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Suitability Assessment and Mapping for Tomato (*Solanum lycopersicum*) in Hot Semi-arid Region of Deccan Plateau, India using Farm-scale Soil Survey Information

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Abstract

A detailed farm-scale soil survey at a 1:8,000 scale was conducted to evaluate soil-site suitability and prepare suitability maps for tomato cultivation in the semi-arid region of the Deccan Plateau, India. The survey identified twelve soil series distributed across upland and lowland areas. Soil depth across these series ranged from moderately deep (75-100 cm) to very deep (>150 cm). The soils were slightly acidic to moderately alkaline (pH 6.64-8.01) and non-saline. Textural classes varied from sandy loam to clay, with mean clay content ranging between 34.12 and 55.51 per cent. Organic carbon content was generally low, ranging from 0.18 to 0.89 per cent. Among these, eleven upland soil series, classified as Typic Haplustepts and Rhodic Paleustalfs, were found to be moderately suitable (S2) to marginally suitable (S3) for tomato cultivation. The lowland soils (TSD series) were assessed as marginally suitable (S3). Site-specific evaluation and mapping of crop suitability provide valuable insights for enhancing tomato cultivation potential in this region.

Keywords : Farm scale, Soil-site suitability, Tomato, Limitation, Soil sustainability

The demand for cultivable land has risen sharply in developing countries to ensure adequate food production for their rapidly growing populations. This pressure is further intensified by anthropogenic climate change, along with ecological challenges such as deforestation, land degradation and biodiversity loss (Jagdish Prasad *et al.,* 2023). These issues are particularly severe in arid and semi-arid ecosystems, which remain highly vulnerable to environmental stressors. Agriculture in arid and semi-arid regions is predominantly rainfed, making the conservation of soil moisture a critical component, often achieved through watershed management practices. Such regions are marked by highly variable rainfall, recurrent droughts, high evaporation rates, scorching temperatures and strong winds. Additionally, the density of human and livestock populations is slightly above the national average, further straining the region's already limited natural resources. Effective management of vegetation in these fragile landscapes requires a thorough understanding of soil properties and landform characteristics, as both directly influence the availability and utilization of scarce water resources. Tomato (*Solanum lycopersicum*), a member of the Solanaceae family, stands out as one of the most significant vegetable crops globally, valued both for fresh consumption and processing. In India, it occupies about 8.65 lakh hectares, contributing an annual production of nearly 165.26 lakh tonnes (IHD, 2011). Being a warm-season crop with high adaptability, tomato cultivation is successful across diverse regions, ranging from plains to hilly areas.

Soil properties play a critical role in determining tomato productivity under specific bioclimatic conditions and management practices. A clear understanding of soil types and their characteristics is essential for identifying and optimizing site-specific, profitable cropping options, including tomato. Farm-scale soil mapping at a 1:8,000 scale offers accurate and scientific information for each agricultural parcel, enabling the assessment of both potential and limiting factors for effective farm planning (Srinivasan *et al.,* 2021a). Furthermore, thematic soil layers-such as texture, depth, organic carbon, stoniness, drainage, acidity and salinity-combined with information on landforms and vegetation, provide valuable inputs for evaluating crop suitability and ensuring sustainable agricultural development (Srinivasan *et al.,* 2022).

In the Kolar taluk, most farmers grow tomato without considering the land suitability and the lack of site-specific land resource information. This leads to inappropriate land management strategies. This is one of the main causes of the low yield, instability and a rapid reduction in soil fertility (Dharumarajan *et al.,* 2018). Sustainable intensification methods that prioritize soil health and conservation practices are essential for long-term productivity and sustainability in intensive tomato cultivation (Ananthakumar and Meghana, 2022). A land suitability assessment is required to address this issue, which can increase crop output by growing particular crops in the most appropriate sites. Land suitability assessment is a land evaluation technique for determining the primary limiting constraints for planting a specific crop. As a result, it is critical to interpret the soil site and its characteristics in terms of potential for this tomato production. An attempt has been made to develop criteria for tomato suitability using different biophysical properties generated through detailed soil survey in a semi-arid part of the Deccan plateau, India.

MATERIAL AND METHODS

Details of the Study Area

The study area is in hot semi-arid region of Deccan plateau lies in between 13°14'40.004" to 13°8'47.316" latitude and 77°57'11.293" to 78°2'5.514" longitude, and part of the Agro-Ecological Region (AER-8) with red loamy soil type and covers an area of 3898 ha in Doddavallabi, Perjenahalli, Singahalli and Seethi Hosur panchayats of kolar mandal, kolar district in Karnataka,

India (Fig. 1). Hills, rock outcrops, uplands and lowlands are the major landforms in the area. The region's average elevation varies from 800 to 900 meters above sea level. Tomato is frequently cultivated as irrigated crop followed by Beans, Marigold and Chrysen Themum. The K. C. valley project, recharging groundwater with treated wastewater in drought-prone areas of Kolar taluk is a major source of irrigation in the area.

Climatic Condition

The study area climate is semi arid and classified as chronically drought-prone, with an average annual rainfall of 763 mm, with about 374 mm falling during the south-west monsoon period (June to September), 235 mm falling during the north-east monsoon period (October to December) and the remaining 154 mm falling during summer season. Rainfall is inconsistent and unevenly distributed, which causes intermittent drought. The *kharif* rainfall (June-Sept) is 49 per cent of the average annual rainfall. The average temperature is consistently above 23°C. The minimum temperature was 12.64°C and maximum temperature was 34.33°C with an average temperature of 32-35°C. The data for potential evapotranspiration (PET) and mean annual rainfall (MAR) were gathered from the Belamanahalli rain guage (TRG_ID is 2060) station installed by KSNDMC, spanning 11 years (2010-2021). According to climate data, the length of the growing period (LGP) is 98-343 days. During the agricultural growing season, life-saving irrigation is required (Fig. 2). The most reliable season for obtaining relatively good rainfall is June 3rd week to September last week.

Soil Characterization and Mapping

Using village cadastral maps and world view 2 imagery, a detailed soil survey was undertaken on a

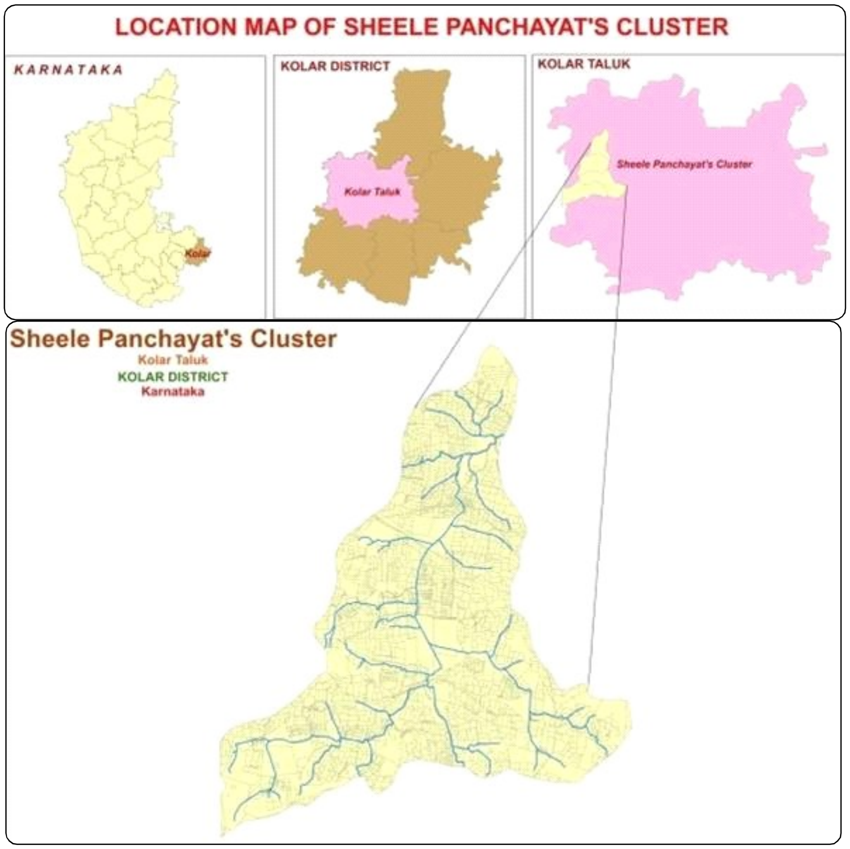

Fig. 1 : Location map of the study area

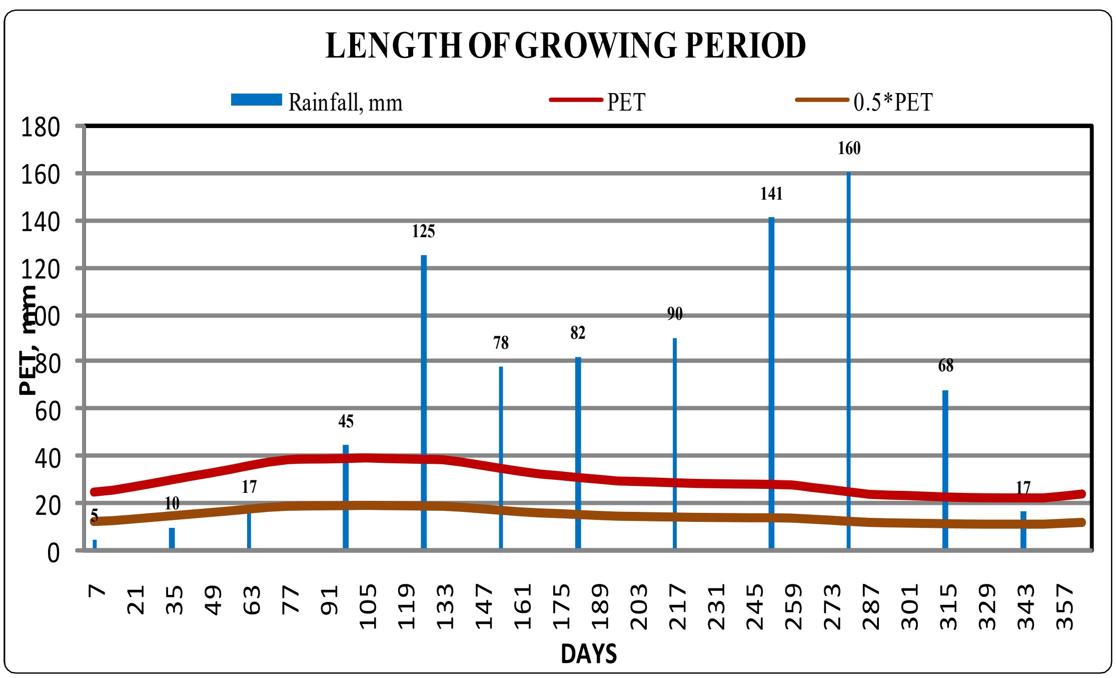

Fig. 2 : Mean annual rainfall (MAR) and potential evapo-transpiration (PET) were recorded (year and month wise) in the study area during 2010 - 2021

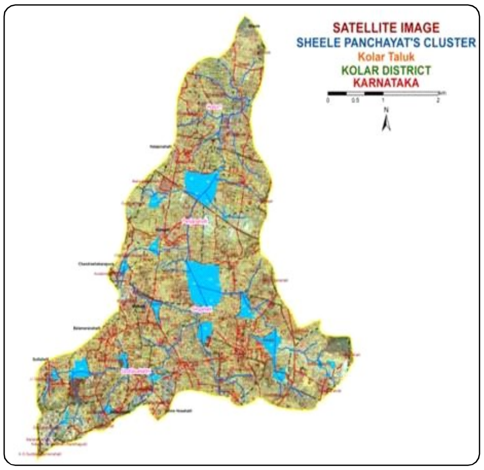

Fig. 3 : Remote Sensing imagery (worldview-2) for the study area

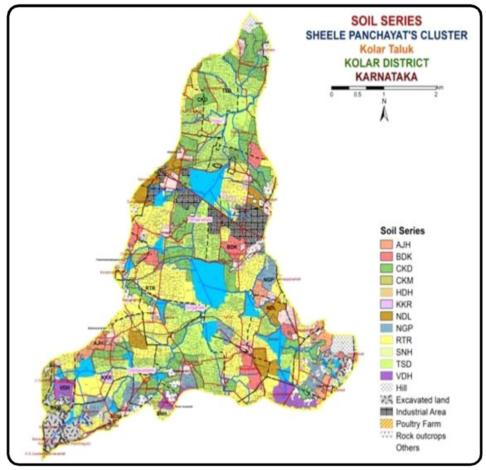

Fig. 4 : Major soils series in the study area

1:8,000 scale in Doddavallabi, Perjenahalli, Singahalli and Seethi Hosur panchayats (Fig. 3). The worldview 2 false colour composites were used to delineate landform, base map for soil mapping. On each landform, soil pits/profiles were excavated to describe morphological characteristics (Soil Survey Staff 2003). In two landforms, 134 soil profiles along with mini pits were investigated and twelve soil series were tentatively identified (Table 1) and mapped (Fig. 4).

Table 1

Landform, major soil series and soil classification in the study area

Land form	Series	Soil family level Classification	Area (ha)	% TGA*
Upland	Aregujjanahalli(AJH)	Fine, mixed, subactive isohyperthermic Rhodic Paleustalfs	85.8	2.20
	Kanchikere(KKR)	Fine silty, mixed, semiactive isohyperthermic Typic Haplustepts	10.2	0.26
	Hooradhanahalli (HDH)	Clayey - skeletal, mixed, active isohyperthermic Rhodic Paleustalfs	17.7	0.45
	Bidarakatte (BDK)	Fine, mixed, semiactive isohyperthermic Rhodic Paleustalfs	124.9	3.20
	Varadarahalli (VDH)	Fine loamy, mixed, semiactive isohyperthermic Typic Haplustepts	82.2	2.10
	Nagalapur (NGP)	Clayey- skeletal, mixed, semiactive isohyperthermic Typic Paleustalfs	132.5	3.39
	Chikkamegheri (CKM)	Fine, mixed, semiactive isohyperthermic Rhodic Paleustalfs	47.7	1.22
	Chikka Madhure (CKD)	Fine, mixed, active isohyperthermic Typic Haplustepts	514.1	13.18
	Ranatur (RTR)	Fine, mixed, semiactive isohyperthermic Rhodic Paleustalfs	327.4	8.39
	Nidavalulu (NDL)	Clayey - skeletal, mixed, semiactive isohyperthermic Rhodic Paleustalfs	133.8	3.43
	Shyanadrahalli (SNH)	Fine, mixed, semiactive isohyperthermic Typic Haplustepts	18.6	0.47
Lowland	Thimmasandra (TSD)	Fine, mixed, semiactive isohyperthermic Typic Haplustepts	849.7	21.79
		Excavated land	130.8	3.35
		Hill	56.4	1.44
		Industrial area	156.4	4.01
		Poultry farm	4.7	0.12
		Rock Outcrops	119.7	3.07
		Habitation and waterbody	539.7	13.84
		Total	3898	100

*TGA- Total geographical area of the study area

Soil Classification

Based on the morphological, physical and chemical properties, the soils were classified up to family level by following Keys to Soil Taxonomy, Soil Survey Staff (Soil Survey Staff, 2014).

Soil Analysis

The horizon-wise soil samples were collected, air dried, powdered, sieved through a 2 mm sieve and used for determination of soil physical and chemical characteristics *viz.* particle-size distribution was determined by the international pipette method (Day 1965). Soil pH and EC were determined using the procedures as described by Jackson (1973) and Page *et al.,* (1982), respectively. Soil organic carbon was determined by the wet oxidation method of Walkley and Black (1934). Cation exchange capacity (CEC) was determined using 1 N ammonium acetate at pH 7.0 (Page *et al*., 1982). Base saturation, CaCO3 (%) and exchangeable sodium percentage (ESP) were determined by using standard methods given by Jackson (1973). The soils were classified as per the guidelines given in Keys to Soil Taxonomy (Soil Survey Staff, 2014).

Land Suitability Evaluation

Land suitability assessment is a vital tool in agricultural land use planning, as it determines the appropriateness of land for cultivating specific crops. For this study, the procedure outlined by Naidu *et al.* (2006) was employed to evaluate tomato suitability. Crop requirements related to climate, site, soil and fertility factors were compiled from existing literature and refined where necessary, based on crop performance observations and farmer interactions during fieldwork. To classify suitability, soil-site characteristics of different soil types were compared with the established crop requirements (Table 2). Key soil parameters considered included depth, texture, gravelliness, pH and calcareousness, while land attributes such as slope, erosion and drainage, along with climatic variables like rainfall amount, distribution and length of the growing season, were also evaluated. Based on the type and severity of limitations, the land was categorized into suitability classes: highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and permanently unsuitable (N2) for tomato cultivation.

Results and Discussion

Landform-soil Relationship

A detailed landform analysis was carried out based on relief, contours and drainage channel networks (Wright, 1993). The landforms were identified based on DEM, digital interpretation of worldview remote sensing data into three land form units, namely hill and part of rock outcrops, upland and lowland. The hill slopes cover forest vegetation and bushes. Poor vegetation makes more erosion and soil loss on topography. Upland slopes were found below the hillside with a slope gradient ranging from 3 to 5 per cent. Major land uses in the upland were mango and tomato with slight soil erosion. The low land is part of river and tank bed region, which are deposited by flowing water with 0-1 per cent slope gradient. Paddy was major crop cultivating in lowland using bore well irrigation.

Soils of Upland

On upland, eleven soil series have been identified *i.e.,* Aregujjanahalli (AJH), Kanchikere (KKR), Hooradhanahalli (HDH), Bidarakatte (BDK), Varadarahalli (VDH), Nagalapur (NGP), Chikkamegheri (CKM), Chikka Madhure (CKD), Ranatur (RTR), Nidavalulu (NDL) and Shyanadrahalli (SNH) occurring on 1-5 per cent slope adjacent to hill and were well drained. Soil depth ranged from moderately deep (CKM, HDH and KKR), deep (AJH, VDH, SNH and NGP) and very deep (BDK, NDL, RTR and CKD) owing to soil-forming factors in the upland landscape system (Vasu *et al*., 2017). Gravel was less than 15 per cent in all the series. The mean value of clay content varied from 34.12 to 55.51 per cent in the soils of different series. The soil texture varied from sandy loam to clay. The wide textural variation may be due to variation in topography, in-situ weathering and clay

TABLE 2
Revised Soil-site suitability criteria for Tomato

Land use requirement			Rating			
Soil –site characteristics		Unit	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N1)
Climatic regime (c)	Mean temperature in growing season	°C	25-28	29-32 20-24	15-19 33-36	<15 >36
	Total rainfall	mm	600-750	500-600 750-1000	400-500 >1000	<400
	Rainfall in growing season	mm	>150	120-150	90-120	<90
Land quality	Soil-site characteristic					
Moisture availability (m)	Length of growing period for short duration	Days	>150	120-150	90-120	<90
	AWC	mm/m	High (>150)	101-150 (medium)	Low (51-100)	Very low (<50)
Oxygen availability to roots (w)	Soil drainage	Class	Well drained	Moderately well drained	Poorly drained	Very poorly drained
Nutrient availability (f)	Texture sub-surface(t)	Class	sl, scl, cl, sc, c (red)	-	ls, c(black)	-
	pH	1:2.5	6.0-7.3	5.0-6.0 7.3-8.4	8.4-9.0	>9.0
	CaCO3 in root zone	%	-	<5	5-10	>10
	OC	%	1.0-1.25	0.5-1.0	0.1-0.5	<0.1
Rooting conditions (r)	Effective soil depth	cm	>75	50-75	25-50	<25
	Coarse fragments (g)	Vol %	<15	15-35	35-60	60-80
Soil toxicity (n)	Salinity (EC saturation extract)	dS/m	<2.0	2-4	4-8	>8.0
	Sodicity (ESP)	%	<5	5-10	10-15	>15
Erosion hazard (e)	Slope	%	<3	3-5	5-10	>10

TABLE 3

Climate, site and important soil characteristics (soil series wise weighted mean) for tomato cultivation in the Semi-Arid part of Karnataka (*data in Paren Theses is denote mean values)

Parameters	Series											
	AJH	KKR	HDH	BDK	VDH	NGP	CKM	CKD	RTR	NDL	SNH	TSD
Rainfall (mm)	763	763	763	763	763	763	763	763	763	763	763	763
Slope %	1-3%	1-3%	3-5%	1-3%	1-3%	1-3%	1-3%	1-3%	1-3%	1-3%	1-3%	0-1%
Drainage	Well	Well	Well	Well	Well	Well	Well	Well	Well	Well	Well	Moderate
Depth (cm)	100-150	75-100	75-100	>150	100-150	100-150	75-100	>150	>150	>150	100-150	>150
pH (1:2.5)	5.51-7.41	6.14-7.01	7.85-8.16	5.88-7.34	6.98-7.94	6.49-6.75	6.51-7.41	6.08-8.67	5.82-6.78	5.40-7.19	6.33 -7.99	6.74-7.58
	(6.45)	(6.59)	(8.01)	(6.86)	(7.60)	(6.66)	(7.13)	(7.82)	(6.40)	(6.49)	(7.36)	(7.32)
EC (dS/m)	0.03-0.10	0.06-0.14	0.30-0.48	0.04-0.06	0.06-0.10	0.13-0.21	0.05-0.06	0.15-0.41	0.04-0.07	0.06-0.10	0.04-0.14	0.05-0.11
	(0.06)	(0.10)	(0.36)	(0.05)	(0.08)	(0.17)	(0.06)	(0.33)	(0.06)	(0.08)	(0.09)	(0.07)
SOC (%)	0.18-0.42	0.18-0.45	0.21-0.45	0.39-0.81	0.75-1.05	0.09-1.02	0.60-0.87	0.15-0.33	0.18-0.42	0.12-0.36	0.12-0.30	0.15-0.87
	(0.29)	(0.32)	(0.29)	(0.60)	(0.89)	(0.49)	(0.73)	(0.18)	(0.31)	(0.23)	(0.20)	(0.37)
Texture (surface)	scl	sc	sc	sc	scl	sl	scl	sc	scl	scl	scl	c
Gravel (%)	<15%	<15%	<15%	<15%	<15%	<15%	<15%	<15%	<15%	<15%	<15%	<15%
AWC (mm/m)	Low	Low	Very low	Medium	Medium	Low	Low	Medium	Medium	Low	Medium	Medium
	(51-100)	(51-100)	(<50)	(101-150)	(101-150)	(51-100)	(51-100)	(101-150)	(101-150)	(51-100)	(101-150)	(101-150)
CEC (cmolP+/kg)	3.26-8.09	8.25-10.84	13.02-16.57	7.2-13.11	7.35-13.72	9.36-13.77	8.97-11.12	13.57-24.81	6.57-11.85	5.11-11.63	13.57-8.21	14.87-19.77
	(6.58)	(9.65)	(15.21)	(11.16)	(11.16)	(12.09)	(10.11)	(21.74)	(10.10)	(9.56)	(12.13)	(18.05)
BS (%)	54.42-75.94	65.37-79.74	75.34-83.61	42.34-61.95	59.41-66.70	57.38-58.69	54.55-72.77	82.40-87.07	57.27-63.46	44.73-63.37	67.48-75.27	75.15-83.05
	(65.88)	(73.40)	(78.55)	(52.78)	(61.81)	(58.07)	(64.29)	(83.96)	(61.24)	(57.15)	(73.06)	(79.57)
CaCO3 (%)	0	0	0	0	0	0	0	0	0	0	0	0
ESP (%)	3.08-7.19	2.45-5.26	3.31-8.34	2.84-6.12	2.52-6.78	2.41-3.74	2.92-7.42	1.43-1.68	1.60-2.65	2.54-4.42	0.93-10.46	1.23-3.40
	(5.70)	(3.50)	(4.80)	(3.70)	(4.12)	(3.36)	(5.73)	(1.58)	(1.94)	(3.21)	(4.11)	(2.02)

translocation by eluviation's and age of the soils (Srinivasan *et al.,* 2020b). The available water holding capacity (AWC) of soils varied from low to medium (Table 3). The irregular distribution of AWC in different depths in soils was due to the clay movement with different levels of deposition influenced by the level of organic carbon contents. The soils are strongly acidic to moderately alkaline in reactions (pH 5.40 to 8.16) and were non-saline. The soil pH varied due to differences in parent material, leaching and exchangeable sodium contents (Srinivasan *et al.,* 2019). The mean SOC contents were low to high and ranged from 0.18 per cent (CKD) to 0.89 per cent (VDH). The SOC contents decreased with depth in the upland soils could be attributed to poor crop cycles which make low biomass production and unsuitable crop management practices (Lalitha *et al.,* 2022). The mean CEC and base saturation ranged from 9.56 (NDL) to 21.74 (CKD) cmol(p^+) kg^{-1} and 52.78 per cent (BDK) to 83.96 per cent (CKD), respectively. Upland soils were classified as Rhodic Paleustalfs and Typic Haplustepts at subgroup level.

Soils of Lowland

Soils having their genesis over upland and along the banks of rivers and canal basins are deep and occur on nearly level (0-1%) with moderate drainage. One soil series represents the lowland is Thimmasandra (TSD). The mean sand, silt and clay contents were 44.01, 9.56 and 45.67 per cent respectively (Table 3) and texture varied from sandy clay to clay. The mean soil pH and EC were slightly alkaline in reaction (7.32) and 0.07 (non-saline). Higher pH in soils of nearly level plains could be due to the presence of exchangeable bases brought by run-off water in surface horizons, as well as the presence of higher temperatures in most of the year, resulting in soluble salt accumulation in surface and sub-surface soils of lowland (Srinivasan *et al.,* 2020a). The SOC contents were low to high and varied from 0.15 to 0.87 per cent (mean-0.37%). Low SOC in the soils could be attributed to frequent alluvium depositional activities and poor soil fertility management. Available water content was 101-150mm/m (medium).

TABLE 4

Degree of limitation and suitability of soils for tomato

Parameters	Series											
	AJH	KKR	HDH	BDK	VDH	NGP	CKM	CKD	RTR	NDL	SNH	TSD
Rainfall (mm)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
Mean temperature (°C)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
Slope %	S_1	S_1	S_2	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
Drainage	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_2
AWC (mm/m)	S_3	S_3	N	S_2	S_2	S_3	S_3	S_2	S_2	S_3	S_2	S_2
Depth (cm)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
pH (1:2.5)	S_1	S_1	S_2	S_1	S_2	S_1	S_1	S_2	S_1	S_1	S_2	S_2
EC (dS/m)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
SOC (%)	S_3	S_3	S_3	S_2	S_2	S_3	S_2	S_3	S_3	S_3	S_3	S_3
Texture (sub-surface)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_3	S_3
Gravel (%)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
CaCO3 (%)	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1	S_1
ESP (%)	S_2	S_1	S_1	S_1	S_1	S_1	S_2	S_1	S_1	S_1	S_1	S_1
Suitability subclass	S_{3mf}	S_{3mf}	S_3f	S_{2mf}	S_{2mf}	S_{3mf}	S_{3m}	S_3f	S_3f	S_{3mf}	S_3t	S_3tf

S1-Highly suitable, S2-Moderately suitable, S3-Marginally suitable

TABLE 5

Series-wise soil constraints and management strategies for tomato production in the semi-arid part of Karnataka

Series	Major constraints	Actual suitability class	Suggested management strategies	Potential suitability class
AJH	Low AWC, Poor soil fertility, Sodicity	S_{3mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_2
KKR	Low AWC, Poor soil fertility, Sodicity	S_{3mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of graded bunds3. Use of short duration and drought resistant varieties	S_2
HDH	Low AWC, Poor soil fertility	S_3f	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of graded bunds 3. Adopt in-situ soil and water conservation techniques. 4. Use of short duration and drought resistant varieties	S_2
BDK	Gently sloping, very low AWC, Poor soil fertility	S_{2mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of graded bunds	S_1
VDH	Medium AWC, Poor soil fertility	S_{2mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_1
NGP	Medium AWC, Poor soil fertility	S_{3mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_2
CKM	Low AWC, Poor soil fertility	S_{3m}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds 3. Use of short duration and drought resistant varieties	S_2
CKD	Low AWC, Poor soil fertility, Sodicity	S_3f	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of graded bunds	S_2

Continued....

TABLE 5 Continued....

Series	Major constraints	Actual suitability class	Suggested management strategies	Potential suitability class
RTR	Medium AWC, Poor soil fertility	S_3f	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_2
NDL	Low AWC, Poor soil fertility	S_{3mf}	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_2
SNH	Heavy texture, moderately well drained, Medium AWC	S_3t	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Construction of contour bunds	S_2
TSD	Heavy texture, Medium AWC	S_3tf	1. Add tank silt and organic manures to improve the soil's water-holding capacity. 2. Add red soil/sand to improve the drainage condition of the soils and adopt surface drainage. 3. Construction of graded bunds 4. Addition of bio-fertilizers and micro-nutrients	S_2

The variations in AWC depend on the soil's depth, clay and OC content. Surface soils have low water holding capacity than sub-surface soils, which was in close relation with clay and sand content. The CEC ranged from 14.87 to 19.77 c mol (p^+) kg^{-1} and was directly related to clay type and content and SOC content. The average ESP was 2.02 per cent.

Soil-site Suitability Evaluation for Tomato

The data presented in Table 4 show the soil characteristics of the various landforms evaluated with twelve soil series used for suitability evaluation, while Tables 4 and 5 show data on the degree of limitations and suitability of soils for tomato. According to the modified suitability criteria for tomato growth, a highly suitable class can provide more than 80 per cent of potential productivity, a moderately suitable class has moderate tomato production limitations and the rest are classified as marginally suitable with one or more severe limitations. Another classification indicates that they are non-suitable (N). It is possible to achieve satisfactory productivity by correcting one or more key limitations. The land and crop suitability evaluation has to be reassessed for the suitability of dry irrigated contingent crops as outlined by (Harsha *et. al.,* 2020) for the degraded lands

Land Suitability Evaluation for Upland Soils

The upland soils belonging to eleven series are marginally suitable (S_3) for tomato cultivation, except for the BDK and VDH series. The major limitations in these series were low AWC, ESP and low organic carbon. The soils of BDK and VDH series are moderately suitable (S_2) for tomato cultivation with limitation of low organic carbon and AWC. The heavy texture, poor water retention capacity, gentle slope of soil and undulating topography are some of the physical constraints for tomato cultivation in upland conditions (Rukmani and Manjula, 2009). Adopting appropriate management measures in the upland soils (Table 5) will ensure increased tomato yield.

Land Suitability Evaluation for Low Land Soils

The soils of the TSD series were marginally suitable (S_3) for tomato, due to limitations of moderate drainage, heavy texture, moderately alkaline soil reaction and low organic carbon. Zhao *et al*., (2015) reported that soil texture like high clay content was the main factor affecting tomato vegetation. Surface drainage through lateral ditches, adoption of salt-tolerant varieties, use of organic manures, gypsum, nitrogenous fertilizers, and soil and water conservation practices are needed to improve tomato suitability in these soils (Table 5). Lowlands produce better yields with the adoption of corrective measures and proper water and nutrient management.

Tomato is a key vegetable crop cultivated extensively in the semi-arid regions of Karnataka. Ensuring soil quality is fundamental for achieving sustainable tomato cultivation and productivity. Therefore, land evaluation based on soil characteristics is essential to enhance yield potential. The study revealed that upland areas are moderately suitable (S2) to marginally suitable (S3), while lowland soils are marginally suitable (S3) for tomato cultivation. Although the region is recognized as a prominent tomato-growing belt, current production is constrained by irregular rainfall, recurring droughts and significant soil and site limitations. Identifying these constraints through suitability evaluation can guide the adoption of site and soil-specific management practices to improve productivity. Detailed soil information at the farm level is thus a valuable tool for farmers and agricultural agencies to strengthen tomato cultivation and management strategies.

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