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Characterization of soil moisture storage and release in soils of Indira Gandhi Canal Command in Rajasthan

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Abstract

The Indira Gandhi Canal project is one of the major irrigation projects irrigating arid lands. Its command has been divided into stage I - comprising the northern and eastern half and stage II - comprising the southern and western half. Of the available irrigation water, 0.45 Mha m was to be utilised in stage I and 0.49 M ha m in stage II. The total water allowance is 147.99 cumecs per million acre and is distributed through warabandi system. Soils of the command comprise relict flood plains, aeolian sandy plains; desert sandy plains and soils with selenite deposits covering 2,24,947, 4,44387, 80, 160 and 2,000 ha area, respectively. Some soils of the relict alluvial flood plain (pedons 1 to 4) and the selenite rich basinal soils are pronouncedly fne textured with abundance of silt, and some are medium textured and have sand overburden. Some flood plain soils are uniformly saline and the others have sub-surface salinity. Basinal selenite rich soils are extensively saline and have turned waterlogged in post irrigation period. Fine textured soils could hold between 56 and 63 cm water at field capacity in 1 m thick profile, of which 28 cm could be made use of by plants, being available water. The medium textured soils could hold up to 22 cm water of which 13 cm water could be made use of by plants at corresponding depth. Soils of the aeolian sandy plain (pedons 5 to 11) were gypsic and non-gypsic and saline to varying degrees. Gypsic soils could hold up to 33 cm water, of which only up to 8 cm water could be made use of at corresponding depth. Other non gypsic soils could hold between 5 and 12 cm water, of which up to 3 cm could be made use of by the plants, being available water (moisture held between 0.03 and 1 Mpa) at corresponding depth. Soils of the desert plain (pedons 12 and 13) were saline to varying degrees and could hold up to 8 cm water, of which only about 1 cm water could be made use of by the plants at corresponding soil depth. The droughtiness of most soils resulted from extremely low water holding capacity of surface horizon and correspondingly low moisture availability, particularly in presence of salts. Soils of aeolian sandy plain, desert plain and medium textured soils of relict flood plain favour maximum deep percolation losses.

Additional Key words : Indira Gandhi Canal, arid lands, irrigation, soil salinity and waterlogging, percolation losses.

Introduction

The Rajasthan Canal or Indira Gandhi Canal Project is one of the major irrigation projects irrigating arid lands. Irrigated agriculture in the command was developed with UNDP/FAO assistance by conducting pre-irrigation survey and pertinent field experiments. The project covers about 2.2 Mha area which has been divided into stage-I comprising the northern and eastern half, and stage-II comprising the sourthern and western half. Of the 0.94 Mha m irrigation water, 0.45 Mha m (3.6 MAF) was to be utilised in stage-I and 0.49 Mha m (4 MAF) in stage-II. Total water allowance is 147.99 cumecs/million acre and is distributed through warabandi system. Upto the end of the year 1991-92 an irrigation potential of 801.97 thousand ha has been created, and ultimate utilization has been only

676.50 thousand ha (Anonymous 1994). The present paper presents the moisture storage capacities and release potential of dominant soil types of the command. The information so generated can be beneficially utilised in evolving efficient water delivery schedule and in evolving appropriate cropping patterns keeping in view the rooting pattern and water requirement of different crops and moisture storage and release potential of the soil.

Materials and methods

Soils of the command were mapped under broad four geomorphic mapping units *viz.* relict flood plains, aeolian sandy plain, desert sandy plain and interdunal flats and soils with selenite deposits (UNDP/FAO 1971). The soils receive irrigation from Anupgarh Shakha and Bikaner lift canal according to warabandi system. Fourteen soil profiles were studied, covering all the mapping units. Pedons 1 to 4 (Camborthids and Calciorthids) represent relict flood plain and pedon 14 (Camborthids) represents selenite containing soils of the desertbasin. Pedons 5 to 11 (Gypsiorthids and Torripsamments) represent aeolian sandy plain and pedons 12 and 13 (Calcic Torripsamments and Fluventic Calcic Torripsamments) represent desert plain. Horizon designations have been given as per Keys to Soil Taxonomy (USDA 1994). Analyses for particle size and organic carbon were carried as per Jackson (1958). Soil moisture retention characteristics were determined using pressure plate apparatus (Richards 1949). Field capacity was determined at 0.01 and 0.03 MPa in sandy and other (finer) soils, respectively. Calcium carbonate equivalent was determined using a Collin's calcimeter (Wright 1939). Bulk density was determined by Keen Raczkowski box method (Piper 1966). Analysis for gypsum content and electrical conductance were carried out as per Richards (1954). Pedon locations have been indicated in table 1. Graphic presentation of pedon characteristics and family level taxomomic characterisation have been presented in figures 1 and 2. Available water capacity was computed Walia *et al* (1999).

Results and discussion

Moisture retention and available water in each pedon is presented in table 2 and salient physical and chemical characteristics are presented in table 3.

Relict alluvial plain soils : Pedons 1 to 4 represent soils of the relict alluvial plain. Pedons 1 and 4 are high in silt content whereas pedons 2 and 3 are medium textured (Table 2). Pedon 4 is saline throughout, pedons 1 and 3 have sub-surface salinity. Pedon 2 is non-saline. Moisture retained at 0.03 MPa ranges between 3.6 and 48.5 per cent, equivalent to 1 to 27 cm of water. Available water (difference between 0.01 and 1 MPa moisture content) ranges between 0.5 and 15.2 cm of water (Table 2). Computing the moisture retained in 1 metre soil depth at 0.03 MPa, the moisture content decreases in the order of Thapto Camborthids (Pedon 1)> Typic Camborthids (Pedon 4)> Typic Calciorthids (Pedon 3)> Fluventic Camborthids (Pedon 2) (Fig. 2). The amount of available water which could be made use of by the plants in the 1 metre deep pedon, decreases in the order of Typic

Table 1. Pedon location and family level classification of soils.

No.	Location	Soil class
1.	70 m NW of stone No. 173/56; Chak No. 78 PSD; Village 9-PSD, Tehsil-Gharsana, Distt. - Ganganagar.	Fine silty loam, hyperthermic, Thapto-Camborthids (saline phase).
2.	60 m N of stone No. 191/38; Chak No. 2B-PSD, Tehsil Gharsana, Distt. Ganganagar.	Coarse loamy, hyperthermic, Fluventic Camborthids.
3.	15 m N of stone No. 191/58; Chak o. 28 PSD, Tehsil Gharsana, Distt. - Ganganagar.	Loamy, hyperthermic Typic camborthids (saline phase).
4.	80 m N of stone No. 153/23; Chak No. 6 PSD; 70 m E of Rawlamandi-Gharsana road, Tehsil Gharsana.	Fine sity loam, hyperthermic Camborthids (saline phase).
5.	Chak No. 1 AM, in Sukhram ki Dhani, Tehsil. Gharsana, Distt. - Ganganagar.	Course loamy, hyperthermic, Typic Gypsiorthids.
6.	2.5 km. S of Rojri-Rawla Road, 12 km from Rojri, Tehsil-Gharsana, Distt. - Ganganagar.	Coarse loamy, hyperthermic, Calcic Gypsiorthids (saline phase).
7.	150 m SE of stone No. 120/60; Chak No. RJM; 200 m S of Rajasthan main canal, Tehsil - Suratgarh, Distt. - Ganganagar.	Sandy skeletal, hyperthermic, Typic Torripsamments.
8.	1.5 km E of Rajasthan main canal, Rd 350; village Hinjrasar, Tehsil - Suratgarh; Distt. - Ganganagar.	Sandy skeletal, hyperhermic, Typic Torripsamments.
9.	8 km NW of Suratgarh and 1 km SW of village Rangmahal; Tehsil-Suratgarh, Distt. - Ganganagar.	Sandy skeletal hyperthermi, Fluventic Torripsamments (saline phase).
10.	500 m N of Main office building of CADA Farm Loonkaransar; Tehsil - Loonkaransar, Distt. Bikaner.	Sandy skeletal, hyperthermic, Fluventic Trorripsamments.
11.	20 m N of store building of CADA, Agrl. Farm Loonkaransar.	Sandy skeletal, hyperthermic, Fluventic Torripsamments.
12.	500 m W of Administrative Block of CADA, Agrl. Farm Loonkaransar, Distt. - Bikaner.	Coarse loamy, hyperthermic Fluvetic Calcic Torripsamments.
13.	800 m NW of Adm. Block of CADA, Agrl. Farm Loonkaransar.	Course loamy, hyperthermic, Calcic Torripsamments.
14.	800 m W of Loonkaransar Rly. Station, Loonkaransar (Bikaner).	Fine silty loam, hyperthermic, Fluventic Camborthids (saline phase).

Camborthids (Pedon 4) > Thapto Camborthids (Pedon 1)> Typic Calciorthids (Pedon 3) > Fluventic Camborthids (Pedon 2) (Table 2). Total soil-water potential in any soil is the sum of matric and osmotic potential. Since the dissolved salts give rise to osmotic potential, the water in saline soils remains difficultly available to plants compared to non-saline ones. With this analogy, availability of water to plants in Typic Camborthids (pedon 4) and

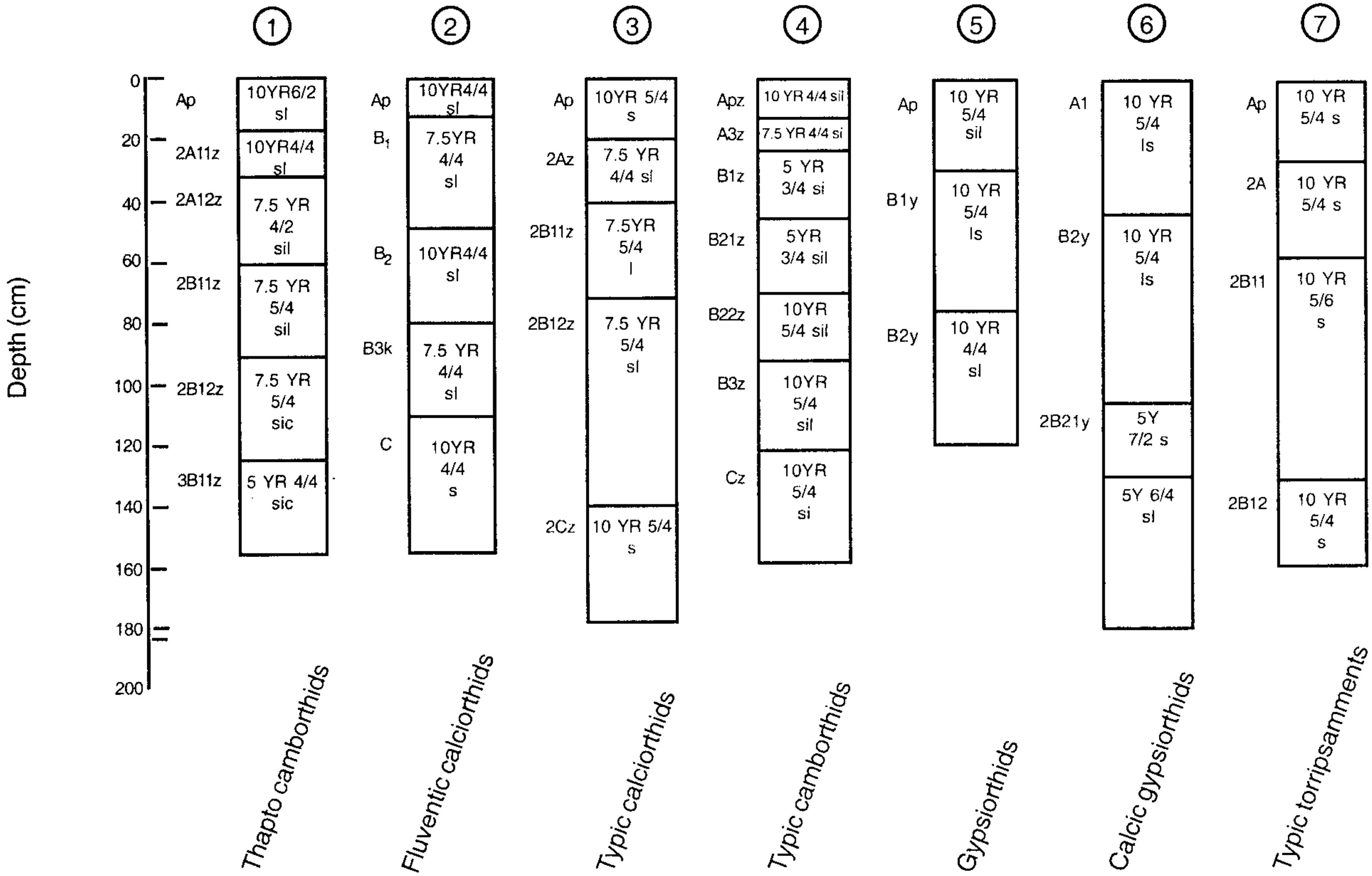

Fig. 1. Pedon characteristics of soils in IGNP command.

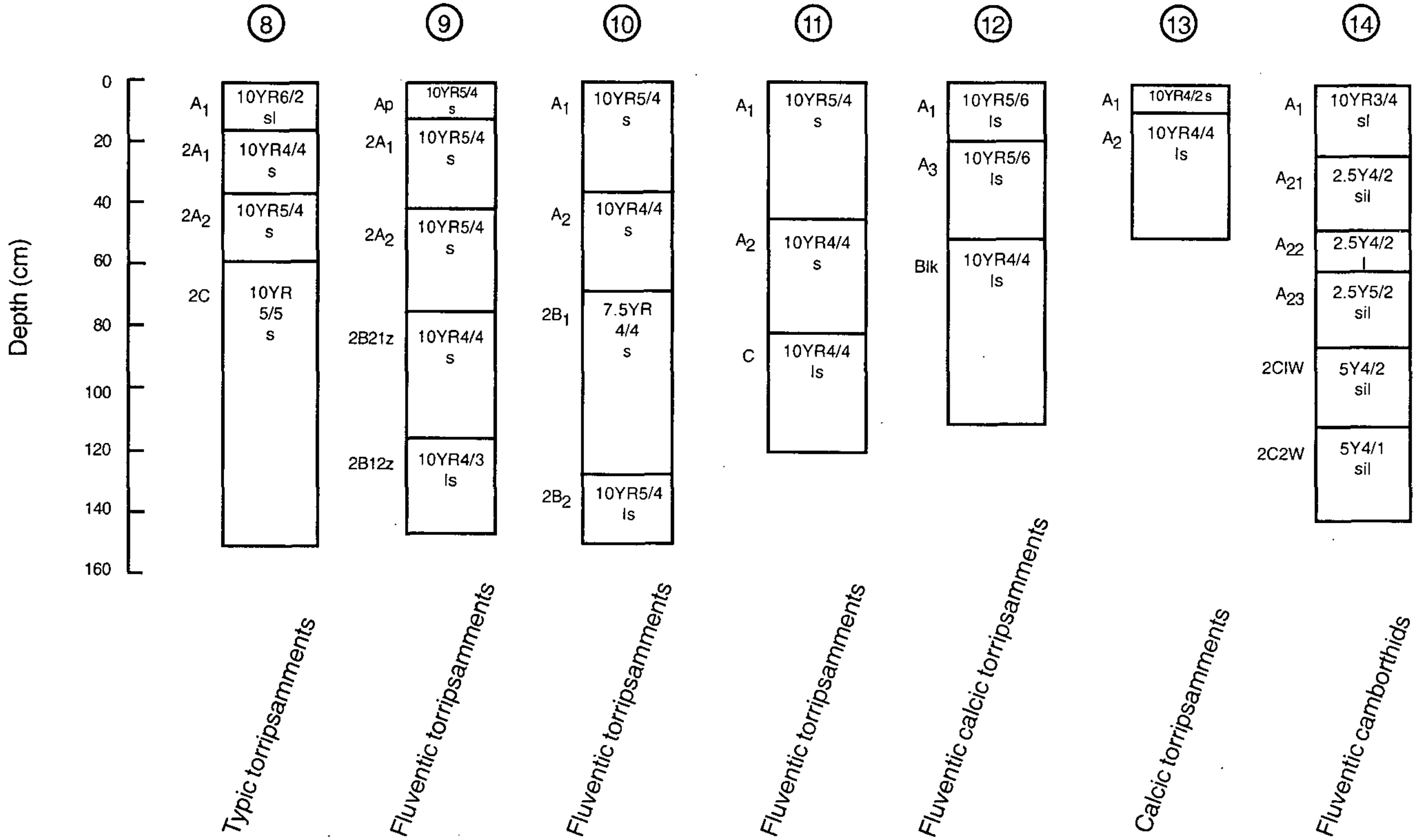

Fig. 2. Pedon characteristics of soils in IGNP command.

Thapto Camborthids (pendon 1) shall in reality be less, compared to Typic Calciorthids (pedon 3) and Fluventic Camborthids (pedon 2). Surface horizons of pedons 1 and 3 and entire pendon 2, with low salt content present conditions of low soil-water potential. Such an environment, ensures greater availability of water to plants. But, the coarse texture of the surface horizons imparts low water storage capacities of only 2.9 and 1 cm in pedons 1 and 3, respectively, of which barely half remains available to plants. The fine textued soils of the relict alluvial plains thus suffer from the limitations arising from high salinity status and the coarse textured ones from low water retaining capacity. Walia *et al.* (1999), studied moisture retention characteristics of some sedentary and alluvial soils of Bundelkhand region and found a relationship between soil texture and available water content.

Soils of the aeolian plain : Pedons 5 to 11 represent soils of the aeolian plain, which includes gypsiferous (Pedons 5 and 6) and non-gypsiferous soils (Pedons 7 to 11) (Table 3). Pedon 5 (Typic Gypsiorthids) and Pedon 6 (Calcic Gypsiorthids saline phase) represent gypsiferous soils (Table 3). Pedon 5 is slightly saline and Pedon 6 has marked salinity in the substratum, above the gypsic horizon and slight below. Both the soils are coarse textured, containing negligible clay. In 1 metre soil depth the Typic Gypsiorthids (Pedon 5) could store 33 cm and the Calcic Gypsiorthids (Pedon 6) could store 23 cm water (Table 2) (Fig. 3). Typic Gypsiorthids (Pedon 5) and Calcic Gypsiorthids (Pedon 6) could store 5.1 and 7.7 cm in the available range. The gypsic horizon in Typic Gypsorthids exhibits physiologically dry nature with no moisture in the available range. The Calcic Gypsiorthids (Pedon 6) however contained 4.5 cm moisture in the gypsic horizon which could be made use of by the plants (Table 2). Moisture storage and the amount of water which could be made use of by the plants is very low in the surface horizons of these soils (Table 2). Despite low salinity levels and low osmotic potential, the Typic Gypsiorthids contain only 0.5 cm available moisture in the upper 75 cm stratum, thus exhibiting severe moisture scarcity. Calcic Gypsiorthids (Pedon 6) on the other hand is more saline and although stores more moisture in the available range shall present similar moisture scarcity condition due to high osmotic pressure of the soil solution. Coarse soil textures, which lend low moisture storage capacity and excessive accumulation of salts attributes very low availalbe moisture storing and supplying capacity to these gypsiferous soils.

Typic Torripsamments (Pedons 7 and 8); Fluventic Torripsamments (Pedons 9, 10 and 11) represent non-gypsiferous aeolian soils, of which pedons 7, 8 10 and 11 are non-saline (Table 3) and exhibit similar moisture storage and release characteristis, indicating prevalence of pronounced stress condition in them. Surface horizons of pedons 7, 8, 10 and 11 could store between 0.8 and 2.6 cm water, of which 0.3 to 0.8 cm water could be made available to plants (Fig. 3). Pedons 7, 8 and 11 were capable of storing only 5 cm water in 1 metre depth, of which respectively 2.1, 0.9 and 0.8 cm water, would have been made available to plants (Fig. 3). Among the Fluventic Torripsamments, pedon 9, which represents a saline phase (Table 3) had the maximum water storage capacity of 12 cm in 1 metre depth and pedon 10 could store 10 cm water in the corresponding depth. Pedon

Table 2. Moisture retention and particle size distribution.

Pedon No.	Depth (cm)	Bulk density Mgm^{-3}	Water retained at (MPa) 0.03 %	(cm)	1 %	(cm)	1.5 %	(cm)	Avail. water (cm)	Particle size class: Sand (2-0.5) % of <2mm soil	Silt (.05-.002) % of <2mm soil	Clay (<0.002) % of <2mm soil	Tex. Class
Relict alluvial plain													
1.	0-18	1.4	11.6	(2.9)	5.7	(1.4)	5.7	(1.4)	1.5	76.5	23.0	0.5	sl
	18-34	1.7	31.6	(7.7)	17.3	(4.6)	15.8	(4.2)	3.1	6.9	90.7	2.4	si
	34-63	1.7	34.4	(16.8)	21.3	(10.4)	16.8	(8.2)	6.4	5.8	78.5	15.7	sil
	63-92	1.8	35.4	(17.9)	22.3	(11.5)	17.9	(9.3)	6.9	2.8	83.9	13.3	sil
	92-125	1.8	45.6	(18.9)	25.8	(15.3)	18.9	(11.2)	11.7	2.6	56.6	40.8	sic
	125-155	1.7	48.5	(21.8)	27.5)	(14.0)	21.8	(11.0)	10.7	2.4	45.5	52.2	sic
2.	0-13	1.6	11.7	(2.3)	6.4	(1.2)	5.5	(1.1)	1.1	76.5	11.5	12.2	sl
	13-49	1.5	12.5	(6.7)	6.1	(3.3)	6.1	(3.3)	3.4	77.0	12.7	10.3	sl
	49-81	1.5	12.5	(6.0)	5.3	(2.5)	4.5	(2.1)	4.5	74.2	19.2	6.6	sl
	81-112	1.5	15.3	(7.0)	6.4	(2.9)	5.1	(2.3)	5.9	60.6	29.1	10.3	sl
	112-155	1.7	5.7	(6.0)	3.0	(3.2)	0.2	(0.2)	2.8	89.3	7.1	3.6	s
3.	0-20	1.5	3.6	(1.0)	1.8	(0.5)	1.2	(0.3)	0.5	91.7	6.5	1.8	s
	20-41	1.5	15.6	(4.9)	6.6	(2.0)	4.9	(1.5)	2.9	67.2	20.8	12.1	sl
	41-71	1.5	21.7	(9.7)	8.9	(4.0)	6.9	(3.0)	5.7	52.3	33.7	14.0	l
	71-140	1.6	19.0	(20.0)	6.8	(7.5)	5.6	(6.0)	12.5	66.4	29.7	3.9	sl
	140-180	1.7	6.0	(4.0)	1.9	(1.9)	2.1	(1.4)	2.1	91.0	6.0	3.0	s
4.	0-11	1.6	24.9	(4.4)	12.8	(2.2)	10.0	(1.7)	2.2	26.3	55.5	18.2	sil
	11-23	1.7	27.2	(5.4)	15.5	(3.1)	12.9	(2.5)	2.3	6.1	90.6	3.3	si
	23-46	1.7	30.1	(11.7)	17.5	(6.8)	14.6	(5.7)	4.9	2.1	95.2	2.7	si
	46-69	1.8	32.9	(13.4)	12.9	(5.2)	10.3	(4.2)	8.2	3.7	93.7	2.6	si
	69-91	1.7	33.1	(12.4)	21.4	(8.0)	17.8	(6.6)	4.4	28.9	68.4	2.7	sil
	91-122	1.6	24.6	(12.2)	6.9	(3.4)	6.7	(3.3)	8.8	27.2	68.7	4.1	sil
	122-160	1.8	31.7	(21.5)	9.3	(6.3)	9.1	(6.1)	15.2	13.3	85.6	1.1	si
Aeolian Plain													
5.	0-30	1.6	4.4	(2.1)	3.5	(1.6)	3.5	(1.6)	0.5	89.3	6.7	4.0	s
	30-75	1.5	21.7	(14.6)	21.7	(14.6)	21.1	(14.2)	nil	85.2	11.4	3.4	ls
	75-120	1.6	31.8	(22.8)	23.8	(17.1)	22.7	(16.3)	5.7	70.4	24.6	5.0	sl

(Contd.)

6.	0-42	1.6	5.2	(3.4)	4.4	(2.9)	4.2	(2.8)	0.5	81.1	17.3	1.6	ls
	42-105	1.6	14.4	(14.4)	7.6	(7.6)	7.2	(7.6)	6.8	75.5	23.6	0.9	ls
	105-130	1.7	35.1	(14.7)	24.3	(10.2)	23.2	(10.2)	4.5	91.1	6.6	2.3	s
	130-180	1.5	13.1	(9.8)	10.2	(7.6)	10.2	(7.6)	2.2	72.1	27.9	nil	sl
	26-57	1.5	3.9	(1.8)	1.7	(0.8)	1.7	(0.8)	1.0	97.0	2.6	0.4	s
	57-130	1.5	3.2	(3.5)	2.0	(2.2)	1.8	(2.0)	1.2	96.3	2.4	1.3	s
	130-180	1.5	3.2	(2.4)	2.0	(1.5)	1.8	(1.3)	0.9	95.9	2.6	1.5	s
8.	0-16	1.5	11.1	(2.6)	8.8	(2.1)	8.5	(2.0)	0.5	74.4	14.2	11.4	sl
	16-36	1.5	4.6	(1.4)	3.9	(1.1)	3.6	(1.0)	0.3	90.7	2.5	6.8	s
	36-60	1.6	3.2	(1.2)	2.6	(1.0)	0.2	(1.0)	0.2	88.0	7.9	4.1	s
	60-150	1.5	1.8	(2.3)	1.5	(1.9)	1.5	(1.9)	0.4	90.8	6.8	2.4	s
9.	0-12	1.5	3.7	(0.7)	2.5	(0.4)	2.2	(0.4)	0.3	94.8	4.3	0.9	s
	12-42	1.5	3.0	(1.3)	2.1	(0.9)	2.1	(0.9)	0.4	95.9	3.1	1.9	s
	42-75	1.6	2.8	(1.6)	2.0	(1.0)	2.0	(1.0)	0.6	95.0	2.8	2.2	s
	75-116	1.5	15.2	(9.2)	7.0	(4.2)	6.8	(4.1)	5.0	79.7	18.3	2.0	ls
	116-145	1.6	11.6	(5.3)	6.6	(3.0)	6.1	(2.8)	2.3	77.4	16.0	6.6	ls
10.	0-35	1.5	2.8	(1.4)	2.2	(1.1)	2.1	(1.0)	0.3	96.2	3.4	0.4	s
	35-68	1.5	7.1	(3.4)	5.3	(2.6)	4.7	(2.3)	0.8	89.2	9.4	1.5	s
	68-125	1.5	8.5	(7.2)	5.9	(5.0)	4.7	(4.0)	2.2	87.6	11.2	1.2	s
	125-150	1.5	8.2	(3.0)	4.4	(1.6)	4.0	(1.5)	1.4	87.2	12.1	0.7	ls
11.	0-45	1.5	1.2	(0.8)	0.8	(0.5)	0.7	(0.5)	0.3	96.2	3.0	0.8	s
	45-80	1.5	4.8	(2.4)	3.7	(1.9)	3.3	(1.7)	0.5	88.4	9.7	1.9	s
	80-120	1.6	5.4	(3.4)	5.0	(3.2)	5.0	(3.2)	0.2	82.7	12.6	4.7	ls
Desert Plain													
12.	0-17	1.5	4.1	(1.0)	3.8	(0.9)	3.8	(0.9)	0.1	85.8	9.9	4.3	ls
	17-49	1.5	4.7	(2.4)	3.8	(1.9)	3.8	(1.9)	0.5	85.8	9.3	4.9	ls
	49-110	1.6	5.5	(5.3)	5.2	(5.0)	5.2	(5.0)	0.3	81.0	16.6	2.4	ls
13.	0-8	1.5	9.2	(1.1)	7.8	(0.9)	7.7	(0.9)	0.2	89.8	7.4	2.8	s
	8-48	1.5	3.8	(2.2)	3.2	(1.9)	3.2	(1.9)	0.3	78.2	20.9	0.9	ls
Selenite Soil													
14.	0-23	1.5	24.4	(8.2)	15.9	(5.4)	13.7	(4.6)	2.8	65.2	31.0	3.8	sl
	23-46	1.6	30.1	(10.8)	20.9	(7.5)	13.7	(4.9)	3.3	37.1	56.5	6.4	sil
	46-60	1.6	31.9	(7.0)	22.1	(4.8)	19.1	(4.2)	7.0	42.8	50.5	6.6	l
15.	60-84	1.6	37.3	(14.1)	27.6	(10.4)	23.6	(8.9)	3.7	40.0	56.3	3.7	sil
	84-110	1.6	41.6	(17.0)	29.7	(12.1)	25.4	(10.4)	4.9	35.8	63.6	0.6	sil
	110-140	1.6	44.5	(21.3)	32.3	(15.5)	27.5	(13.2)	5.8	34.7	63.7	1.6	sil

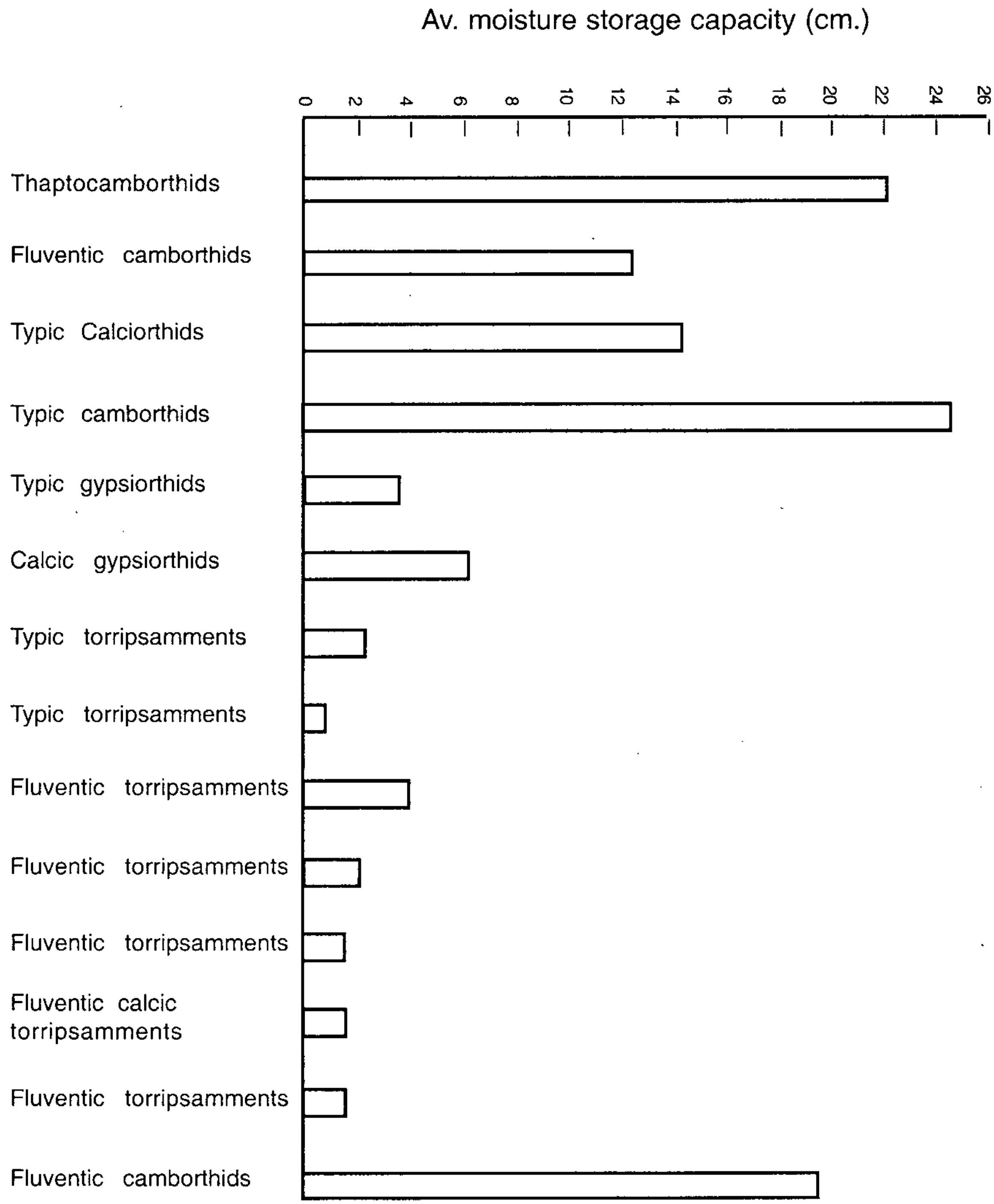

Fig. 3. Available moisture storage capacity in 1 m. depth in soils IGNP command.

9 could have released 5.9 cm water to the plants and pedon 10 only 3.1 cm in 1 metre depth (Fig. 3). But in reality due to high osmotic potential in presence of salts the water availability in pedon 9 shall be less than projected. The surface horizon of pedon 9 remains droughty as it can store only 0.7 cm water, of which just 0.3 cm remains available to plants (Fig. 3). Considering the mositure storage and available water supplying capacities of non-saline aeolian soils, all the soils appeared droughty and their droughtiness decreased in the order : Pedon 10 < Pedon 7 < Pedon < Pedon 8 < Pedon 11.

Soils of the desert plain : Fluventic Calcic Torripsamments (Pedon 12) and Calcic Torripsamments (Pedon 13) represent the soils of the desert plain and their properties are similar to the soils of the aeolian sandy plain. The difference is, pronouncedly the saline nature of the soils of the desert plain. The Fluventic Calcic Torripsamments could store 8 cm water in 1 metre soil depth and the Calcic Torripsamment could store 7 cm water in the same depth (Table 2) (Fig. 3). These two soils could have supplied 0.8 and 1 cm water respectively to the plants. Their surface horizons can store only 1 cm water, of which only 0.1 to 0.2 cm could be made available to plants (Table 2) (Fig. 3). Course texture and presence of excess salts lend them droughty character.

Selenite rich soils of the desert basin : Characterised as Fluventic Camborthids these are represented by pedon 14. These are fine textured with dominance of silt (Table 3). These are moderate to highly saline and are exposed to the vagaries of saline seep accumulation from adjacent elevated areas. These can retain 56 cm water in 1 metre depth, of which 19.6 cm can be utilized by the plants (Fig. 3). The presence of excess salts shall lead to rise in osmotic potential, consequently reducing availability of water to plants. Water logging caused by saline water seep shall further put serious limitation on use of these soils for raising one or the other plant types.

Irrigation scheduling and quantum of water released each time should be based on the available water storage capacity of each soil. Torripsamments require almost daily irrigation and sprinker or drip irrigation with suitable water storage facility may be necessity. Fluventic Torripsamments shall respond better to irrigation than Typic Torripsamments. Typic and Calcic Gypsiorthids have better available moisture storage capacity but the physical impediment of the gypsic horizon shall prove more limitng to irrigated farming and even planting of orchards of forest species. The fine textured soils i.e. Camborthids (Pedons 1 and 4) and Calciorthids (Pedon 3) although bestowed with high moisture storage and release potential, require desalinisation, to remove excess salts out of the root zone. Desalinisation will make the environment in the root zone favourable and shall alleviate the adverse impact of salts in increasing the osmotic potential of soil solution. But such an exercise is tedious and cost intensive. The medium textured soils i.e. Fluventic Camborthids (Pedon 2), free of salinity hazard are the ones to be irrigated judiciously, monitoring the water table rise to reap maximum benefits of irrigated agriculture in this arid environment. Drip and sprinkler irrigation systems shall help efficient water-use, adopting suitable cropping

Table 3. Physical and chemical characteristics of soils.

Pedon No.	Depth (cm)	ECe dSm^{-1}	Organic carbon g kg^{-1}	$CaCO_3$ % <2mm	Gypsum % <2mm	CEC [cmol(p+)kg^{-1}]	Exchangeable bases [cmol(p+)kg^{-1}]			
							Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
1.	0-18	1.0	3	4.8	nil	2.0	1.6	1.8	0.2	0.2
	18-34	4.0	2	8.7	nil	3.6	1.0	2.4	0.2	0.1
	34-63	7.3	2	8.2	nil	8.9	1.6	3.8	2.5	1.1
	63-92	8.2	2	8.3	nil	9.8	1.4	3.6	3.4	1.2
	92-125	13.6	2	8.9	nil	15.6	5.0	5.2	4.1	1.3
	125-155	16.5	2	7.5	nil	17.2	4.2	8.2	3.5	1.3
2.	0-13	0.9	3	3.0	nil	6.3	2.4	1.5	1.1	1.3
	13-49	0.4	1	2.1	nil	6.0	1.6	1.8	1.5	1.3
	49-81	0.3	2	3.4	nil	3.8	1.2	0.8	0.1	0.8
	81-112	0.6	2	7.3	nil	6.3	1.7	2.3	1.2	1.1
	112-175	0.4	1	2.3	nil	2.0	0.4	0.8	0.5	0.3
3.	0-20	0.5	2	1.1	nil	0.6	0.2	0.2	0.2	0.1
	20-41	8.6	2	5.3	nil	5.0	1.8	1.5	0.7	1.0
	41-71	15.9	2	9.7	nil	7.9	3.4	2.9	0.7	0.9
	71-140	18.5	2	6.5	nil	2.0	1.1	0.8	0.2	0.1
	140-180	9.9	1	5.0	nil	1.6	0.8	0.4	0.2	0.3
4.	0-11	24.7	3	10.5	nil	7.9	3.7	3.2	0.9	0.1
	11-23	17.1	3	10.4	nil	3.7	1.7	1.5	0.4	0.1
	23-46	20.0	2	9.9	nil	3.3	1.9	0.9	0.3	0.2
	46-69	20.6	2	10.8	nil	2.3	1.5	0.6	0.3	0.1
	69-91	20.7	3	4.9	3.6	2.5	-	-	0.2	0.1
	91-122	19.6	3	8.0	0.5	2.7	-	-	0.1	trace
5.	0-30	2.9	4	3.0	0.8	1.6	-	-	0.9	0.3
	30-75	2.5	2	1.7	52.4	3.1	-	-	1.9	0.1
	75-120	2.6	2	3.7	5.2	5.0	-	-	1.6	0.3
6.	0-42	1.5	3	5.3	nil	2.0	-	-	0.2	0.1
	42-105	13.6	3	5.1	4.1	1.8	-	-	0.3	0.2
	105-130	3.9	3	2.1	51.6	1.1	-	-	0.3	0.1
	130-180	3.4	2	4.5	4.7	1.1	-	-	0.2	0.1
7.	0-26	0.4	1	0.1	nil	0.9	0.1	0.5	0.2	0.2
	26-57	0.3	1	10.3	nil	1.2	0.2	0.5	0.4	0.1
	57-130	0.3	1	0.5	nil	1.5	0.2	0.7	0.6	0.1
	130-180	0.3	1	0.3	nil	2.3	0.5	1.2	0.6	0.1
8.	0-16	0.9	1	19.8	nil	5.1	1.3	2.9	0.5	0.4
	16-36	0.8	1	4.1	nil	3.6	0.5	2.4	0.5	0.2
	36-60	0.7	1	2.1	nil	3.2	0.3	2.2	0.5	0.3
	60-150	0.5	1	1.2	nil	1.8	0.1	1.3	0.4	0.2

(Contd.)

9.	0-12	2.1	2	4.7	tr.	0.5	0.5	0.2	0.1	0.1
	12-42	2.1	1	2.0	trace	1.2	1.1	0.8	0.1	0.2
	42-75	2.7	2	1.3	trace	1.4	1.3	0.7	0.2	0.3
	75-116	6.8	2	3.0	trace	1.9	0.2	0.9	0.4	0.3
	116-145	9.4	3	2.5	trace	2.8	1.8	0.9	0.4	0.5
10.	0-35	0.5	4	0.7	nil	0.5	0.3	0.2	0.1	tr.
	35-68	0.4	5	1.9	nil	1.2	0.4	0.5	0.2	0.2
	68-125	0.4	3	.5	nil	1.0	0.4	0.5	0.1	0.1
	125-150	0.3	3	4.3	nil	0.5	0.2	0.3	0.1	tr.
11.	0-45	0.5	3	1.3	nil	0.4	0.2	0.1	0.1	0.1
	45-80	0.3	5	2.1	nil	1.2	0.5	0.4	0.3	0.1
	80-120	0.3	3	4.7	nil	3.0	0.7	1.8	0.4	0.2
12.	0-17	28.8	1	9.4	trace	2.3	-	-	0.1	0.6
	17-49	18.8	nil	9.0	trace	3.0	-	-	1.1	0.9
	49-110	29.9	1	11.4	trace	2.0	-	-	0.8	0.8
13.	0-8	48.6	5	9.5	1.0	1.3	-	-	0.6	0.8
	8-48	23.9	1	15.2	trace	3.6	-	-	2.3	1.0
14.	0-23	8.7	2	0.8	4.1	2.5	-	-	0.5	0.4
	23-46	8.6	9	0.5	4.4	4.3	-	-	1.1	0.8
	46-60	10.4	7	0.3	4.6	4.8	-	-	1.3	0.6
	60-84	14.0	5	0.8	5.0	2.0	-	-	0.6	0.6
	84-110	16.0	7	4.4	4.6	1.5	-	-	0.4	0.2
	110-140	24.3	12	6.2	4.5	1.8	-	-	0.6	0.3

pattern. Horticultural or forest species like ber, anar, neem, khejri, babool, and salvadora alongwith grasses shall guarantee sustainability on marginal lands (Pedons 13, 14, 4, 1, 12, 6 and 5) which have constraints of salinity, coarse or very fine texture, low moisture retention capacity, compact gypsic or calcic horizon or water logging.

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