Annals of Plant and Soil Research 23(1): 23-29(2021)
https://doi.org/10.47815/apsr.2021.10024

Application of geo-spatial technologies in soil suitability assessment for village level crop planning in Chittaurgarh, Rajasthan

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Received: August, 2020; Revised accepted: October, 2020

ABSTRACT

The agro-eco-sub region (AESR) 4.2 encompasses Aravalli foot hills, central Rajasthan plains and adjoining areas. Visual interpretation of geo-coded satellite data (IRS-P6, LISS IV MX) on the same scale was done before starting the field work. Based on the interpretative units a high intensity detailed soil survey was carried out in cluster of ten villages of Bhadesar tehsil of Chittaurgarh district on cadastral map (1:4000 scale) and the soils were characterized with respect to landforms. In all, 14 soil series were established and assessed for soil site suitability for maize, wheat, mustard and soybean. Daulatpura-c series soils are suitable for maize, mustard, soybean, and Daulatpura-d soils for soybean and moderately suitable for other crops. Soils of Bagund and Narbadiya-a series are moderately suitable for maize and marginally suitable for other crops. The soils of Bhadsoda-b series are marginally suitable only for mustard but moderately suitable for all other crops. Soils of Parliya series are moderately suitable only for mustard crop and marginally suitable for remaining crops. The soils of Guda series are marginally suitable for maize, wheat, mustard but not suitable for soybean. The soils of Nardhari-a and Nardhari-b are moderately suitable, Daulatpura-b, Bhadsoda-a and Narbadiya-b are marginally suitable whereas soils of Madanpura and Daulatpura are not suitable for all the crops due to limitations of shallow soil depth.

***Key words*:** Soil suitability assessment, crop planning, hot-moist semi-arid region, Rajasthan

INTRODUCTION

Land use planning is a systematic assessment of physical, social and economic factors to encourage and support land user in selecting options, which increase productivity and sustainability of lands. Soil site suitability provides information on the choice of crops to be grown on best soil unit for maximizing crop production per unit of land, labour and inputs. Further, detailed soil survey provides the information necessary to identify homogeneous management units in the field to develop different cropping models according to their soil information and agronomic practices. Management of soil resources on scientific basis is very essential to maintain present level of soil production and soil degradation. In the recent years major emphasis has been given on soil-site characterization and developing rational and scientific criteria for land evaluation and interpretation of soils for diversified land uses. Therefore, it is very essential to know the spatial extent, physico-chemical characteristics, taxonomic distribution, limitations and potentials of soils for developing proper land use plan of the area. Remote sensing and GIS technology have emerged as powerful tool for studying soil resources in spatial domain in time and cost-effective manner. Bhadesar tehsil is the maize-wheat growing area of Chittaurgarh district and contributing major share of maize and wheat production of the Rajasthan state. Assessment of land suitability for crops can enhance the agricultural productivity of the area manifold. This may be achieved by developing cluster wise crop plan for sustainable land use planning of the area by using modern technologies like remote sensing and GIS. Soil resource information and land use planning options for village level crop planning are very scanty. Therefore, systematic and site-specific land resource information must be generated to develop land use plan for cluster of ten village.

MATERIALS AND METHODS

Study area

The study was conducted in clusters of ten villages in Bhadesar tehsil of Chittaurgarh district Rajasthan. The area lies between 24°41′14.5″ to 24°45′11.6″ E latitudes and 74°20′16.4″ to 74°26′34.4″ N longitudes and occupying about 5160 ha. The elevation of the study area is 540-542 m above mean sea level

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(MSL). The climateof the area is semi-arid moist and monsoonic type with mean annual rainfall of 886 mm and about 95 % of the annual rainfall received during June to September. Mean annual soil temperature is 30.1ºC; the mean annual summer and mean winter soil temperatures are 36.2ºC and 21.2ºC, respectively. The length of growing period (LGP) of the area varies from 105-130 days. Soil moisture and soil temperature regimes of the study area are ustic and hyperthermic, respectively.

Soil mapping

The detailed soil survey of the villages was carried out by using cadastral maps.Since the scale of the maps available is uniform for all the villages (1:4000 scale) and reduced to a uniform scale of 1:12,500 with precision geo-coded satellite data (IRS-P6, LISS IV MX) on same scale before starting the field work.Apart from the cadastral maps of 10 villages and imageries, survey of India (SOI) toposheets at 1:50,000 scale have been used as a base for initial traversing, identification of geology, landforms, drainage features, present land use and for the selection of transects at tehsil level for preparation of preliminary legend to establish good soil-physiographic relationship in the area. The geo-coded satellite data were visually interpreted based on image elements like tone, texture, pattern, and shape of the features. The field investigation was carried out in the whole area by intensive traversing of each physiographic unit like ridge, uplands, valleys and plain etc. Based on the variability observed on the surface, transects were selected across the slope, covering all the physiographic units to identify sites for soil profile examination. The soil and site characteristics have been recorded for all the profile sites as per the guidelines given in USDA Soil Survey Manual (Soil Survey Division Staff 2000). At each site, latitude, longitude and altitude were also recorded with the help of hand held GPS. Based on the soil-site characteristics recorded during soil survey, the soils were grouped into different soil series through soil correlation. After grouping the soils into different soil series, the phases of soil series were identified by intensive field traversing, checking thoroughly for variability in surface texture and the boundaries of soil mapping units were delineated on the base maps (IARI 1971). Besides this, 190 surface soil samples were also collected from different mapping units and analyzed for physical and chemical properties in laboratory as per standard procedures (Jackson 1973). The soils were classified into the subgroups of Inceptisols, Vertisols and Entisols orders (Soil Survey Staff 2014).Laboratory data were processed in GIS environment using Arc GIS 10.3 and thematic maps were generated for soil site suitability of each crop.

RESULTS AND DISCUSSION

The slope varied from 1-3% in gently sloping upland and nearly level to gently sloping plain whereas it was 8-15% in gently sloping to undulating hillocks landform (Table 1). Most of the soils having very slight to moderate erosion but very severe erosion was observed in the soils of gently sloping to undulating hillocks landform. Most of the soils were moderately well drained.The soils of series varied from very shallow to deep having sandy cay loam to clay loam texture. The pH of soil varied from 7.5 to 8.2 whereas electrical conductivity ranged from 0.08 to 0.23 dS/m. The organic carbon content of the soils varied from 0.39 to 0.94 per cent and decreased with depth. The cation exchange capacity (CEC) of the soils ranged from 15.2 to 34.30 cmol(p+) kg^{-1} soil.

Land capability classification(LCC)

The land capability classes (LCC) and their extent in the watershed are presented in Table 2. Land capability class II occupied highest area (41%) followed by class III (39%), class V (14%) and least area by class IV (3%). Land capability class II have major problem of fine soil texture which mostly occurs in Bhadsoda, Narbadiya, Parliya, Sohankhera and Bagund villages covering about 75% area of this class. Land capability class III having major problems of erosion, gravelliness, salinity-sodicity, fine texture, and shallow depth occurring in Parliya, Bhadsoda, and Narbadiya villages and covering about 75-85% area of this class. Land capability class V having problems regarding erosion, gravelliness and shallow depth occurring in Bagund, Parliya and Narbadiya villages and covering about 73% area of this class. Land capability class IV having major constraint of salinity and sodicity in Bhadsoda, Bagund,

Table1: Soil-site characteristics of cluster of ten villages in Bhadesar tehsil for land evaluation

Soil series	Climatic characteristics (c)		Site characteristics			Physico-chemical characteristics (f)					
	Rainfall (mm)	LGP (days)	Slope (%)	Erosion (e)	Drainage (w)	Depth (cm)	Texture	pH	EC (dS m^{-1})	OC (%)	CEC [cmol (p+) kg^{-1}]
Madanpura	885.6	105-130	8-15%	Very severe	Moderate	<25	scl	7.9	0.09	0.46	21.5
Daulatpura- a	885.6	105-130	8-15%	Very severe	Moderate	25-50	scl	8.0	0.16	0.54	19.0
Daulatpura- b	885.6	105-130	3-8%	Severe	Somewhat excessively drained	50-75	sl	7.8	0.16	0.55	15.2
Bhadsoda- a	885.6	105-130	3-8%	Severe	Well	25-50	cl	8.2	0.08	0.76	25.0
Bagund series	885.6	105-130	1-3%	Moderate	Well	25-50	l	7.5	0.23	0.84	21.5
Narbadiya-a	885.6	105-130	1-3%	Moderate	Well	25-50	cl	7.8	0.23	0.94	30.0
Bhadsoda- b	885.6	105-130	3-8%	Severe	Well	50-75	sl	7.7	0.23	0.41	18.7
Daulatura-c	885.6	105-130	1-3%	Very slight	Well	50-75	sl	7.7	0.16	0.72	33.2
Nardhari-a	885.6	105-130	1-3%	Very slight	Well	50-75	cl	8.0	0.20	0.76	34.3
Nardhari-b	885.6	105-130	1-3%	Moderate	Well	75-100	scl	8.2	0.19	0.84	22.4
Daulatura-d	885.6	105-130	1-3%	Very slight	Moderate	75-100	cl	8.2	0.21	0.97	27.1
Guda	885.6	105-130	1-3%	Very slight	Moderate	100-150	scl	9.1	0.87	0.39	21.4
Narbadiya-b	885.6	105-130	1-3%	Very slight	Moderate	100-150	l	8.7	0.82	0.53	18.5
Parliya	885.6	105-130	1-3%	Very slight	Moderate	100-150	cl	8.7	0.46	0.90	28.0

Parliya, Daulatpura, and Narbadiya villages and covering about 90% area of this class.The rating index between 2 and 3 was calculated in Bagund and Parliya villages indicating predominance ofland capability class III. Whereas, rating index between 3 and 3.3 in Bhadsoda, Daulatpura, Guda, Madanpura, Narbadiya, Nardhari, Sohankhera and Surajpura villages indicating predominance of land capability class II.

Table 2: Land capability and land irrigability classification of soils in cluster of tenvillages in Bhadesar tehsil

S.No.	Soil Series	Mapping Unit	LCC	LIC
1.	Madanpura	1.MdGdD3	Ves	4st
2.	Daulatpura-a	2.DpaGcC3	Ves	4st
		3.DpaGcD3	Ves	4st
3.	Daulatpura-b	4.DpbgcC3	IVes	4st
4	Bhadsoda-a	5.BsaGeC2	IVes	3st
5	Bagund	6. BggcB2	IIIes	3st
		7. BgGcB2	IIIes	3st
6	Narbadiya-a	8.NbageB2	IIIes	3st
7.	Bhadsoda-b	9. BsbcB2	IIIes	3st
		10. BsbgcC2	IIIes	3st
8.	Daulatpura-c	11.DpccB1	IIs	2s
		12.DpccB2	IIs	2s
		13.DpceB1	IIs	2s
		14.DpceC2	IIs	2s
9.	Nardhari-a	15.NdaeA1	IIs	2s
		16.NdaeB2	IIs	2s
		17.NdadB1	IIs	2s
10.	Nardhari-b	18.NdbdB1	IIs	2s
		19.NdbdC2	IIs	2s
		20.NdbeB2	IIs	2s
11.	Daulatpura-d	21.DpdeA1	IIs	2s
		22.DpdeB1	IIs	2s
		23.DpdeB2	IIs	2s
12.	Guda	24.GjdB1	IVs	4sd
13.	Narbadiya-b	25.NbbdB1	IIIs	3s
		26.NbbdB2	IIIs	3s
14.	Parliya	27.PrdB1	IIIs	3s
		28.PreA1	IIIs	3s
		29.PreB2	IIIs	3s

Land irrigability classification (LIC)

Land irritability classification is the grouping of mapping units into land irritability classes and subclasses based on the degree of limitation observed in the land resources of the area for sustained use under irrigation (IARI, 1971). The criteria used for irritability classification are effective soil depth, surface soil texture, permeability, coarse fragments, slope, erosion, drainage and so on. In this system, there are 6 classes, of which, first four classes are considered to be irrigable lands with slight, moderate, severe and very severe limitations respectively (Table 2). Class 5 lands are treated as presently not suitable and class 6 land is considered permanently not suitable for irrigation. Land irritability classes identified were divided into sub-classes depending on the nature of the limitations for irrigation namely soil (s), topography (t) and drainage (d). The land irrigability classes 2, 3 and 4 have been occurred in the cluster of villages. The land irrigability class 2 have highest area (41%) followed by class 3 (39%), and class 4 (16%). Land irrigability class 4 have major problems of slope, soil depth, coarse fragments and salinity-sodicity and occurs mostly in Parliya, Bagund, Bhadsoda, Narbadiya and Daulatpura villages covering about more than 75% area of this class. Whereas, land irrigability class 2 have major constraint of fine texture which was identified in Bhadsoda, Narbadiya, Parliya, Sohankhera and Bagund villages covering about 76 % area of this class. Land irrigability class 3 have major constraints pertaining to soil depth, slope and salinity-sodicity and occurs in Bhadsoda, Nardhari, Bagund, Madanpura and Sohankhera villages covering about 77% area of this class. Rating index between 2 and 3 in Bagund, Daulatpura, and Parliya villages indicating predominance of land irrigability class 3, whereas rating index between 3.1 and 3.6 in Bhadsoda, Guda, Madanpura, Narbadiya, Nardhari, Sohankhera and Surajpura villages indicating predominance of land irrigability class 2.

Soil suitability for major crops

Maize *(Zea mays* L.*)*

Soils of Daulatpura-c series rated as highly suitable which do not have any limitation regarding physical and chemical constraints (Table 1). Soils of Bagund, Narbadiya-a, Bhadsoda-b, Nardhari-a, Nardhari-b and Daulatpura-d rated as moderately suitable on account of shallow depth, low fertility and moderate slope (Table 3).

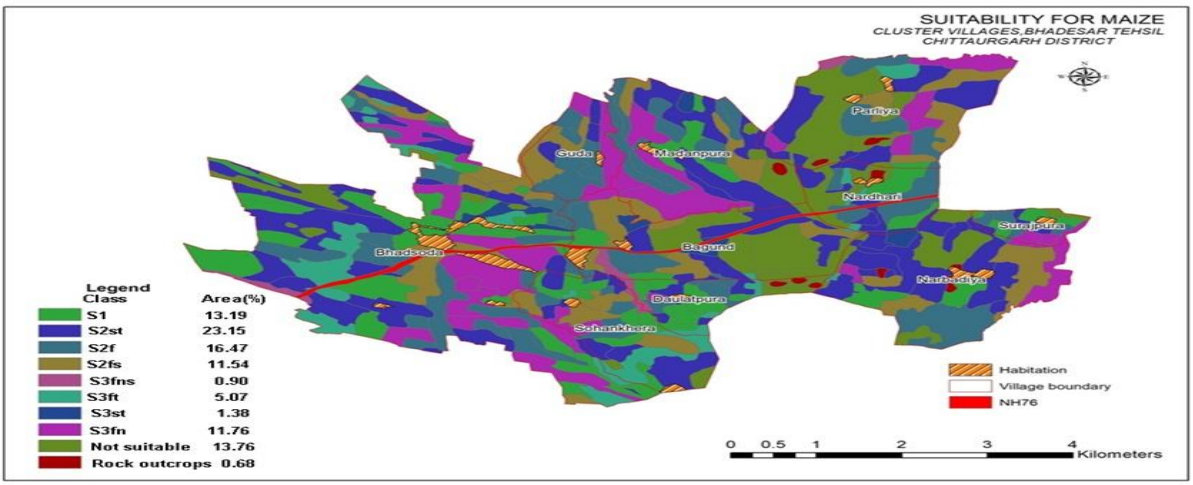

Fig.1 Soil suitability map for maize in cluster of Bhadesar tehsil

Soils of Daulatpura-b, and Bhadsoda-a, series are marginally suitable which have constraints regarding soil texture and low nutrient content. Gudha, Narbadiya-b andalkaline pH and slight salinity to moderateParliya series are also rated as marginally suitable due to strongly sodicity due to strongly sodicity problem besides this this these soils have moderate to high water holding capacity and slow permeability due to clay texture and low in nutrient status hence these soils are not suitablefor the cultivation of maize crop (Table 3). Madanpura and Daulatpura-a series rated as not suitable for maize cultivation due to severe

erosion, gravelliness and very shallow to shallow depth of soil. Hegde*et al.* (2019) also reported the similar results for soil-site suitability evaluation of maize crop. According to the assessment, 13% land is highly suitable, 51% land is moderately suitable, 19% land is marginally suitable and 14% land is unsuitable for maize cultivation in the cluster (Fig. 1).

Wheat (*Triticum vulgare*)

The computation of limitations as per Sys *et al.* (1993) indicated that Bhadsoda-b, daulatpura-c, Nardhari-a, Nardhari b, and Daulatpura-d are moderately suitable with medium nutrient status, generally moderate in depth and mainly clay loam in texture. Marginally suitable soils occur in Daulatpura-b, Bhadsoda-a, bagund, Narbadiya-a, Guda, Narbadiya-b and Parliya series (Table 3). Daulatpura-b and Bhadsoda-a series having limitations of severe erosion, shallow depth, moderate water holding capacity and nutrient retention are rated as marginally suitable. Soils of Madanpura and daulatpura-a series are also not suitable for wheat cultivation due to very severe limitations of erosion with strong stoniness, excessive relief, excessively drained with rapid permeability, shallow depth and loamy skeleton texture. Mustafa *et al.* (2016) and Gandhi and Savalia (2016) also presented similar results for soil suitability of wheat crop. The suitability evaluation indicated that 61% area is mapped in the cluster is moderately suitable, 23% is marginally suitable and rest 14% area is unsuitable for the cultivation of wheat (Fig. 2). Any improvement in these characteristics except texture may elevate the suitability to the next higher grade.

Table 3: Soil-site suitability for different crops grown in cluster of ten villages in Bhadesar tehsil

Soil series	Maize	Wheat	Mustard	Soybean
Madanpura	N	N	N	N
Daulatpura-a	N	N	N	N
Daulatpura-b	S3ft	S3stf	S3ft	S3tf
Bhadsoda-a	S3st	S3st	S3st	S3st
Bagund series	S2st	S3st	S3st	S3st
Narbadiya-a	S2st	S3st	S3st	S3st
Bhadsoda- b	S2st	S2fst	S3st	S2st
Daulatura-c	S1	S2s	S1	S1
Nardhari-a	S2fs	S2fs	S2s	S2fs
Nardhari-b	S2f	S2fs	S2s	S2f
Daulatura-d	S2f	S2fs	S2s	S1
Guda	S3fns	S3fns	S3fns	N
Narbadiya-b	S3fn	S3fn	S3fn	S3fn
Parliya	S3fn	S3fs	S2s	S3fn

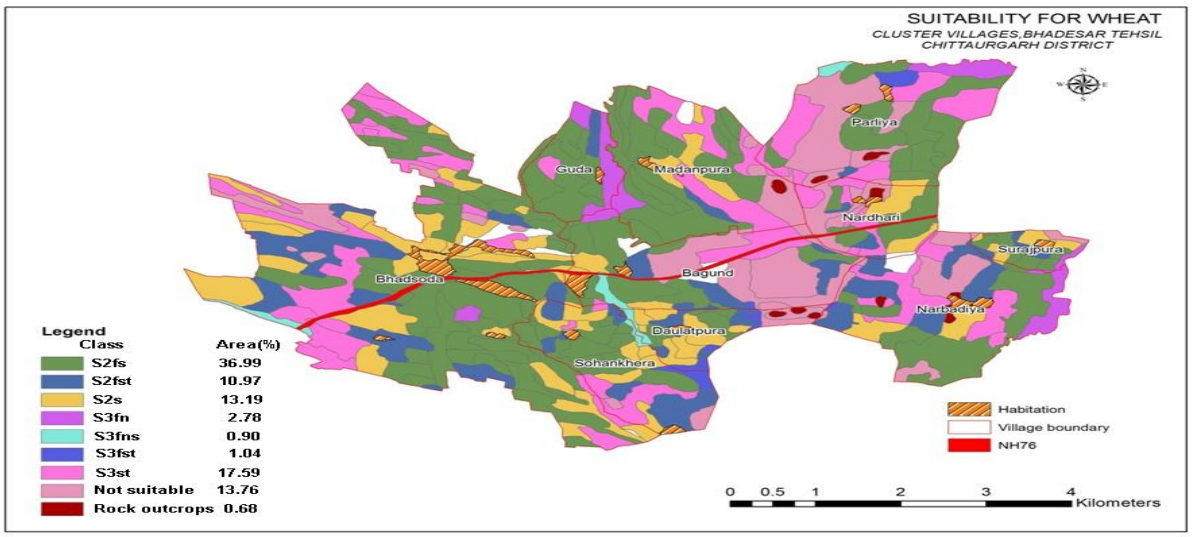

Fig.2. Soil suitability map for wheat in cluster of Bhadesar tehsil

Mustard(*Brassica comprestis*)

Nardhari-a, Nardhari b, Daulatpura-d and Parlia series were moderately suitable soils due to physical constraints like slope and erosion (Table 3). Marginally suitable soils occur in Daulatpura-b, Bhadsoda-a, Bagund, Narbadiya-a, Bhadsoda-b Guda and Narbadiya-b series. Gudha and Narbadiya-b series are rated as marginally suitable due to constraints of strongly alkaline pH and slight salinity to moderate sodicity problem and poor in nutrient status hence these soils are not suitable for the cultivation of mustard crop. Madanpura and daulatpura-a series are not suitable for mustard cultivation due to very severe limitations of erosion with strong stoniness, excessive relief, excessively drained with rapid permeability, shallow depth and loamy skeleton texture. Similar results were reported by Garhwal *et al,* (2013). It is revealed that about 13% area is highly suitable means has no any limitation for mustard cultivation (Fig. 3). About 51% of the study area represents the soils under moderately suitable class (S2) for mustard cultivation in the cluster. The major limitations in these soils are fertility, texture and slight salinity and slight sodicity. Marginally suitable soils occupy about 19% of area with major limitations of salinity-sodicity, severe erosion, gravelliness, slope and soil depth. About 14% area is unsuitable for the cultivation of mustard.

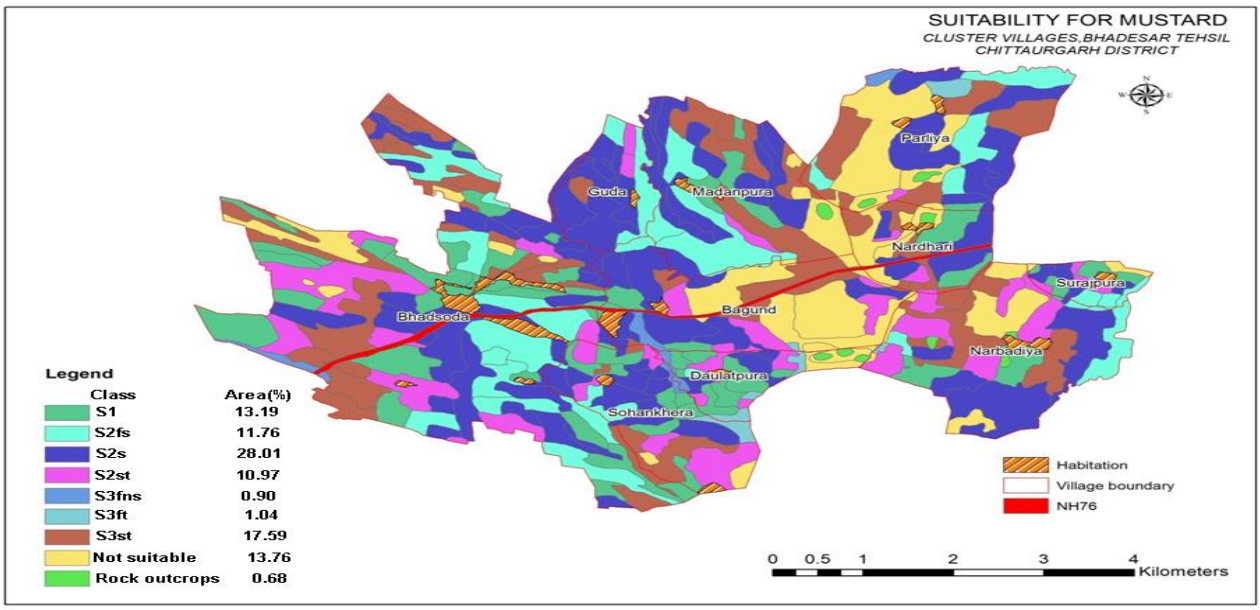

Fig.3. soil suitability map for mustard in cluster of Bhadesar tehsil

Soybean (*Glycine max*)

Soils of Daulatpura-c and d series are highly suitable without any constraint (Table 3). The soils of Bhadsoda-b, Nardhari-a and Nardhari-b are moderately suitable for soybean cultivation. Bhadsoda-b series have constraints of slope (3-8%) and shallow depth of soil whereas Nardhari-a and Nardhari-b have shallow depth and low fertility constraints. Marginally suitable soils occur in Daulatpura-b, Bhadsoda-a, Bagund, Narbadiya-a, Narbadiya-b and Parliya series. Soils of Madanpura and daulatpura-a are not suitable for soybean cultivation due to very severe limitations of erosion with strong stoniness, excessive relief, excessively drained with rapid permeability, shallow depth, loamy skeleton texture. Similar results were reported by Naveen Kumar *et al.* (2018) and Hegde*et al.* (2019). It is revealed that about 21% area of the cluster is highly suitable for cultivation of soybean without any limitation (Fig. 4).

Moderately suitable soil covers about 31% of area with major limitations of slope, depth, fertility and soil texture. Marginally suitable soils occupy about 30% of area with major limitation of slope, depth, severe erosion, gravelliness and low soil fertility. About 15% area is unsuitable for the cultivation of Soybean.

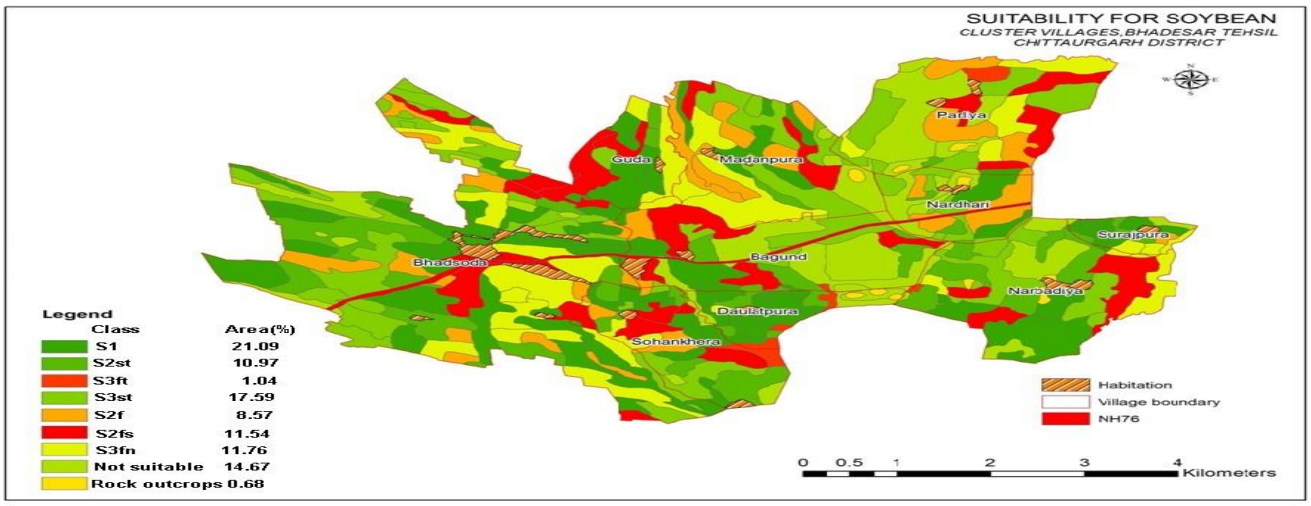

Fig.4. Soil suitability map for soybean in cluster of Bhadesar tehsil

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