Annals of Arid Zone 45(2): 139-149, 2006

Sandy Soils of Jaisalmer District: Their Morpho-genesis and Evaluation for Sustainable Land Use

B.K. Sharma, Nepal Singh and Mahesh Kumar
Central Arid Zone Research Institute, Jodhpur 342 003, India

Abstract: The coarse textured soils occupy 26871 km^2 (71.0%) area in Jaisalmer district. Nine soil series spread over four physiographic units viz. dune complex, flat inter-dunal plain, sandy plain with scattered hummocks, and buried pediments have been recognized. Among these, the soils associated with dune complex and some of the flat inter-dunal plain and sandy plain with scattered hummocks are excessively drained, highly sandy and loose with hardly any aggregation. These have poor water retention and nutrient status. The moderately deep to deep loamy sand soils in some of these landforms and on pediments are slightly more stable and have weak sub-angular blocky solum over various types of substrata. These posses slightly higher water retention capacity and nutrient status. The flat inter-dunal part of these soils can be used for crop production during the normal rainfall years. For proper utilization, these lands have been evaluated for their suitability for crop production, horticulture, agro-forestry, silvi-pasture and pasture development. Based on climatic limitations and other soil physical constraints, each soil series has been evaluated for its land use capability. The soils have been classified into capability classes IV c s e, VI c s e, VI c sh e and irrigability classes 4 t d s, 4 d s, 3 d s and 2 d s. The soils were also classified as per Soil Taxonomy (Soil Survey Staff, 1998) at sub-group and family level.

Key words: Sandy soils, morpho-genesis, characteristics, soil suitability for agricultural and non-agricultural purposes.

The Jaisalmer district is located in extreme north-west part of the country along Indo-Pakistan international border and it has the largest stretch of sandy soils in association with various types of dune forms. The district experiences a low and erratic distribution of rainfall, high temperature and high wind speed with dust storms during summer. Due to severe climatic limitations, low moisture status and high biotic interference, the soils of the district suffer with severe wind erosion problem. These sandy soils differ widely in their morpho-genesis and physico-chemical characteristics, which limit their proper utilization. Very little information is available on these sandy soils (Kolarkar *et al.*, 1989; Singh and Kolarkar, 1992), The present paper aims to make up this gap.

Materials and Methods

The Jaisalmer district is situated between 26° 1′ to 28° 2′ N latitude and 69° 30′ to 72° 20′ E longitude, covering a total area of 38,401 km^2. Climate of the area is arid, with mean annual rainfall of 188 mm at Jaisalmer town. However, for the district as a whole, the mean annual rainfall ranges from 100 mm in north-western to 200 mm in the south-eastern part. Besides,

a very low rainfall, the inter annual variation is large, the coefficient of variation being around 60. The area has mean daily maximum temperature of 44°C and minimum mean temperature of 10° C, which often reaches 47°C during summer and 2°C during winter. The annual evapo-transpiration is 2040 mm and mean wind speed is 10 km h^{-1} which remains between 25 and 37 km h^{-1} during summer (May and June) with dust storms. The relative humidity remains below 50% (Rama Krishna *et al.*, 1992).

Semi-detail soil survey was carried out on 1:50,000 scale SOI topo-sheets as base maps. Physiography-soil series relationship was studied by using aerial photographs and Landsat Imageries. Following standard soil survey methods outlined in Soil Survey Manual (IARI, 1971) detail morphological characteristics of soil profiles were studied. In all nine soil series of two families i.e., sandy and coarse loamy were identified and mapped. The soil map was prepared on 1:50,000 scale and further reduced to 1:250,000 scale. Horizon-wise soil samples from representative soil profiles were collected, processed and analyzed for particle size distribution, physico-chemical properties, cation exchange capacity and fertility parameters using the standard procedures (Piper, 1950; Jackson, 1967). Soils were classified as per the Keys to Soil Taxonomy (Soil Survey Staff, 1998). Soil suitability, land capability and irrigability ratings were done according to FAO framework (FAO, 1976) and Soil Survey Manual (IARI, 1971), respectively.

Results and Discussion

Physiography-soil series relationship

The physiography soil series relationship and classification of soil series according to Soil Taxonomy (Soil Survey Staff, 1998) is presented in Table 1 and spatial distribution of various soil series is shown in Fig. 1.

Morpho-genesis

The morphological characteristics of soil series associated with different physiographic units are discussed below:

Table 1. Physiography - soil series relationship

Physiography	Associated soil series	Classification	Extent	
			km^2	%
Dune complex	Dune	Typic Torripsamments	15470	40.3
Flat inter-dunal plain	Modasar	Coarse loamy Typic Torripasamments	3797	9.8
	Parewar	Coarse loamy, Fluventic Torripsamments	94	0.3
Sandy plain with scattered hummocks	Chirai	Coarse loamy Typic Haplocambids	881	2.3
	Thar	Coarse loamy Typic Torripsamments	1293	3.4
	Dabla	Coarse loamy Typic Haplocambids	1864	4.9
	Sam	Coarse loamy Typic Haplocalcids	1784	4.6
	Kolu	Coarse loamy Typic Petrocalcids	1340	3.5
Buried pediments (shallow)	Chacha	Coarse loamy Lithic Haplocambids	348	0.9

Mineralogy: mixed; Soil temperature regime: hyperthemic.

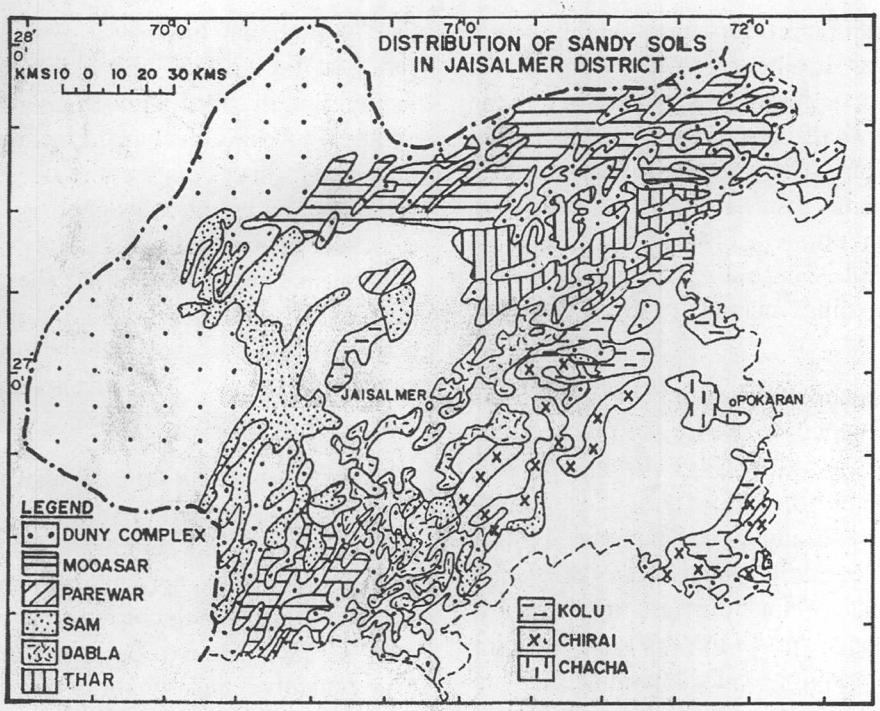

Fig. 1. Distribution of sandy soils in Jaisalmer district.

Dune complex

The dune soils are slightly to moderately calcareous, uniformly structureless sandy mass with color at different locations ranging from pale brown to light yellowish brown (10YR6/3, 6/4, 5/3D) and devoid of any pedogenic features. The dune series has developed by the aeolian sand deposition (2.51 to 3.0 phi sand grains) in the form of parabolic, longitudinal, transverse, linear, barchans and meghabarchanoids dunes. The barchanoids and meghabarchanoids are quite younger in age and as such are devoid of vegetative cover and do not exhibit any pedogenic manifestation. The thermo-luminescence chronology of aeolian succession conducted by Chawla *et al.* (1992) indicated that the oldest age of Aeolian dynamism is late Pleistocene and that of younger is recent. The older stabilized dunes are covered with natural vegetation and have segregated very weak lime concretions below 2 to 3 m depth while compound megabarchanoids and barchans dunes of shifting nature are devoid of such formations.

The dune height varies from 5 to 60 m. The Asutar, Ghotaru and Tanot sectors recorded highest dune height.

Flat inter-dunal plain

The soil series namely Modasar and Parewar have been recognized in the inter-dunal areas. Modasar series has developed from aeolian sediment deposition over Eocene to Quaternary formation. Soils

of its hummocky phase are highly sandy and loose in the top 50-70 cm, while non-hummocky surface is sandy only in top 20-50 cm. The subsoil is calcareous, loamy sand, dark yellowish brown (10YR 4/4) in color and has 20 to 30% weak lime concretions at 140-160 cm depth in the substrata. These soils have slightly better water holding capacity than hummocky phase.

Parewar series of this physiographic unit has developed both from fluvio-aeolian sediments in valley-fills. The runoff water from adjoining limestone and sandstone hills brought strongly calcareous coarse sediments and deposited in the valley-fills area. Soils of this unit are light gray to light brownish gray (10YR6/1, 6/2) in color, massive, strongly calcareous underlain by coarse sand to gravelly coarse sandy, porous and highly calcareous substrata over the buried limestone/ sandstone bed rock.

Sandy plain with scattered hummocks

The soil series viz. Thar, Chirai, Dabla, Sam and Kolu have been mapped in this physiographic unit. Soils associated with sandy plain with scattered hummocks occur in flat to gently sloping plain infilled with aggradations during Holocene/late Pleistocene fluvial/aeolian and desert pavement processes. The soils seem to have developed during ameliorated climate interludes of late Quaternary that lead to surface stability and development of genetic feature. However at present these lands are undergoing denudation and truncation of soil profile. The thickness of soil solum is variable and exhibits pedogenic manifestation in the form of calcification of free lime in subsoil and weak sub-angular blocky structure. In general these soils are sandy at the surface and either sandy or loamy sand in subsoil, underlain at variable depths by weakly developed or moderately developed lime concretionary zone or weathered rock or gravels/pebbles. Because of severe aeolian activities these soils have both flat and hummocky relief. The substrata of soils is moderately well drained to ill drained which on excessive irrigation may cause water logging. Characteristics of soil series are described below.

Thar series occurs on undulating sandy plain in north-eastern part of the district in association with stabilized sand dunes. Soils of this physiographic unit are very deep, uniformly pale brown in color i.e., hue 10 YR, value 6 and chroma 3 with a dominantly sandy texture. The solum is calcareous throughout and has a tendency for some increase in the lowest part and has occasional soft nodules. The surface is often hummocky. Recently, the hummocks have been leveled due to extension of irrigation in the area.

Soils of Dabla series of this physiographic unit are yellowish brown to dark yellowish brown (10YR5/4, 4/4), loamy sand, single grain, very weak sub-angular blocky in hummocky phase and weak sub-angular, blocky, loamy sand to sandy loam, strongly calcareous in subsoil in non hummocky phase underlain by lime coated weathered rock of sandstone, The soils in inter rocky plains have hummocky relief whereas central part of unit has dominantly flat relief.

Sam series in extreme north-western part of the district has developed from highly calcareous aeolian sediments over basal rock

Table 2. Physico-chemical characteristics of soil series

Soil series	Depth (cm)	pH (1:2)	EC (dS m^{-1})	$CaCO_3$ (%)	Particle size distributon (%)				WHC (%)	CEC [cmol $(P+)kg^{-1}$]	OC (%)
					Coarse sand	Fine sand	Silt	Clay			
Dune complex											
Dune	0-30	7.7	0.12	0.0	10.0	86.2	1.8	2.0	18.0	1.8	0.03
	30-90	7.9	0.15	0.0	10.1	84.5	2.2	3.2	21.0	2.4	0.04
	90-140	8.0	0.23	0.8	19.0	76.2	2.3	2.5	22.0	2.8	0.04
	140-200	8.1	0.24	1.5	20.3	74.6	2.7	2.4	23.0	2.2	0.02
Flat interdunal plain											
Modasar	0-30	8.0	0.19	0.8	13.3	82.5	1.8	2.4	23.0	2.1	0.12
	30-60	8.4	0.25	3.2	14.8	77.2	3.8	4.2	24.0	3.2	0.22
	60-115	8.5	0.70	5.8	19.0	67.5	6.7	6.8	26.0	5.6	0.20
	115-160	8.5	0.26	8.6	22.8	62.2	7.4	7.6	26.8	6.2	0.08
	160-200	8.5	0.58	11.2	28.6	64.0	3.2	4.2	22.0	3.2	0.06
Parewar	0-20	8.3	0.14	5.0	66.4	30.5	1.3	1.8	19.0	1.6	0.04
(Humm-	20-60	8.4	0.24	9.6	61.4	34.5	1.8	2.3	22.0	2.1	0.10
ocky)	60-120	8.3	0.29	13.5	68.4	22.1	4.3	5.2	24.0	4.8	0.21
	120-160	8.1	0.26	16.5	73.6	19.6	3.2	3.6	23.0	2.8	0.03
Sandy plain with scattered hummocks											
Kolu	0-10	8.4	0.22	5.0	14.8	76.2	3.6	5.4	24.0	3.8	0.18
	10-30	8.3	0.29	18.0	12.2	69.8	8.0	10.0	29.0	8.4	0.26
	30-50	8.3	0.30	36.0	14.6	66.4	9.0	10.0	30.0	9.6	0.24
Chirai	0-20	8.1	0.19	2.1	12.4	78.0	3.7	5.9	26.0	3.8	0.22
	20-55	8.1	0.22	3.8	11.3	73.9	6.9	7.9	27.0	6.9	0.26
	55-85	8.2	0.23	4.8	10.7	72.6	8.7	8.0	28.0	9.2	0.20
	85-120	8.4	0.29	18.2	10.0	72.9	7.1	10.0	29.0	6.0	0.08
Thar	0-20	8.3	0.23	6.8	8.7	83.1	3.7	4.5	24.8	2.0	0.09
	20-55	8.0	0.41	7.5	7.1	82.7	5.5	4.7	24.8	2.3	0.12
	55-90	8.2	0.31	7.9	6.2	81.0	6.0	6.8	26.6	2.6	0.10
	90-115	8.2	0.44	8.9	6.5	80.2	7.2	6.1	26.9	2.8	0.06
	115-140	8.2	0.49	9.7	7.4	78.5	7.3	6.8	27.1	3.0	0.06
Dabla	0-20	8.5	0.16	2.2	15.0	79.7	2.4	2.9	24.0	2.4	0.08
(Humm-	20-60	8.4	0.16	2.9	15.4	72.6	6.2	5.8	26.0	6.4	0.22
ocky)	60-90	8.4	0.24	4.5	10.0	75.3	6.8	7.9	28.0	7.2	0.21
	90-120	8.3	0.31	5.2	11.4	76.6	6.2	5.8	27.0	4.8	0.08
Sam	0-20	8.2	0.20	10.1	11.7	77.6	4.4	6.3	23.0	5.4	0.16
	20-60	8.1	0.40	12.6	12.8	71.1	7.3	8.8	26.0	6.0	0.23
	60-90	8.4	0.46	18.2	8.8	72.8	8.6	9.8	27.0	6.4	0.12
	120-160	8.5	0.56	40.6	11.8	74.6	6.6	7.0	28.0	6.0	0.04
Burried pediment (Shallow)											
Chacha	0-10	8.2	0.18	6.8	11.6	79.0	4.2	5.2	28.0	5.0	0.26
	10-25	8.2	0.29	11.7	11.4	72.6	7.2	8.8	32.0	8.0	0.20
	25-35	8.3	0.54	21.8	22.8	59.4	8.8	9.0	36.0	10.0	0.08

Table 3. Land characteristics, land use capability and irrigability classification of soils

Soil series	Texture	Physiography/ slope	Solum drainage	Substrata drainage	Wind erosion	Water holding capacity	Fertility status	Land capability classes and sub-classes*	Irrigability classes**
Dune	fs	Duny (10-35%)	Excessively drained	Excessively drained	Very severe	Very low	Very low	VI c s e	4 t d s
Modasar	Is	Flat (1-3%)	Well drained	Well drained	Moderate	Low	Low	IV c s e	3 d s
Modasar	fs	Highly hummocky (3-5%)	Excessively drained	Excessively drained	Very severe	Low	Low	VI c s e	4 t d s
Sam	Is	Flat (1-3%)	Well drained	Imperfectly drained	Moderate	Low	Low	IV c s e	3 d s
Sam	fs-Is	Highly hummocky (3-5%)	Well drained	Imperfectly drained	Very severe	Low	Low	VI c s e	4 t d s
Kolu	Is	Moderately hummocky (1-3%)	Well drained	Poorly drained	Moderate	Low	Low	VI c sh e	4 d s
Dabla	Is	Flat (1-3%)	Well drained	Imperfectly drained	Moderate	Low	Low	IV c e	3 d s
Chirai	Is	Moderately hummocky (1-3%)	Well drained	Moderately well drained	Moderate	Low	Low	IV c e	3 d s
Thar	fs-Is	Moderate to highly hummocky (3-5%)	Well drained	Moderately well drained	Moderate to severe	Low	Low	VI c s e	3 d s
Chacha	Is	Flat (1-3%)	Moderately well drained	Poorly drained	Moderate	Low	Low	VI c sh e	4 d s

* Land capability class: Limitations, c- climate, s- soil texture depth and slope, e- wind erosion/sand deposition;
** Irrigability class: 1- good, 2- moderate; 3- poor, 4- very poor; Sub-class: t - topography, s- soil conditions, d- drainage.

that lies at a depth of 1 to 2 m. These soils are fine sandy, pale brown (10YR 6/3), single grain and strongly calcareous at surface and stable loamy sand, yellowish brown (10YR 5/4), weak sub-angular blocky with segregation of 2 mm size lime concretions in subsoil over moderately drained to impervious thick substrata at 40-80 cm depth.

In central, southern and south-eastern parts of the district, Kolu soils have developed over old denuded surfaces and are distinguished by indurated zone of petrocalcic layer at 30 to 70 cm depth. Morphologically the surface layer of these soils is fine sandy, pale brown (10YR6/3), single grain, strongly calcareous and subsoil is loamy sand, occasionally sandy loam, weak sub-angular blocky and strongly calcareous underlain by petrocalcic layer.

Chirai soils have also developed in sandy plains in association with low dunes. The soils are fine sandy, light yellowish brown (10YR6/4), single grain and slight to moderately calcareous at surface and loamy sand to light sandy loam, yellowish brown to dark yellowish brown (10YR5/4, 4/4), weak sub-angular blocky and strongly calcareous in subsoil underlain by weak to moderately well developed zone of lime concretions (2 to 5 mm) at 50 to 80 cm depth. These are moderately well drained.

Buried pediments (shallow)

Soil of Chacha series of this physiographic unit occur on buried pediments of ferruginous sandstone and are characterized by thin solum and well-formed desert pavements. Because of thin solum these support only bushy vegetation and grasses. The surface layer is gravelly sandy to gravely loamy sand, yellowish brown to brown (10YR5/3, 7.5YR5/4), strongly calcareous and massive. The subsoil is gravelly loamy sand to gravelly sandy loam, massive to weak subangular blocky, strongly calcareous underlain by weathered lime coated gravels/pebbles over the sandstone/red ferruginous hard rocky substrata. Because of hard substrata these soils have inherent risk for water logging. Similar observations have also been made by Dhir and Kolarkar (1977) and Kar (1992).

Physico-chemical characteristics

The analytical data on physico-chemical characteristics (Table 2) of these soils of different physiographic units revealed that soils of dune complex comprise of over 95% sand, of which 74 to 86% is fine sand. These are excessively drained with low water holding capacity (18-23%). These soils contained very little amount of clay (2.0-3.2%), silt (1.8-2.7%), organic carbon (0.02-04%) and other major nutrients.

The soils of flat inter-dunal plain also showed dominance of fine sand (62.2-82.5%) except Parewar series which is having higher amount of coarse sand (61.4-73.6%) and lower fine sand (19.6-34.5%) in the profile. Free lime content ranged from 0.8-16.5%. The water holding capacity dominantly ranged from 22 to 26%. The cation exchange capacity values were almost low and varied from 1.6 to 6.2 [cmol (p+) kg^{-1}]. The soils were very low in organic carbon (0.03-0.22%) and low in available phosphorus (6-17 kg ha^{-1}), but rated low to medium in available K content.

The soils associated with sandy plain with scattered hummocks and buried pediments are more calcareous ($CaCO_3$, 2.0 to 40.6%) and contained somewhat higher amount of silt (2.4-9.0%) and clay

Table 4. Land suitability evaluaton for various land uses on the assumptions that water is not a limitation

Soil seires	Crop cultivation		Horti-culture	Agro-forestry	Forestry	Silvi-pasture	Pasture
	Rainfed	Irrigated					
Dune	N	N	N	S3	S1	S1	S1
Modasar	S2	S2	S1	S1	S3	S3	S3
Modasar (Hummocky)	S3	S3	S3	S3	S1	S1	S1
Parewar	N	N	N	N	S1	S1	S1
Sam	S2	S2	S1	S1	S3	S3	S3
Sam (Hummock)	S3	S3	S3	S3	S1	S1	S1
Kolu	S3	N	S2	S2	S2	S2	S1
Dabla	S2	S2	S1	S1	S3	S3	S3
Dabla (Hummocky)	S3	S3	S2	S3	S1	S1	S1
Chirai	S2	S2	S1	S1	S3	S3	S3
Thar	S2	S2	S1	S1	S3	S3	S3
Chacha	S3	N	S2	S2	S2	S2	S1

Suitability - S1: Highly suitable, S2: Moderately suitable, S3: Marginally suitable, N: Not suitable.

(2.9-10.0%). The coarse and fine sandy fractions in these soils varied from 6.2 to 22.8 and 59.4 to 83.1%, respectively. The water holding capacity was somewhat higher (24-36%). The soils are alkaline in reaction (pH 8.1-8.5) with low electrical conductivity (0.16-0.56 dS m^{-1}). The cation exchange capacity values in these soils mostly ranged between 2.0 and 10.0 [cmol (p+) kg^{-1}]. These values are apparently low due to dominance of coarse fractions in the soils. The soils also contained very low amount of organic carbon (0.06-0.26%) and somewhat better amount of available potassium and phosphorus. These results are comparable with similar types of soils in some parts of Haryana (Ahuja *et al.*, 1992; Ahuja *et al.*, 1996) and Western Rajasthan (Dhir, 1977).

Soil suitability for sustainable land use

Based on various physico-chemical properties, slope, drainage pattern, erosion/ deposition hazards, climatic limitations and rainfall distribution pattern, the soils were evaluated for their suitability for various land use (FAO, 1976). In all five categories i.e., suitable (S), not suitable (N), highly suitable (S1), moderately suitable (S2) and marginally suitable (S3) were suggested for their suitability for rainfed crops, irrigated crops, horticulture, agroforestry, silvipasture and pasture development (Table 4). These are described as follows:

The Modasar, Sam, Thar, Dabla and Chirai series occurring in the interdune and sandy plain with loamy sand texture are moderately suitable (S2) for rainfed agriculture for growing pearl millet, mung bean, moth bean and clusterbean. The dune and hummocky part of Modasar and Parewar series are not suitable (N) for rainfed cultivation, while, hummocky phase of loamy sand soils of Sam, Dabla, Modasar, Kolu and Chacha series are marginally (S3) suitable for these crops only in good rainfall

years. However, if rains fail completely, these soils qualify for not suitable (N) category.

Under irrigated conditions with Indira Gandhi Canal, the Modasar, Thar, Sam, Dabla and Chirai series are moderately suitable (S2) for wheat, mustard, gram and groundnut. Due to undulating relief, the hummocky part of Modasar, Sam and Dabla series are marginally suitable (S3), while Chacha series because of thin solum is not suitable (N) for irrigated crops.

Because of strong wind regime and shifting sand, agroforestry or plantation of shelterbelts is a key requirement. For agroforestry the Thar, Modasar, Sam, Dabla and Chirai series are highly suitable (S1) for pearl millet, mung bean, moth bean and clusterbean under rainfed and wheat, mustard and gram under irrigated conditions in command areas in combination with *Prosopis cineraria*, *Tecomella undulata*, *Acacia senegal*, *Acacia albida* and *Albizia lebbeck* tree species. The hummocky part of these soil series is marginally suitable (S3). The Kolu and Chacha series are moderately suitable (S2) with *Ziziphus nummularia*, *Capparis deciduas* and *Acacia senegal*.

Due to crop preference the Modasar, Sam, Thar, Dabla and Chirai series are marginally suitable (S3) while hummocky part of these soil series is highly suitable (S1) for forestry. The Kolu and Chacha series are moderately suitable (S2) and Dune and Prewar series are highly suitable (S1) with *Prosopis cineraria*, *Tecomella undulata*, *Acacia tortilis*, *Acacia senegal*, *Calligonum polygonoides* and *Prosopis juliflora* plantations (Gupta and Sharma, 1997).

Besides the lands can be used for horticultural crops. The Modasar, Sam, Thar, Chirai and Dabla series are highly suitable (S1) for growing ber, karonda and kair while hummocky part of these soil series is moderately suitable (S2). The Kolu and Chacha series having hardpan are marginally suitable (S3). The dune series due to highly undulating relief, droughtiness and high requirements of water are neither suitable (N) for horticultural plantation (Vashishtha and Prasad, 1997) nor for agroforestry. The Dune, Prewar and hummocky part of Modasar, Dabla and Sam series are highly suitable (S1) for silvipasture and pasture systems for growing grasses along with indigenous and exotic arid zone tree species and deep rooted grasses like *Lasiurus sindicus*, *Panicum antidotale*, *Panicum turgidum*, *Cenchrus ciliaris, C. biflorus* and *Eleusine compressa* respectively. Shankar and Kumar (1986, 1987) reported that pasture system on such sandy habitats provides 275 to 687 kg ha^{-1} dry biomass. The flat interduanl part of these soils is marginally suitable (S3) for silvopasture and pasture development. The hardpan soils of Kolu and Chacha series are moderately suitable (S2) for silvopasture and deep rooted grasses while highly suitable (S1) for shallow rooted grasses such as *Eleusine compressa* and *Aristida funiculata.*

Land capability and irrigability classification

Due to sever climatic limitation, soil texture and wind erosion/deposition the Dune, Parewar, highly hummocky part of Modasar, Sam, Thar and Dobla soil series qualify for land capability class VI c s e and are more prone to wind erosion (Table

3). The flat interdunal part of Modasar, Sam, Dabla and Chirai, fall under capability class IV c s e; c e and have somewhat better potential for cultivation. Soils of Kolu and Chacha series qualify for class VI c sh e and have severe drainage and root zone limitations.

For land irrigability assessment, because of undulating relief, light texture, excessively drained substrata the Dune, Parewar and hummocky part of Modasar, Dabla and Sam series have been placed under class 4 and sub class 4 t d s. The Thar, flat inter-dunal part of Sam, Modasar, Dabla and Chirai series, due to light texture and substrata hardness, is placed under class 3 and sub-class 3 d s. By virtue of having impermeable ill drained substrata and light texture, the Kolu and Chacha soil qualify for class 4 and subclass 4 d s of irritability (Table 3). These results are similar to those reported by Ahuja *et al.* (1996) for similar soils of Haryana.

Acknowledgements

The authors are grateful to Head, Division of Natural Resources and Environment, and Director, Central Arid Zone Research Institute, Jodhpur, for their keen interest, constant encouragement and for providing necessary facilities during the course of this study.

References

Ahuja, R.L., Manchanda, M.L., Sangwan, B.S., Goyal, V.P. and Agarwal, R.P. 1992. Utilization of remotely sensed data for soil resources mapping and its interpretation for land use planning of Bhiwani district (Haryana). *Journal of the Indian Society of Remote Sensing* 2&3: 105-120.

Ahuja, R.L., Singh, Partipal, Jagan Nath and Dinesh 1996. Land evaluation of sand dunal topo sequences of Haryana. *Agropedology* 6: 37-42.

Chatterji, P.C. and Kar, A. 1992. Geological framework of Jaisalmer. In *Integrated Natural and Human Resources Appraisal of Jaisalmer District* (Eds. P.C. Chatterji and Amal Kar), pp. 12-13, CAZRI, Jodhpur.

Chawla, J., Dhir, R.P. and Singhvi, A.K. 1992. Thermo-luminescence chronology of sand profile in the Thar Desert and their implication. *Quaternary Science Review* 10: 25-32.

Dhir, R.P. 1977. Western Rajasthan soils: Their characteristics and properties. In *Desertification and Its Control*, pp. 102-115. ICAR, New Delhi.

Dhir, R.P. and Kolarkar, A.S. 1977. Observations on genesis and evolution of arid zone soils. *Journal of the Indian Society of Soil Science* 25: 260-264.

FAO 1976. A frame work for land evaluation. *Soils Bulletin* 32, FAO, Rome.

Gupta, J.P. and Sharma, A.K. 1997. Agroforestry for desertification control in arid ecosystem. In *Desertification Control in the Arid Ecosystem of India for Sustainable Development* (Eds. Surendra Singh and Amal Kar), pp. 292-297. Agro Botanical Publishers (India), Bikaner.

IARI 1971. *Soil Survey Manual.* Indian Agricultural Research Institute, New Delhi.

Jackson, M.L. 1967. *Soil Chemical Analysis*. Prentice Hall of India Ltd., New Delhi.

Kolarkar, A.S., Jain, S.V., Dhir, R.P. and Singh, N. 1989. Distribution, morphology and land use in Rajasthan. In *Review of Research on Sandy Soils in India*, pp. 1-20. CAZRI, Jodhpur.

Kolarkar, A.S. and Singh, N. 1992. Soil and land use capability of Jaisalmer district. In *Integrated Natural and Human Resources Appraisal of Jaisalmer District* (Eds. P.C. Chatterji and Amal Kar), pp. 26-34. CAZRI, Jodhpur.

Piper, C.S. 1950. *Soil and Plant Analysis.* University of Adelaide, Adelaide, Australia.

Rama Krishna, Y.S., Rao, A.S. and Singh, R.S. 1992. Climatic features of Jaisalmer district. In *Integrated Natural and Human Resources Appraisal of Jaisalmer District* (Eds. P.C. Chatterji and Amal Kar), pp. 4-11, CAZRI, Jodhpur.

Shankar, Vinod and Kumar, Suresh 1986. Herbage yield and carrying capacity of grass lands in Jaisalmer district. *Tropical Ecology* 28: 239-245.

Shankar, Vinod and Kumar, Suresh 1987. *Grazing Resources of Jaisalmer: Ecology and Developmental Planning with Special Reference to Sewan Grassland.* CAZRI Publ. No. 28, pp. 92, CAZRI, Jodhpur.

Soil Survey Staff 1998. *Key to Soil Taxonomy.* 8th Ed. SMSS Technical Monograph 6, USDA, Washington, DC.

Vashishtha, B.B. and Prasad, R.N. 1987. Horti-silvi-pasture systems for arid zone. In *Silvi-pasturoal System in Arid and Semi-arid Ecosystems* (Eds. M.S. Yadav, Manjit Singh, S.K. Sharma, J.C. Tiwari and Udai Burman), pp. 277-284. CAZRI, Jodhpur.