

Characterization and Classification of Soils of Ghaggar Plains of Patiala, Punjab

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Abstract: Soils in the alluvial plains of Ghaggar river in Patiala tehsil are characterised. The physiography of the area is classified as: recent flood plains, meander plains and old flood plains. Soil variability was mapped by conducting high intensity detailed soil survey in three sample areas of Sanaur, Kapuri and Bahal. Recent flood plains and left - out meander plains occupy majority of the soil series in heterogeneous pattern, while that of old floodplains giving a homogeneity to the land occupy four soil series. Of the seven soil particle size families in the area, three were mapped in the old flood plain, four in the recent flood plain and five in meander plain. The recent flood plain have 13 mapping units with 21 polygons, while meander plain have 10 mapping units with 54 polygons. However, old flood plain have 4 mapping units and 6 polygons. The spatial variability can be generalized in the following order: meander plain > recent flood plain > old flood plain. Wide textural differences have influenced the available moisture in various soil horizons. The soils have been classified as Entisols and Inceptisols, and further upto family level. Two contrasting particle size classes viz. coarse-loamy over fine-silty and fine-silty over coarse-loamy have been suggested. A subdivision in coarse loamy particle size class also needs consideration.

Textural variation with depth in the flood plain soils is a common feature. Soils vary with depth and spatial variability in their characteristics at relatively shorter distance. Homogeneous and heterogeneous soils occur in the flood plain. During reconnaissance soil survey of Patiala tehsil, it was observed that the soils of Ghaggar plain are heterogenous and distinctly different than the soils of Ghaggar plain of Haryana (Ahuja & Khanna 1988). Soils of the area are deep, reddish brown and clayey (NBSS&LUP 1981) but some soils are intensively stratified and show greater

spatial variability (Saxena 1975). For identifying and mapping of these variabilities, three samples areas were selected for detailed investigation.

MATERIAL AND METHODS

The study area is a part of Patiala tehsil, Punjab, located between 30°05' to 30°27' N latitude and 76°10' to 76°39' E longitude with an average elevation of 275 m above msl. The climate is semiarid with an average annual rainfall of 870 mm. The monthly mean maximum and mean minimum temperatures recorded in the area are 39.9° C and 6.3° C, respectively with the

mean annual temperature of 24.5° C. Physiographically, the Ghaggar plain can be divided into three units: Recent flood, Meander plain and Old flood plain (Fig. 1) Three sample areas, namely Kapuri, Sanaur and Bahal, one in each

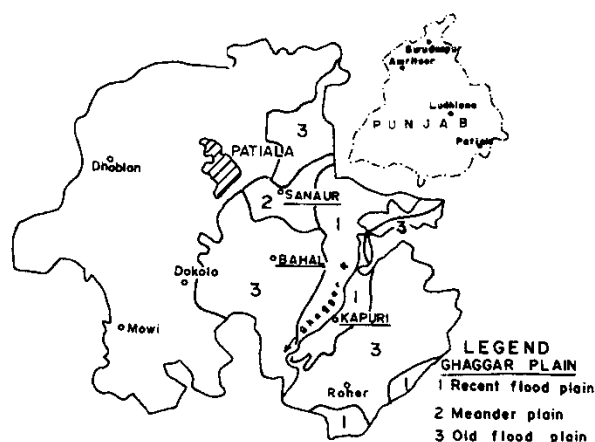


Figure 1.
Map showing three sample areas in
Patiala Tahsil (Punjab)

physiographic unit were selected for high intensity detailed soil survey. The cadastral map on 1:2,640 (Kapuri and Sanaur) and 1:2,280 (Bahal) were used. The Sanaur and Kapuri area having heterogeneous soils, were mapped at 55m grid interval, and Bahal area with homogeneous soils at 100m interval. Out of the eleven soil series, eight, namely Sanaur, Banru, Daun, Julkan, Kapuri, Bahadurgarh, Jalalpur, and Patiala were selected and classified according to Soil Taxonomy (Soil Survey Staff 1990). Horizonwise soil samples were analysed. Mechanical analysis was done by the International Pipette Method (Piper

1950). Five mechanical fractions were separated as required for USDA textural classification. Bulk density was estimated by clod method (Black *et. al.* 1965). The pH and EC were determined in 1:2.5 and 1:2 soil water suspension, respectively. CEC was determined with \underline{N} NaOAc extractant (pH 8.2) (Richards 1954). Calcium carbonate was estimated by calcimeter using VAN Slyke-Beil manometric apparatus. Soil moisture retention at 33 kPa and 1500 kPa was estimated by following the procedure of Richards (1947) and the available moisture status in soil profile was calculated as suggested by Isrealsen and Vaughan (1962).

RESULTS AND DISCUSSION

Soil maps of Kapuri, Sanaur and Bahal areas are presented in Fig. 2. Eleven soil series were identified and mapped at phase level; six in recent flood plain (Kapuri area), eight in meander plain (Sanaur area) and four in old flood plain (Bahal area) (Table 1). Morphological and physico-chemical characteristics of soils are given table 2.

Soils of Recent Flood Plain and Meander Plain.

Sanaur series: It is a member of the mixed, hyperthermic family of Typic Ustipsamments. It comprises very deep, rapidly permeable and excessively drained, sandy calcareous soils of yellowish brown to dark brown colour and occur on nearly level to gently sloping lands. The series control section has sand to loamy sand texture with single grain to weakly granular structure. Stratification of different grades of sands is noticed in the entire profile. The pH range, from 7.9 to 8.4, calcium carbonate 0.45 to 0.85 per cent, and organic carbon 0.04 to 0.07 per cent. The available water

Table 1. Distribution pattern of soil series and phases in three sample areas (ha)

Soil series	Soil map unit	Heterogenous Recent flood plain Kapuri area	Homogenous Old meander Plain Sanaur area	Homogenous Old flood Plain Bahal area
1	2	3	4	5
Sanaur	1bA*	-	0.20	-
	1cA	-	0.40	-
	1aB	-	2.83	-
	1db	-	4.43	-
	1aBc	-	4.64	-
Banru	2bA	0.80	3.22	-
	2bB	-	5.64	-
	2cA	2.41	-	-
Daun	3bA	0.60	7.66	-
	3cA	4.03	4.83	-
	3bB	4.83	1.61	-
Julkan	5bA	-	4.43	-
	5cA	4.43	4.83	-
	5dA	2.01	2.01	-
Bahad- urgarh	6cA	0.40	5.64	7.25
	6dA	0.80	5.64	-
Urdan	7cA	-	-	12.09
Kapuri	8bA	-	7.25	-
	8cA	2.01	6.04	-
	8	12.50	4.43	-
	8dB	0.80	-	-
Bolar	10bA	-	0.80	-

1	2	3	4	5
	10cA	0.40	-	-
Jalapur	11dA	-	-	1.61
Patiala	12eA	-	-	11.69
Devigarh	13cA	-	1.20	-

*1bA - First numeral: Series name;
Second letter: Surface texture, a-loamy sand; b-sandy loam; c-loam; d-clay loam; e-silty clay

Third letter: A = 0-1 per cent; B = 1-3 per cent

for 60, 100 and 150 cm depth is 1.96, 3.2 and 3.4 cm, respectively.

Banru series: It is a member of the coarse loamy, mixed, calcareous, hyperthermic, family of Typic Ustorthents. It comprises very deep, rapidly permeable, well drained coarse loamy, calcareous soils of light brown colour. The series control section is generally sandy loam, occasionally followed by sand at lower depth. Its colour is brown to dark brown and has weak subangular blocky structure. The soils are stratified. The pH ranges from 7.6 to 8.3, calcium carbonate 0.6 to 4.9 per cent, organic carbon 0.04 to 0.21 per cent, and CEC 2.25 to 2.98 $\text{cmol}^{(+)} \text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 4.1, 7.1 and 8.7 cm, respectively.

Daun series: It is a member of the coarse loamy, mixed, hyperthermic family of Typic Ustifluvents. It comprises very deep, well drained, yellowish brown to dark brown coarse-loamy, calcareous soils with

TABLE 2. Physico-chemical properties of soil

Hori- Zons	Depth (cm)	Particle size Distribution (%)			pH (1:2.5)	E.C. dsm-1	CaCo3 (%)	O.C (%)	LEC (Cmo) (+) Kg	B.D g/cc	Moisture		Avai. Water %/cc (Vol- basis)	
		Sand	Silt Course	Clay Fine							33kPa	1500kPa		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SANAUR SERIES														
A1	0-20	80.6	9.9	2.7	6.9	8.2	0.15	0.45	0.07	2.4	1.73	3.7	1.1	4.5
C1	20-45	79.6	12.9	12.9	1.6	6.1	8.4	0.15	0.45	0.06	2.2	1.72	2.5	1.0
C2	45-70	76.0	16.1	1.4	5.9	7.9	0.20	0.60	2.2	1.72	2.6	1.0	2.8	
C3	70-95	81.0	9.3	2.5	7.1	8.0	0.20	0.50	0.06	2.3	1.34	3.7	1.2	3.4
C4	95-150	84.6	8.4	2.1	5.9	8.1	0.20	0.70	0.06	2.1	1.43	2.6	0.9	2.4
C5	150+	84.8	8.2	1.8	5.1	8.1	0.20	0.85	0.04	2.1	1.64	1.6	0.9	1.5
BAHRU SERIES														
A1	0-15	63.3	19.8	5.2	8.7	7.6	0.25	0.60	0.21	2.98	1.55	8.0	2.7	8.2
C1	15-28	77.6	19.8	5.8	8.3	8.1	0.20	0.60	0.16	2.71	1.67	6.2	2.2	6.7
C2	28-55	81.1	12.1	4.2	6.9	8.2	0.20	0.35	0.07	2.21	1.54	5.8	1.7	6.3
C3	55-65	83.0	26.7	7.6	7.6	8.3	0.20	1.50	0.07	2.25	1.59	5.2	1.6	5.7
C4	65-78	95.8	18.0	4.0	6.0	8.3	0.20	1.00	0.06	2.25	1.59	5.2	1.6	5.7
C5	78-94	85.6	27.1	11.1	8.6	8.2	0.20	4.90	0.06	2.25	1.32	11.5	3.6	10.4
2C6	94-140	83.8	6.0	3.4	5.6	8.4	0.15	0.85	0.04	2.10	1.54	3.2	1.1	3.2
2C7	140-160	68.1	15.6	3.0	5.9	8.5	0.15	1.10	0.06	2.10	1.62	3.0	0.9	3.4
DAUN SERIES														
Ap	0-17	38.3	41.0	11.3	8.5	8.0	0.20	0.90	0.33	4.25	1.45	16.2	3.2	18.9
C1	17-42	26.1	39.5	24.8	10.2	8.1	0.15	2.50	0.22	5.15	1.41	16.9	3.6	18.8
C2	42-60	38.6	37.1	13.2	10.9	8.2	0.15	1.70	0.12	5.20	1.48	14.6	2.6	17.8
2C3	60-86	51.3	33.2	9.8	5.2	8.2	0.15	1.60	0.07	2.50	1.47	10.9	2.0	13.1
2C4	86-118	60.3	28.5	5.8	5.1	8.2	0.15	1.40	0.04	2.50	1.51	11.4	2.3	13.7
2C5	118-160	2.8	13.1	55.9	27.9	8.1	0.30	2.60	0.24	16.25	1.51	33.3	10.2	26.6
JULKAN SERIES														
Ap	0-14	23.0	25.7	35.4	16.9	7.8	0.60	2.45	0.36	10.65	1.32	27.2	5.8	28.2
AC1	14-40	14.1	25.4	45.9	15.2	7.8	0.20	2.55	0.24	10.10	1.27	26.2	5.5	28.8
C2	40-57	27.4	34.7	26.9	10.8	7.9	2.20	2.40	0.13	6.50	1.33	27.0	4.9	29.4
C3	57-79	14.0	18.1	52.5	14.0	7.9	0.25	3.00	0.22	9.50	1.22	33.9	7.6	32.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C4	79-90	25.3	35.9	25.3	12.5	7.9	0.20	0.13	7.76	1.42	27.9	5.8	31.4	
2C5	90-114	5.9	11.1	50.8	31.4	7.8	0.25	3.40	0.27	20.85	1.14	32.5	10.3	25.2
3C6		37.9	42.1	11.4	8.6	7.9	0.20	2.25	0.08	5.69	1.39	16.6	3.1	18.8
4C7		9.8	19.3	11.4	8.6	7.9	0.20	2.25	0.08	5.69	1.39	16.6	3.1	18.8
5C8	144-160	42.4	30.2	9.7	7.7	8.0	0.20	1.35	0.06	5.00	1.39	11.6	2.2	13.1
KAPURI SERIES														
Ap	0-13	10.2	19.4	43.3	26.9	7.6	0.40	1.55	0.51	14.37	1.48	28.6	10.9	26.2
A3	13-32	14.8	22.2	38.2	25.1	7.8	0.20	1.50	0.30	13.29	1.61	24.8	8.0	27.1
2C1	32-53	24.8	39.3	25.2	9.9	7.8	0.20	1.75	0.18	4.50	1.39	17.7	3.5	19.7
2C2	53-72	23.6	29.9	30.2	17.3	7.9	0.20	1.80	0.12	7.48	1.35	23.9	3.6	27.4
3C3	72-96	19.0	34.5	36.4	8.4	7.9	0.20	2.45	0.10	4.90	1.31	26.5	3.6	30.0
3C4	96-105	64.5	26.9	3.1	4.7	7.8	0.30	1.00	0.07	2.60	1.58	10.4	2.0	13.3
4C5	105-117	2.7	60.3	27.0	8.6	8.0	0.15	2.45	0.12	4.86	1.39	27.5	4.0	32.7
5C6	117-137	62.0	24.3	6.6	6.4	8.0	0.15	1.20	0.09	3.60	1.70	9.2	2.0	12.2
6C7	137-150	11.1	10.7	67.5	1.6	7.9	0.20	2.15	0.18	6.50	1.23	32.4	9.0	28.0
BAHADURGARH SERIES														
Ap	0-14	27.6	25.7	29.5	17.0	7.8	0.45	1.0	0.58	11.40	1.66	22.9	7.6	25.4
BW1	14-46	18.9	23.0	33.2	25.8	7.9	0.45	1.7	0.25	13.57	1.67	24.9	8.8	26.9
BW2	46-67	15.2	27.7	32.6	24.7	8.0	0.45	2.8	0.21	14.11	1.73	24.9	8.2	28.9
C1	67-103	12.0	26.7	39.8	22.6	8.2	0.35	4.0	0.18	13.03	1.73	26.7	7.8	32.7
C2	103-124	7.0	4.1	43.9	43.0	8.6	0.80	2.65	0.19	21.72	1.80	32.0	16.0	28.8
JALALPUR SERIES														
Ap	0-18	5.4	16.5	52.8	24.8	7.9	0.45	0.75	0.45	18.00	1.58	30.3	10.0	32.0
BW	18-60	3.0	7.9	63.6	26.0	25.	8.00	0.35	0.75	0.24	19.00	1.64	34.5	11.4
2C1	60-85	4.5	8.3	34.3	48.9	7.9	0.60	0.80	0.38	26.43	1.71	29.3	16.4	22.1
2C2	85-118	8.1	10.2	33.7	47.2	8.0	0.80	1.15	0.33	25.47	1.73	27.0	14.5	21.6
2C2	118-150	9.1	12.8	33.4	43.0	8.1	1.30	2.00	0.35	24.12	1.86	27.0	14.5	23.2
PATIALA SERIES														
Ap	0-18	9.3	12.7	34.6	41.7	7.5	0.75	-	0.83	26.06	1.67	29.9	17.2	21.2
BW1	18-47	10.1	12.4	33.9	42.7	7.5	0.25	-	0.38	23.89	1.72	27.8	15.1	21.8
BW2	47-66	12.6	12.0	37.2	36.7	7.5	-	-	0.36	21.17	1.71	27.3	14.9	21.4
BW3	66-86	8.2	8.3	38.7	44.0	7.5	0.20	-	0.90	0.29	21.17	1.71	27.5	21.2
C1	86-116	8.7	6.9	44.0	40.1	7.6	0.20	0.90	0.29	21.17	1.71	27.5	14.9	21.5
C2	116-146	14.7	9.3	38.9	35.9	7.3	0.20	0.05	0.25	21.00	1.71	25.6	12.0	23.2
C3	146-174	13.9	9.4	41.8	34.7	7.5	0.20	0.70	0.70	0.21	21.70	1.70	24.7	21.0

moderately rapid permeability, sandy loam texture and weak blocky to single grain structure in the control section and is stratified below 60cm. The pH ranges from 8.0 to 8.2, calcium carbonate 1.4 to 2.5 percent, organic carbon 0.04 to 0.33 percent and CEC 2.50 to 5.2 $\text{Cmol}(+)\text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 11.0, 16.4 and 27.4 cm, respectively.

Julkan series: It is a member of the coarse loamy over fine silty, mixed, calcareous, hyperthermic family of Typic Ustifluvents. It comprises very deep, well drained calcareous soils of dark brown to reddish brown colour with moderate to moderately rapid permeability. The series control section have silt loam to silty clay texture with weak to strong angular blocky structure. These are highly stratified below 60 cm depth as evidenced by the presence of sand pockets and sudden change in texture and colours from 5YR to 10YR hues. The soil pH ranges from 7.8 to 8.1, calcium carbonate 2.2 to 3.4 per cent, organic carbon 0.06 to 0.36 per cent and CEC 5.0 to 20.8 $\text{Cmol}(+)\text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 17.4, 29.4 and 41.4 cm respectively.

Kapuri series: It is a member of the fine-silty over coarse-loamy, mixed, calcareous, hyperthermic family of Typic Ustifluvents. It comprises very deep, well drained soils with moderate to moderately rapid permeability and dark brown to reddish brown colours. The series control section has sandy loam to silt loam texture with single grain to

moderate blocky structure. These are the intensively stratified soils, which is evidenced by sudden changes in colour of 5YR, 7.5YR, 10 YR hues and texture from loam to silt loam at short intervals.

The pH ranges from 7.6 to 8.0, calcium carbonate 1.0 to 2.4 per cent, organic carbon 0.07 to 0.51 per cent and CEC 2.6 to 14.37 $\text{Cmol}(+)\text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 14.6, 25.6, and 36.4 cm, respectively.

Soils of Old Flood Plains

Bahadurgarh series: It is a member of the fine-loamy, mixed, calcareous hyperthermic family of Typic Ustochrepts. It comprises very deep, moderately well drained, fine-loamy, calcareous soils of dark brown to reddish brown colours moderate and permeability. The texture of the series control section varies from silt loam to silty clay loam followed by silty clay at 124 cm depth and medium to coarse blocky structure. The pH ranges from 7.8 to 8.6, calcium carbonate 1.0 to 4.0 per cent, organic carbon 0.18 to 0.58 per cent and CEC 11.4 to 21.7 $\text{Cmol}(+)\text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 16.2, 29.0 and 44.1 cm, respectively.

Jalalpur series: It is a member of the fine silty over clayey, mixed, hyperthermic family of Fluventic Ustochrepts. It comprises very deep, moderately well drained, dark brown to reddish brown, calcareous soils moderate with permeability. The control series section has silt loam to silty clay texture with medium to coarse angular

blocky structure. Fine stratification due to very thin layers of very fine sand and silty texture, Fe, Mn concretions and mottlings are noticed below 60 cm depth. The pH ranges from 7.9 to 8.1, calcium carbonate 0.75 to 2.00 per cent, organic carbon 0.24 to 0.45 per cent and CEC 18.0 to 26.4 $\text{Cmol}(+)\text{kg}^{-1}$. The available moisture for 60, 100 and 150 cm depth is 21.4, 30.2 and 41.5, respectively.

Patiala series: It is a member of the clayey, mixed, hyperthermic, family of Fluventic Ustochrepts. It comprises very deep, moderately well drained, light reddish brown to dark reddish grey, noncalcareous clayey soils. The control section has silt loam to silty clay texture and medium to coarse angular blocky structure. Fine stratification is noticed within the profile and few, fine, faint mottles are also encountered below 60cm depth. The pH ranges from 7.3 to 7.5, organic carbon 0.2 to 0.8 per cent and CEC 21.0 to 26.0 $\text{Cmol}(+)\text{kg}^{-1}$. The available water for 60, 100 and 150 cm depth is 10.7, 19.3 and 30.5 cm, respectively.

Spatial variability

Sanaur and Kapuri areas represent heterogeneous, while Bahal area has homogeneous soils. The soil maps show the mapping unit at soil phase level. The soils show greater vertical and horizontal variability due to deposition pattern of transported material. This variability is observed in texture, colour, sequence of horizons, stratification and soil classification.

TABLE 4. Spatial variability in soils of Ghagar Plain

Parameters	Kapuri area	Sanaur area	Bahal area
Area (ha)	36.0	77.7	32.6
Series	6	8	4
Mapping unit	13	10	4
No. of polygon	21	54	6
Min. area of Mapping unit(ha)	0.40	0.20	1.61
Soil classification			
T. Ustips-ament	-	16.1%	-
T.Ustorthents	8.9%	11.4%	-
T.Ustifluvent	7.8%	58.0%	-
T.Ustochrepts	3.3%	14.5%	59.8%
Particle size family in soil control section			
Sandy	-	16.1%	-
Coarse loamy	35.2%	29.6%	-
Fine loamy	3.3%	14.5%	59.3%
Clayey	-	-	35.8%
Coarse over fine silty-loamy	19.0%	17.1%	-
Fine silty over coarse loamy	42.5%	22.7%	-
Fine silty over clayey	-	-	4.9%

Out of the seven textural families identified in the area, four were mapped in the recent flood plain, five in the meander plain and

three in the old flood plain (Table 3). Variability is also reflected in the number of mapping units and the number of polygons mapped. The recent flood plain have 13 mapping units with 21 polygons, while meander plain has 10 mapping units with 54 polygons. However, old flood plain has 4 mapping units and 6 polygons. Thus the soil spatial variability can be generalised in the following order.

meander plain > recent flood plain > old flood plain.

Soil Classification

The soil classification upto family level (Table 4) indicated that Sanaur, Banru, Daun, Julkan and Kapuri series belong to Entisol order. They have only an ochric epipedon. Sanaur series being sandy are Psammets and Daun, Julkan, Kapuri having irregular decrease of organic carbon are Fluvents. Banru series with sandy loam texture and regular decrease in organic carbon comes under Orthents. The soils of Bahadurgarh, Patiala and Jalalpur have Ochric epipedon and Cambic subsurface horizon and come under Inceptisols order and Ochrept suborder. There is an irregular decrease in organic carbon content in Jalalpur series while in Patiala series, organic carbon remains above 0.2 per cent at 125 cm depth and qualify for Fluventic Ustochrepts at subgroup level. However, Bahadurgarh series come under Typic Ustochrepts.

The mineralogy of soils is mixed. All the soils are calcareous except Patiala series. The soil temperature regime is hyperther-

mic. The soils of Sanaur series have 5 to 7 per cent clay, 10 to 17 per cent silt and more than 70 per cent sand, and thus qualify for sandy particle size class. The soils of Banru and Daun series have an average clay of 8.2 per cent, while silt in Banru series is 24.2 per cent and 48 per cent in Daun series. Both the soils qualify for coarse-loamy particle size class but have contrasting difference in available water capacity. Banru has 7.1 cm/100 cm depth while Daun has 16.4 cm/100 cm depth. The contrasting difference in available water in the same particle size class of coarse-loamy is attributable to total silt content and hence, it is suggested that coarse-loamy class may be divided in two parts based on silt content. Soils of Julkan and Kapuri are intensively stratified showing lithological discontinuities in the soil profile. In Julkan series lithological discontinuity at 90 cm depth is evident as clay is 12.5 per cent in C₄ horizon (79 to 90 cm) and 31.4 per cent in 2C₅ (90-114 cm). Though total silt content in C₄ and 2C₅ horizon is around 61 per cent, the variation in fine silt and coarse silt fraction is appreciable. The coarse silt content is 35.9 per cent and 11.1 per cent and the fine silt content is 25.3 per cent and 50.8 per cent in C₄ and 2C₅, respectively. Increase in clay per cent in 2C₅ horizon is reflected in high moisture retention at 1500 kPa with the result that available moisture in both the horizon is around 31 per cent. Lithological discontinuity is also noticed below the control section. The soils of Julkan series qualify for coarse-loamy over fine-silty contrasting particle size class family.

TABLE 4. Soil classification

Sub-order	Great Group	Sub-Group	Family	Series
Psamments	Ustipsamments	Typic Ustipsamments	Sandy	Sanaur
Fluents	Ustifluents	Typic Ustifluents calcareous	Coarse-loamy, Coarse-loamy over Julkan fine-silty calcareous	Daun Kapuri
Orthents	Ustorthents	Typic Ustorthents	Coarse-loamy, calcareous	Banru
Ochrepts	Ustochrepts	Typic Ustochrepts Fluentic Ustochrepts	Fine-loamy, calcareous Fine-silty over clayey, calcareous Clayey, non-acid	Bahadurgarh Jalalpur Patiala

Mixed mineralogy and hyperthermic temperature regime were common.

In Kapuri series, stratification causing lithological discontinuities with depth have been observed at 32, 72 and 96 cm. The contrasting particle size class finesilty over coarseloamy at 32 cm shows 6 per cent difference in available moisture, while the clay difference in between A₃ and 2C₁ horizon is 16 per cent. However, difference in total silt content is 4 per cent but the difference in coarse silt and fine silt is 10 and 17 per cent, respectively. Further going deep at 72 cm depth, the difference in silt and clay per cent is 11 per cent and 9 per cent, respectively which is also reflected in available moisture status (27.4 per cent). The horizon 3C₃ (72-96 cm) and 3C₄ (96-105 cm) have particle size family of coarse loamy but shows contrast in silt, clay and

available moisture. The 3C₃ horizon has coarse silt 34.5 per cent, fine silt 36 per cent and 8.4 per cent clay, while 3C₄ horizon has 26.9 per cent coarse silt, 3.1 per cent fine silt and 4.7 per cent clay. The available moisture in 3C₃ and 3C₄ horizons is 30 per cent and 13.3 per cent, respectively.

The Bahadurgarh soils have weighted average clay, silt and sand of 24.1 per cent, 61.9 per cent and 14.8 per cent, respectively and qualify for fine silty family. In case of Jalalpur series lithological discontinuity at 60 cm depth shows variation in clay and silt distribution. The Bw horizon (18-60 cm) has 26 per cent clay and 71.5 per cent silt, whereas 2C₁ horizon (60-85 cm) is having 48.9 per cent clay and 42.6 per cent silt. Though clay has increased by absolute 22

per cent in 2C₁ horizon, the water availability has decreased from 37.4 per cent in Bw to 22.1 per cent in 2C₁ horizon. This decrease in water availability is due to decrease in silt content and increase in clay content leading to higher water retention at 1500 kPa. Patiala soils qualify for clayey (fine) particle size class family as the clay ranges from 36 to 44 per cent and silt ranges from 46 to 51 per cent. There is uniform moisture availability throughout the profile.

The strongly contrasting particle size class does not include coarse loamy over fine silty and fine silty over coarse loamy classes, which are important in Indian context specially in Indo- Gangetic alluvial plain as they affect movement and retention of water. It is suggested that the above contrasting particle size classes may be included. Coarse-loamy particle size class is wide with respect to silt content which influences the availability of water. Hence the coarse loamy particle size needs consideration for subdivision.

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