Original Research Article

Land resources inventory of Central Dry Agro-climatic Zone of Karnataka- A case study from in Gollarahatti-2 micro-watershed employing geo-spatial techniques

Abstract:

Detailed land resource inventory (1:7920 scale) was carried out in Gollarahatti-2 micro-watershed located in Jagalur taluk of Davanagere district, Karnataka using geo-spatial techniques. Based on the landform and physiographic units, the Gollarahatti-2 micro-watershed soils were categorized into eleven soil series and twenty two soil phases and mapping units and all the typifying soil pedons representing the study area were sampled. Morphological, Physical, Chemical and Physico-chemical properties of the identified soils were characterized under field and laboratory conditions and the soils were classified into family level as per USDA soil taxonomy. The soils were very shallow or shallow and deep, reddish brown (5 YR4/4 to very husky red (2.5YR2.5/2), slightly acidic to alkaline and non-saline. The texture of the soil was varied into sandy clay, clay loam and clay. The organic carbon ranged between low to medium. Further, the soils have high base saturation. Pedon 11 had higher exchangeable sodium percentages in sub soil layers. The differentiated soils were grouped under 11 soil series mapped into 22 mapping units and classified into Lithic Ustorhents, Typic Haplustepts, Typic Rhodustalfs, Kanhaplic Rhodustalfs and Rhodic Kanhaplustalfs at sub group level as per USDA soil taxonomy.

Key words: Land resource inventory, Soil classification, Geo-spatial techniques, Land form, Physiographic units and soil series

Introduction

In the recent years land resources are under pressure due to degradation of soil and water, which play an important role in human as well as plant life. Soil as a medium, supports the plant growth through supply of essential nutrients and man in-turn depends on plant for food. Soil is a dynamic natural resource developed over a period of thousands of years by weathering of arable lands because of growing population, and competing demands of the various land uses. Indiscriminate use of land resources, in general, leads to their degradation and in-turn decline in productivity. Degradation of land resources happening at an alarming rate minimizes productivity and stability of production. Self-sufficiency and food security are the biggest tasks for most populous nation like India. They need to be used according to their capacity to satisfy the needs of its inhabitants. This can be achieved through proper inventory of land resources and their scientific evaluation. Soil survey provides a valuable resource inventory connected with the survival of life on earth. It provides an accurate and scientific inventory of different soils, their kind and nature and extent of distribution so that one can make prediction about their limitations and potentialities. It also provides adequate information in terms of land form, slope, land use as well as characteristics of soils *viz.*, texture, depth, structure, stoniness, drainage, acidity, salinity *etc.*, which can be utilized for the planning and development. Information of soil and related properties obtained from the soil survey and soil classification can help in better delineation of soil and land suitability for irrigation and efficient irrigation water management. So, depending on the suitability of the mapped agro-ecological units for a set of crops, optimum cropping patterns have to be suggested taking into consideration the present cropping systems and the socio-economic conditions of the farming community (Sehgal *et al.,* 1996). Integrated management of land resources is the best way to solve the present day challenges. Therefore the knowledge of soil and land resources with respect to their spatial distribution, characteristics, potentials, limitations and their suitability for alternate land use helps in formulating strategies to obtain higher productivity on sustained basis. This calls for systematic and reliable inventory of natural resources like soil, water, land use, *etc*., at a quicker pace through scientific and modern tools like remote sensing and geographic information system (GIS). Satellite remote sensing data provides information on geology, geomorphology, soil and land use or land cover through systematic appraisal following the synoptic and multispectral coverage of a terrain and the information generated can be interpreted for various themes *viz*., land capability, land irrigability and crop suitability *etc.* for better management and conservation of resources on watershed basis. Keeping these facts in view, the detailed soil survey of Gollarahatti-2 micro-watershed, Jagalur taluk, Davanagere district representing Central Dry Zone of Karnataka state was carried out with the objective of characterization and classification of Gollarahatti-2 micro-watershed, Jagalur taluk, Davanagere district**,** using remote sensing and GIS techniques.

Material and methods

The study area is Gollarahatti-2 micro-watershed in Jagalur taluk, Davanagere district, Karnataka and falls under central dry zone (zone no-04) of Karnataka and agro ecological sub region of 8.2 (AESR), which receives its major annual rainfall during *kharif* season (June-September). The length of growing period is 120-150 days. The major crops growing are Ragi, Maize, Ground nut and cotton etc. Red soils occupy major portion of the area. The study area located at 50 km from Davanagere district. It covers an area of 719 ha, lies between 13° 23' 42" and 31° 25' 39" N latitudes and 77° 33' 36.8"and 77° 33' 54.3"E longitudes. The elevation is in the range of 575 m to 687 m MSL. The dominant geology of the study area is Archean schist with small patches of granite gneiss. Neem, Pongamia, *Mimosa pudica* and grasses are the major natural vegetation apart from forest species. Detailed soil survey was carried out by using 1:7920 (scale) cadastral map, Google Earth Image and high resolution satellite imagery of the watershed were used as base map in conjunction with Survey of India toposheet to map the land resources. Physiography soil relationship was established using ground truth data by using satellite imagery of the Gollarahatti-2 micro-watershed. Pedon sites were located in transects along the slope from the upper to lower slopes. Totally in this micro-watershed, 25 profiles were exposed and studied for morphological characteristics as per Soil Survey Manual (Soil Survey Staff, 2014). The representative 11 master profiles of typifying pedons of series identified were selected. Horizon-wise soil samples were collected, air dried and passed through 2 mm sieve and analyzed for particle-size distribution following International Pipette method (Richards, 1954), pH and electrical conductivity (EC) in 1:2.5 soil: water suspension (Piper, 1966). Organic carbon was estimated by Walkley and Black (1934) method. The cation exchange capacity (CEC) and exchangeable cations were determined as described by Jackson (1973). The soils were classified following the USDA system of soil classification (Soil Survey Staff, 2014).

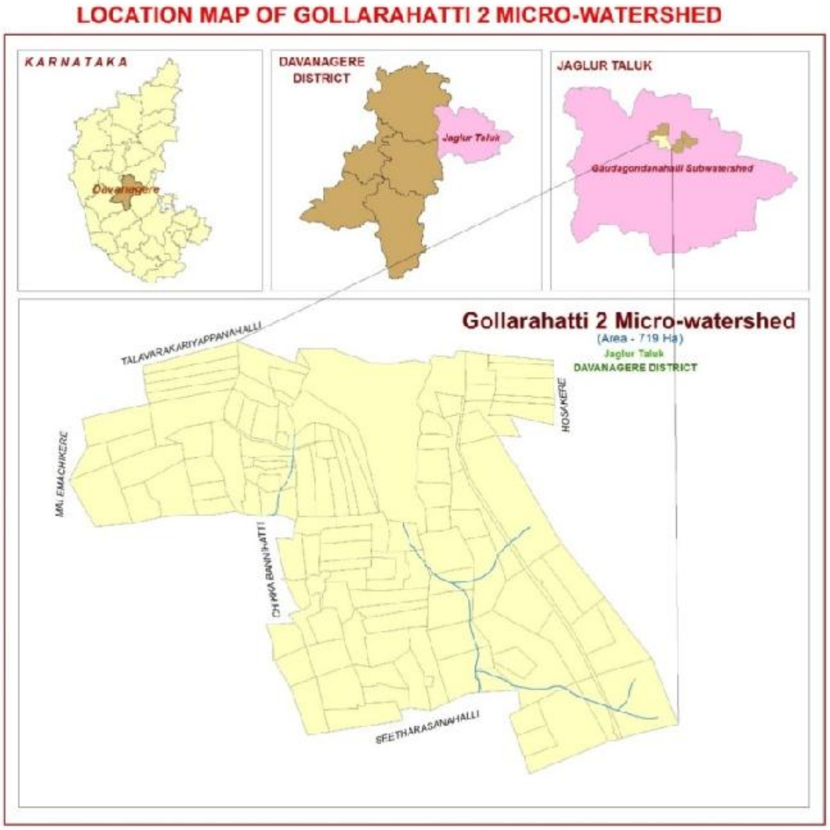

Fig. 1: Location map of study area

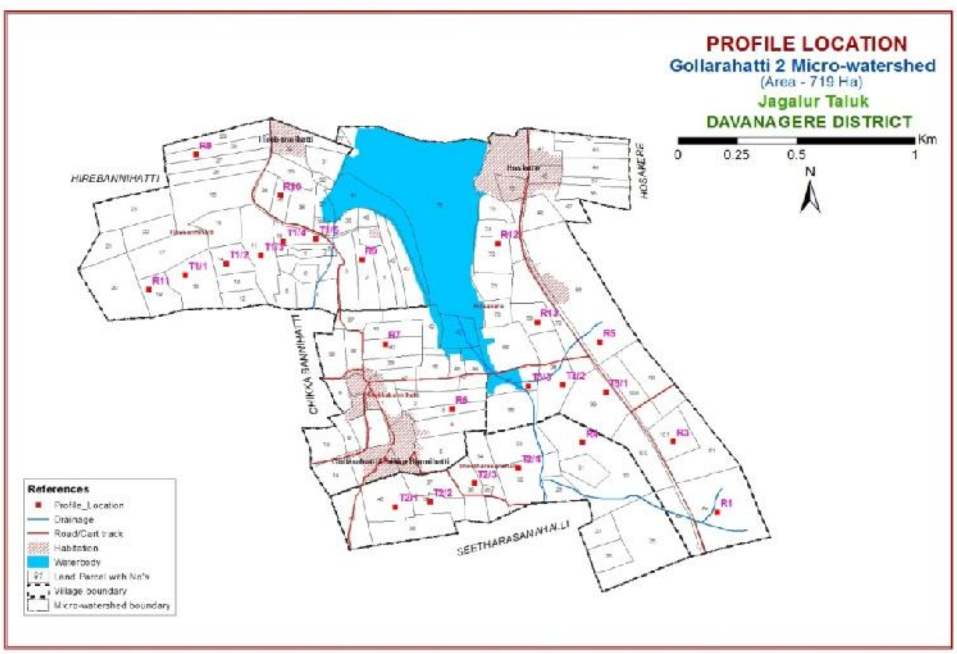

Fig. 2: Cadastral map with profile location of Gollarahatti -2 Micro Watershed, showing plot numbers and soil profile locations.

Results and discussion

Morphological properties

The study area have a combination of moderately shallow (3) or shallow/very shallow soils (3) and deep (3) or moderately deep (2) soils. The pedons 6, 8, 9, 10 and 11 were in deep category, remaining all pedons (pedons 1 to 5 & 7) were in shallow group. The depth resulted shallow soils in uplands and deeper soils in lowland physiographic units. The depth of pedons were varied because of manifestation of topography. Similar observations were made by Vinay (2007) in Bhanapur micro-watershed of Koppal. The variation of depth in relation to physiography, mainly because of non-availability of adequate amount of water for prolonged period on upland soils associated with removal of finer particles and their deposition at lower pediplain. The results obtained in the present study are in agreement with the findings of Ramprakash and Rao (2002). In all soil pedons, hue was 2.5YR-5YR. This colour hue was due to dominance of sesquioxides over silica. The darker colour values in the surface horizons (2.5-3) than sub-surface horizon (2.5-4) was due to the presence of relatively high organic matter content (Tripathi *et al.*, 2006). The sub-surface horizons had comparatively brighter colour chroma (3-6) against 3-4 of surface, which might be due to low organic matter content and higher iron oxide there. The results obtained in the present study are in agreement with the findings of Sidhu *et al.* (1994). This variation in colour is a function of chemical and mineralogical composition, topographic position, textural makeup and moisture regimes of the soils. The results of the were in accordance with the findings of Thangaswamy *et al.* (2005), who also indicated the gradation in the colour from higher topographic position to the lower topographic units. The structure was sub-angular blocky in surface and sub-surface horizons. The consistency was slightly hard to hard when dry and friable to firm when moist.

Soil physical properties

The clay content in different pedons in surface horizon ranged from 26.9 to 69.7 per cent. The sub-surface horizons exhibited higher clay content as compared to surface horizons due to the illuviation process occurring during soil development. Similarly, the illuviation process also affected the vertical distribution of silt and sand content. Similar observations were made by Dasog and Patil (2011) in soils of North Karnataka. Silt content ranged from 10.2 to 43.6 per cent. It exhibited an irregular trend with depth. This might be due to variation in weathering of parent material. These results were in agreement with the findings of Naidu and Hunsigi (2001), who observed an irregular trend in silt content with depth in sugarcane growing soils of Karnataka. Similar results were also reported by Kumar *et al.* (2002). Sand content varied from 10.2 to 54.8 per cent it was more in the surface compared to sub-surface horizons. The sand content is much higher than the silt and clay fractions. The coarser fractions dominate in silicaceous, granite-gneiss parent material (Dutta *et al.*, 1999). The texture of pedons varied from clay, clay loam, sandy clay loam to sandy clay. The texture was clay loam because of lesser mobilization and translocation of finer fractions. Similar findings were reported by Pulakeshi *et al.* (2014). The major area of red soil pedons varied between sandy clay and sandy clay loam. Water holding capacity of various pedons ranged from 36.5 to 63.1 per cent. Irrespective of the pedons, the water holding capacity of sub-soil was higher than surface soil. These differences were due to the variation in clay and organic carbon content of the pedons. Similar results were reported by Singh *et al.* (1999) in soils of Ramganga catchment in Uttar Pradesh and Thangasamy *et al.* (2005) in soils of Sivagiri micro-watershed in Chittoor district of Andhra

Pradesh. Bulk density of the pedon samples varied from 1.22 to 1.41 Mg m^{-3} (Table 1), followed a common pattern of increasing with increasing depth. It was attributed to the pressure of the overlying horizons and diminishing amounts of organic matter. Similar results were quoted by Marathe *et al.* (2003) in mandarin orchards of Nagpur and in rice soils of Eastern region of Varanasi (Singh and Agrawal, 2005).

Soil chemical properties

The pH of red soil pedons ranged from slightly acidic to neutral and alkaline. Iron hydroxide species might have contributed for higher H^+ concentration leading to lower pH values. Similar observations were made by Dasog and Patil (2011) and Satyanarayana and Biswas (1970). In soils of all the pedons, EC ranged from 0.03 to 0.98 dS m^{-1} indicating non-saline nature of soils. These soils did not show any specific relationship with depth. This may be due to free drainage conditions, which removed the released bases by percolation or by drainage water. These results were in confirmation with the findings of Kumar (2011) and Shivasankaran *et al.* (1993). Organic carbon content in surface horizons ranged from 0.34 to 0.72 per cent and in sub-surface horizon it varied from 0.11 to 0.6 per cent. The lower contents of organic carbon apparently resulted because of high temperature, which induced rapid rate of organic matter oxidation, while the declining trend towards accumulation of crop residues every year, without substantial downward movement. These observations are line with the-findings of Balpande *et al.* (2007). Similar results were reported by Basavaraju *et al.* (2005) in soils of Chandragiri mandal of Chittoor district in Andhra Pradesh. The exchangeable bases in all the pedons were in order of Ca^{+2}> Mg^{+2}> Na^+> K^+ on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it is evident that Ca^{+2} shows the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K^+ and Na^+) it was clear that Mg^{+2} was present in low amount than Ca^{+2}.

These results were in conformity with findings of Sharma (1996). The low value of exchangeable monovalents as compared to divalents was due to preferential adsorption of divalents than monovlent. These findings were in accordance with the reports of Das and Roy (1979). Cation exchange capacity of the pedons varied both location-wise and depth-wise. The values of cation exchange capacity of soils increased with profile depths and followed the trend of clay content. Similar findings have been reported by Mruthunjaya and Kenchanagowda (1993) and Shadaksharappa *et al.* (1995) in Vanivilas command and Malaprabha command area, respectively. There was a high degree of correlation between clay and CEC in red soils. The ESP ranged from 0.06 to 13.2 percent indicated initiation of the process of sodification in a downward direction. A measure of relative amounts of exchangeable sodium in comparison with the total cations in the soil are dependent on factors such as type of minerals, concentration of electrolytes and status of soluble cations (Sehgal, 1996). The findings were in accordance with the works of Srinath (1979) and Pulakeshi (2010).

The soils in the Gollarahatti-2 micro-watershed were highly base saturated. The base saturation was high in all surface horizons. In most of the soils, the base saturation increased with the depth. The increase of base saturation with the depth is due to the downward movement of bases along with percolating water from the upper horizon to the lower horizons. Similar results were found by Sitanggang *et al.* (2006) (Table 2).

Soil taxonomy

Based on morphological characteristics of the pedons, physical, chemical characteristics (Challa, 2000) eleven pedons from the study area were classified into order, suborder, great group and sub-group. Pedons 2, 3, 4, 5, 6, 7, 8 and 9 have argillic sub-surface horizon and do not have plaggan epipedon and spodic or oxic sub-surface horizons above the argillic horizon. Further, the argillic horizon was developed due to clay illuvation and was identified by the presence of clay cutans and the thickness of the horizon is more than 7.5 cm and also more than one-tenth as thick as the sum of the thickness of all the overlying horizons. The base saturation was more than 35 per cent throughout the depth of the argillic horizon. Hence, Pedons 2, 3, 4, 5, 6, 7, 8 and 9 are keyed out as Alfisol at order level. Pedon 1 is classified into Entisols owing to root restricting layer within 25 cm and no diagnostic horizons either on surface or subsurface. Pedons 10 and 11 are classified into Inceptisols due to the absence of any other diagnostic horizons other than colour or texture altered cambic horizon. As the moisture regime is Ustic, Pedons 2, 3, 4, 5, 6, 7, 8 and 9 were classified as Ustalfs at sub-order level. Pedon 1 classified at sub-order level as Orthents as they are better drained than Aquents, non-fluviatile. Pedon 10 and 11were classified as Ustepts. Pedon 5 did not have either Duripan or Calcic horizon and the base saturation was more than 60 per cent at a depth between 0.2 to 0.7 m from the soil surface. These characters indicated that these pedons confirmed to the central concept of Ustalfs. So, this pedon grouped under Haplustalfs at great group level. Similarly, the pedons 10 and 11 were keyed out as Haplustepts, as they do not have Duripan, Kandic and Petrocalcic horizons. Pedon 2, 3, 5, 6, 7, 8, 9 keyed out as Rhodustalfs at great group level as they have within upper 100 cm or the entire argillic horizon more than 50 per cent 2.5YR or redder, and values (moist) ≤ 3 and dry values are no more than 1 unit higher than moist values. Pedon 1 classified as Ustorthonts as they have Ustic moisture regime. At the sub-group level, pedon 5 do not exhibit inter-gradation with other taxa or an extra-gradation from the central concept, hence keyed out as Typic Haplustalfs. Pedons 2, 6, 7, 9 keyed out as Typic Rhodustalfs. Pedon 10 and 11 as Typic Haplustepts, Whereas pedon 1 was classified as Lithic Usterthents due to lithic contact within 100 cm of mineral soil surface. Pedon 3 and 8 were classified as Kanhaplic Rhodustalfs, owing to a lower

CEC per kg clay of less than 24 cmol(p+) kg^{-1} in the argillic horizon. Pedon 4 as Rhodic Kanhaplustalfs, owing to the presence of kandic horizon with very low CEC per kg clay of less than 24 cmol (p+) kg^{-1} in the argillic horizon. CEC per kg clay of less than 16 cmol (p+) kg^{-1} in the kandic horizon with a hue redder than or equal to 2.5 YR in at least half of the depth of kandic horizon (Soil Survey Staff, 2014).

Conclusions

Gollarahatti-2 micro-watershed soils are grouped under eleven soil series and they were characterized and mapped into 22 mapping unis. These soils come under Entisol, Inceptisol, and Alfisol soil orders. Based on base saturation, organic carbon content and clay content of the soil, the soils of the study area are classified as Lithic Ustorhents, Typic Haplustepts, Typic Rhodustalfs, Kanhaplic Rhodustalfs, Rhodic Kanhaplustalfs at sub-group level. The major crops cultivated in this watershed are in the order of short duration and rainfed in a combination of pulse crop adjusting monsoon, main cereal or millet crop, followed by a very short duration oil seed crop (sesamum, ground nut or mustard) or coriander, utilizing the residual moisture and all based on rainfall probability. The climate is highly responsible for the crop selection. Since, the probable length of growing period is 120-150 days, the farmers can go for deep ploughing before first showers, harrowing to keep land ready to receive and accept water reaching through rainfall and to provide crops, two subsequent short duration crops (Maize, sorghum, Ragi) to reap higher economic benefits.

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Table 1: Physical properties of Gollarahatti-2 micro-watershed pedons

Horizon	Depth (cm)	Colour	Coarse sand (2-0.25 mm)	Fine sand (0.25-0.05 mm)	Total sand (2.0-0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)	Texture	B.D Mg m^{-3}	WHC (%)
			-------------------------%----------------------							
	Pedon 1									
Ap	0-21	5 YR 3/4	31.30	14.40	45.70	16.60	37.70	sc	1.34	39.88
	Pedon 2									
Ap	0-15	2.5 YR 2.5/4	37.60	12.10	49.70	16.60	33.70	sc	1.31	36.14
Bt1	15-30	2.5 YR 2.5/4	24.25	16.75	44.00	22.02	33.98	cl	1.35	51.00
Bt2	30-41	2.5 YR 2.5/4	32.25	9.50	41.75	23.75	34.50	cl	1.39	53.02
BC	41-50	2.5 YR 2.5/4	32.50	9.25	41.75	21.75	36.50	cl	1.41	52.16
	Pedon 3									
Ap	0-15	5 YR 3/4	37.10	12.60	49.70	12.50	37.80	sc	1.31	39.88
Bt	15-32	2.5 YR 2.5/4	12.75	21.50	34.25	22.50	43.00	c	1.34	56.33
BC	32-50	2.5 YR 2.5/4	23.20	11.30	34.50	24.65	41.10	c	1.36	59.18
	Pedon 4									
Ap	0-22	2.5 YR 2.5/4	38.20	15.60	53.80	10.40	35.80	sc	1.26	37.27
Bt1	22-32	2.5 YR 2.5/2	22.50	16.50	39.00	25.00	36.00	cl	1.32	39.76
Bt2	32-47	2.5 YR 3/6	22.50	15.40	37.90	22.60	39.50	cl	1.35	52.15
Bt3	47-60	2.5 YR 2.5/3	26.26	10.15	36.40	22.46	41.14	cl	1.36	55.45
BC	60-74	2.5 YR 3/4	25.50	10.50	36.00	23.50	40.50	cl	1.36	53.02
Pedon 5										

Ap	0-19	5 YR 3/4	25.50	18.75	44.25	26.00	29.75	scl	1.31	33.63
Bt1	19-38	5 YR 4/4	8.82	11.75	20.57	43.23	36.20	cl	1.34	58.18
Bt2	38-54	5 YR 3/2	28.09	8.31	19.40	42.48	38.12	cl	1.36	57.51
Pedon 6										
Ap	0-24	2.5 YR 2.5/3	21.43	18.57	43.00	27.50	29.50	scl	1.27	35.24
Bt1	24-34	2.5 YR 3/6	13.75	10.50	24.25	16.25	59.50	c	1.28	59.20
Bt2	34-51	2.5 YR 2.5/4	8.75	5.75	14.50	16.75	68.75	c	1.34	61.52
Bt3	51-69	2.5 YR 2.5/4	8.75	5.25	14.00	17.25	68.75	c	1.34	62.76
BC	69-81	2.5 YR 3/4	7.75	6.25	14.00	16.28	69.72	c	1.35	63.15
Pedon 7										
Ap	0-22	2.5 YR 3/4	34.4	11.20	45.60	18.70	35.70	sc	1.22	51.96
Bt1	22-48	2.5 YR 2.5/2	6.00	12.50	18.50	23.25	58.25	c	1.29	39.09
Bt2	48-60	2.5 YR 2.5/3	5.75	6.25	12.00	18.25	69.75	c	1.34	61.52
BC	60-74	2.5 YR 2.5/3	6.00	7.61	13.61	33.00	53.39	c	1.38	62.76
Pedon 8										
Ap	0-20	2.5 YR 3/4	39.20	15.60	54.80	18.30	26.90	scl	1.26	31.02
Bt1	20-47	2.5 YR 4/6	12.10	13.77	25.87	31.79	42.34	c	1.31	57.24
Bt2	47-66	2.5 YR 2.5/3	5.87	8.74	14.61	32.06	53.33	c	1.33	60.67
Bt3	66-76	2.5 YR 2.5/4	14.09	7.52	21.61	33.32	45.07	c	1.35	56.79
Pedon 9										
Ap	0-17	2.5 YR 2.5/4	27.75	18.75	46.50	26.15	27.35	scl	1.30	33.56
Bt1	17-32	2.5 YR 2.5/4	27.50	17.00	44.50	27.25	28.25	scl	1.28	36.53
Bt2	32-55	2.5 YR 2.5/4	28.50	16.50	45.00	24.25	30.75	scl	1.31	36.98
Bt3	55-80	2.5 YR 2.5/4	38.20	15.60	53.80	10.40	35.80	sc	1.31	37.28

Bt4	80-104	2.5 YR 3/6	27.75	17.25	45.00	28.75	36.25	cl	1.33	50.13
Pedon 10										
Ap	0-30	5 YR 3/3	37.00	15.80	52.80	12.10	35.10	sc	1.29	35.47
Bw1	30-70	5 YR 3/3	22.50	17.50	40.00	24.50	35.50	cl	1.32	51.00
Bw2	70-87	5 YR 3/3	21.50	17.00	38.50	25.25	36.25	cl	1.32	55.02
Bw3	87-107	5 YR 3/3	29.50	9.75	39.25	22.25	39.50	cl	1.35	59.16
Bw4	107-142	5 YR 3/3	5.65	5.00	10.25	31.50	58.25	c	1.41	54.56
Pedon 11										
Ap	0-21	5 YR 3/4	30.1	13.40	43.50	12.40	44.10	c	1.27	52.44
Bw1	21-46	5 YR 2.5/2	35.50	5.70	41.20	10.10	48.70	c	1.31	58.14
Bw2	46-71	5 YR 3/4	23.40	15.20	38.60	8.10	53.30	c	1.32	59.65
Bw3	71-102	5 YR 3/4	1.48	17.30	18.78	43.61	37.61	cl	1.34	57.63
Bw4	102-140	5 YR 3/4	1.05	25.50	26.55	37.85	35.60	cl	1.34	55.98

Table 2: Chemical properties of Gollarahatti-2 micro-watershed pedons

Horizons	Depth (cm)	pH (1:2.5) Water	EC (1:25) (dS m^{-1})	O.C. (%)	Exch.Ca	Exch.Mg	Exch. Na	Exch. K	CEC	BS	ESP
					--------------- cmol (p+)kg^{-1} ------------					----%---	
Pedon 1											
Ap	0-21	6.88	0.38	0.53	11.14	5.78	0.16	0.18	19.92	86.64	0.80
Pedon 2											
Ap	0-15	6.65	0.08	0.50	11.20	4.40	0.61	0.31	19.02	86.85	3.20
Bt1	15-30	7.05	0.09	0.38	12.60	3.40	0.79	0.38	21.37	80.35	3.70
Bt2	30-41	7.30	0.08	0.33	9.60	1.90	0.35	0.09	14.87	80.29	2.35
BC	41-50	7.33	0.08	0.31	12.50	0.80	0.29	0.10	15.89	86.16	1.82
Pedon 3											
Ap	0-15	6.81	0.08	0.34	11.12	2.80	0.86	0.33	19.31	78.25	4.45
Bt	15-32	7.24	0.06	0.30	12.60	3.40	0.79	0.38	21.37	80.35	3.70
BC	32-50	7.43	0.06	0.11	10.26	3.60	0.68	0.23	18.51	79.80	3.67
Pedon 4											
Ap	0-22	6.71	0.11	0.51	5.80	3.80	0.57	0.23	14.00	74.29	4.07
Bt1	22-32	6.72	0.10	0.48	8.40	5.20	0.76	0.41	17.94	82.17	4.24
Bt2	32-47	6.71	0.17	0.45	10.00	3.00	0.81	0.33	16.72	84.45	4.85
Bt3	47-60	6.75	0.14	0.39	11.00	1.20	0.74	0.28	15.55	81.99	4.76
BC	60-74	6.90	0.14	0.32	12.45	4.01	0.30	0.33	19.40	88.14	1.57
Pedon 5											

Horizons	Depth (cm)	pH (1:2.5) Water	EC (1:25) (dS m^{-1})	O.C. (%)	Exch.Ca	Exch.Mg	Exch. Na	Exch. K	CEC	BS	ESP
					--------------- cmol (p+)kg^{-1} ------------					----%---	
Ap	0-19	6.19	0.15	0.54	6.85	3.10	0.09	0.03	13.00	75.38	0.69
Bt1	19-38	6.45	0.08	0.43	7.01	3.45	0.10	0.02	15.50	68.25	0.64
Bt2	38-54	6.94	0.05	0.35	6.98	3.47	0.13	0.01	14.60	72.53	0.89
Pedon 6											
Ap	0-24	6.46	0.06	0.57	7.46	3.00	0.10	0.02	12.50	84.64	0.80
Bt1	24-34	6.27	0.09	0.55	8.00	3.40	0.21	0.20	13.85	85.27	1.51
Bt2	34-51	6.76	0.06	0.51	10.46	4.10	0.28	0.09	16.95	88.08	1.65
Bt3	51-69	7.10	0.06	0.45	11.20	4.56	0.23	0.18	18.90	85.55	1.21
BC	69-81	7.14	0.05	0.32	11.22	5.40	0.13	0.19	19.15	88.45	0.67
Pedon 7											
Ap	0-22	6.58	0.05	0.62	8.30	3.40	0.10	0.21	12.73	83.50	0.78
Bt1	22-48	6.56	0.04	0.57	8.50	2.30	0.02	0.01	15.10	71.72	0.13
Bt2	48-60	6.61	0.05	0.51	10.10	4.40	0.01	0.01	16.60	87.57	0.06
BC	60-74	6.64	0.03	0.40	10.60	3.40	0.02	0.01	17.02	87.07	0.11
Pedon 8											
Ap	0-20	6.65	0.07	0.63	10.23	3.80	0.35	0.29	17.09	84.24	1.96
Bt1	20-47	7.16	0.07	0.51	11.20	4.40	0.61	0.31	19.02	86.85	3.20
Bt2	47-66	7.90	0.15	0.51	12.60	2.60	0.48	0.31	17.90	89.30	2.67
Bt3	66-76	8.11	0.11	0.43	7.40	2.60	0.48	0.36	14.08	76.98	3.40
Pedon 9											
Ap	0-17	6.36	0.04	0.56	4.81	2.40	0.15	0.11	9.60	77.81	1.56

Horizons	Depth (cm)	pH (1:2.5) Water	EC (1:25) (dS m^{-1})	O.C. (%)	Exch.Ca	Exch.Mg	Exch. Na	Exch. K	CEC	BS	ESP
					--------------- cmol (p+)kg^{-1} ------------					----%---	
Bt1	17-32	6.45	0.04	0.53	5.20	2.50	0.26	0.09	11.01	73.11	2.36
Bt2	32-55	6.47	0.03	0.52	7.11	3.40	0.37	0.10	14.10	77.23	2.62
Bt3	55-80	6.55	0.05	0.48	8.00	3.40	0.28	0.09	14.29	83.20	1.95
Bt4	80-104	6.61	0.03	0.45	8.50	4.30	0.41	0.09	15.58	87.22	2.63
Pedon 10											
Ap	0-30	7.93	0.25	0.72	11.50	3.30	0.48	0.39	16.42	83.25	2.92
Bw1	30-70	7.87	0.20	0.69	13.53	2.50	0.58	0.31	19.89	85.06	2.91
Bw2	70-87	8.03	0.21	0.64	11.80	1.50	0.43	0.25	16.08	86.94	2.60
Bw3	87-107	8.05	0.20	0.41	12.40	5.70	0.58	0.31	22.50	88.84	2.57
Bw4	107-142	8.09	0.22	0.40	15.60	7.20	0.45	0.36	25.05	88.84	1.79
Pedon 11											
Ap	0-21	7.74	0.11	0.51	7.45	3.67	0.18	0.04	12.70	89.29	1.41
Bw1	21-46	8.13	0.55	0.43	9.18	5.32	1.44	0.04	17.10	93.45	8.41
Bw2	46-71	8.11	0.96	0.39	11.56	5.35	1.97	0.04	19.40	97.52	10.15
Bw3	71-102	8.12	0.98	0.35	9.67	4.30	2.43	0.08	18.30	90.05	13.27
Bw4	102-140	8.01	0.49	0.19	10.43	4.24	1.57	0.10	18.50	88.32	8.48