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Research Article

LAND RESOURCE CHARACTERIZATION, SOIL RESOURCE MAPPING FOR FARM LEVEL LAND USE PLANNING – A CASE STUDY IN UPPER GANGETIC PLAINS

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Abstract: Land resource characterization and detailed inventorization of soil resources for farm planning was carried out in block level in Haryana as a case study in upper Gangetic plains. Satellite data(IRS-P6, LISS-IV) interpretation in conjunction with legacy data and cadastral maps was undertaken using latest techniques identified broad physiographic units and generated base map for soil survey. Eleven soil series along with eighteen mapping units were identified as phases of soils series in six broad physiographic units. Soil-physiographic relationship was established during detailed soil resource mapping. Soils occur on old alluvial plain are very deep, well drained to moderately well drained, calcareous, loam/clay loam and classified as Fine loamy, Typic Haplustepts /Typic Haplustalfs, while on old alluvial plain with high water table (Salt affected soils) are very deep, imperfectly to poorly drained, calcareous, clay loam, saline-sodic in nature (Fine loamy, Natric Haplustepts/ Typic Halaquepts). Soils on very gently sloping reclaimed sand dunes are sandy/loamy sand, excessively to somewhat drained (Typic Ustipsamments). Soils were characterized, classified for their constraints/potentials and suitability for different uses were identified. The majority of soils are moderately alkaline, slightly saline, high in lime content, and low to medium in available nutrients. Salinity/sodicity, drainage, erosion and low fertility are the major constraints in the region. Resource database generated were interpreted and integrated in Geographical Information System (GIS) for several thematic information *viz*., landform, land use/land cover, soils, drainage, particle size, and soil salinity/sodicity. Suitable land use options were suggested for each parcel of land by considering its constraints/potentialities. Village level site-specific database was generated for farm planning which could be easily applicable for land use and management strategies in similar area of upper Gangetic plain.

Keywords: land resource characterization, soil resource mapping, Farm planning

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Introduction

The land resources of the Upper Gangetic plain particularly in Haryana state are under severe strain due to competing demands of various land uses and increasing population pressure. The ever-increasing food requirement demands optimum utilization of land resources. The challenge before us is not only to increase the productivity per unit area but also to reduce the severity of degradation [1]. The situation needs immediate attention and correction. The problems and issues are site-specific and can be addressed effectively by having a thorough knowledge of the situation, and evolving location-specific solution [2]. This calls for detailed site-specific database on various land resources of the state in a specified period of time. The information available at present for most of the land resources is at smaller scale and not site or location specific. The site-specific farm level information on soil and other land resources can easily identify the constraints and potentials. This will help in evolving a rational, site-specific and viable land use options suitable for each and every farm and managing the scarce resources in a sustainable manner [3,4]. It will also help most of the developmental activities at district/state level. In central Haryana, the agrarian front is faced with multitudes of problems like water logging, salinity/sodicity, low fertility, mono-cropping system, fragmentations, declining factor productivity. [5,6] and soil erosion for the past few decades [7]. There has been an alarming rise in the water table during past two decades in some parts, and decline of water table reported in some other parts of the state [8]. The causative factors for the above problems exist at the grassroots level. The soil information of some districts of Haryana is available on small scale (1:50, 000) which do not seems to be effective for devising suitable land use plan for micro-level variations and the information on detailed scale (1:12,500) is almost non-existent. Keeping this in view, the present study was undertaken to generate the detailed database of existing land resources and mapping of soils by using remote sensing and GIS techniques, to identify the problems and potentials of the area for various uses and to suggest sustainable land use options suitable for each and every land holding for achieving sustainable crop production, management and conservation of vital natural resources.

Materials and Methods

Study area

The case study was carried out as a representative site of upper Gangetic alluvial plain in Lakhan Majra block, Tahsil & district Rohtak,Haryana, It is bounded by districts Sonepat in North, Jind in North-west; tahsil Maham in west and is situated 15 km away from district head quarters Rohtak. General topography is inland drainage basin (Saucer shape topography) [8]. Sand dunes and reclaimed sand dunes are present in some parts of study area. The climate is semi-arid sub-tropical with dry summer and cold winters. Mean annual rainfall is 528 mm and maximum rainfall is recorded between the months of July to September brought by south west monsoon. Maximum temperature ranges between 40 to 45ºC and minimum 3 to 6ºC. The mean annual temperature is 24.5ºC. The estimated mean annual summer temperature (MAST) is 29ºC and mean annual winter temperature (MAWT) is 15ºC. The relative humidity remains low up to 60 % during summer months but during rainy season it is recorded as high as up to >90%. The length of growing period (LGP), which indicates the availability of water for plant growth, is about three months in a year [Fig-1]. It starts from the end of July (33rd week) and continues up the end of October (46th week).

However, the probability of getting the mean rainfall is only about 40 percent. Therefore, LGP remains less than 120 days in five out of 10 years in the area.

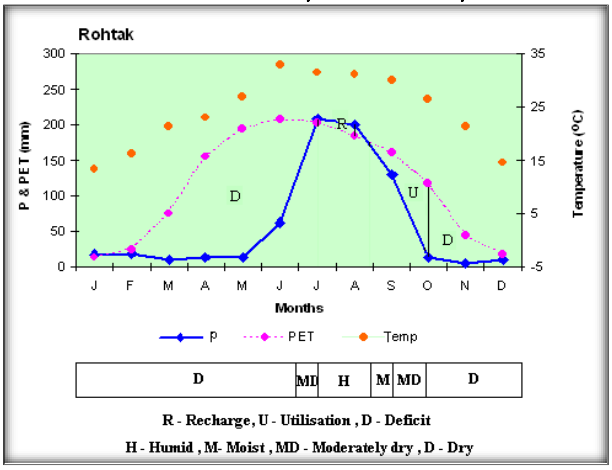


Fig-1 Water balance diagram, Lakhan Majra, Haryana

Methodology

Resource characterization for farm level planning was carried out by detailed characterization and mapping of all the existing land resources. Crops and cropping pattern data were collected from statistical departments [5] and village records. Soil resource characterisation and mapping was carried out by adopting the latest available procedures [10,11] by conducting detailed soil survey on 1:12,500 scaleby using base maps prepared from Survey of India toposheets, cadastral maps (1:2640 and 1:4000 scale), demarcating field boundaries, Khasara/field numbers and interpretation of remote sensing data. The LANDSAT-LISS-IV, IRS-P6 satellite data was interpreted visually as well as digital analysis in conjunction with ground truth for identification of landform and land use using photo-interpretation key. Physiographic units were delineated. Google-earth data was also used for identification of landforms and land use. After ground truth, soil survey work was carried out by studying representative pedons (soil profiles) in different physiographic units for morphological properties, and horizon-wise soil samples were collected from representative soil profiles for laboratory characterization. Soils were grouped into different soil series and mapped as phases of soil series [12]. Soil samples of were analyzed for physico-chemical properties by following standard procedures [13-15]. The soils were classified according to Soil Taxonomy [16].On the basis of landform analysis, field surveys and laboratory studies, the soil resource map of Lakhan Majra Block was prepared on 1:12,500 scale. The soils were classified under different land capability as per standard procedures [17, 18].The soil and climatic data were assessed to work out the suitability of soils for dominant crops grown in the area following a parametric approach [19]. The soil and other maps thus prepared were digitized using the ARC-GIS Software. Each mapping unit has been evaluated and interpreted for land capability, suitability for land use, fertility status of soils and generated information were integrated for suggesting optimum land use options for each parcel of land and maps were generated under GIS environment.

Results

Resource Characterization

Geologically the study area is tract of Indo-Gangetic alluvial plain ranging from Pleistocene to Recent in age with gentle slopes [20]. The general direction of the slope is from south west to north east and from north-west to south east. The elevation ranges from 219 to 228 m above mean sea level (MSL) [8]. The area is a part of inland drainage basin. Because of gently sloping to nearly level topography the drain water from higher elevation creates flood problems in the lower areas during rainy season. However, in order to avoid floods, drains have been dug out in these areas.

Physiography

The general physiography of the Block is nearly level to gently sloping old alluvial plain and gently sloping aeolian deposits (Sand dunes) in some localized areas. The major physiographic units delineated are undulating sand dunes; very gently sloping reclaimed sand dunes; very gently sloping to nearly level upland plain; nearly level old alluvial plain; level old alluvial plain with high water table (saline patches); level old alluvial plain with concave relief (low-lying). The physiography map of the block is shown in the [Fig-2].

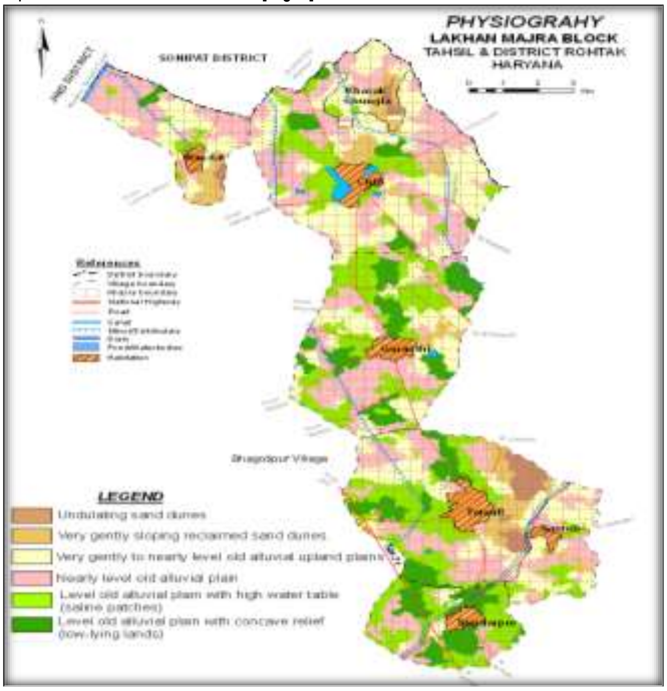


Fig-2 Physiography map

Land use / Land cover

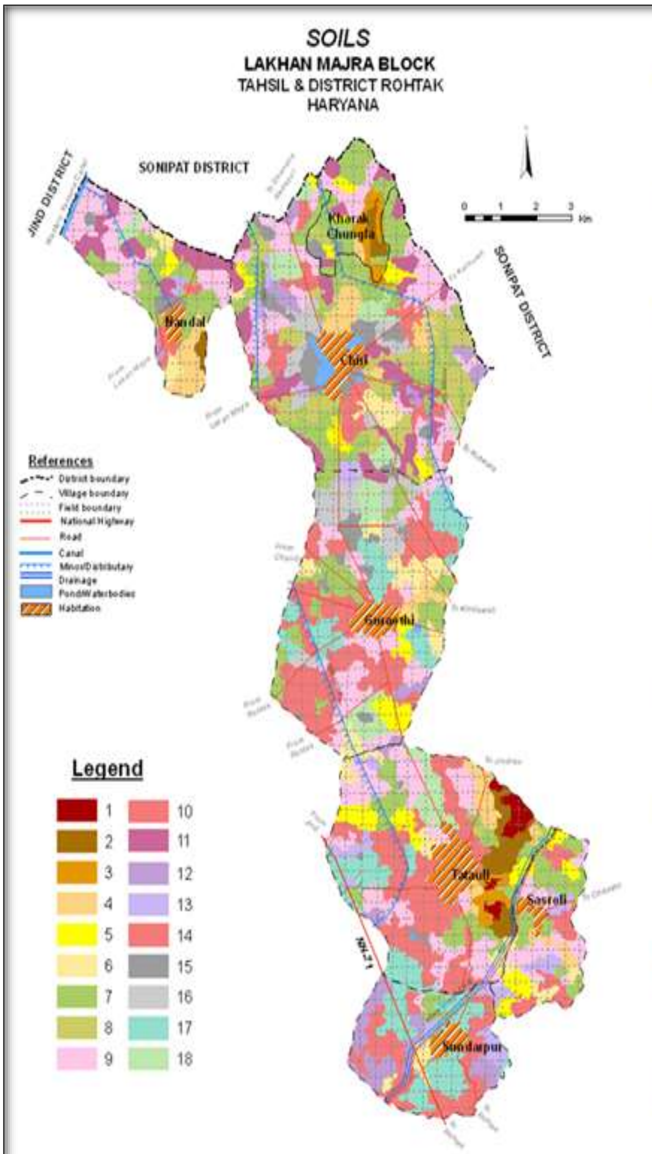
Major land use has been identified after interpretation of remote sensing data coupled with field checks. About 89.6 % area is under intensive cultivation and about 8.3% area is under miscellaneous use while negligible area is under pasture/scrub lands. At present, no fallow lands occur in the study area while the cultivation of single cropping is also observed in the scraped/ stabilized sand dune areas. Some patches of dunes have been put under social forestry plantation. The natural vegetation is sparse, comprising few tree species, shrubs and herbs. The 2.2 % area is under cultivable wasteland mostly covered by bushy salt affected lands or sandy patches. The entire area is under cultivation of double cropping under assured irrigation. The net area sown is 6430 hectare (86.8 %),

Crops and cropping pattern

Rice-wheat/mustard, rice/pulses-sugarcane, pearlmillet/pulses-wheat are the dominant cropping systems of the Block. Wheat, mustard and sugarcane are main *rabi* crops sown in the area while, paddy, pigeonpea, bajra, and sorghum are main *Kharif* crops. Vegetables like cauliflower, cabbage, bottle guards, lady finger, and tomato are grown in patches. Fodder crops and barley are also sown in patches. Few orchards of guava, amla (Gooseberry) and ber (*Zizypus*) are also found in packets. In upland areas of study area sorghum, pearl millet and cotton are the main crops.

Soil resources

Detailed soil resource inventory of the block was carried out and in total eleven soil series were identified and mapped into 18 mapping units as phases of soil series [Fig-3]. Soils occurring on undulating sand dunes are sandy, excessively drained and classified as Typic Ustipsamments. Loamy sand, somewhat excessively drained soils occur on very gently sloping reclaimed sand dunes (Typic Ustipsamments). These soils are neutral in reaction with low cation exchange capacity (CEC), and organic carbon [Table-1]. Very deep, well drained, calcareous, sandy loam soils (Coarse loamy, Typic Calciustepts/Typic Haplustepts) occur on old alluvial upland plain while soils on nearly level old alluvial plain are very deep, well drained to moderately well drained, calcareous, loam/clay loam and classified as Fine loamy, Typic Haplustepts/Typic Haplustalfs. These soils are good in nutrient status.



Soil Legend	Area (ha)	% of TGA
Soils of Undulating Sand Dunes		
Tatauli-I Series : Very deep, excessively drained, yellowish brown, sand (***Typic Ustipsamments***)	**190**	**2.6**
1 Tatauli-I, sand on 3-5% slopes and severely eroded	49	0.7
2 Tatauli –I sand on 1-3% slopes and moderately eroded	141	1.9
Soils of Very Gently Sloping Reclaimed Sand Dunes		
Nandal Series : Very deep, somewhat excessively drained, dark yellowish brown, loamy sand (***Typic Ustipsamments***)	**384**	**5.2**
3 Nandal, sand on 1-3 % slopes and Moderately eroded	97	1.3
4 Nandal, loamy sand on 1-3% slopes and slightly eroded	288	3.9
Soils of Old Alluvial Upland Plain		
Guraothi-I Series : Very deep, well drained, yellowish brown, calcareous, sandy loam, calcic layer present within 1m ***(Typic Calciustepts)***	**570**	**7.7**
5 Guraothi-I, sandy loam on 0-1% slopes and slightly eroded	275	3.7
6 Guraothi-I, sandy loam on 0-1% slopes, slightly eroded and slight salinity	295	4.0
Sasroli - I Series : Very deep, well drained, dark yellowish brown, sandy loam ***(Typic Haplustepts)***	**1465**	**19.8**
7 Sasroli -I, sandy loam on 0-1% slopes and slightly eroded	1099	14.8
8 Sasroli -I, sandy loam on 0-1% slopes, slightly eroded and slight salinity	366	4.9
Soils of Old Alluvial Plain		
Series Tatauli - II : Very deep, well drained, dark yellowish brown, calcareous, loam ***(Typic Haplustepts)***	**1110**	**15.0**
9 Tatauli -II , Sandy loam, 0-1% slopes	1110	15.0
Sasroli –II Series : Very deep, moderately well drained, brown, calcareous, clay loam, thin patchy clay cutans ***(Typic Haplustalfs)***	**669**	**9.0**
10 Sasroli -II, Sandy loam on 0-1% slopes	669	9.0
Chiri -I Series : Very deep, moderately well drained, dark yellowish brown, calcareous, loam ***(Fluventic Haplustepts)***	**423**	**5.7**
11 Chiri-I, Sandy loam on 0-1% slopes and slight erosion	42	5.7
Soils Of Old Alluvial Plain With High Water table (Salt Affected Soils)		
Tatauli–III Series : Very deep, imperfectly drained, light olive brown, calcareous, clay loam. saline-sodic in nature ***(Natric Haplustepts)***	**401**	**5.4**
12 Tatauli -III, Sandy loam on 0-1% slopes and slight salinity	256	3.4
13 Tatauli -III, Sandy loam on 0-1% slopes and moderate salinity	146	2.0
Guraothi-II Series : Very deep, moderately well drained, light olive brown, calcareous, loam, saline soils ***(Typic Calciustepts)***	**607**	**8.2**
14 Guraothi –II, Sandy loam on 0-1% slopes and severe salinity	607	8.2
Chiri -II Series : Very deep, poorly drained, light olive brown, calcareous, loam, saline soils ***(Typic Halaquepts)***	**459**	**6.2**
15 Chiri –II, Sandy loam on 1-3% slopes and severe salinity	206	2.8
16 Chiri –II, Sandy loam on 0-1% slopes and moderate salinity	253	3.4
Soils Of Old Alluvial Plain with Concave Relief (Low lying)		
Sunderpur Series : Very deep, imperfectly drained, dark grayish brown, calcareous, clay loam, saline-sodic soils ***(Aquic Haplustepts)***	**756**	**10.2**
17 Sunderpur, Loam on 0-1% slopes and slight salinity and slight sodicity	491	6.6
18 Sunderpur, Sandy loam on 0-1% slopes and slight salinity and slight sodicity	265	3.6
Habitation	312	4.2
Miscellaneous use	24	0.3
Ponds / water bodies	38	0.5
Total	7409	100

Fig-3 Soil map of Lakhan Majra Block, Tahsil & District Rohtak, Haryana

Waterlogged soils in the study area

Salt affected soils in the study area

Soils of old alluvial plain with high water table (Salt affected soils) are very deep, imperfectly drained, calcareous, clay loam, saline-sodic in nature (Fine loamy, Natric Haplustepts) andvery deep, poorly drained, calcareous, loam, saline soils (Fine loamy, Typic Halaquepts). These soils have glayed color or characteristics associated with wetness such as mottling and Fe-Mn nodules, very strongly alkaline (pH >9) and moderate to strongly saline/sodic in nature. These soils have low permeability but high available water capacity, low in organic carbon as well as CEC. Soils of old alluvial plain with concave relief (low lying lands) are very deep, imperfectly drained, dark grayish brown, clay loam in texture and strongly alkaline (pH 8.9) and classified as Aquic Haplustepts. The lime nodules and Fe-Mn nodules are present in the soil control section due to stagnation of water and low permeability. These soils have glayed colours or characteristics associated with wetness such as mottling and Fe-Mn nodules and are affected by slight salinity and sodicity. The available water capacity is high but low to medium in organic carbon and CEC.

Soil Degradation

The soil resource data and its interpretation indicated that about 8 % area has moderate to severe problem of soil erosion which is confined to undulating sand dunes and reclaimed sand dune areas respectively and need intensive reclamation measures like scrapping, land shaping, land leveling, bunding etc., to check soil erosion . Nearly 5.4 and 18.4% area are very strongly and strongly alkaline in nature whereas nearly 14% of TGA is affected by strong salinity and 5.4 % is moderately saline/moderately sodic. Saline groundwater is mainly responsible for development of salinity/sodicity by increasing salt concentration within the root zone through capillary rise during dry climate. These areas need addition of amendments like FYM and green manures to improve physical condition of soils. Soils of nearly 22 % of TGA are suffering from imperfect to poor drainage conditions. About 10.2 % area is affected by seasonal water logging due to presence of low-lying lands and some areas are also affected by fluctuating water table or persistence of high water table.

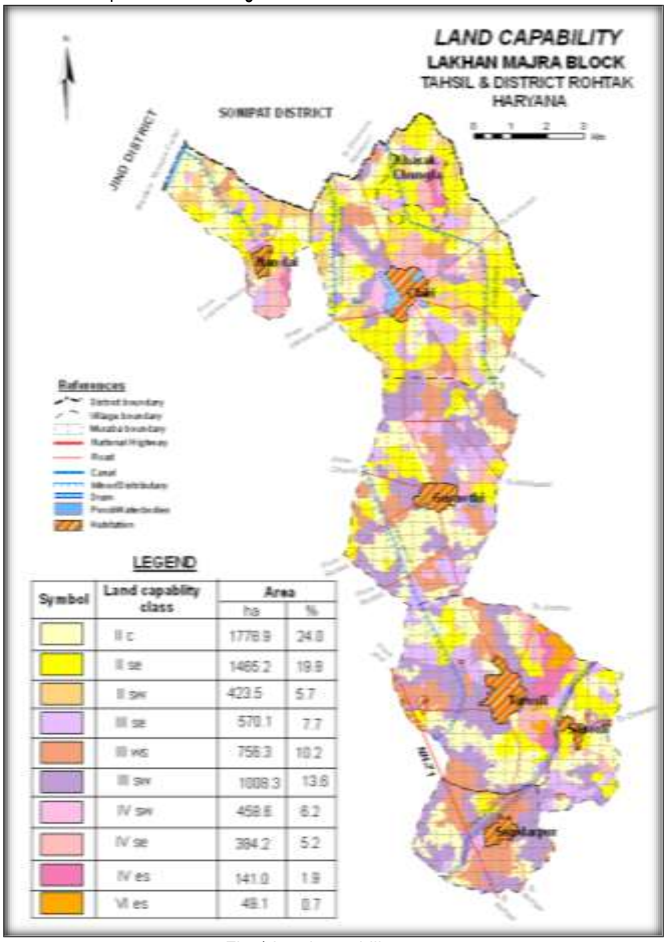


Fig-4 Land capability map

Land capability classification

The soil resource data have been interpreted for land capability classes. The land capability classification is an interpretative grouping of different soils mainly on the basis of inherent soil characteristics, external land features and environment factors. According to USDA, [17, 18] land capability classification (LCC) land is divided into eight classes from I to VIII and the classes may further be divided into subclasses depending on the number and severity of limitations. These limitations include erosion (e), wetness (w), soil root zone (s) and climate (c).The land capability grouping, their description and extent of occurrence are presented in [Table-2] and [Fig-4]. Nearly 50 % lands are grouped into class II, 32 % lands into class III, 13 % lands into class IV and 1 % into class VI. Soil salinity/sodicity, drainage and erosion are the major problems of the soil. The land capability classification serves as an important tool in land-use planning to show the relative suitability for soils for cultivation of crops, horticulture, pastures, forestry in addition to focusing the problems which need preventive measures [21-23].

Land Suitability

Land suitability analysis revealed that soils of old alluvial plains (30% area) are best suitable for agri-horti/floriculture with crops like wheat, potato, oilseeds, pulses [22, 23]. About 13 % lands (saline-sodic soils) suited for agri-pasture, paddy may be rotated with salt tolerant crops like barley, oat, mustard and forage crops. Nearly, 6 % area is marginally suitable lands (strongly saline) are best suited for silvi-pasture and salt tolerant tree species [21]. The salt affected wastelands may be the best option for non-agricultural uses and 10 % area under low-lying lands and in the vicinity of canals is suitable for Agri-floriculture. Rice-based cropping system is encouraged in these areas with oilseed, vegetable and floriculture in *rabi* seasons on residual moisture. Undulating sand dune areas (3%) may be stabilized by putting under silvi-pasture/horti-pasture. The reclaimed sand dune (5%) areas may be preferred to agro-forestry. Crops like *Kharif* pulses, oilseeds, vegetables and fodder crops can be grown. The viable and sustainable land use options were demarcated in [Fig-5].

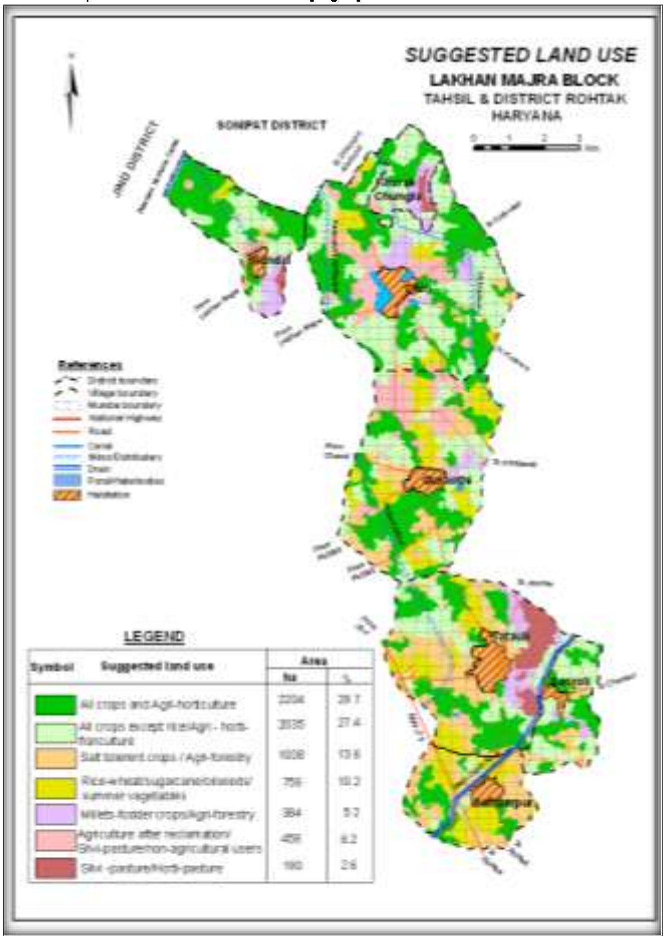


Fig-5 Suggested land use map

Table-2 Land capability classification, area and extent

Land capability sub class	Description	Soil Units	Area ha (%)
IIc	Very good cultivable lands. All climatically adapted crops can be grown under irrigation	9, 10	1779(24.0)
IIse	Good cultivable lands include coarse loamy soils with slight erosion and low moisture and nutrient retentivity	7, 8	1465(19.8)
IIsw	Good cultivable lands include fine loamy soils with moderate problem of drainage and salinity	11	424(5.7)
IIIse	Moderately good cultivable lands include coarse loamy soils with slight erosion, presence of calcic layer, low moisture and nutrients retentivity	5, 6	570(7.7)
IIIws	Moderately good cultivable lands include fine loamy soils but crop choice is restricted due to waterlogging and stagnation of water in rainy season and slight problem of salinity/sodicity	17, 18	756(10.2)
IIIsw	Moderately good cultivable lands with fine loamy soils, imperfect drainage and moderate salinity/sodicity. Need drainage and gypsum application	12, 13, 14	1008(13.6)
IVsw	Fairly good lands with fine loamy soils. Soils have severe problem of drainage, strong salinity and need reclamation measures for cultivation of crops	15, 16	459(6.2)
IVse	Fairly good cultivable lands include sandy soils with problem of high permeability, very low AWC, low fertility and slight to moderate erosion	3, 4	384(5.2)
IVes	Fairly good lands with sandy soils having problem of moderate erosion, and droughtiness. Marginally suitable for crop cultivation and can be done only after leveling. Suitable for horti–pasture /agro- forestry	2	141(1.9)
VIes	Land unsuitable for arable farming including sandy soils with problem of severe erosion. Suitable for social forestry/ pasture /grazing	1	49(0.7)

Table-3 Physico-chemical properties of soils

Layers	Particle size distribution (%)			Textu-ralclass	Calcareousness	Organic Carbon (%)	pH (1:2.5 H_2O)	EC* (dSm^{-1})	CEC* $Cmol(p+)kg^{-1}$	ESP* (%)	BS *(%)
	Sand (0.05-2.0mm)	Silt (0.02-0.05mm)	Clay (<0.02mm)								
Soils on sand dunes											
(Tatauli - I –sandy, *Typic Ustipsamments*)											
Surface	89.0	5.5	5.5	s	-	0.08	7.5	0.32	4.0	2	85
Sub-surface	92.80	4.43	2.8	s	-	0.04	7.3	0.24	1.7	4	86
Soils on reclaimed sand dunes											
(NandalSeries -*sandy, Typic Ustipsamments)*											
Surface	84.6	10.5	5.0	ls	-	0.11	7.3	1.10	3.2	4	92
Sub-surface	84.0	8.8	7.3	ls	-	0.11	7.6	0.74	3.8	3	90
Soils on old alluvial upland plain											
(Sasroli- I series - Coarse-loamy, Typic Haplustepts)											
Surface	68.1	16.9	15.0	sl	4.7	0.38	8.5	0.99	7.5	12	91
Sub-surface	65.4	18.4	15.2	sl	5.6	0.11	8.5	1.04	8.8	10	92
Soils on nearly level old alluvial plain											
(Tatauli – II series –*Fine-loamy, Typic Haplustepts)*											
Surface	58.5	29.1	12.5	sl	3.2	0.38	8.0	1.44	6.7	6	88
Sub-surface	44.0	39.6	16.4	l	7.4	0.18	8.6	0.97	11.6	11	87
(Sasroli – II series –*Fine-loamy, Typic Haplustalfs)*											
Surface	55.5	25.8	18.7	Sl	5.5	0.49	8.3	0.94	10.5	8	85
Sub-surface	31.3	37.5	31.2	cl	4.6	0.15	8.1	0.55	17.8	12	85
Soils on old alluvial plain with high water table (salt affected soils)											
Tatauli – III series –*Fine-loamy, NatricHaplustepts*											
Surface	54.55	31.70	13.75	Sl	1.38	0.62	7.7	2.15	8.3	5	87
Sub-surface	35.56	34.06	30.38	cl	10.71	0.23	9.1	2.28	12.7	23	93
Chiri – II - *TypicHalaquepts*											
Surface	55.8	29.2	15.0	sl	7.38	0.23	8.2	4.9	8.3	9	91
Sub-surface	40. 9	40.1	19.0	l/sl	16.15	0.11	8.6	3.9	9.0	14	92
Soils on concave relief (low-lying lands)											
Sunderpurseries –*Fine-loamy, Aquic Haplustepts*											
Surface	43.60	35.90	20.50	l	5.50	0.41	8.8	1.12	13.7	9	85
Sub-surface	32.16	33.04	34.8	cl	6.20	0.18	8.9	1.46	17.9	18	92

Where, Textural class: s-sand, ls- loamy sand, sl – sandy loam, cl- clay loam, l- loam.

*eEC- Electrical conductivity, CEC – Cation exchange capacity, ESP – Exchangeable sodium Percentage, BS- Base saturation

Land resources such as climate, present land use, soils and physiography etc. through remote sensing and GIS in combination with cadastral maps and Google Earth data helped to make an inventory of soil resources and assess their potentials for land use. The database thus generated for each village can be stored, processed and integrated in GIS environment for generation of interpretative information. It will be helpful for providing the exact nature and severity of water logging/salinaization in the irrigated areas, and also provide the required site-specific database for farm level planning to manage natural resources [3, 23]. The basic information generated in this study can effectively be used as input for management and planning of natural resources at micro level planning and land use decision options to the farmers and its governing institutions.

Application of research: Land resources characterization and its assessment provided their detailed site-specific problems & potentials. The detailed characterization of soils and mapping is helpful for providing the exact nature and severity of problems like erosion, salinization and water logging for its management. It also provides the site-specific database for farm planning to manage natural resources. The basic information generated in this study can effectively be used as input for management and planning of natural resources at micro level planning and land use decision options to the farmers and its governing institutions.

Research Category: Land resource characterization, Soil resource mapping

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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