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DETERMINATION OF LAND SUITABILITY USING MULTI CRITERIA APPROACH: A CASE STUDY OF BHILWARA DISTRICT RAJASTHAN

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Abstract: *Land is one of the most important natural resource which facilitates the physical basis of various kinds of activities and natural process like habitations, agriculture, recreation etc. Every type of land and every piece are suitable for some kind of utilization depending upon their capabilities, potential and suitability for various uses. Methods and types of decisions for utilization must be on its suitability for different purposes. Now a days land resources are being used without assessing/ determining capabilities of land and optimum method of utilization like marginal land & unproductive land are being utilized for cropping, good fertile agricultural lands are being engulfed by settlements, industries, construction of roads etc. As a result large areas are losing their productivity and are converted into degraded wasteland. The purpose of the study is to determine the land suitability analysis through Remote Sensing & Geographical Information Systems (GIS) technology (By assessing parameters like slope, geomorphology and land-use/land-cover) in which decision rules are applied on the multi-criteria basis. Decision rules are used for the categorization of lands for various purposes like intensive agriculture, rainfed agriculture recreation, horticulture, pasture development, forest plantation, Settlement etc. The present research is an attempt to analyse suitability of land resources of Bhilwara district of Rajasthan state and suggests optimum utilization for various purposes through integration of various thematic layers, present utilization carrying capacity of land in framework of multi-criteria decision rule and also suggested optimum purposes of utilization for each piece of land in Bhilwara district.*

Key words: Agriculture, Land Suitability, Remote Sensing & GIS, Multi-Criteria Decision Rule

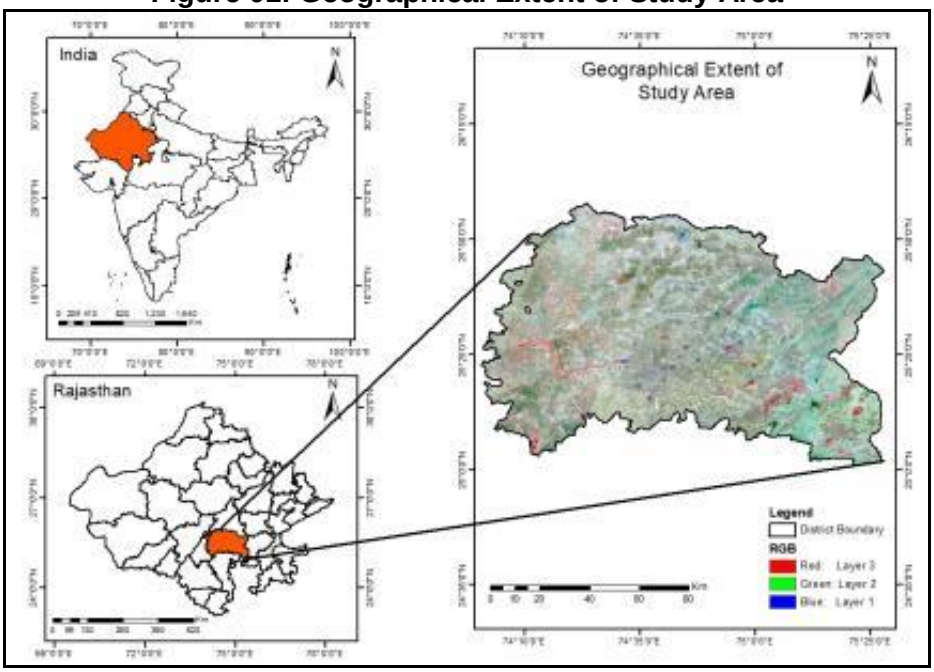
Introduction

Land is considered to be the most important component of earth system and evaluation of land plays major role for agriculture and other human activities of production and its classification acts as an important tool for its better use. Proper use of land depends on the suitability or utilization of land. Land suitability analysis is needed for various purposes. It reduces the human influence on natural resources. Land resource inventories are used to determine land suitability which becomes a standard part of planning process at different levels. In India agriculture is one of the major economic activities in which two-third of Indian's population is engaged. Due to over exploitation and mismanagement land is being degraded specifically when land is utilized for the purpose it is not suitable. This problem of land degradation can be managed through land suitability analysis and land should be utilized for the purpose, it is utilized. All the land is classified as per their suitability depending upon various parameters such as physical and chemical properties of soil, slope, present use etc. Our study focused on proper utilization and management of land at field level which is very much essential for farmers. Multi-criteria approaches have been applied for the land suitability analysis of Bhilwara district. Remote sensing and GIS technology is being used to monitor agriculture and crop growth status in term of both space and time (Jeyaseelan 2003; Seelan et al. 2003). It provides facility to the user for detecting the changes on the Earth's surface at different scales. Whereas specific characteristics of remotely sensed data like; large area coverage, good spatial resolution, accessibility to remote areas and faster interpretation with higher degree of objectivity and reproducibility made remote sensing becoming progressively important for mapping land use and land cover (Ibrahim M.S, et.al. 2013). The use of land is not only determined by the user but also by its suitability.

Study Area

Bhilwara district is located in south eastern part of Rajasthan state. The coordinates of this district are 25º 00' 38.87 to 25º 57' 53.70 North latitude and 74º 00' 31.67 to 75º 27' 46.25 east longitude. The total geographical area of the district is 10,455 sq km. According to the 2011 census Bhilwara district has a population of 2,408,523 of which male and female were 1,220,736 and 1,187,787 respectively. It is bounded in the north by Ajmer district in the north-west, west and south-west by Rajsamand district; in the south and south-east by Chittaurgarh district and in the east and north-east by Bundi and Tonk district. The mostly area of district is covered by gently slope except in western & northwestern part where slope is high. Fig.1. shows the geographical extent of study area.

Figure 01: Geographical Extent of Study Area



Many seasonal rivers such as Kothari, Banas, Menali, Bedach, Khari and Mansi meander their way through Bhilwara district of Rajasthan. The district falls in the Banas (9157.2 sq km), Chambal (1164.9 sq.km) & Luni basins (133.0 sq.km) (CGWB report- 2013). Banas is the major river of the district which flows towards east direction and its tributaries are Bedach, Kothari & Khari. The highest amount of water is received by the rainfall which is the most important factor for agriculture, industry and domestic purpose. Figure 2 shows that study area has good network of drainage, road and railway.

Figure 02: Base Map of Bhilwara district

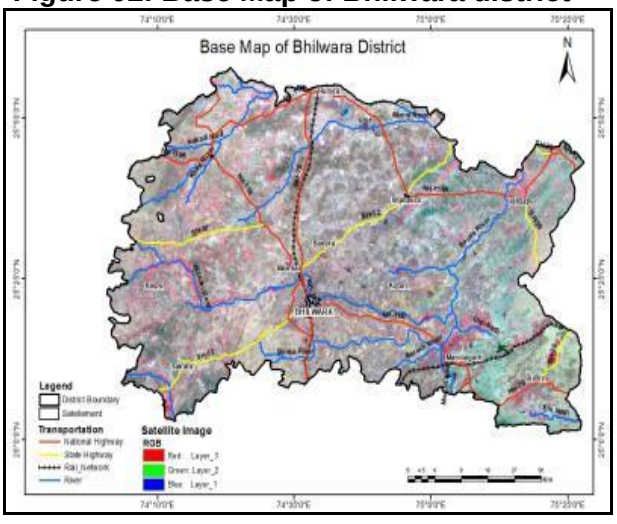
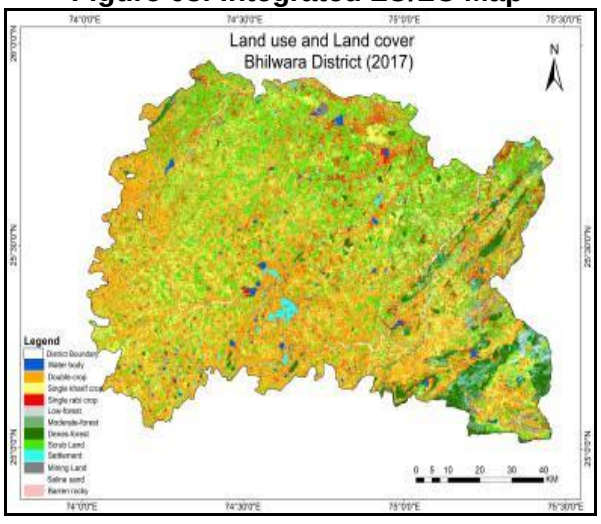


Figure 03: Integrated LU/LC Map



Data Used

In the research, Landsat 8 satellite data for the period of 2017 for both Rabi season (23rd -30th November, 2017) and kharif season (20th-27th September, 2017) data was downloaded from https://www.usgs.gov./. Abstraction of slope has been done from DEM (30m). Administrative map were collected from Survey of India. Geo-morphology map is collected from Geological Survey of India.

Remote Sensing & GIS Analysis

Landsat-8 satellite image of the year 2017 is used to calculate the land-use/land-cover of entire district. There are total 11 Lulc classes categorizes in which crops are categorized in three classes i.e., double crop, Single rabi crop & single kharif crop and forest is also classified in three classes i.e., dense forest, degraded forest & open forest and remaining classes waterbody, built-up, scrubland, saline, barren rocky and mining/ dump areas which are done through the unsupervised classification in ERDAS 2014. LULC map is presented in Figure 3. By applying unsupervised classification on both Rabi & Kharif satellite data and further classified this information classify into two classes, crop & non-crop for both the seasons. Further these two classes were converted from raster to vector data and then intersected both vector layers using ArcGIS 10.4. Through which 3 classes of crops are derived i.e, double crop, single Rabi & single Kharif crop. Thereafter we observed four combinations which are given below:

Kharif crop x Rabi crop = Double crop.

Kharif crop x Rabi-non-crop = Single Kharif.

Rabi crop x Kharif-non-crop = Single Rabi. Kharif-non-crop x Rabi-non-crop = Non-crop.

By applying Normalized Difference Vegetation Index (NDVI) forest are classified into three categories i.e. dense forest, degraded forest & open forest.

Table 01: Area of Land use and Land Cover

#	Landuse/Landcover Classes	Area in Percent
1	Water Body	01.15
2	Scrub Land	28.33
3	Settlements	1.23
4	Mining	0.66
5	Saline Land	2.71
6	Barren rocky	0.62
7	Dense Forest	3.24
8	Degraded Forest	1.16
9	Open Forest	0.88
10	Double-crop	26.48
11	Single kharif crop	23.30
12	Single rabi crop	10.25

Thematic Mapping and Database Generation

Various thematic maps such as lulc Geomorphology map & slope map were also prepared in ArcGIS 10.4. Digitizing is the process of converting features on a paper map into digital format. Slope map is generated using SRTM 90m DEM data. Slope was further classified in 3 classes i.e. Gentle Slope, Moderate Slope & Steep Slope as presented in table 2.

Table 02: Percentage of Area under Each Slope Category

#	Slope Types	Slope in Degree	Area in Percent
1	Gentle Slope	0-3	92.11
2	Moderate Slope	3-5	4.5
3	Steep Slope	5 +	3.39

The earth's surface can be classfied into different geromorphic units/landforms based on their physiographic expression, origin, material contant and climatic condition, etc. Geo-morphology map is collected from Geological survey of India (GSI) and digitized in ArcGIS 10.4. Major geomorphic units of Bhilwara district are flood plain along rivers'-Khari, Masi, Banas, and Kothari, Valley Fill occurs in Small scattered patches in east & west, Pediment

Scattered in entire district, mainly in east & west parts. Denudation hills plateau and pediments are found across the entire district (Fig.5).

Figure 04: Slope Map of Bhilwara District.

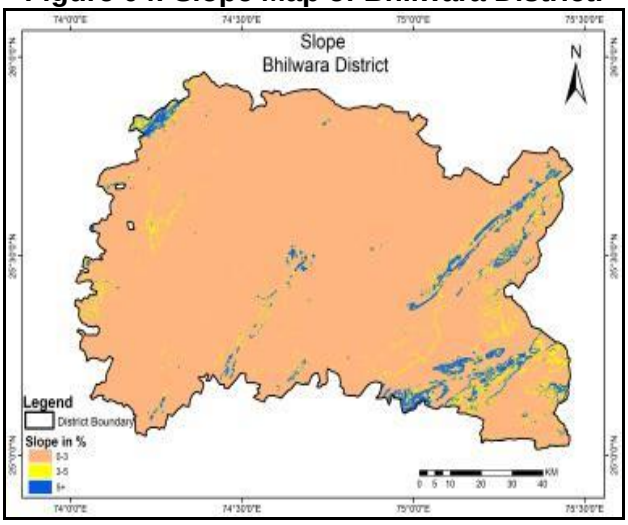
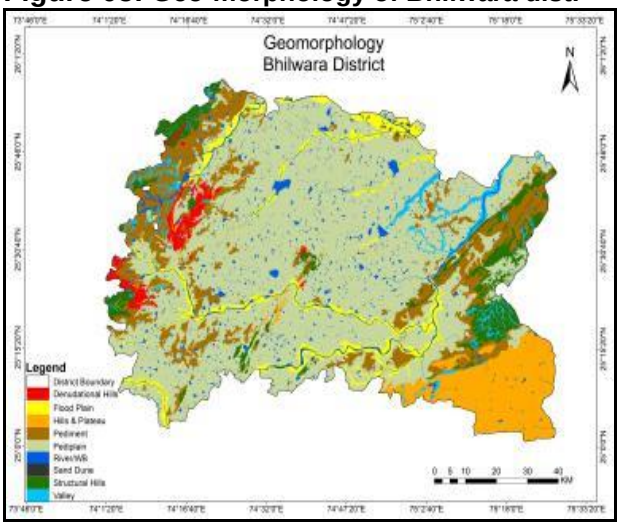


Figure 05: Geo-morphology of Bhilwara dist.



Decision Making for Land Suitability

Overlay analysis is used to identify the suitable area for the intensive agriculture, rainfed agriculture, pasture development, Horticulture development, forest plantation and Settlement. Land use, geo-morphology & slope layers are integrated and a decision rule for land suitability is prepared for various land utilization by taken multi-criteria analysis, presented in table 3. This study facilitates the farmer's decision makers to identify the suitable area for various purposes.

Result Discussion

Land suitability classification is the first and most essential task to be taken for the sustainable use of land. In the study, multi-criteria decision rule is developed on basis of three layers i.e., lulc, geo-morphology, slope and their different classes (table 3) by applying intersect method using Spatial Analyst tools in ArcGIS 10.4. Multi-criteria decision rules are applied for identification of land suitability for the various purposes which are intensive agriculture, rainfed agriculture, recreation, horticulture, pasture development, forest plantation.

Table 03: Multi-Criteria Decision Rules for Suitability Analysis

Classes	Lulc	Geomorphology	Slope
Intensive Agriculture	Double & Single rabi crop	Padiplain, Flood Plain & Valley Fill	0-3 degree
Rainfed Agriculture	Single Rabi, Single Kharif & Scrubland	Pediment, Flood Plain & Padiplain	0-3 & 3-5 degree
Horticulture Development	Single Kharif, Scrubland & saline land	Flood Plain & Pediment	0-3 & 3-5 degree
Pasture Development	Scrubland & saline land	Denudational Hills, Pediment & Sandunes	5+ degree
Settlement	Scrub land& settlement with 5 km buffer	any Geo-Morphology	0-3 & 3-5 degree
Forest Plantation	Degraded forest	any Geo-Morphology	any slope
Recreation	Water bodies & Barren rocky	Structural Hills, Denotational Hills & Waterbodies	5+ degree

Decision rule have been developed for different land utilization which are as follows:

a) Decision Rule for Intensive Agriculture.
b) Decision Rule for Horticulture Development.
c) Decision Rule for Rainfed Agriculture.
d) Decision Rule for forest-plantation.
e) Decision Rule for Pasture development.
f) Decision Rule for settlement.

For preparing these rules we considered different lulc classes which were intersected with layer of geomorphology and layer of slope. The Land suitability map for different parameters discussed above is shown in Figure 6.

Area found suitable for intensive agriculture is already being used almost optimally except few areas under single Rabi crop can be converted into double cropping with suitable irrigation. This area is mainly confined to central and south-western part of district especially in Sahara, Suwana and total portably of Bhilwara district.

Figure 06: Intensive Agriculture

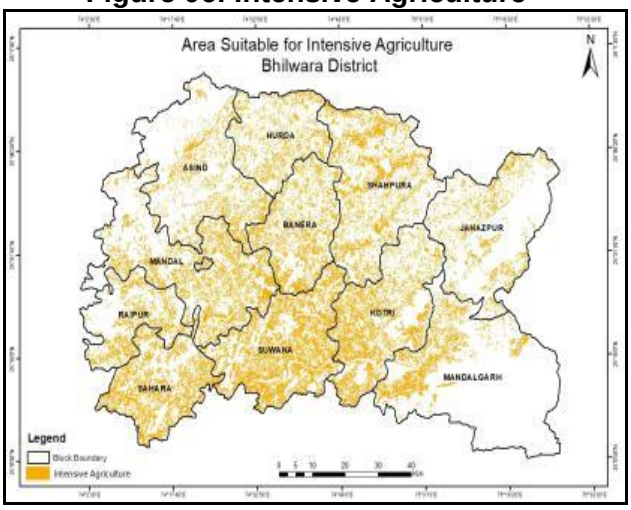
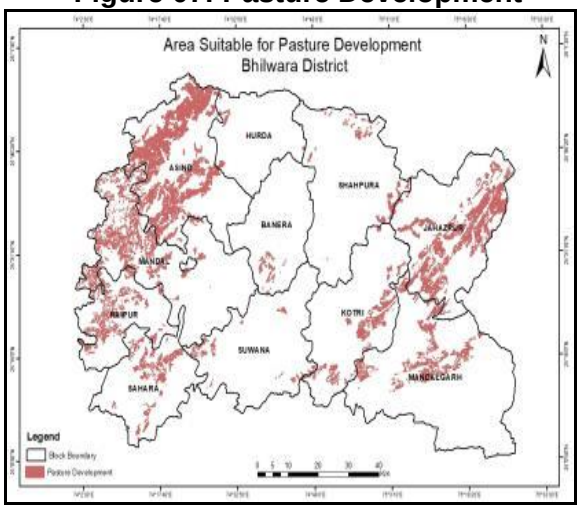


Figure 07: Pasture Development



Decision rule for Intensive Agriculture = Double crop & Single Rabi crop ∩ Pedi plain, Flood Plain & Valley fill ∩ Plain area (slope 0-3 degree)

Pasture Development = Scrubland & saline land. ∩ Denudational hills, Pediment & sandunes ∩ Steep slope (above 5 degree).

Low altitude of denudation hills and moderate to steep slope with small soil cover are found for suitable for pasture development in north-western & north-eastern part of Bhilwara district. 514.69 sq. km. (4.92 percent) of total area Bhilwara district is suitable for pasture development.

More than 50 percent of area suitability for rainfed agriculture which is kharif crop specially concentration in northern blocks like Banera, Hurda, Shahpura and Asind block. 5273.78 sq. km. (50.44 percent) area of total area of Bhilwara district is suitable for rainfed agriculture.

Figure 08: Rainfed Agriculture

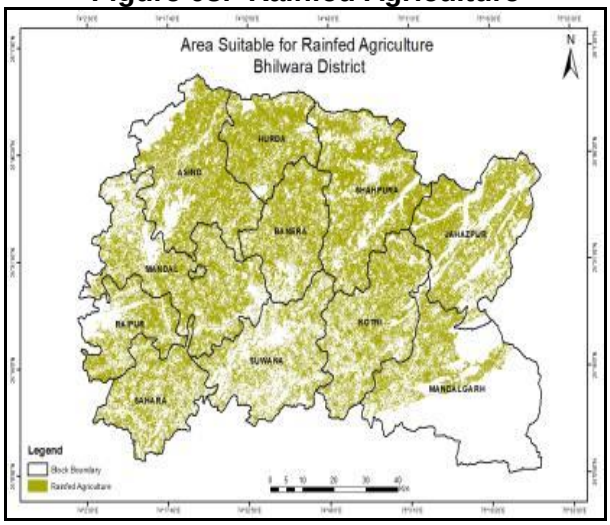
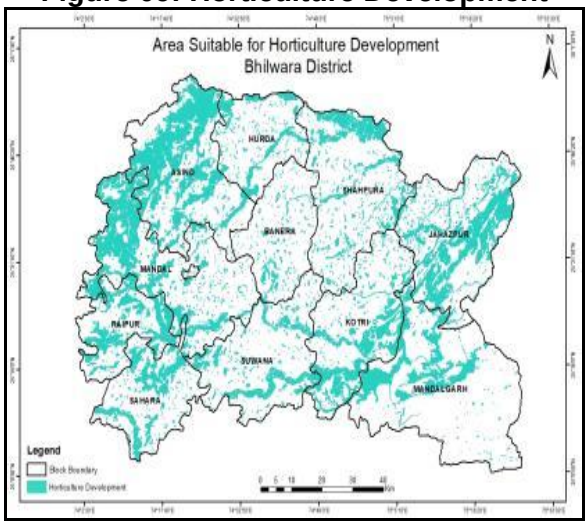


Figure 09: Horticulture Development



Rainfed Agriculture = Single kharif, single Rabi crop & scrubland ∩ Pedi plain, Flood Plain & Pediment ∩ Plain area & moderate slope (0-3 & 3-5 degree).

Horticulture Development = Single kharif crop, scrubland & saline land. ∩ Pediment and flood plain ∩ Plain & moderate slope (0-3 & 3-5 degree).

Area of foothill having slight and moderate slope up to 5 degree and having soil cover is found suitable for horticulture plantation. Such area is found along the hills in Asind, Jahazpur, Mandal, Raipur and portable blocks of Bhilwara district. 1286.23 sq. km. (12.30 percent) of total area Bhilwara district is suitable for horticulture development.

Figure 10: Forest Plantation

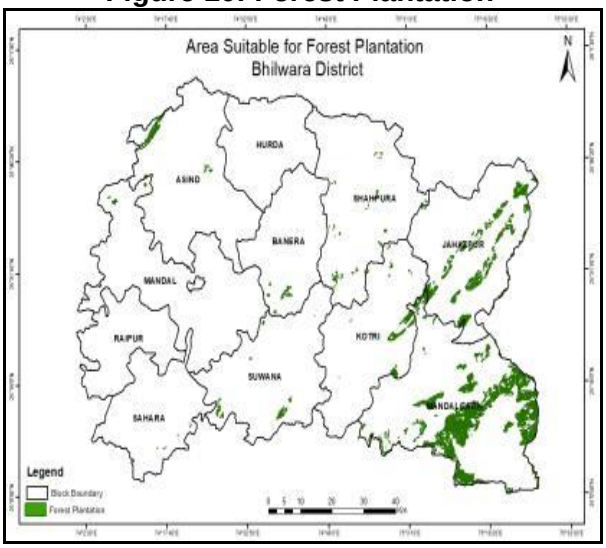
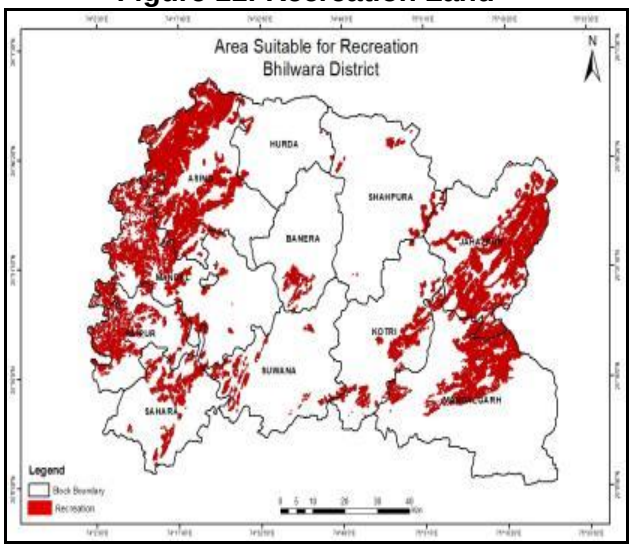


Figure 11: Recreation Land



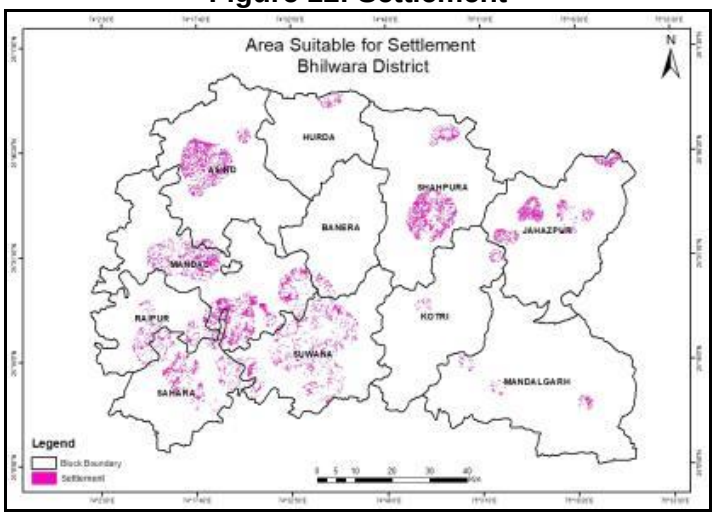
Forest Plantation = Degraded forest ∩ Any Geo-morphology ∩ Any slope.

Recreation = Water bodies & barren rocky ∩ denudation hills, structural hills & water bodies ∩ Steep slope (above 5 degree).

All degraded forest areas a must be covered for forest plantation specially Mandalgarh & Jahazpur blocks. 119.42 sq. km. (1.14 percent) of total area Bhilwara district is suitable for pasture development. 716.81 sq. km. (6.86 percent) area of total area of Bhilwara district is suitable for rainfed agriculture.

Area surrounding to the settlement with little slope and under any land-use categories are suitable for expansion of habitation. 402.88 sq. km. (3.85 percent) of total area Bhilwara district is suitable for pasture development.

Figure 12: Settlement



Settlement = Scrub land & settlement 5km buffer ∩ Any Geo-morphology ∩ Plain & moderate slope (0-3 & 3-5 degree).

Table 03: Area Suitable for Optimum Utilization of Land

Block Name	Area Suitable for Intensive Agriculture (sq. km.)	Total Geographical Area Of Block in (sq. km.)	Total Area of each Block in % for Intensive Agriculture	Total Area of each block in % for Rainfed Agriculture	Total Area of each Block in % for Horticulture	Total area of each Block in % for Pasture Land	Total area of each Block in % for Forest-Plantation	Total Area of each Block in % for Recreation	Total Area of each Block in % for Settlement
Asind	184.03	1124.00	16.37	58	25.29	15.82	0.25	19	5.23
Banera	205.52	669.00	30.72	64	2.73	0.86	0.12	2	0.64
Hurda	140.80	609.00	23.12	72	9.22	1.12	1.86	1	0.78
Jahazpur	141.92	1039.00	13.66	53	17.59	10.02	0.37	16	4.38
Kotri	315.39	927.00	34.02	58	12.13	3.53	0.04	4	0.54
Mandal	320.40	1214.00	26.39	50	14.07	4.90	5.78	6	8.28
Mandalgarh	175.35	1545.60	11.34	20	8.72	2.83	0.01	7	0.52
Raipur	126.76	520.00	24.38	49	18.17	6.02	0.14	8	3.86
Sahara	258.84	636.00	40.70	54	11.96	4.25	not available	5	6.52
Shahpura	305.59	1129.00	27.07	68	8.65	1.47	not available	1	5.07
Suwana	419.75	932.46	45.02	42	6.27	1.01	not available	2	6.14

Conclusion

Decision rule prepared for land suitability analysis for various purposes are working very well and the system is able to identify appropriate areas suitable for intensive agriculture, rainfed agriculture, horticulture development, pasture development, recreation, forest plantation etc. The result shows that every piece of land can be utilized optimally with science and technology interventions through well designed decision rules.

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Links:

1. http://bhuvan.nrsc.gov.in/bhuvan_links.php
2. https://www.rajras.in/index.php/soils-of-rajasthan-2/
3. http://plan.rajasthan.gov.in/statistics
4. https://www.nrsc.gov.in/Careers
5. http://www.censusindia.gov.in/2011census/dchb/0824_PART_B_DCHBpercent20_BHILWARA.pdf