Remote Sensing and GIS in Identification of Soil Constraints for Sustainable Development in Ajmer District, Rajasthan

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Abstract

Soil is an integral part of eco-system nurturing the biological system. Sustainable management of soil resources based on the consideration of constraints is the key to check land degradation, water erosion and maintain soil fertility and productivity of biological system. Remote sensing and GIS technology has been used for identification of soil constraints in resources potential of Ajmer district. The Ajmer district is located in the centre of the state covering 8481 Sq. Km. area. The district comes in semi-arid climate with mean annual rainfall of 560 mm. The land forms occurring in the district are alluvial plain and plain with scattered gravely / stony uplands in central part. IRS LISS-III FCC images were interpreted for soil constraints using physiography soil approach, verified through field traverses and samples were analysed in Soil Testing laboratory. IRS LISS-III FCC images of salt affected soil series of Parbatsar Sodic appear in bright white to light grey tone, smooth texture with white mottles. These were also verified during ground truth and soil analysis for salinity (EC 0.90 to 3.46 dsm-1) and sodicity (pH 9 to 9.40 and ESP 15.2 to 18.7). Similarly, on the LISS-III FCC, constraints due to water erosion of Jalkhera Ratwai and Vijaypura soil series (0 to 24 cm. depth, pH 7.8 to 8.2, EC 0.5 to 0.7 dsm-1, ESP 1 to 5) were apparent in light gray to whitish tone, intercepted by medium grey streaks indicating streams and exposed sub-soil. The constraints due to shallow depth associated with rock out crops and hilly areas of Kama, Bir. Goriya and Balda (depth 0-17 cm. pH 7.6 to 7.9, EC. 0.20 to 0.35 dsm-1, ESP 1.6 to 2.9) series appeared in greenish grey tone and coarse texture. There was close relationship between image characteristics, field observation and analytical data.

The study revealed that out of total geographical area of the district, 5 per cent area has constraints due to salinity / sodicity and physical properties, which need to be overcome through amelioration and management to realize high crop yields. About 32 per cent area have constraints due to uneven terrain, shallow soils mixed with gravels, low AWC, low nutrients retention, moderate to severe water erosion which are difficult to overcome and these areas should be put under agro forestry and silvi-pasture management. Remaining 63 per cent area has no soil constraint, the soils have medium to high potential and with in-situ water harvesting technique, intensive irrigation and better nutrient management high crop yield can be obtained.

Keywords: Remote Sensing, Soil Constrains, Sustainable Development, Ajmer

Introduction

Soil is one of the most important natural resources and understanding of the soil system is key to the success and environmental harmony of any human use of land. Sustainable

development involves technologies and management which work in harmony with natural resources and promote agro-eco-resilience which minimizes adverse effect on environment. During last five decades, high pressure of human population, industrial activities and intensive agricultural activities have resulted into substantial degradation of soil resources.

Deep to very deep soils having good soil moisture and high nutrient retention capacity are an asset for sustained higher crop productivity as well as higher soil fertility. But at places, soils have constraints for crop production due to shallow depth, low available water capacity (AWC), low nutrient retention capacity, wilting point in plants, high salinity and sloping uneven terrain which need specific management practices (Eswaran, 1992). The properties are result of inherent soil / terrain characteristics. Soil physiography relationship has been helpful for identification of the nature and extent of soil / terrain constraints. In western arid part of Rajasthan, the Kolu and Kalyanpur soil series (Coarse loamy lithic petrocalcids) associated with buried pediment (BP) have constraints due to shallow depth, low AWC, low nutrient retention and significant wind erosion. Similarly, the Baytu and Molasar soils (Typic Torripsamments) associated with aeolian plain are characterized by low AWC, low nutrient retention, faster infiltration and severe wind erosion (Joshi, 1996).

Remote sensing technology has brought revolution in the management of natural resources and has been successfully employed for conservation and sustainable management of land resources and environment. This technology has been successfully employed for identification of type and degree of salt affected soils (Kalra and Joshi, 1996). Remote sensing technology is very helpful tool for identification of degraded land of water erosion, wind erosion and severely salt affected soil (Chopra,2009).Remote sensing and GIS indification of soil constraint(Laxman singh 2012) In the resource potential district Ajmer though a lot of development activities including watershed (Anicut / Khadin) salt affected land improvement programme of State Government has started but gains due to these activities could not be realized because of constraints associated with soil / terrain constraints and absence of application of modern technology like remote sensing and GIS in Ajmer district.

Materials and Methods

Study Area: The Ajmer district is located in the centre part of the State between 25.38 and 26.57 N and 73.57 and 74.55 E (degree decimal) covering 8481 Sq. Km. area. Climate is semi-arid with mean annual rainfall of 560 mm. It has good potential in agriculture as many streams flow through the area but mostly the area is under rainfed agriculture. Ground water is very deep and less quantity availability affected areas are also encountered.

Methodology:

Interpretation of satellite data and ground truth: Following Geo-coded satellite FCC images of IRS P6 LISS-III (1:50,000 scale), data acquired on May, 2005 were visually interpreted in conjunction with the Survey of India (SOI) sheets (Table 1)

Physiography units viz, hills, pediments, buried pediment, alluvial plain viz. medium to fine textured in alluvial plain and valley hills were delineated. Within the physiographic unit tentative soil boundaries were delineated by adopting the elements of image interpretation including tone, texture, pattern, association, land use and vegetation pattern. Field traversing was carried out for ground truth, soil augar holes were examined at close

interval depending upon terrain variability, and morphological characteristics. For each soil series at typical sites, profiles were examined and for each horizon morphological characteristics including soil colour, texture, structure, consistency and calcareousness were recorded (Soil Survey Manual, 1970). The salinity and erosion status were also observed. Soil samples of each horizon of the typical profiles were collected for analysis in laboratory. Based on field observation and chemical analysis the soil series were recognized and classified according to Keys to Soil Taxonomy (2006).

Table 1 Geocoded data used in this research.

S No.	Toposheet number	Path and Row
1	45-G/13,14.	93,53,54
2	45-J/7,8,9,10,11,12,13,14,15,16	94,53
3	45-K/1, 2,4, 5,9,13	94,53
4	45-N/1,2,3,4,8	92,53
5	45-O /1,2,5,6	95,53

Remote Sensing technique for identification of site-specific soil constraints: For identification of site-specific constraints the satellite image IRS LISS-III FCC of January, 2006 were interpreted, ground checked and chemical analysis of soil samples carried out.

Soil analysis: Soil samples were analyzed for particle size distribution (Hydrometer Method), pH and Electrical conductivity (1:2 soil water suspension), CaCo3 (Acid titration method), organic carbon and cation exchange capacity according to Jackson (1973) and Richard (1954).

Application of GIS: The soil series maps prepared toposheet wise for entire district at 1:50,000 scale was scanned and boundaries for each mapping unit were digitized using ARC-INFO version 9.2 GIS software. The digitized maps have been used to generate the maps showing soil series and constraints viz, salinity / sodality, water erosion and depth. The soil series have been evaluated for soil / terrain constraints viz. Salinity / sodicity, effective soil depth, water erosion, AWS and physical constraints as per Eswaran (1992).

Results and Discussion

Salient morphological characteristics of soil series having soil / terrain constraints are presented in table-2 and analytical data in table-3. Geographical distribution of soil series in presented in Fig. 1.

Soil Constraints due to depth and erosion: The image characteristics, ground truth and chemical data of specific sites of soil series having constraints due to depth and undulating/ sloping terrain are presented in table-5. LISS-III images and ground truth correlated for Ratwai, Vijaypura and Jalkheda series revealed that shallow soils appeared in light grey to whitish tone. The pH and electrical conductivity of soils were in normal range. The Goriya, Kama, Bir and Balda series represented rocky out crop and hills appear in greenish grey tone with pink area due to vegetation cover.

The coarse texture, alluvium derived soil series Sambhar and Parbatsar sodic soil series characteristics shows salinity / sodicity, substrata is very compact restricting infiltration

and permeability of water and plant root environment. These soil cover 424Km 2 (5.00 %) of district area.Amelioration and management efforts are needed to realize high crop yields from these soils. During similarly study for Jamnagar district Joshi (1994) observed that Okha soil series was associated with physical constraints like shallow depth, low AWC and was found suitable only silvi pasture where as Khambhaliya soils were free of these hazards and thus good crop of groundnut was cultivated.

Table 2. Salient characteristics of Soil Series having Soil / Terrain Constraints.

S. No.	Physiography	Name of Soil Series & Area (Km 2)	Colour (Moist)	Texture	Structure	Depth (cm.)	Soil Classification Common to all mixed, hyperthermic.
Constraints due to Shallow depth erosion							
1	Hills (High)	Goriya (777)	Yallow brown (10 YR 5/6)	Gravelly sandy loam	Massive friable	0-8	Loamy skeletal lithic Ustorthents
2	Hills (Lower) and Rock out crops	Kama (4)	Pale brown (10YR 6/3)	Gravelly sandy loam	Granular Friable	0-10	Sandy skeletal Lithic Torriorthents
3	Hills (Lower) and Rock out crops	Bir (663)	Pinkish gray (7.5 YR) 6/2)	Gravelly sandy loam	Granular Friable	0-15	Loamy skeletal Lithic Ustorthents.
4	Pediment	Balda (22)	Yellow brown (10 YR 5/6)	Gravelly loam Sand	Single grain Friable	0-20	Loamy Skeletal Lithic Ustorthents
5	Buried Pediment	Jalkheda (607)	Yellowish brown (10 YR 5/4)	Gravelly sandy loam	Friable	0-22	Loamy skeletal Lithic Ustorthents
6	Buried Pediment	Ratwai (324)	Dark grayish brown (10 YR 4/4)	Fine sandy clay loam	Sub angular blocky	0-24	Fine loamy Lithic Haplu stepts
7	Buried Pediment	Vijaypura (66)	Yellowish brown (10YR 5/4)	Sandy loam	Weak subangular blocky	0-24	Coarse loamy Lithic Haplustepts
8	Eolian Plain	Pushker (145)	Dark Brown (7.5 YR 5/4)	Loamy coarse sand	Granular friable	0-110	Ustipsammen ts
Constraints due to Salinity/Sodicity							
9	Playa	Sambhar (20)	Yellow brown (10 YR 5/4)	Loamy sand to sandy loam	Sub angular Blocky	0-120	Coarse Loamy Haplosalids.
10	Alluvial Plain	Parbatsar sodic (404)	Yellowish brown (10 YR 5/4)	Loam	Sub angular blocky	0-110	Coarse Loamy sodic Haplocambid s

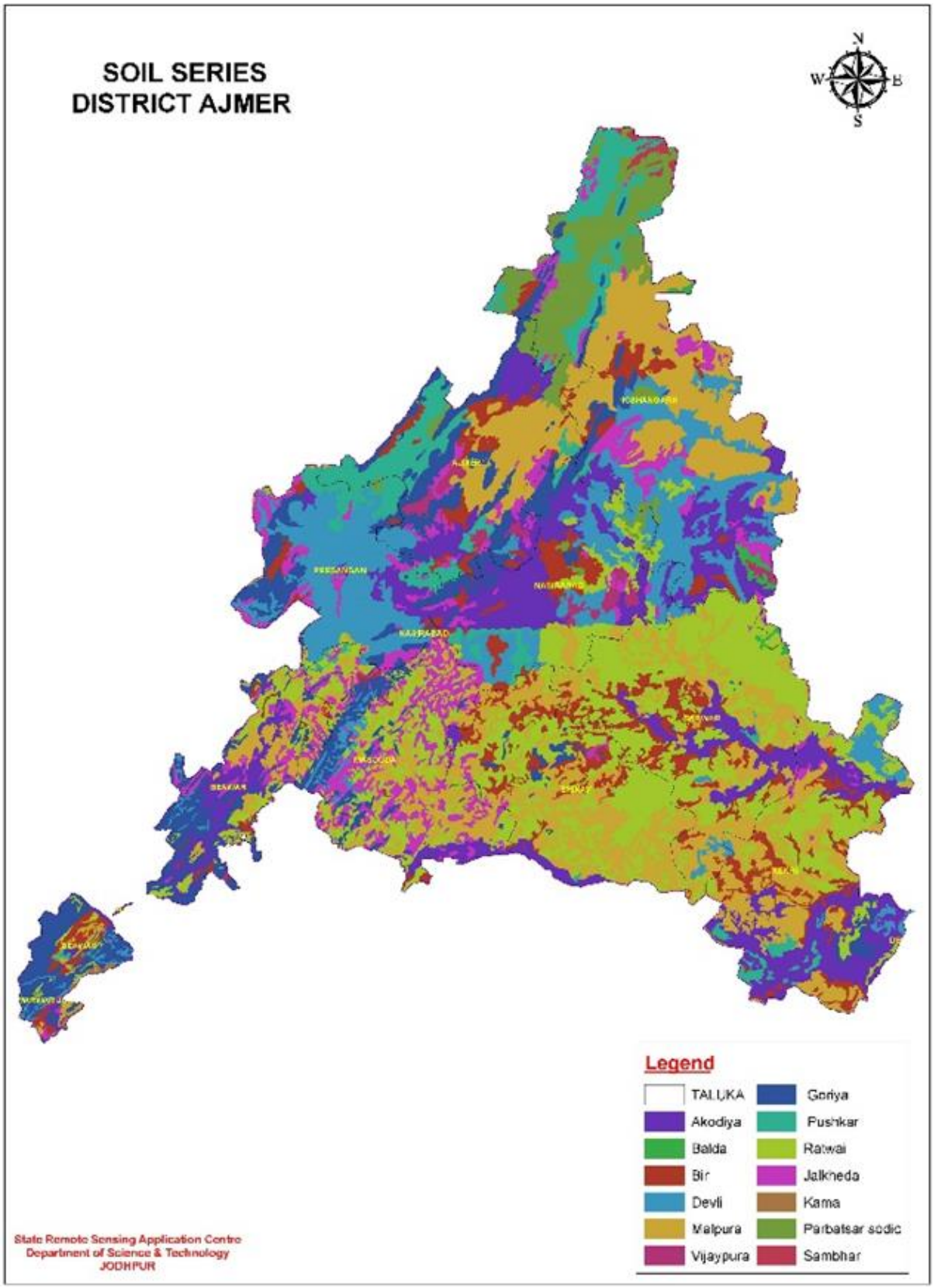

Fig. 1 Soil series map of Ajmer District.

Table 3 Physico-chemical characteristics of Soil Series.

Name of Soil Series	Depth (Cm)	pH	Electrical conductivity (dsm^{-1})	Sand (%)	Silt (%)	Clay (%)	CaCo3 (%)	Cation exchange Capacity $Cmol\ kg^{-1}$	ESP
Constraint: Due to Shallow depth & erosion									
Goriya	0-8	7.6	0.20	65.3	19.4	18.3	0.0	8.5	1.6
Kamai	0-10	8.0	0.24	8.74	7.5	4.8	0.0	3.8	1.8
Bir	0-15	7.7	0.35	73.7	17.1	11.20	0.2	6.1	2.9
Balda	0-17	7.9	0.24	80.7	8.28	9.27	1.0	6.6	2.7
Jalkhera	0-22	8.0	0.70	73.8	11.2	8.50	4.4	7.8	1.0
Ratwai	0-24	8.2	0.56	60.02	12.43	27.55	8.5	7.1	1.9
Vijaypura	0-24	7.8	0.50	68.7	15.7	15.6	0.0	8.2	5.0
Pushker	0-110	8.0	0.60	91.0	1.7	7.2	0.6	7.2	2.1
Constraint: Due to Salinity/Sodicity									
Sambhar	0-120	9.0	3.46	85.2	5.6	9.2	2.9	7.9	16.40
Parbatsar sodic	0-110	8.8	1.20	71.3	12.3	16.4	2.1	16.2	18.70

Table 4 Image Characteristics ground truth and analytical data of soil series constraints due to Salinity / Sodicity.

Name of Soil Series	IRS LISS-III FCC Image Characteristics	Ground truth characteristics	Depth (Cm)	pH	EC dsm^{-1}	ESP	Texture	CaCo3 %
Sambhar	Bright white to light grey tone, smooth texture, white mottle.	Salt crust on surface and compact solum, poor drainage bare surface with ephemperal salt tolerant grasses	0-15	8.5	1.4	15.3	Loamy sand to sandy loam	2.0
			15-30	9.00	3.46	16.4	Sandy loam	2.9
Parbatsar sodic	whitish to modarate grey tone, smooth texture, white mottle.	Salt mixed with soil and compact solum, poor drainage	0-15	8.3	0.90	14.9	Loam	1.8
			15-30	8.8	1.20	16.3	Loam	2.3

Table 5. Image Characteristics ground truth and analytical data of soil series having Constraints due to Shallow depth and Water erosion.

Name of Soil Series	IRS LISS-III FCC Image Characteristics (January)	Ground truth	Depth (Cm)	pH	EC dsm $^{-1}$	Texture
Goriya	Bare hills appear in dark grey tone and those with thin vegetation are in light pink	High hills with steep slope	0-8	7.6	0.25	Gravelly loam
Kama	Greenish grey tone coarse texture	Low hills with moderate to severe slope	0-10	8.0	0.24	Gravelly sandy loam
Bir	Greenish grey tone coarse texture	Rock out crops in pediment area	0-15	7.7	0.45	Gravelly sandy loam
Balda	Medium grey to dark gray spots	Soils 15-20 cm depth with skeletal materials.	0-20	8.o	0.24	Gravelly loam
Jalkheda	Medium grey with light grey spots	Surface soil mixed with gravels	0-22	8.0	0.91	Sandy loam
Vijaypura	Medium grey with light grey spots	Soils 15-25 cm depth with exposed substrata	0-24	7.8	0.50	Sandy loam
Ratwai	Light grey to whitish tone and smooth texture	Soils 10-24 cm with rock fragmental material	0-24	8.1	0.56	Gravelly loam
Pushker	Whitish tone with smooth texture	Sand accumulated on surface	0-110	8.0	0.60	Sand

Management of constraints and sustainable development: Based on these criteria for soil constraints due to salinity / sodicity, shallow depth, available water capacity, erosion hazards and physical constraints (Eswaran, 1992) each soil series has been examined and associated constraints are presented in table-6 and soil constraints map in Fig. 2.

The coarse texture, alluvium derived soil series Sambhar and Parbatsar sodic soil series characteristics shows salinity / sodicity, substrata is very compact restricting infiltration and permeability of water and plant root environment. These soil cover 424Km 2 (5.00 %) of district area.Amelioration and management efforts are needed to realize high crop yields from these soils. During similarly study for Jamnagar district Joshi (1994) observed that Okha soil series was associated with physical constraints like shallow depth, low AWC and was found suitable only silvi pasture where as Khambhaliya soils were free of these hazards and thus good crop of groundnut was cultivated.

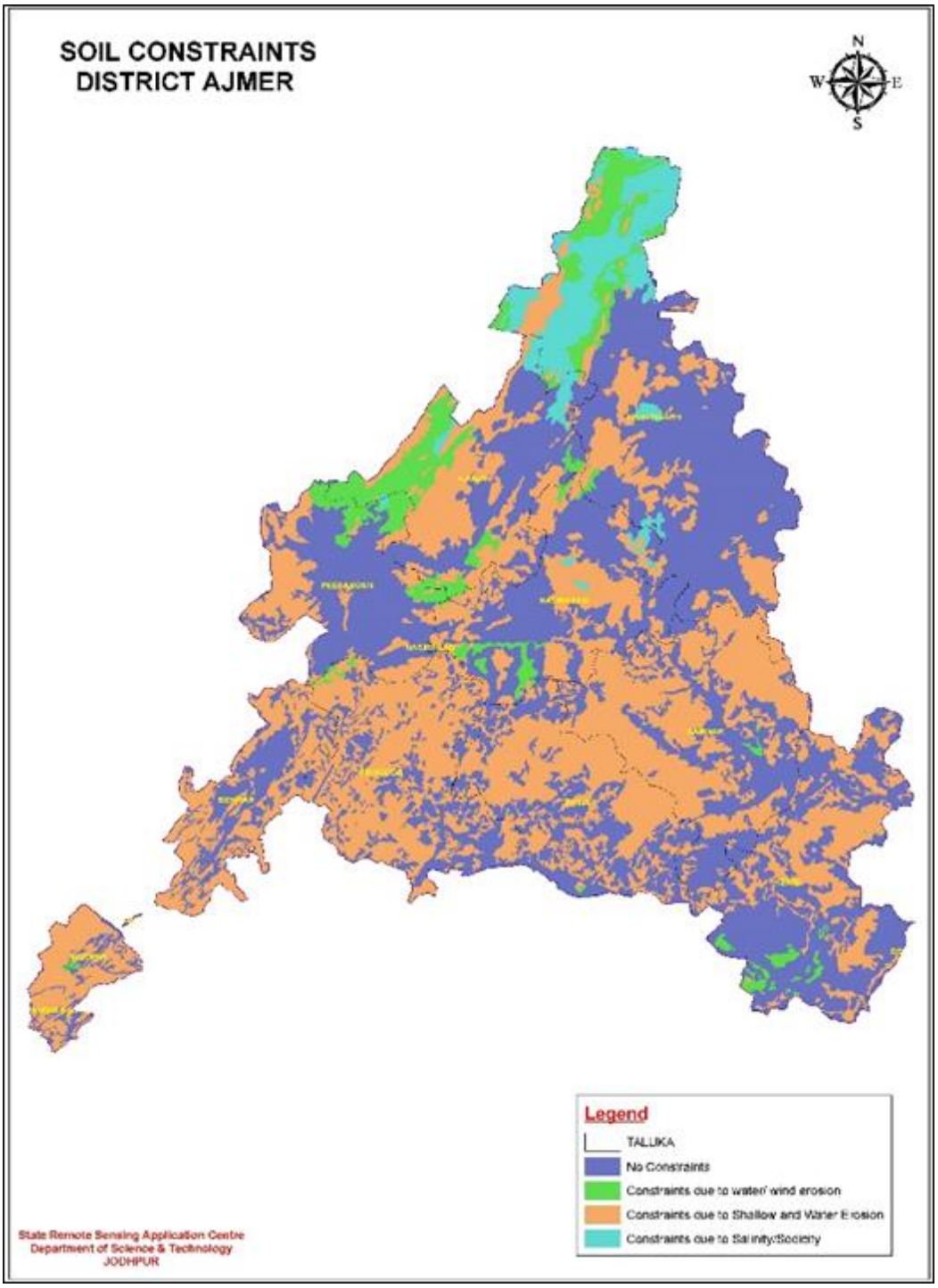

Fig. 2 Soil constraints map.

Table 6. Constrains (X) associated with Soil Series.

Name of Soil Series	Effective soil depth	Available water holding capacity	Soil aridity	Vulnerable to erosion	Salinity Sodicity	Nutrient Retention	Physical constraints
Loamy skeletal Lithic Ustorthents							
Goriya	X	X	X	X	-	-	-
Sandy skeletal LIthic Torriorthents							
Kama	X	X	X	X	-	-	-
Loamy skeletal Lithic Ustorthents							
Bir	X	X	X	X	-	-	-
Balda Jalkheda	X	X	X	X	-	-	-
Fine loamy Lithic Haplustepts							
Ratwai	X	X	X	X	-	-	-
Coarse Loamy Lithic Haplustepts							
Vijaypura	X	X	X	X	-	-	-
Sandy Ustipsamments							
Pushker			X	X	-	-	-
Coarse Loamy Haplosalids							
Sambhar	--	--	X	--	X	-	X
Loamy Sodic Haplocambids							
Parbatsar sodic	--	--	X	--	X	-	X

The soil series / association viz., Goriya ,Kama,Bir, Balda, have a number of constraints including shallow depth, low AWC, moderate to sever water erosion and low nutrients retention capacity and occur in 1426 Km2 (16.68 % of district area). These soils are unsuitable for agriculture and need to be conserved by providing canopy cover. Similarly Ratwai,Jalkheda and Vijaypura series are also characterized by shallow depth, water erosion and low AWC and have constraints for deep rooted crops. These type soils are suitable for agrofostry and silvipasture These are spread in 1288 Km2 (15.18 % of district area).

The soil associated with deep buried pediment viz. Akodiya,and Malpura are deep to very deep, having good AWC and nutrients retention capacity, free of salinity / sodicity and erosion hazards and physical constraints. Similarly the soils developed on coarse / fine alluvium viz. Devli and Saradhana are also free of constraints. These occur in 5343 Km2 (63.00 % of district area). These soils have medium to high potential and with insitu moisture conservation, intensive irrigation and better nutrient management high crop yield can be obtained.

Conclusions

Thus, it can be inferred from the study that nearly 63.00 per cent area of the district has no soil constraints, 5.00 percent area needs efforts to overcome constraints and 32.00 percent area have constraints which are difficult to overcome and these areas should be put under agroforstry and Silvi Pasture Management. Modern technologies like Remote Sensing data and GIS can play a very pivotal role in identifying and mapping of these constraints.

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