



Application of Fertility Capability Classification System to the Soils in the Ganjigatti Sub-watershed of Dharwad District, Karnataka

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ABSTRACT

Background: The fertility capability classification (FCC) system has been used to group soils with the same kind of limitations from the point of view of fertility management in the Ganjigatti sub-watershed of Dharwad district of Karnataka.

Methods: A detailed soil survey of the study area was carried out using a high-resolution satellite image (Worldview2 - 50cm SR) and cadastral maps. The image and scanned toposheet were geocoded and subsets were created in ArcGIS 10.8.2 at 1:7,920 scale. After correlating the soil properties of pedons, nine representative pedons were selected and presented in the present research paper. The information of nine soil series identified during the detailed soil survey has been analyzed into eight FCC units.

Result: According to FCC, the representative pedons were classified as CRdmr+(MRK), LCdkr++ (UGK), LRdr++ (KMD), LRdemr+ (SSK), Cdr+ (KRK and MVD), LCdkr+ (BGH), Ldr+ (GJG) and Cbdmv (ASR). The major soil constraints identified through condition modifiers in the descending order were dry soil moisture (d), graveliness (r), low organic carbon content (m), low K reserve (k), low cation exchange capacity (e), basic reaction (b) and vertic properties (v). By computing FCC units an attempt has been made to highlight the fertility constraints and measures to revert the situation for sustainable production.

Key words: Condition modifiers, Fertility capability classification, Soil series, Taxonomy.

INTRODUCTION

Land resource inventory (LRI) mapping (1:10000 or larger scale) assists in the planning of land use because it assesses the land resource and its potential for sustainable agricultural production. Effectively managing these resources with minimal negative environmental impact is crucial, not just for sustainable development but also for human survival (Kalaiselvi *et al.*, 2017). The LRI report provides information on the relative suitability of soils for different uses, but its usefulness could be improved by grouping taxonomic units into management units. This would clearly indicate an area's potential and constraints in terms of fertility. The fertility capability classification (FCC) system is a technical soil classification system that quantitatively focuses on the soil's physical and chemical properties important for soil fertility management (Sanchez *et al.*, 1982). This system was created to bridge the gap between soil classification and soil fertility, interpreting soil taxonomy and additional soil attributes in a way that is directly relevant to plant growth (Buol *et al.*, 1975; Buol and Couto, 1981; Sanchez *et al.*, 1982). While soil taxonomy emphasizes sub-surface properties due to their more permanent nature, the FCC system emphasizes soil fertility within the top 50 cm of the surface.

FCC was originally conceived as dealing only with inherent soil properties that are the product of soil genesis and cannot be easily changed with time (Sanchez *et al.*, 1982). FCC considers topsoil parameters as well as specific subsoil properties. This is why the FCC system does not include

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routine soil tests used for N and P fertilizer recommendations. A further reason is that such soil tests are not very useful in farming systems where fertilizer use is not the main nutrient input (Smithson and Sanchez, 2001; Jagdish Prasad, 2000). Chandrakala *et al.* (2020) attempted to convert taxonomic units into fertility capability classes for the soils of Rayachoty mandal in the Kadapa district of Andhra Pradesh. They concluded that the FCC can provide basic guidance for the best soil and water conservation measures and good agronomic practices at the farm level for sustainable production. In this study, an effort has been made to convert the soil taxa (classification) of the Ganjigatti sub-watershed in the SAT area of Dharwad district, Karnataka, into FCC units.

MATERIALS AND METHODS

The study was conducted in 2021-2023, in the Ganjigatti sub-watershed (5B1A4F) of Dharwad district, Karnataka (15°10'10.114" to 15°17'1.147"N; 75°0'57.672" to 75°4'50.525"E), with the highest elevation of 610 m above mean sea level (Fig 1). The total geographical area of the Sub-watershed is about 4323.84 ha. The annual temperature ranges from 24.68 to 26.67°C. The average rainfall in the watershed was 917.00 mm. The coarse textured soils, originated from chlorite schist parent material, are relatively shallow at higher elevations, but become finer and deeper downwards. The predominant soil types in the area are black and red soils. Black soils of the area are well-suited for cultivating crops such as cotton, wheat, ragi, sorghum and oilseeds. Maize and soybean are the crops grown during the *kharif* season, while sorghum and greengram are cultivated during the *rabi* season. Generally, the length of the crop growing period (LGP) is 150 days and starts from 3rd week of June to the third week of November.

A detailed soil survey of the study area was carried out using a high-resolution satellite image (Worldview2 - 50cm SR) and cadastral maps. The image and scanned toposheet were geocoded and subsets were created in ArcGIS 10.8.2 at 1:7,920 scale. During the detailed soil survey, based on geology, drainage pattern, surface features, slope characteristics and land use, landforms and physiographic divisions were identified. Twenty-seven

soil profiles on different physiographic units were studied to establish the physiography-soil relationship and horizon-wise soil samples were collected and analyzed for physical and chemical properties. Particle size analysis was carried out by international pipette method (Piper, 1966); Gravel content was determined by Gravimetry method (Govindarajan and Koppar, 1975), soil pH and electrical conductivity (EC) were measured with a 1:2.5 soil: water ratio (Jackson, 1973), Organic carbon (OC) were determined by Walkley and Black (1934) method. Cation exchange capacity was determined by neutral normal ammonium acetate method (Schollenberger and Dreibels, 1930), calcium carbonate (CaCO₃) equivalent (%) was determined by 0.5 Normal hydrochloric acid (0.5 N HCL) method (Piper, 1966). The ESP was calculated using the formula given by USDA (Richards, 1954). Soils were classified following the USDA system of soil classification (Soil Survey Staff, 2022). After correlating the above-referred properties of pedons, nine representative pedons were selected and presented in the present research paper.

Fertility capability classification was done as per the procedure outlined in Sanchez *et al.* (1982) and Sanchez *et al.* (2003) by considering both surfaces as well as subsurface physicochemical soil properties. The FCC system consists of three categorical levels viz, i) 'Type', i.e., the texture of the upper 20 cm of surface soil. There were four type levels (sandy top soils (S), loamy top soils

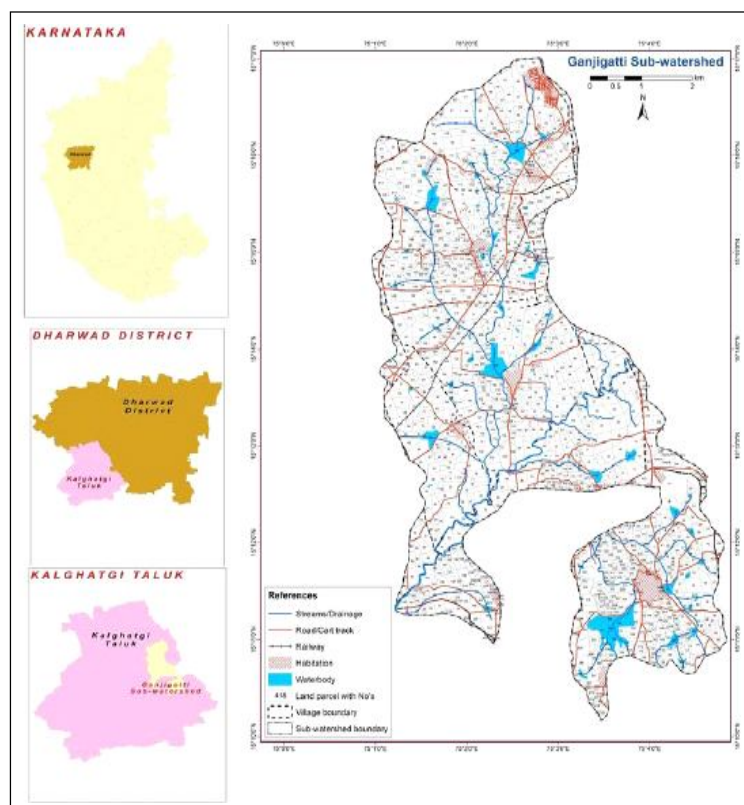


Fig 1: Location map of the Ganjigatti sub-watershed, Karnataka, India.

(L), clayey top soils (C) and organic top soils (O), ii) 'substrata type' which indicates sub-soil texture between 20 and 50 cm depth. Four substrata type levels (sandy sub-soils (S), loamy sub-soils (L), clayey sub-soils (C) and rock or other hard root-restricting layer (R) and iii) 'modifiers' represents soil physical and chemical characteristics. Condition modifiers such as dry soil moisture (d), low CEC (e), low K reserves (k), basic reaction (b), low soil organic carbon (m), cracking clays (v) gravel content (r^{++} for >35% gravel and r^{+} for 10–35% gravel) and slope (%), etc.

RESULTS AND DISCUSSION

Based on morphological, physical and chemical properties, Ganjigatti sub-watershed soils were classified as Entisols, Inceptisols, Alfisols and Vertisols (Fine, mixed, isohyperthermic, Lithic Ustorthents (MRK); Fine, mixed, isohyperthermic Lithic Haplustalfs (UGK); Fine-loamy, mixed, isohyperthermic, Typic Ustorthents (KMD); Fine-loamy, kaolinitic, isohyperthermic, Lithic Ustorthents (SSK); Very fine, mixed, isohyperthermic, Typic Haplustepts (KMK); Fine, mixed, isohyperthermic Typic Haplustalfs (BGH); Fine, mixed, isohyperthermic, Typic Ustorthents (GJG); Fine, mixed, isohyperthermic, Vertic Haplustepts (MVD); Fine, smectitic, isohyperthermic, Typic Haplusterts (ASR)) are the major soils encountered in the Ganjigatti sub-watershed. The weighted mean values of considered soil properties for all nine pedons was given in Table 1. Based on the surface (0-20 cm) and subsurface (20-50 cm) soil properties, fertility capability units were identified by applying the type, sub-strata type and condition modifiers to soil taxonomic units (soil series). The type of the soil was loamy and clay whereas substrata type was loamy, clayey and rock or other hard root restricting layer within 50 cm, 'R'. The condition modifiers appropriate for the soils under study were 'b' basic reaction within 50 cm depth (pH above 7.3); (ii) soil moisture stress, 'd' indicating dry season longer than three months and ustic soil moisture regime; (iii) low cation exchange capacity, 'e' with $\text{CEC} < 7 \text{ cmol (p}^{+}\text{) kg}^{-1}$ of soil at pH 7); (iv) low nutrient reserves, 'k' with exchangeable K $< 0.2 \text{ cmol (p}^{+}\text{) kg}^{-1}$ soil or exchangeable K $< 2\%$ of sum of bases, if sum of bases is $< 10 \text{ cmol (p}^{+}\text{) kg}^{-1}$ soil; (v) low organic carbon status, 'm' (SOC is $< 5 \text{ g C kg}^{-1}$ soil within 20 cm depth); (vi) gravel content [$r^{+} = 10\text{--}35\%$ by volume of gravel size (2-25 cm in dm), $r^{++} = >35\%$ gravel by volume in 50 cm of the soil]; (vii) cracking clays 'v' indicating vertic properties.

From the perspective of soil fertility management, the fertility capability classification groups soils that share similar conditions. Therefore, we only group the soils based on characteristics that contribute to their similarity in fertility management. Table 1 displays the soil coding for nine series, which organizes the soils into eight FCC units (Table 2). This clearly shows that soil individuals within a single FCC class can belong to different taxonomic classes. The upland soil series KMD, SSK and MRK exhibited loamy (L)

and clay (C) types, with weathered rock (R) serving as the substrate type. The condition modifiers identified in MRK soils were soil moisture stress (d), low OC status (m) and graveliness (r^{+}) and the FCC class was CRdmr⁺. The UGK soils had condition modifiers such as soil moisture stress (d), low nutrient reserve (k) and graveliness (r^{++}) and the FCC class was LCdkr⁺⁺. In KMD soils, condition modifiers were soil moisture stress (d) and graveliness (r^{++}), so the FCC class was LRdr⁺⁺. The SSK soil series includes condition modifiers for low cation exchange capacity (e), low OC status (m) and graveliness (r^{+}). Consequently, we assigned the FCC class as LRdemr⁺. KMK and MVD soils possess condition modifiers such as moisture stress (d) and graveliness (r^{+}); hence, the FCC class was Cdr⁺. The BGH soils contained condition modifiers such as soil moisture stress (d), low nutrient reserve (k) and graveliness (r^{+}), while the FCC class was LCdkr⁺. In GJG soils, condition modifiers were soil moisture stress (d) and graveliness (r^{+}), so the FCC class was Ldr⁺. The ASR series of soils contained condition modifiers such as soil moisture stress (d), cracking clay (v), low OC status (m) and calcareousness (b) and its FCC class was Cbdmv.

Soil moisture stress (d) and graveliness (r) are the most predominant condition modifiers observed in all FCC classes of the Ganjigatti sub-watershed. This suggests that the soils have a limited amount of available water, this can be overcome by application of soil and water conservation methods and suitable irrigation methods. The FCC classes found in upland soils exhibit very shallow to shallow soil depths, this phenomenon caused by the erosion of fertile top soil due to inadequate soil conservation measures (Jagdish Prasad, 2000; Bhattacharyya *et al.*, 2016). The less surface horizon depth and high gravel content were the indicators of top soil loss due to severe sheet erosion, which limits the availability of WHC and nutrients (Rajeshwar and Mani, 2014). Hence, poor nutrient supply and low available water content due to limited depth are major limiting factors for crop production in these soils. Pasture development may be a viable option for limiting soil erosion and protecting it from degradation. The soil series of BGH and GJG (midland soils) feature a loamy type and substrata, as well as a loamy type and clay substrate, respectively. These soil types are conducive to crop production, as they allow for adequate infiltration through both rain and irrigation. Low cation exchange capacity (e) and biological condition modifier (m) have to be managed by the addition of organic manures, FYM and compost in the FCC units with those modifiers. High pH and CaCO_3 content are major limitations in the soils of ASR (lowland). The accumulation of base cations due to leaching in the sub-surface layer enhances the development of CaCO_3 . It induces a deficiency of micronutrients and phosphorus by forming Ca-P compounds (Jagdish Prasad, 2000). The high clay content of these soils reduces their workability when they are wet and dry. Despite the high clay content, which makes leaching a challenging process, we need to use suitable

Table 1: Relevant averaged values of soil properties for fertility capability classification in soils of Ganjigatti sub-watershed.

Depth (cm)	Sand	Silt	Clay	Gravelines	pH (1:2.5)	EC (dS m ⁻¹)	OC (g/kg)	CaCO ₃ (%)	Exchangeable bases				CEC	ESP	Colour (moist)	
									Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺				
	[cmol (p ⁺) kg ⁻¹]											Sum				
	Fine, mixed, isohyperthermic, Lithic Ustorthents (MRK)															
	0-20	47.00	12.64	40.36	28.00	7.18	0.28	4.80	3.21	10.18	5.80	0.39	0.67	17.04	26.49	1.48
Fine, mixed, isohyperthermic, Lithic Haplustaifs (UGK)																
0-20	44.62	18.76	36.62	35.00	6.04	0.14	6.05	2.50	7.94	3.75	0.22	0.15	12.06	23.58	0.93	7.5YR 4/3
20-50	29.00	24.05	46.95	40.00	6.86	0.18	4.60	3.20	13.68	6.00	0.28	0.16	20.12	38.48	0.73	7.5YR 3/3
Fine-loamy, mixed, isohyperthermic, Typic Ustorthents (KMD)																
0-20	67.95	7.32	24.73	38.00	5.36	0.10	7.30	0.91	3.82	1.34	0.18	0.13	5.47	11.15	1.82	7.5YR 3/3
Fine-loamy, kaolinitic, isohyperthermic, Lithic Ustorthents (SSK)																
0-20	59.00	16.50	24.50	32.00	5.49	0.28	4.70	1.25	2.66	1.21	0.16	0.22	4.25	6.18	2.56	5YR 5/4
Very fine, mixed, isohyperthermic, Typic Haplustepts (KRK)																
0-20	29.95	14.60	55.45	12.00	6.78	0.18	6.30	6.40	15.52	12.18	0.47	0.30	28.47	36.19	1.29	10YR 3/1
20-50	27.50	13.35	59.15	17.00	7.25	0.21	5.00	6.50	19.16	15.44	0.52	0.22	35.34	41.54	1.25	10YR 2/1
Fine, mixed, isohyperthermic, Typic Haplustaifs (BGH)																
0-20	48.75	12.40	38.85	18.00	5.83	0.11	10.80	2.30	7.56	5.40	0.22	0.19	13.37	18.52	1.19	7.5YR 4/4
20-50	47.10	7.00	45.90	21.00	7.13	0.10	5.10	2.50	9.72	6.96	0.29	0.19	17.16	21.30	1.36	7.5YR 3/3
Fine, mixed, isohyperthermic, Typic Ustorthents (GJG)																
0-20	46.00	14.50	39.50	26.00	7.02	0.16	7.30	3.40	11.04	5.34	0.17	0.37	16.92	23.91	0.71	10YR 3/3
20-50	52.50	13.50	34.00	29.00	7.30	0.25	6.25	3.92	10.56	4.58	0.19	0.28	15.61	22.15	0.86	10YR 4/3
Fine, mixed, isohyperthermic, Vertic Haplustepts (MVD)																
0-20	22.00	21.80	56.20	10.00	6.65	0.31	10.90	2.90	7.56	6.48	0.23	0.28	14.55	17.70	1.30	10YR 2/3
20-50	18.10	24.45	57.45	14.00	7.02	0.23	8.20	3.10	8.88	4.20	0.24	0.23	13.55	16.26	1.48	10YR 3/3
Fine, smectitic, isohyperthermic, Typic Haplusterts (ASR)																
0-20	18.15	28.65	53.20	7.00	8.38	0.32	4.75	8.40	23.38	12.86	0.28	0.45	36.97	43.11	0.64	10YR 2/2
20-50	21.67	20.15	58.18	9.00	8.61	0.33	3.50	15.80	26.20	14.68	0.35	0.32	41.55	47.10	0.74	10YR 2/2

Table 2: Type, substrata and condition modifiers and final fertility capability classification in soils of Ganjigatti sub-watershed.

Landform	Taxonomic units with soil series name	Type/Substrata	Check list							Modifiers	Slope (%)	FCC unit
			b	d	e	k	m	r	v			
Upland	Fine, mixed, isohyperthermic, Lithic Ustorthents (MRK)	QR	-	X	-	-	X	+	-	dmr ⁺	1-3	CRdmr ⁺
	Fine, mixed, isohyperthermic Lithic Haplustals (UGK)	LC	-	X	-	X	-	++	-	dkr ⁺⁺	1-3	LCdkr ⁺⁺
	Fine-loamy, mixed, isohyperthermic, Typic Ustorthents (KMD)	LR	-	X	-	-	-	++	-	dr ⁺⁺	1-3	LRdr ⁺⁺
	Fine-loamy, kaolinitic, isohyperthermic, Lithic Ustorthents (SSK)	LR	-	X	X	-	X	+	-	demr ⁺	1-3	LRdemr ⁺
Midland	Very fine, mixed, isohyperthermic, Typic Haplustepts (KRK)	OC	-	X	-	-	-	+	-	dr ⁺	1-3	Cdr ⁺
	Fine, mixed, isohyperthermic Typic Haplustals (BGH)	LC	-	X	-	X	-	+	-	dkr ⁺	1-3	LCdkr ⁺
	Fine, mixed, isohyperthermic, Typic Ustorthents (GJG)	LL	-	X	-	-	-	+	-	dr ⁺	1-3	Ldr ⁺
Lowland	Fine, mixed, isohyperthermic, Vertic Haplustepts (MVD)	OC	-	X	-	-	-	+	-	dr ⁺	0-1	Cdr ⁺
	Fine, smectitic, isohyperthermic, Typic Haplusterts (ASR)	OC	X	X	-	-	X	-	X	bdmv	0-1	Cbdmv

amendments, such as gypsum or organic manures, to mitigate the alkalinity threat. Although calcareousness may not support gypsum application in the soil, foliar sprays of micronutrients can address their deficiency. The differences in the presence of modifiers in different FCC units are due to the variability in landform, land use and management practices that influence soil properties. Condition modifiers can serve as drivers for the selection of appropriate management for increasing soil productivity, apart from indicating soil characteristics (Vasu *et al.* 2016). Chandrakala *et al.* (2020), Dhale *et al.* (2019) and Lalitha *et al.* (2018) also reported similar studies.

CONCLUSION

Soil fertility is largely determined by the qualities of the topsoil and subsoil, which impact sustainable crop production and reveal the soil's fertility capability. To ensure the continued health and productivity of our land and soil resources, it is necessary to have an accurate picture of our land's resources and constraints and to allocate individual parcels of land to activities that will not negatively impact those constraints. Soil moisture stress and gravelly are big problems for all soils, but valley soils don't always have to be because they have a lot of clay and not much gravelly, so they can hold more water. Dry soil moisture (d), graveliness (r), low organic carbon content (m), low K reserve (k), poor cation exchange capacity (e), basic reaction (b) and vertic characteristics (v) were the main condition modifiers. Upon arrival at the sub-watershed, these units aid in the adoption of optimal water and soil conservation measures, as well as good agronomic management practices on farms, taking into account the constraints and possibilities of the land units. This boosts crop production and productivity, decreases land degradation and erosion and improves soil health. In order to better understand soil fertility capability units and to convert soil taxonomic data into practical terms, this study has implications for future research into the relationships between the definition of condition modifiers and the properties of soil diagnostic horizons.

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Conflict of interest

All authors declare that the contents and data published in the manuscript do not have a conflict of interest for any party. If this is discovered in the future, it will be the author's full responsibility.

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