8.19			6.82			0.33			0.39	

Watershed	Depth (Cm)	Sample no	Fe (mg kg^{-1})			Mn (mg kg^{-1})			Cu (mg kg^{-1})			Zn (mg kg^{-1})		
			V	M	R	V	M	R	V	M	R	V	M	R
Galigkere-3	0-20	1	6.46	5.63	5.13	20.86	13.6	5.27	2.81	1.14	0.75	1.15	0.67	0.34
		2	6.36	4.38	3.52	20.22	17.4	3.44	2.25	1.29	0.34	1.64	0.58	0.29
		3	6.48	5.16	2.73	13.84	13.38	5.15	1.96	1.33	0.54	1.3	0.77	0.19
		4	6.08	4.67	2.6	16.8	8.26	2.68	2.37	0.98	1.02	2.01	0.81	0.45
		5	5.86	4.83	2.83	14.28	7.99	1.69	1.63	1.19	0.19	0.82	1.03	0.67
	20-40	1	6.32	5.58	5.06	20.81	13.25	5.52	2.75	1.04	0.72	1.04	0.65	0.29
		2	6.28	4.27	3.35	20.13	17.13	3.28	2.18	1.21	0.28	1.59	0.51	0.21
		3	6.44	5.02	2.66	13.65	13.29	5.03	1.88	1.19	0.53	1.21	0.73	0.11
		4	5.98	4.48	2.45	16.65	8.04	2.61	2.28	0.04	1	1.95	0.73	0.39
		5	5.78	4.77	2.71	14.19	7.83	1.55	1.56	1.03	0.17	0.77	1.01	0.64
	Range			2.45-6.48			1.55-20.86			0.04-2.81			0.11-2.01	
	Mean			4.80			10.93			1.25			0.82	
Haradagere	0-20	1	8.5	13.41	22.87	5.26	5.56	11.16	2.07	1.42	7.63	2.08	0.9	3.23
		2	12.38	16.19	25.67	6.45	7.34	12.78	1.85	1.7	4.12	1.17	0.5	0.94
		3	12.17	29.66	22.89	7.15	2.45	10.44	2.41	0.78	2.1	1.27	0.36	0.49
		4	5.28	23.01	18.45	7.1	4.66	1.76	1.4	2.6	1.7	2.11	0.54	0.78
		5	16.17	21.75	16.55	7.04	10.32	8.32	5.53	1.67	1.61	0.93	0.58	0.65
	20-40	1	8.3	13.29	22.76	5.24	5.53	11.14	2.02	1.41	7.59	2.05	0.7	3.21
		2	12.16	16.12	25.46	6.34	7.31	12.75	1.82	1.5	4.08	1.14	0.2	0.91
		3	12.08	29.61	22.76	7.03	2.42	10.41	2.38	0.76	1.6	1.24	0.34	0.44
		4	5.26	22.98	18.33	6.89	4.64	1.74	1.1	2.4	1.4	2.06	0.51	0.75
		5	16.12	21.56	16.43	6.99	10.27	8.3	5.49	1.65	1.56	0.89	0.55	0.63
	Range			5.26-29.66			1.74-12.78			0.76-7.63			0.2-3.23	
	Mean			17.61			7.16			2.52			1.07	
Singadahalli	0-20	1	2.56	4.21	5.89	2.76	13.59	17.89	1.01	1.1	1.02	0.36	0.58	0.6
		2	3.65	1.89	2.65	4.73	5.49	3.29	1.91	1.01	0.6	1.01	1.79	0.49
		3	2.8	2.75	4.48	4.01	15.28	10.49	1.03	0.47	0.56	1.23	0.41	1.29
		4	2.78	4.2	5.49	8.4	13.19	22.4	1.5	0.58	0.71	0.8	1.23	0.65
		5	4.4	3.59	6.37	4.77	4.01	20.29	1.28	1.64	0.93	0.55	3.01	0.76
	20-40	1	2.51	4.17	5.87	2.74	13.48	17.83	0.98	0.8	0.97	0.33	0.55	0.42
		2	3.6	1.85	2.62	4.68	5.44	3.23	1.85	0.78	0.42	0.88	1.72	0.43
		3	2.62	2.73	4.44	3.99	15.21	10.46	1.01	0.42	0.51	1.18	0.33	1.25
		4	2.74	4.17	5.47	8.2	13.08	22.12	1.32	0.56	0.67	0.6	1.21	0.61
		5	4.1	3.55	6.32	4.71	3.99	20.14	1.19	1.61	0.88	0.53	2.88	0.74
	Range			1.85-6.37			2.74-22.4			0.42-1.91			0.33-3.01	
	Mean			3.81			9.99			0.97			0.94	
Appanahalli	Range			1.71-29.66			1.55-22.4			0.04-7.63			0.11-3.23	
	Mean			8.98			8.83			1.10			0.76	

V = Valley, M= Midland, R = Ridge

TABLE 4

Status of soil microbial biomass carbon and nitrogen in soils of Appanahalli sub watershed of Tumkur district

Watershed	Depth (Cm)	Sample no	SMBC (µg g^{-1})			SMBN (µg g^{-1})		
			V	M	R	V	M	R
Appanahalli	0-20	1	556.70	476.42	390.00	64.51	53.21	39.02
		2	495.70	425.70	156.20	56.01	49.67	18.22
		3	524.53	425.60	286.51	61.20	49.65	32.54
		4	320.19	305.06	108.90	34.71	35.12	12.71
		5	505.90	407.20	445.02	59.02	45.25	52.15
	Range		305.06-556.70	12.71-64.51				
	Mean		388.64	44.19				
Galigkere-1	0-20	1	527.81	482.13	365.18	62.13	52.81	35.84
		2	518.98	416.98	287.23	60.08	49.87	32.67
		3	488.19	420.81	141.13	55.02	49.63	17.83
		4	239.89	365.18	129.32	31.16	32.41	14.31
		5	423.15	333.54	165.42	49.63	30.08	20.19
	Range		129.32-527.81	14.31-62.13				
	Mean		353.66	39.57				
Galigkere-2	0-20	1	445.02	356.71	285.12	52.15	37.57	32.06
		2	157.92	425.70	505.90	19.53	49.67	59.02
		3	205.00.	284.50	325.60	22.55	31.96	36.01
		4	215.00	300.84	300.84	25.13	34.21	34.21
		5	195.06	220.00	108.90	24.01	27.00	12.71
	Range		108.9-505.9	12.71-59.02				
	Mean		288.80	33.18				
Galigkere-3	0-20	1	497.70	300.84	157.92	57.01	34.21	19.53
		2	556.67	280.50	125.00	64.51	32.03	17.51
		3	505.90	290.06	106.80	59.02	32.15	12.46
		4	519.23	476.42	170.60	62.32	53.21	19.60
		5	480.12	268.80	171.57	54.28	31.36	20.02
	Range		106.80-556.67	12.46-64.51				
	Mean		327.20	37.94				
Haradagere	0-20	1	524.53	213.45	567.99	61.20	24.90	66.27
		2	505.90	586.23	476.98	59.02	68.39	55.64
		3	515.24	476.98	312.45	60.11	66.64	36.45
		4	498.76	432.69	215.60	58.19	50.48	25.15
		5	556.78	129.87	345.98	64.96	15.15	40.36
	Range		129.87-586.23	15.15-68.39				
	Mean		423.96	50.19				

Watershed	Depth (Cm)	Sample no	SMBC (µg g^{-1})			SMBN (µg g^{-1})		
			V	M	R	V	M	R
Singadahalli	0-20	1	495.70	586.23	324.15	56.01	68.39	35.61
		2	556.70	407.20	321.05	64.51	45.25	34.98
		3	505.90	524.53	325.60	59.02	61.20	36.01
		4	524.53	241.77	320.19	61.20	28.21	34.71
		5	476.42	356.71	305.06	53.21	37.57	35.12
	Range		241.77-586.23	28.21-68.39				
	Mean		418.11	47.40				
Appanahalli	Range		106.80-586.23	12.46-68.39				
	Mean		366.73	42.08				

V = Valley, M = Midland, R= Ridge

lowland or valley of watershed when compared to upland.

Available Micronutrients

Available Fe, Mn, Cu and Zn content in the soil of Appanahalli sub-watershed ranged from 1.36-29.66 mg kg^{-1}, 1.55-22.4 mg kg^{-1}, 0.04-7.63 mg kg^{-1} and 0.11 to 3.23 mg kg^{-1}, respectively (Table 3). Available Fe, Mn, Cu and Zn were in sufficiency range for surface soils of all micro watersheds. The availability of micronutrients content was higher on the surface soils with increase in organic matter because organic matter acts as a chelating agent for complexation of these micronutrients, which reduces their adsorption, oxidation and precipitation into unavailable forms (Mahesh Kumar *et al.,* 2011). Due to higher microbial activity in the surface soil Mn content were also observed sufficient range in the study area. Results were in line with the findings of Murthy *et al.* (1997). Srikanth *et al*. (2008) reported higher available manganese content in soils originated from granite gneiss parent material with semi-arid climate. The content of Zn increases with high organic carbon content but decreases with increase in pH. Since, some of the grid points show alkaline soil reaction, low in OC and dominated by $CaCO_3$, zinc may be precipitated as hydroxides and carbonates and as a result, their solubility and mobility might have decreased and reduced the availability. Similar results were reported by Patil *et al.* (2019).

Soil Microbial Biomass Carbon and Nitrogen

In Appanahalli sub watershed, microbial biomass carbon and nitrogen ranged from 106.8 to 586.23 µg g^{-1} and 12.46 to 68.29 µg g^{-1}, respectively (Table 4). Haradagere micro watershed recorded highest microbial biomass carbon and nitrogen with a mean value of 423.96 and 50.19 µg g^{-1}, respectively among all six micro watersheds. Valley portion of watershed has higher microbial biomass carbon and nitrogen than ridge because of nutrient enrichment in valley portion, in particular, carbon and nitrogen. Crops in intercropping, crop rotation and various cropping systems possess unique exudate deposition near its roots. These organic and inorganic substances contribute key nutrients to microbial community. This interpretation is in accordance with the study of Duchene *et al.* (2017).

A thorough understanding on the fertility status of soil is essential for planning of better management for the resource. It is evident from the results that soils of Appanahalli sub watershed were very acidic to moderately alkaline in nature. Among the three major landforms studied, pH values in lowland were better than midland and upland physiography. The soils of sub-watershed were non saline. In all the micro watersheds, soil pH and EC of soil increased with depth. The higher SOC and available N was observed on the surface soil layer and it is decreasing with increasing soil depth. The available P_2O_5 and K_2O

contents were low to medium in Appanahalli sub watershed. Available Fe, Mn, Cu, Zn and soil microbial biomass carbon and nitrogen were in sufficiency range for surface soils of all micro watersheds. The availability of micronutrients was increased on the surface soils with increase in organic matter. Since nutrients are expected to be available at a favourable soil reaction, proper and adequate measures like amelioration of soil acidity / alkalinity need to be adopted for bringing these soils to a better fertility and productivity conditions. Balanced fertilization and correcting soil reaction while maintaining soil health is a key to soil quality and thereby sustainable crop production.

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