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CONTENTS

Characterization and classification of guava growing soils of North-East Haryana according to frame work of land evaluation (FAO, 1993)

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ABSTRACT: In the present study, undertaken in 2021-23 at CCS Haryana Agricultural University, fifteen guava orchards were selected based on variation in soils properties and guava crop dominance from five districts viz. Ambala, Yamunanagar, Kurukahetra, Karnal and Kaithal from North-East region of Haryana. Representative pedons were excavated and morphological features were examined systematically in situ in the field, and horizon wise samples were collected and analyzed in the laboratory for physico-chemical properties. Results indicated that soils of the study area were placed under three orders *i.e.,* Inceptisols, Entisols, and Alfisols and taxonomically classified as coarse loamy, calcareous, *Typic Ustorthents/Ustochrepts* for recent alluvial plains, *Typic Haplustepts*, and *Typic Natroustlf* for old alluvial plains. Also, the results differentiated the soils into two land capability classes (II and III), three land suitability classes (S1, S2, and S3), and three land irrigability classes (S1, S2, and S3) due to soils, pedogenic processes, and topographic limitations. Thus, the results indicated that the variation in geomorphic units affects soil properties. The information generated in the study would be useful for effective management of the guava-growing soils in the study area, and further mapping of the suitable areas may pave the way for effective implementation of policy decisions for the development of a particular area for a specific purpose.

Key words: Capability, horizon, irrigability, pedons, pedogenic, suitability, taxonomic classification

Haryana is a landlocked state in the north-western region of India. It lies between 27°39' to 30°35' N latitude and 74°28' and 77°36' E longitude, with an altitude between 700 and 3600 feet above sea level. It shares its boundaries with the states of Himachal Pradesh in the north, Rajasthan in the south, and the U.P. and Delhi in the east, and Punjab in the north-west. The geographical area of the state is 4.42 m ha, which comprises 1.34% of the total geographical area of the country (Anonymous, 2016). The climate of Haryana experiences severe hot temperatures in the summer at around 45°C and mild temperatures during the winter months; however, the hottest months are May and June and coldest are December and January. The whole year is divided into four seasons: the winter season, the southwest monsoon season, the post-monsoon period, and winter. The rainfall data of the past several years shows that the state received a maximum rainfall of 216 cm and a minimum in the range of 25 cm (Horticultural Statistics at a Glance, 2018). The climate varies from arid to humid and varying combinations of elevations and climatic regimes have resulted in a large number of agro-ecological regions with contrasting physiographic elements and conditions for agricultural and horticultural production. The different soil groups are formed in turn by various soil-forming factors and pedogenic processes. The genesis and distribution of soils of Haryana are mainly influenced by the different agroecological zones and its geology and physiograpy (Kumar *et. al*., 2019).

Characterization and classification of soils are important to under stand the nature of available soil resources. The data generated through profile study will help in monitoring and evaluating the changes occur in soil properties over the time under different cropping systems and introduction of different soil management techniques. Therefore, a renewed attention should be given to the soils due to rapidly declining agriculture/horticulture area and soil fertility, increasing soil degradation, unsystematic land use policies and imbalanced use of inputs (Sahoo *et al.,* 2019).

Horticultural crops, mainly fruit crops, are important for ensuring nutritional as well as livelihood security. However, the state of Haryana occupies very little area under fruit crops as compared to cereals and other agricultural crops, which may be due to the fast-growing population and urbanization. Thus, the possibilities of alternate land use options for the cultivation of horticultural crops, mainly fruit crops, need to be explored to ensure effective and efficient utilization of the lands. According to FAO (1993), suitability is a statement of the adaptability of a given area for a specific kind of land use. The evaluation process, therefore, provides information on the major constraints and opportunities for the use of land for particular use types, which will guide decision-makers on how resources are optimally utilized. The main purpose of agricultural land suitability evaluation is to predict the potential and limitations of the land for crop production. Therefore, land evaluation in terms of soil suitability assessment is an important tool for identifying suitable areas for fruit crop production, as the lack of information on soil-site suitability poses a great challenge to policy planners and other development agencies (Kumar *et al.,* 2021).

Among fruits, guava (*Psidium guajava* L.) is an important fruit crop and is ascribed as the 'Apple of the Tropics' and the most familiar fruit crop of North India due to its high adaptability to a wide range of climatic and soil conditions. Guava is the fourth most important fruit crop in India after mango, banana, and citrus. It is grown commercially in India on an area of about 315 thousand hectares with an annual production of 4.92 million metric tons, and in Haryana on an area of 15.54 thousand hectares with a production of 271.181 thousand metric tons (GOH, 2022). Guava is the second most important fruit crop after Kinnow in Haryana and can be grown in a wide range of soils but thrives best in deep, fertile, and well-drained loamy soils. Although guava can tolerate drought conditions and a wide range of pH from 4.5 to 8.2, much better than other tropical fruits, water logging conditions adversely affect its growth (Arshad, 2015). Also, it thrives best in tropical climatic conditions. There is an emerging need today to sustain soil productivity, besides the limited available soil resources. This requires information on the nature and extent of the distribution of different kinds of soils in an area and their prevailing problems, potentials, and capabilities for various land uses. Among the different land uses, horticultural crops, mainly fruit crops, are important for ensuring nutritional as well as livelihood security. However, the state of Haryana occupies very little area under fruit crops as compared to agricultural crops such as cereals, pulses, oilseeds, sugarcane, cotton, etc., and this may also be due to the fast-growing population and urbanization. Thus, the possibilities of alternate land use options for the cultivation of crops such as fruits need to be explored to ensure effective and efficient utilization of the lands. Therefore, land evaluation in terms of soil suitability assessment is an important tool for identifying suitable areas for fruit crop production, as the lack of information on soil-site suitability poses a great challenge to policy planners and other development agencies (Kumar *et al.,* 2021). All the above information could be obtained through the systematic characterization and classification of soils in an area. Therefore, under the present study, fifteen representative pedons were excavated from the guava-growing soil in the North-Eastern Agro climatic Zone of Haryana. The morphological features of the studied pedons were examined systematically in situ in the field; horizon-wise samples were collected and analyzed in the laboratory for physico-chemical properties. Thus, this study is targeted at the guava-growing area in the north-east region of Haryana to classify the soil according to soil taxonomy (Soil Survey Manual, 2017), and land capability, land irrigability, and land suitability classification will be evaluated according to the framework of land evaluation (FAO, 1993).

MATERIALS AND METHODS

The present study was carried out to characterize and classify guava-growing soils in the North-East region of Haryana, which lies between 29°09' to 30°29' N latitude and 76°09' and 77°36' E longitude and comprises Kaithal, Karnal, Kurukshetra, Ambala, and Yumunanagar districts in Haryana, India. The general characteristics of the geomorphic units of the study area in North-East Haryana are presented in Table 1, which recognizes two major geomorphic units, viz. recent alluvial plains and old alluvial plains. The flood plains and alluvial plains

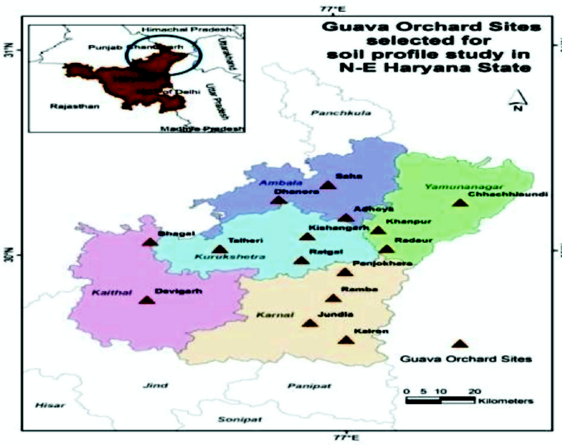

Fig. 1: Map of Guava Orchard sites selected for study

are part of the Great Plains of India, formed by alluvial sedimental deposition from recent to Pleistocene times. The plains are extraordinarily homogenous, with slight variation in relief features. The shifting of river courses in areas of frequent floods is a specific geomorphic process in the plains. The seasonal streams, locally called chos, engendered erosion and adversely altered the undulating topography to the south of the Shivaliks.

Therefore, fifteen guava orchards (two to four from each district) were selected based on the variation in soils and guava dominance (Fig. 1) and profiles were exacavated. Profile study was carried out and the morphological characteristics of soils were recorded in field as per Soil Survey Manual (2017). Horizon-wise soil samples of each profile, guava fruit trees leaves samples and water samples from the source of irrigation used at selected orchards were collected for laboratory analysis during the month of February-April 2022 before on-set of monsoon.The collected soil samples from each pedon were dried in shade, and these dried soil samples were ground with a wooden pestle and mortar and passed through a 2 mm sieve to separate the coarse fragments (>2 mm) and analyzed in the laboratory for physicochemical properties. Soil colour was determined by using Munsell Colour Chart. Bulk density of the soils was determined by core method (Black, 1965). Mechanical separation (Sand, silt and clay) was determined by International pipette method (Piper, 1966) and moisture retention capacity of soils at 0, 33 and 1500 KPa was determined with Richard's pressure plate (Richard, 1954). The pH and electrical conductivity of the soils in soil: water (1:2) suspension was measured by glass electrode and conductivity meter respectively (Jackson, 1973). Organic carbon and macro nutrients (N, P and K) were determined by rapid titration method (Walkley and Black, 1934), N by alkaline potassium permanganate method (Subbiah and Asijja, 1956), P by colorimetric method (Olsen *et al.*, 1954) and K by flame-photometric method

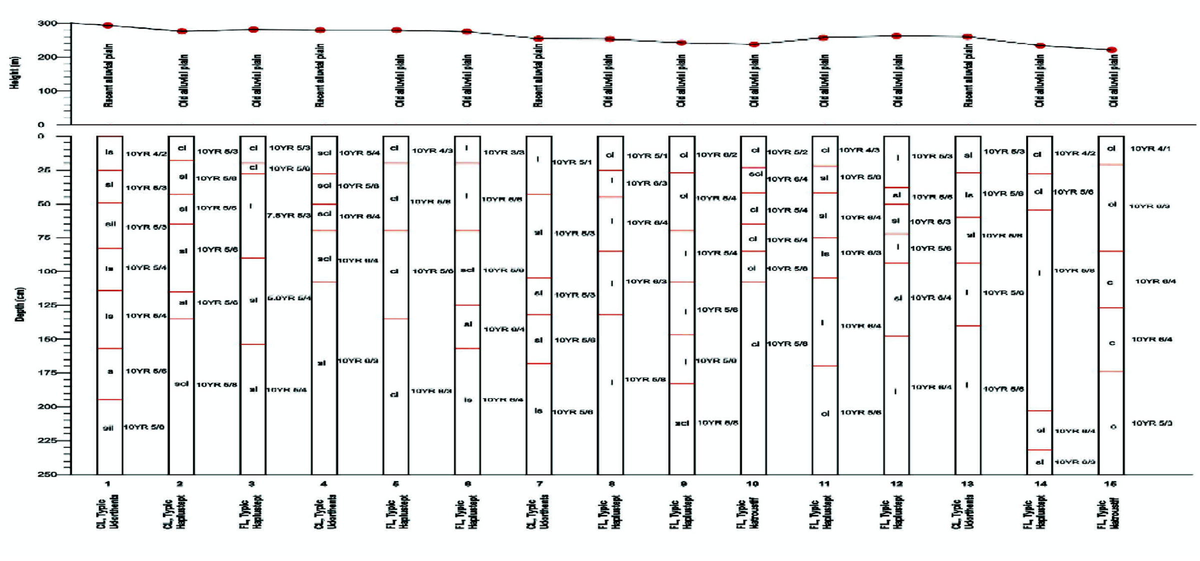

Fig. 2: Geomorphic-soil relationship of guava growing soils in North-East Haryana (Schemetic cross-section)

(Merwin and Peech, 1950). CEC was determined by neutral normal ammonium acetate extraction (Jackson, 1973).

RESULTS AND DISCUSSION

Morphological Characteristics

The guava-growing soils of North-East Haryana occur on nearly level to level sloping and are developed on parent materials derived mainly from sedimentary rocks, viz. sandstone. These soils are coarse sandy to clayey in texture, mixed, hyperthermic, recent to old alluvial plains physiographic, deep (>100 cm) to very deep (>180 cm), moderate to well drained, yellowish to grey brown red (dry), structureless to strong sub-angular blocky structure, soft to slightly hard in surface or subsurface horizons, and non- to slightly calcareous in nature.

Geomorphic-soil relationship

The guava-growing area under study was differentiated into different geomorphic units, such as recent alluvial plains and old alluvial plains. Recent alluvial plains comprise the Ghaggar, Markanda, and Yamuna River flood plains. The recent alluvial plains area was found to have a level to nearly level topography with very deep and well-drained soils, an altitude of 194 to 292 m above average mean sea level, and a mean annual rainfall of 800-1100 mm with slight to moderate erosion. The coarse sedimentary parent material was deposited in these plains and carried along by rivers from the upper northern Shivalik hills. These soils were under different land uses, i.e., agriculture, horticulture, and pasture. Out of fifteen studied pedons, only four represented these areas and were taxonomically classified as coarse loamy, calcareous, and *Typic Ustorthents/Ustochrepts* (Fig. 2). The old alluvial plains in the study area were found to have alluvium of high productivity, very deep soil depth, and poor to imperfect drainage due to different textural classes. The old alluvial plains were comprised of nearly level to level plains with an altitude of 217 to 278 m above average mean sea level, having mean annual rainfall of 500–800 mm with the least erosion and deposition throughout the

Table 1: The general characteristics of geomorphic units of the study area in North-East Haryana

Pedon	Profile Site	Physiography	Drainage	Erosion	Land Use	Parent Material	Slope (%)	Location		Slope
								Latitude	Longitude	Direction
1.	Chhachhrauli	Recent alluvial	Well drained	Slight	Guava Orchard	Alluvium	Level to nearly-level (2-4%)	30°14'26"	77°22'03"	N-S
2.	Khanpur	Old alluvial	Imperfectely drained	Low	Guava Orchard	Alluvium	Nearly-level (0-1%)	30°06'38"	77°06'57"	N-S
3.	Radaur	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (1-2%)	30°01'06"	77°08'23"	N-S
4.	Dhanora	Recent alluvial	Moderately drained	Moderate	Guava Orchard	Alluvium	Nearly-level (2-3%)	30°15'45"	76°48'59"	N-S
5.	Adhoya	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (0-1%)	30°06'16"	77°01'12"	N-S
6.	Saha	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Level to nearly-level (0-1%)	30°19'60'	76°58'04"	N-S
7.	Kishangarh	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (0-1%)	30°04'06"	76°53'34"	N-S
8.	Ratgal	Recent alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (<1%)	29°58'01"	76°52'49"	E-W
9.	Talheri	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (<1%)	30°01'40"	76°37'55"	N-S
10.	Panjokhara	Recent alluvial	Well drained	Nil	Guava Orchard	Alluvium	Nearly-level (1-2%)	29°39'35"	77°00'15"	N-S
11.	Ramba	Old alluvial	Moderate to well drained	Nil	Guava Orchard	Alluvium	Nearly-level (0-1%)	29°46'49"	76°58'23"	N-S
12.	Kalron	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (0-1%)	29°34'32"	77°00'29"	N-S
13.	Jundla	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (<1%)	29°39'35"	76°54'03"	E-W
14.	Bhagal	Old alluvial	Moderately drained	Nil	Guava Orchard	Alluvium	Nearly-level (<1%)	30°03'42"	76°25'24"	N-S
15.	Devigarh	Old alluvial	Imperfectly drained	Nil	Guava Orchard	Alluvium	Nearly-level (0-1%)	29°46'46"	76°24'37"	N-S

Table 2: Correlation between physical properties of pedons

	Depth	*Sand*	*Silt*	*Clay*	*BD*	*CEC*	*EC*	*pH*	*OC*
Depth	1.000								
Sand	0.121	1.000							
Silt	0.009	-0.762	1.000						
Clay	-0.194	-0.813	0.251	1.000					
BD	0.740	0.444	-0.109	-0.576	1.000				
0KPa	-0.258	-0.796	0.447	0.798	-0.615				
33KPa	-0.251	-0.739	0.430	0.733	-0.588				
1500KPa	-0.263	-0.700	0.289	0.811	-0.554				
CEC	-0.126	-0.685	0.365	0.707	-0.590	1.000			
EC	-0.055	-0.335	0.131	0.390	-0.368	0.601	1.000		
pH	0.007	-0.255	0.010	0.378	-0.254	0.558	0.308	1.000	
OC	-0.908	-0.167	0.017	0.247	-0.818	0.198	0.049	0.048	1.000

Table 3: Taxonomic classification of soils according to soil taxonomy (Soil Survey Manual, 2017)

Pedon	Location	Physiography	Soil Classification	
			Soil taxonomy	FAO system
1	Chhachhrauli (Yamunanagar)	Recent alluvial	Coarse loamy, Mixed, Hyperthermic, TypicUdorthents	OchricCambisols
2	Khanpur (Yamunanagar)	Old alluvial	Coarse loamy, Mixed, HyperthermicTypicHaplustepts	OchricCambisols
3	Radaur (Yamunanagar)	Old alluvial	Fine loamy, Mixed, Hyperthermic, TypicUdocrepts	OchricCambisols
4	Dhanora (Ambala)	Recent alluvial	Coarse loamy, Mixed, Hyperthermic, TypicUdorthents	EutricRegosols
5	Adhoya (Ambala)	Old alluvial	Fine loamy, Mixed, Hyperthermic, TypicHaplustepts	OchricCambisols
6	Saha (Ambala)	Old alluvial	Fine loamy, Mixed, Hyperthermic, TypicHaplustepts	OchricCambisols
7	Panjokhara (Karanal)	Recent alluvial	Coarse loamy, Mixed Hypethermic, TypicUstorthents	EutricRegosols
8	Ramba (Karanal)	Old alluvial	Fine loamy, Mixed Hypethermic, TypicHaplustepts	OchricCambisols
9	Kalron (Karanal)	Old alluvial	Fine loamy, Mixed Hypethermic, TypicHaplustepts	OchricCambisols
10	Jundla (Karanal)	Old alluvial	Fine loamy, Mixed Hypethermic, TypicNatroustlf	NatricCambisoils
11	Talheri (Kurukshetra)	Old alluvial	Fine loamy, Mixed, Hyperthermic, TypicHaplustepts	OchricCambisols
12	Kishangarh (Kurukshetra)	Old alluvial	Fine loamy, Mixed, Hyperthermic, TypicHaplustepts	OchricCambisols
13	Ratgal (Kurukshetra)	Recent alluvial	Coarse loamy, Mixed, Hyperthermic, TypicUstorthents	EutricRegosols
14	Bhagal (Kaithal)	Old alluvial	Fine loamy, Calcareous, Mixed, Hyperthermic, TypicHaplustepts	OchricCambisols
15	Devigarh (Kaithal)	Old alluvial	Fine Loamy, Calcareous, Mixed, HyperthermicTypicNatroustlf	NatricCambisoils

study area. These soils were intensively cultivated with different crops, i.e., rice, wheat, sugarcane, mustard, vegetables, and horticultural crops. Depending upon the variations in soils and dominance of guava orchards, eleven pedons were taken under the present study from an old alluvial plains area. Based on geomorphic units and morphological characteristics, these soils of old alluvial plains were classified according to soil taxonomy (Soil Survey Manual, 2017) as fine loamy, calcareous, and T*ypicUstochrepts/Haplustalfs* (Fig. 2).

The guava-growing soils of the study area showed wide variation in texture from sandy to clay, which might be attributed to variation in parent material, position of the soil in the landscape, and differential degrees of weathering. The particle size distribution indicated the highest clay content of 52 percent and the lowest of 6 percent for pedon 10 old alluvial plains and pedon 1, 4 recent alluvial plains, respectively. The soils exhibited a gradual fining of texture from flood plains to alluvial plains. The soils were finely textured on subsurface horizons as compared to overlying horizons. The soils in terms of chemical reaction varied from neutral to strongly alkaline (7.05-8.71). The lowest pH was found in recent alluvial plains (pedon 1), whereas the highest pH was found in old alluvial plains (pedon 15). A substantial variation in pH among different geomorphic units was observed, which may be due to the presence of different parent materials and organic matter (OM), as the decomposition of OM releases organic acids, resulting in a decrease in soil pH as observed in Shivalik Foot Hills. In general, the pH increased with depth in all the pedons; however, the increasing trend may be due to an increase in the accumulation of exchangeable sodium and calcium carbonate in the lower horizons (Rajeshwar *et al.*, 2009). The results of the EC of soil revealed that soils of all geomorphic units might be result of higher clay content and organic carbon found in these soils. The positively significant correlation (Table 2) between CEC with clay (r = 0.707), silt (r were low in soluble salt content (0.27 to 1.13 dS m^{-1}) except pedon 15 (1.12-2.12 dS m^{-1}). The cation exchange capacity of soils varied from 5.18 to 36.70 cmol (p^+) kg^{-1} across all the studied pedons. The CEC of the soil pedons was found to be low, which may be due to the dominance of illite minerals in these soils; however, a higher CEC in some soil pedons (r = 0.365), and organic carbon (r = 0.247), however, with sand, a significant negative correlation (r = -0.685) may be ascribed to the relatively large surface area, resulting in a proportionately greater number of cation exchange sites compared to the sand fraction (Papadopoulos *et al.*, 2009). This relationship also suggests that clay contributed to the CEC of these soils. The organic carbon was less than one percent in all of the pedons and varied between 0.14 to 0.14 and 0.14 to 0.83% in recent alluvial plains and old alluvial plains, respectively. Sharma *et al.* (2004) also reported higher organic carbon in Shivalik soils due to high rainfall and the comparatively low temperature (udic moisture regime) prevailing in the region. The organic carbon generally decreased with depth in all of the pedons; this may be due to the low biological activity and prevailing high temperature in the area, which are responsible for the rapid mineralization of organic matter, as also reported in subtropical and tropical climates by Bhat *et al.* (2017). Calcium carbonate varied from 0.17 to 2.00% across all the geomorphic units and was absent in pedons 3, 9, 10, 13, and 14. An irregular distribution of calcium carbonate was observed, which described the fluvial nature of these soils. A higher amount of calcium carbonate was observed in soils developed on old alluvial and flood plains. The higher amount of calcium carbonate in the soils developed on the toe slopes, which may be due to the finer texture of the soils that slows down the infiltration rate of water and/or the accretion of carbonates due to lateral subsurface water flow (Sawhney *et al.,* 1996). However, the results indicated that geomorphic position affects soil properties.

Soil classification

Soil classification: Soil taxonomy is a morphogenetic soil classification system for interpreting soil survey data for the evaluation of the agricultural potential of land and making predictions for current and future land use planning. The guava orchard soils under study were classified in accordance with the USDA Soil Taxonomy (Soil Survey Manual, 2017) based on the parameters climate variation, geomorphic position, morphology, and physico-chemical characteristics into different taxonomic units (Table 3). The soil moisture regime is an important function of climate, soil, and landform for understanding pedogenesis. The two dominant kinds of soil moisture regimes based on rainfall, evaporation, and geomorphic position that were noticed in the study area were Ustic and Udic. Based on the mean annual temperature and minerals present in the area, the soils of the study pedons were placed under the hyperthermic (22^o to < 28^o) and mixed mineralogy families, respectively. The soils of the pedons were placed under the order Inceptisols, except pedons 1, 4, 7, and 13 under the order Entisols, and pedons 10 and 15 under the order Alfisols. The soils under Entisols were immature, with less pedogenic development and horizon differentiation. The soils of pedon 1, 4, 7, and 13 fall under the order Entisols, formed by recent alluvial parent material. Pedons 1 and 4 were placed under great groups of udorthents due to the presence of udic soil moisture regimes in the area, and pedons 7 and 13 were placed under great groups of *Udorthents*. The soils of pedon 2, 3, 5, 6, 7, 8, 9, 11, 12, and 14 were placed under the order Inceptisols, formed from old alluvial parent material, and suborder *Haplustepts* because of the ustic soil moisture regime. The soils of pedons 10 and 15 were placed under the order Alfisols formed from old alluvial parent material and suborder *Natroustalfs* because of natric horizons and the ustic soil moisture regime. Similar results were also reported by Dinesh *et al.* (2017) and Simmi (2019 and Gill *et al.* (2022) for the soils of the North-Eastern agro-climatic zone, district Yamunanagar, and Eastern agro-climatic zones of Haryana, respectively. Sahoo *et al.* (2019) reported similar results while classifying the soils of Jhumpa Kalan watershed in Bhiwani, Haryana, and classified the soils as *Typic Torripsamments/ Ustipsamments* and *Typic Calciorchids/ Cambiorchids* due to the presence of ustic/arid soil moisture regimes, hyperthermic temperature regimes, and low organic matter content. Arya (2021) classified the soils of Ber orchards in district Rewari, Haryana, as Sandy, Mixed, Hyperthermic, *Typic Ustipsamments*, Sandy mixed (calcareous) hyperthermic, and Coarse Sandy mixed (calcareous) hyperthermic.

Land Capability Classification

Land capability classification is an estimation of the suitability of the land units for agricultural and non-agricultural purposes based on inherent soil characteristics, external land features, and environmental factors. Based on the soil criteria (Kilngebiel, 1958) and limitations such as erosion (e), soil (s), climate (c), topography (t), and wetness (w), the soils of the block have been grouped into two (II and III) land capability classes evaluated using the Frame Work of Land Evaluation (FAO, 1993). The results evaluated in Table 4 indicated that the soils were classified as IIs (Pedon-5, 6, 8, 9, 10, 11, 12 & 14) due to soil limitations, IIes (Pedon-

Table 4: Land capability classification of soils according to frame work land evaluation (FAO, 1993)

Sr. No.	Soil unit	Land form chacteristics					Physical characteristic	Chemical characteristics				LCC
		Slope (%)	Erosion	Drainage	Depth (cm)	Profile development	Texture	EC (dS m^{-1})	OC (%)	CEC (cmol (P+) kg^{-1})	Base Saturation	
1	Pedon 1	II	II	I	I	I	IV	I	III	II	I	IIest
2	Pedon 2	II	I	III	II	II	III	II	II	II	I	IIds
3	Pedon 3	I	I	III	I	II	III	II	II	II	I	IIds
4	Pedon 4	I	I	III	I	II	III	II	III	II	I	IIds
5	Pedon 5	I	I	II	II	III	II	II	II	III	I	IIs
6	Pedon 6	I	I	II	I	II	I	II	II	III	I	IIs
7	Pedon 7	II	I	VI	I	III	III	I	II	III	I	IIIdst
8	Pedon 8	I	I	II	II	II	II	I	II	II	I	IIs
9	Pedon 9	I	I	II	I	II	II	I	II	II	I	IIs
10	Pedon 10	I	I	II	II	II	II	I	II	II	I	IIs
11	Pedon 11	I	I	II	I	II	III	II	II	II	I	IIs
12	Pedon 12	I	I	II	II	II	II	II	II	III	I	IIs
13	Pedon 13	II	II	II	II	III	III	I	II	III	I	IIest
14	Pedon 14	I	I	II	I	II	II	II	II	II	I	IIs
15	Pedon 15	I	I	III	I	II	II	II	II	II	I	IIds

EC-electrical conductivity; OC-organic carbon; CEC-cation exchange capacity; LCC- land capability classification

Table 5: Land suitability classification of soils according to frame work land evaluation (FAO, 1993)

Sr. No.	Soil unit	Maize	Wheat	Sugarcane	Paddy	Vegetable	Horticulture
1	Pedon 1	S2	S1	S2	S3	S2	S2
2	Pedon 2	S2	S1	S2	S2	S2	S2
3	Pedon 3	S2	S1	S2	S2	S2	S2
4	Pedon 4	S2	S1	S2	S2	S2	S2
5	Pedon 5	S2	S1	S2	S2	S2	S2
6	Pedon 6	S2	S1	S2	S2	S2	S2
7	Pedon 7	S2	S1	S2	S3	S2	S2
8	Pedon 8	S2	S1	S2	S2	S2	S2
9	Pedon 9	S2	S1	S2	S2	S2	S2
10	Pedon 10	S2	S1	S2	S2	S2	S2
11	Pedon 11	S2	S1	S2	S2	S2	S2
12	Pedon 12	S2	S1	S2	S2	S2	S2
13	Pedon 13	S2	S1	S2	S2	S2	S2
14	Pedon 14	S2	S1	S2	S2	S2	S2
15	Pedon 15	S2	S2	S2	S2	S3	S3

Table 6: Land irrigability classification of soils according to frame work land evaluation (FAO, 1993)

Sr. No.	Soil unit	Land form characteristics			Physical characteristic	Chemical characteristics			Land Irrigability Classification
		Slope (%)	Drainage	Depth (cm)	Texture	EC (dS m^{-1})	ESP (%)	Free $CaCO_3$	
1	Pedon 1	S2	S1	S1	S3	S1	S0	S1	S1st
2	Pedon 2	S1	S1	S1	S2	S1	S0	S1	S1s
3	Pedon 3	S1	S2	S1	S2	S1	S0	S1	S1ds
4	Pedon 4	S2	S2	S1	S2	S1	S0	S1	S2st
5	Pedon 5	S1	S2	S1	S1	S1	S1	S1	S1d
6	Pedon 6	S1	S2	S1	S3	S1	S1	S1	S1ds
7	Pedon 7	S1	S3	S1	S2	S1	S1	S1	S1ds
8	Pedon 8	S1	S1	S1	S1	S1	S1	S1	S1
9	Pedon 9	S1	S1	S1	S1	S1	S2	S1	S1s
10	Pedon 10	S1	S1	S1	S1	S1	S1	S1	S1
11	Pedon 11	S1	S1	S1	S1	S1	S0	S1	S1
12	Pedon 12	S1	S1	S1	S2	S1	S1	S1	S1s
13	Pedon 13	S1	S1	S1	S3	S1	S1	S1	S1s
14	Pedon 14	S1	S1	S1	S1	S1	S1	S1	S1
15	Pedon 15	S1	S2	S1	S1	S1	S3	S1	S1ds

EC-electrical conductivity; ESP-exchangable sodium percentage; $CaCO_3$-calcium carbonate

1 & 13) due to erosion and soil limitations, IIds (Pedon-2, 3, 4 & 15) due to drainage and soil limitations, and IIIdst (Pedon-7) due to drainage, soils, and topographic limitations, according to Land Capability Classification.

Soil Suitability Classification

Soil suitability classification was evaluated using the framework of land evaluation (FAO, 1993). The results presented in Table 5 revealed that the soils of the study area according to soil suitability criteria for different crops were found suitable (S1) for wheat, moderately suitable (S2) for maize, sugarcane, vegetables, horticulture, and paddy. Similar findings were also reported by Simmi (2019) while studying the pedogenic characterization of the district of Yamunanagar, Haryana.

Land Irrigability Classification

Land irrigability classification was derived on the basis of soil characteristics related to moisture holding capacity like soil texture, depth, available water, moisture retention, salinity, infiltration, and permeability, along with the topography, drainage requirement, quantity and quality of water, water table depth, ground water aquifer, etc. Irrigability classes were also divided into sub-classes depending on the limitations, like soil limitations (s), topographic limitations (t), and drainage limitations (d). Soil irrigability classification was evaluated using the framework of land evaluation (FAO, 1993). The results presented in Table 6 inferred that the soils of the pedons were classified as suitable classes (S1s to S2s) for irrigation, and pedons 5 and 6 were forest land, but for future cultivation planning, they may be put under class marginally suitable (S3d) due to drainage problems. These results are in conformity with those of Nagaraju *et al.* (2014) and Choudhary *et al.* (2019).

CONCLUSION

The soils of the study area were found to be deep to very deep, neutral to strongly alkaline in reaction, non-saline to saline, low to medium in organic carbon content, and low to medium in CEC and base saturation, and taxonomically placed under three orders, viz., Inceptisols, Entisols, and Alfisols. However, the soils of recent alluvial plains under Entisols were immature, lacked pedogenic development and horizon differentiation, and were classified as *Typic Udorthents* and *Ustorthents*. Moreover, the soils of old alluvial plains were placed under the order Inceptisols and Alfisols formed from old alluvial parent material and the great group *Haplustepts* because they have austic moisture regime and a hyperthermic soil temperature regime and are classified as *Typic Haplustepts* and *TypicNatroustlf*. Soil capability, suitability, and irrigability classification provide immense help for effective implementation of technological interventions designed to achieve higher productivity and are also helpful in developing strategies for planning, implementing, and adopting best management practices for soil and water conservation measures. Further, mapping the suitable areas may pave the way for effective implementation of policy decisions for the development of a particular area for a specific purpose.

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