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Geospatial Land Evaluation of Medinapur Sub-watershed for Crop Suitability and Sustainable Crop Plan

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was conducted to reveal the land capability and its suitability to crops in the semi-arid region of North-Eastern Karnataka state, India. Alternate crop plan was proposed with suitable interventions at soil phase level, based on the prevailing climatic regimes and soil-land limitations. Cadastral parcels of Medinapur sub-watershed overlaid on IRS-P6 LISS-IV merged Cartosat-1 satellite imagery was used for interpreting soil units. Soil profiles and morphological studies were

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made to classify entire sub-watershed (covering 4890.46 ha) into ten soil series and these soil series, further classified into 23 soil phase/management units. The results revealed that major area of 1163 ha (23.79%) covers the soil phase unit “KMLmC2” with deep (100-150 cm) clay textured, gently sloping (3-5 %) and moderately eroded (e2) lands. Two land capability classes (IIIes and IVes) were found in the study area with topography, soil erosion, texture, drainage and soil fertility as major limitation factors. Red gram (59.64%) and Sorghum (18.86%) covering maximum area in the sub watershed were assessed for crop suitability to land. To estimate the significance of crop suitability criteria to land, linear regression analysis was performed with assigned rank values of independent variables. Suitability of these crops was found that the 77.84 % of land was moderately suitable (S2) to redgram with limitations of rooting condition, erosion and topography, only depth showed significant contribution to redgram suitability with R^2 = 0.744. Sorghum was highly suitable (S1) to 21.12 % of land and soil depth and pH were significantly contributing to suitability of sorghum with R^2 = 0.746. The estimation of criteria for land suitability to Sorghum and Redgram was significant at 5 per cent level. In common soil depth resulted as major contributing factor in deciding land suitability to crops.

Keywords: Geospatial land evaluation; soil-phase unit; land suitability to crops; crop plan.

1. INTRODUCTION

The comparison of the inputs requirements of land use with the resources supplied by land is possible through a systematic methodological land evaluation. Land evaluation is the basis for sustainable land resource scheduling and managing since it assists us to know whether the resources are degraded or improved in quality [1]. The land capability is determined by different land characteristics such as the types of soil, which is critical for productivity, fundamental geology, topography and hydrology. A Land use capability classification system can be defined as classification of land according to its capability for agricultural production on permanent basis under specified agri-management practices to maintain the soil and land productivity [2,3]. The LCC helps the farmers, the banks, the government and various agencies and also the public for sale and purchase of land, criteria for giving subsidy and for giving loan on the land; The various land classes directly reflects upon the productivity of land and degree of management practices adopted to maintain its productivity; A class I land is more productive and need least management practices to maintain its productivity and a class IV or V land has low productivity and need higher degree of management practices. This classification is helpful since it allows for more precise land utilization types because some soils may be more suited for some crops than others. The detailed land resources inventory (LRI) will help in addressing these issues site specifically [4] for specific crop production [5].

The principal purpose of land suitability assessment is to predict the potential and limitations of the land for crop production. Geographic Information Systems (GIS) techniques have been used to identify spatially and evaluate the physical land capability and suitability [6]. They have been proved to be helpful and successful tools in studying, mapping, processing, and presenting certain problems [7] for this reason, the assessment of land characteristics for the present and potential capability and suitability of crop production are necessary. Therefore, the objective of this study was to assess the capability and suitability of the land.

Earlier several researchers have already demonstrated the potential of an integrated approach in using RS and GIS data for quantitative land evaluation [8,9]. Therefore, the high resolution satellite imagery was used to carry out the land evaluation study. Spatial maps of various themes of land resources were prepared using GIS, for addressing site specific limitations. Assessment of suitability of land to a particular crop depends on prevailing climatic regime, soil and land limitations. The variables which are used to assess different classes of crop suitability to land can be estimated using linear regression to understand highly correlated variable. Developing soil phase wise crop plan module with suitable interventions would maximize production productivity of the crop. Therefore, in this study a comprehensive crop plan was prepared for land use suiting to respective management unit limitations.

2. MATERIALS AND METHODS

Medinapur sub-watershed is situated in Lingasugur Taluk, Raichur District of Karnataka state, India. Agro-climatically, it belongs to Northern Dry Zone of Karnataka, located between $16^{0}11'$ N – $76^{0}33'$ E and $16^{0}7'$ N – $76^{0}39'$ E, covering a total area of about 4,892 ha (Fig. 1). The sub-watershed is having undulating topography with MSL ranging from 445 m to 556 m. The average annual rainfall of this region is about 335 mm. Potential Evapo-Transpiration (PET) ranges from 81 mm in December to 199 mm in May, with the average PET being 141 mm. The Potential Evapo-Transpiration (PET) is always higher than the precipitation throughout the year except at the end of june to end of September months. The Length of Crop Growing Period (LGP) typically lasts 0 to 50 days and begins in the third week of August and ends in the first week of October (Fig. 2). Granite and gneiss are the dominant geological types in the study area.

In 2016, a detailed land resource survey at 1:8000 scale was carried out at Medinapur sub-watershed. Cadastral map overlaid on IRS P6 LISS-IV merged Cartosat-1 imagery having 2.5 m spatial resolution (Fig. 1) used as base map for traversing and interpretation of the imagery for delineation of mapping/soil-phase units. In order to record soils at various physiographic positions, rapid traversing was done. Landforms and soil profiles were identified based on geology, drainage pattern, surface features, slope characteristics and land usage [10]. The feel method and a dumpy level were used to assess the texture and slope of the soil, respectively. Surface soil samples (0-15 cm depth) were collected at 320X320 square meter grid intervals, so that each parcel boundary possess more than one sample with even distribution. The care was also taken to collect soil samples with heterogeneity in visible surface characteristics. Organic carbon (OC) was determined by using wet oxidation method developed by Walkley and Black in 1965. Using a glass electrode, the soil reaction (pH) of 1:2.5 soil to water suspensions of the soil was measured [11]. Using a conductivity bridge, electrical conductivity in the soil water (1:2.5) suspension was measured [12].

ArcGIS 10.7 (ESRI make) was used for vectorization of scanned interpreted satellite imagery at 1:8000 scale, attributing non-spatial data to mapping units, and for overlaying thematic layers namely soil phase, parcel

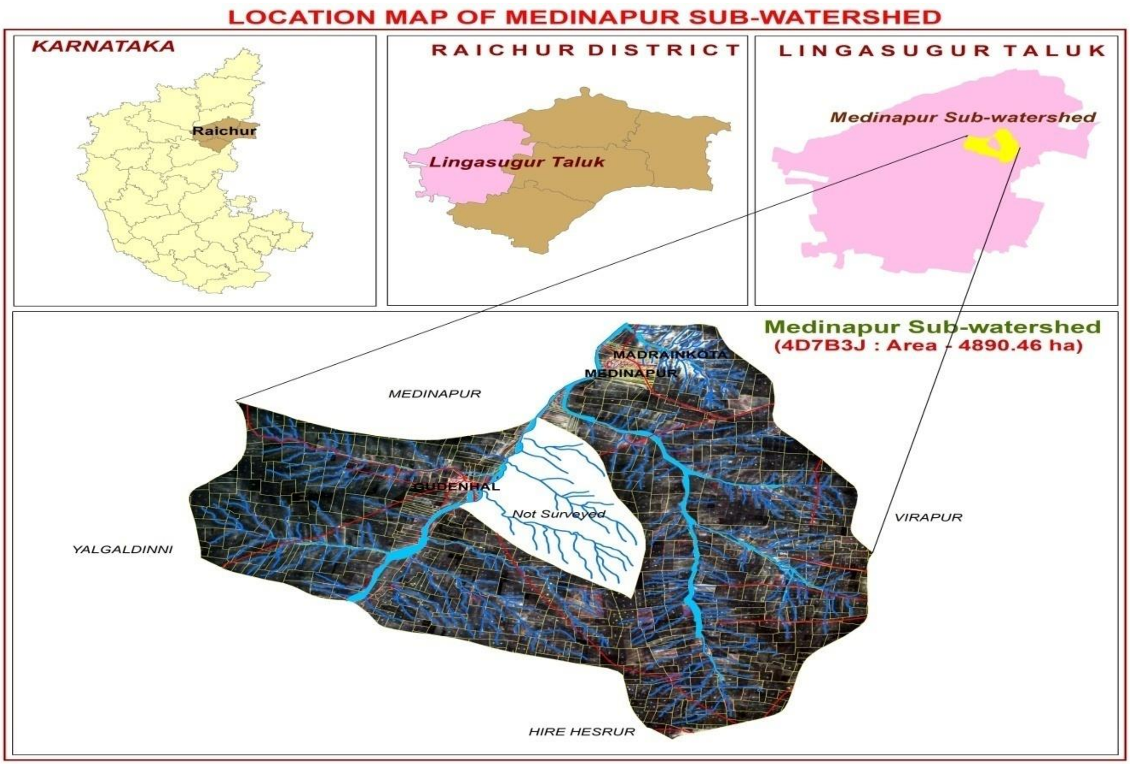

Fig. 1. Location of Medinapursub watershed is located in Lingasugur taluk, Raichur district

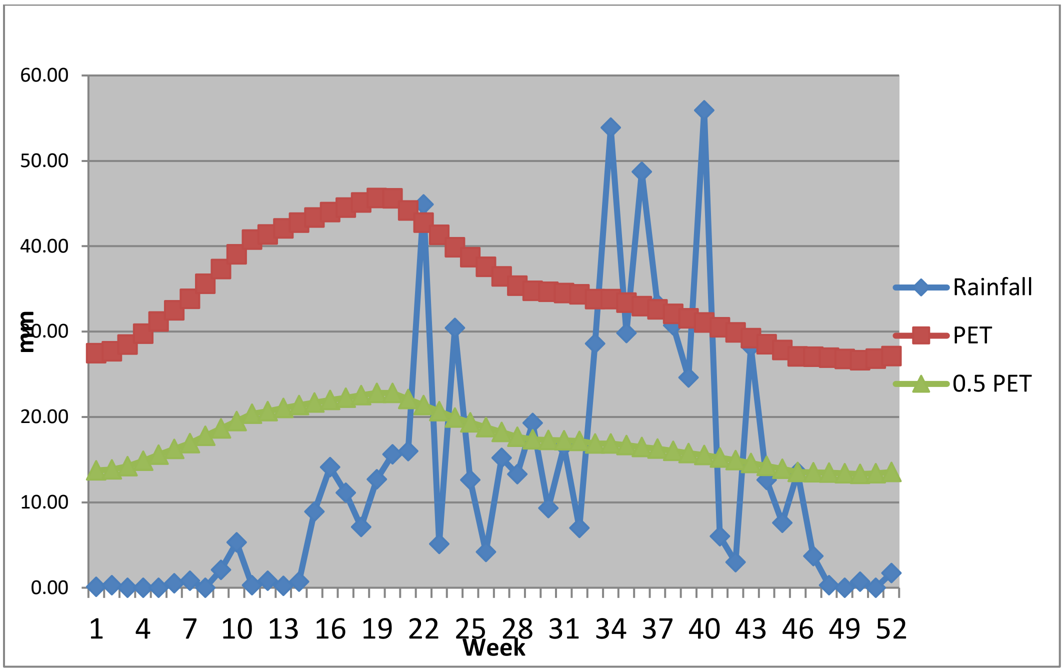

Fig. 2. Annual rainfall of 335 mm in the Gurugunta Hobli, LingasugurTaluk and Raichur District

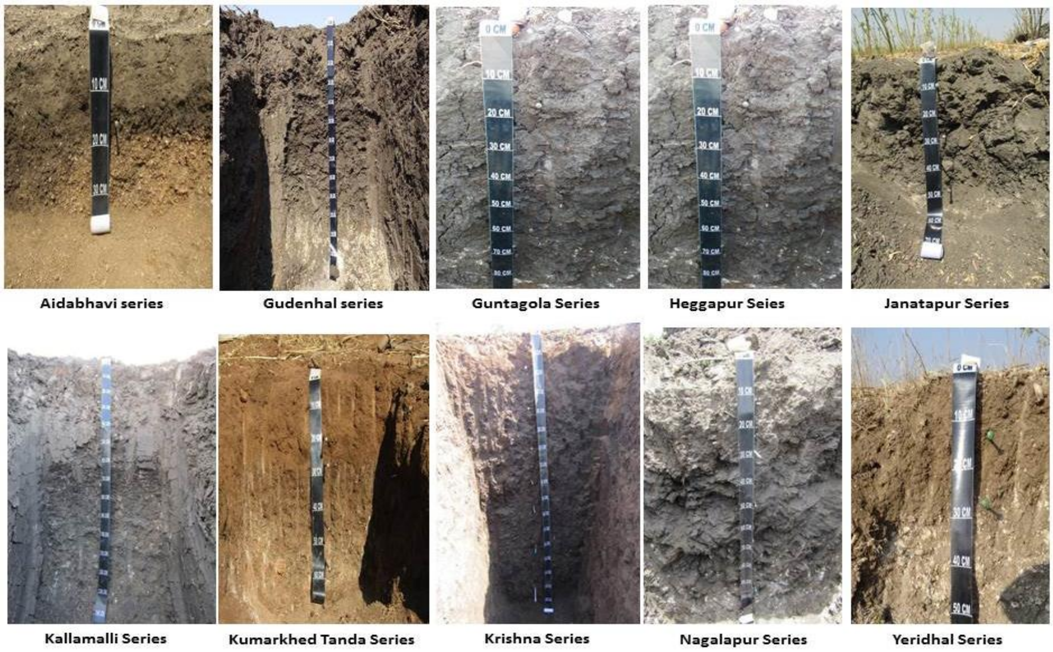

Fig. 3. Soil series wise profile identified in Medinapur Sub-watershed

boundaries with survey numbers and to layout maps with area statistics. Soil pH, EC and per cent OC were interpolated using Kringing techniques and suitable Kriging model (Exponential) was chosen based on the lowest nugget value (0.00). Further these kriged outputs were converted to vector data to derive soil-phase wise area statistics through overlay analysis. Ten soil series (Fig. 3) were identified in Medinapur sub-watershed and further divided into 23 soil-phase units and their per cent of area distribution and description were mapped (Fig. 4 and Table 1). These data helps in evaluating the land capability classification and land suitability. Based on the soil constraints [13], climate regimes, and land features the suitable interventions with crop plans were designed for a various field and horticulture crops [14,15].

Linear regression was carried out to estimate the variables of soil limitations (soil depth, pH, EC and % OC) and land characteristics (LCC, slope, erosion, surface gravel) influencing the crop suitability to land. The text variables having range values were initially transformed by assigning ranks (Table 4). Similarly, the dependent variable crop suitability classes were also given rank as 4 to 1 (S1 as 4, S2 as 3, S3 as 2 and N as 1).

3. RESULTS AND DISCUSSION

The criteria for classifying the land capabilities are linked with the soil site characteristics of the soil units in Table 2 [13]. Fig. 5 displays the land capability classification of mapping units and their extent in the sub-watershed. Ten soil series were identified in the Medinapur SWS and these series were named after nearby village names *viz*., Aidabhavi, Gudenhal, Guntagola, Heggapur, Jantapur, Kalamali, Kamarkhed Tanda, Krishna, Nagalapur, and Yerdhal. These series were divided into 23 mapping units consisting of soil family linked with dominant phases based on, field survey reviews, landform characteristics and laboratory investigations. The data pertaining to description of soil mapping unit of Medinapur sub- watershed is described in Table 1.

In the study area, depth of soil (Fig. 6) varied from very shallow (10–25 cm) to shallow (25–50 cm), moderately shallow (50–75 cm) to moderately deep (75–100 cm) and deep (100-150 cm) to very deep (>150 cm). The soil texture (Fig. 7) of the most part of sub-watershed was clay (4557 ha) and very few area has sandy (18 ha) or sandy clay loamy texture (136 ha). Basavaraj et al. [16] observed that major area (83.96 %) of Dabarabad subwatershed has clay textured soils and the heavier textures of the soils are due to less erosion, less slope and good managements by the farmers. A large area (4523 ha) of non-gravelly class having <15% gravel was covered with field crops, and part of the sub-watershed soils were gravelly having 15% to 35% (g1) of gravels (189 ha) as shown in (Fig. 8). Slope class (Fig. 9) varied from very gently (1-3%) to gently (3–5%) and to moderate slope (5-10%). The major area covered by gently slope class in the sub watershed. Similar investigations were also conducted by Rajendra-Hegde et al. [17] in yaadhalli-1 microwatershed of Yadgir District of Karnataka, and they observed that the soils were varied from deep to very deep in depth, sandy clay loam to sandy clay in texture, very gently sloping, moderate erosion and non-gravelly in nature.

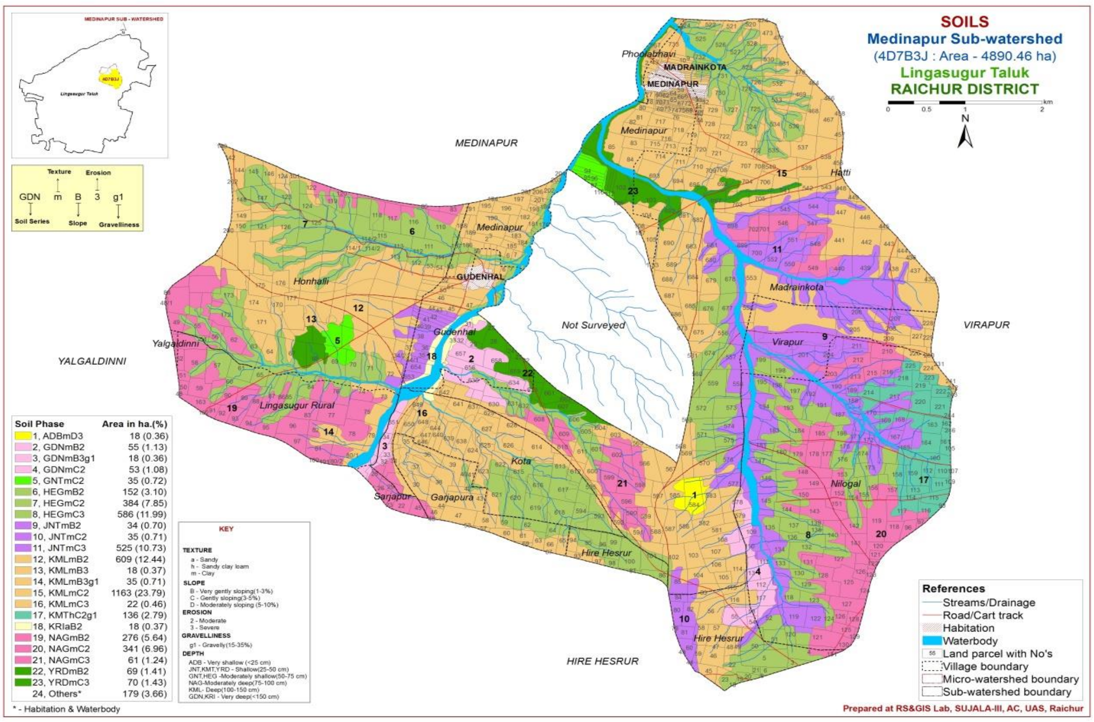

Fig. 4. Soil map of Medinapur Sub-watershed

Table 1. Map unit description of Medinapur Sub-watershed

Sl. No	Soil series	Soil Phase	Description	Area in ha. (%)
1	Aidabhavi	ADBmD3	Aidabhavi series, Very shallow (<25cm), Clay texture, Moderately sloping (5-10%) with Severe erosion.	18(0.36)
2	Gudenhal	GDNmB2	Gudenhal series, Very deep (>150 cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	55(1.13)
		GDNmB3g1	Gudenhal series, Very deep (>150 cm), Clay texture, Very gently sloping (1-3%) with Severe erosion and Gravelly (15-35%).	18(0.36)
		GDNmC2	Gudenhal series, Very deep (>150 cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	53(1.08)
3	Guntagola	GNTmC2	Guntagola series, Moderately shallow (50-75 cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	35(0.72)
4	Heggapur	HEGmB2	Heggapur series, Moderately shallow (50-75cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	152(3.10)
		HEGmC2	Heggapur series, Moderately shallow(50-75cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	384(7.85)
		HEGmC3	Heggapur series, Moderately shallow(50-75cm), Clay texture, Gently sloping (3-5%) with Severe erosion.	586(11.99)
5	Jantapur	JNTmB2	Jantapur series, Shallow (25-50cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	34(0.70)
		JNTmC2	Jantapur series, Shallow (25-50cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	35(0.71)
		JNTmC3	Jantapur series, Shallow (25-50cm), Clay texture, Gently sloping (3-5%) with Severe erosion.	525(10.73)
6	Kalamali	KMLmB2	Kalamali series, Deep (100-150cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	609(12.44)
		KMLmB3	Kalamali series, Deep (100-150cm), Clay texture, Very gently sloping (1-3%) with Severe erosion.	18(0.37)
		KMLmB3g1	Kalamali series, Deep (100-150cm), Clay texture, Very gently sloping (1-3%) with Severe erosion and Gravelly (15-35%).	35(0.71)
		KMLmC2	Kalamali series, Deep (100-150cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	1163(23.79)
		KMLmC3	Kalamali series, Deep (100-150cm), Clay texture, Gently sloping (3-5%) with Severe erosion.	22(0.46)

Sl. No	Soil series	Soil Phase	Description	Area in ha. (%)
7	Kamarkhed Tanda	KMThC2g1	Kamarkhed Tanda series, Shallow (25-50 cm), Sandy clay loam texture, Gently sloping (3-5%) with Moderate erosion and Gravelly (15-35%).	136(2.79)
8	Krishna	KRIaB2	Krishna series, Very deep(>150 cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	18(0.37)
9	Nagalapur	NAGmB2	Nagalapur series, Moderately shallow (50-75 cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	276(5.64)
		NAGmC2	Nagalapur series, Moderately shallow (50-75 cm), Clay texture, Gently sloping (3-5%) with Moderate erosion.	341(6.96)
		NAGmC3	Nagalapur series, Moderately shallow (50-75 cm), Clay texture, Gently sloping (3-5%) with Severe erosion.	61(1.24)
10	Yerdhal	YRDmB2	Yerdhal series, Shallow (25-50 cm), Clay texture, Very gently sloping (1-3%) with Moderate erosion.	69(1.41)
		YRDmC3	Yerdhal series, Shallow (25-50 cm), Clay texture, Very gently sloping (1-3%) with Severe erosion.	70(1.43)
11	Others*		Habitation and Water body	179(3.66)
Total				**4890.46 (100.00)**

Table 2. Soil-site characteristics of Medinapur sub-watershed for land evaluation

Mapping unit	Land form characteristics			Physico- chemical characteristics (f)				
	Slope (t) (%)	Erosion (e)	Drainage (w)	Depth (cm)	Texture	pH (1:2.5) (soil: water)	EC (dS/m)	OC (g/kg)
ADBmD3	5-10	Severe	Moderately well drained	<25	Clay	Moderately alkaline	Non saline	Low
GDNmB2	1-3	Moderate	Moderately well drained	>150	Clay	Slightly to Moderately alkaline	Non saline	Medium
GDNmB3g1	1-3	Sever	Moderately well drained	>150	Clay	Slight to Moderately alkaline	Non saline	Medium
GDNmC2	3-5	Moderate	Moderately well drained	>150	Clay	Slight to Moderately alkaline	Non saline	Medium
GNTmC2	3-5	Moderate	Moderately well drained	50-75	Clay	Moderately alkaline	Non saline	Medium
HEGmB2	1-3	Moderate	Moderately well drained	50-75	Clay	Neutral to Strongly alkaline	Non saline	Low to Medium
HEGmC2	3-5	Moderate	Moderately well drained	50-75	Clay	Neutral to Strongly alkaline	Non saline	Low to Medium
HEGmC3	3-5	Severe	Moderately well drained	50-75	Clay	Neutral to Strongly alkaline	Non saline	Low to Medium
JNTmB2	1-3	Moderate	Moderately well drained	25-50	Clay	Moderate to strongly alkaline	Non saline	Low to Medium
JNTmC2	3-5	Moderate	Moderately well drained	25-50	Clay	Moderate to strongly alkaline	Non saline	Low to Medium
JNTmC3	3-5	Severe	Moderately well drained	25-50	Clay	Moderate to strongly alkaline	Non saline	Low to Medium
KMLmB2	1-3	Moderate	Moderately well drained	100-150	Clay	Slight to Strongly alkaline	Non saline	Low to Medium
KMLmB3	1-3	Severe	Moderately well drained	100-150	Clay	Slight to Strongly alkaline	Non saline	Low to Medium
KMLmB3g1	1-3	Severe	Moderately well drained	100-150	Clay	Slight to Strongly alkaline	Non saline	Low to Medium
KMLmC2	3-5	Moderate	Moderately well drained	100-150	Clay	Slight to Strongly alkaline	Non saline	Low to Medium

Mapping unit	**Land form characteristics**			**Physico- chemical characteristics (f)**				
	Slope (t) (%)	**Erosion (e)**	**Drainage (w)**	**Depth (cm)**	**Texture**	**pH (1:2.5) (soil: water)**	**EC (dS/m)**	**OC (g/kg)**
KMLmC3	3-5	Severe	Moderately well drained	100-150	Clay	Slight to Strongly alkaline	Non saline	Low to Medium
KMThC2g1	3-5	Moderate	Moderately well drained	25-50	Clay loam	Moderate to strongly alkaline	Non saline	Low
KRIaB2	1-3	Moderate	Moderately well drained	>150	Clay	Moderately alkaline	Non saline	Medium
NAGmB2	1-3	Moderate	Moderately well drained	50-75	Clay	Strongly alkaline	Non saline	Low
NAGmC2	3-5	Moderate	Moderately well drained	50-75	Clay	Strongly alkaline	Non saline	Low
NAGmC3	3-5	Severe	Moderately well drained	50-75	Clay	Strongly alkaline	Non saline	Low
YRDmB2	1-3	Moderate	Moderately well drained	25-50	Clay	Slightly alkaline	Non saline	Medium
YRDmC3	1-3	Severe	Moderately well drained	25-50	Clay	Slightly alkaline	Non saline	Medium

Note: Climate (c): Rainfall-350 mm, Temperature-Max: 45^{0}C Min: 29.5 ^{0}Cand RH-64%

Table 3. Per cent distribution of Field and Horticultural crop suitability

Crops	S1	S2	S3	N
Sorghum	21.12	56.71	18.15	0.36
Bengal gram	16.67	78.94	0.36	0.37
Red gram	-	77.84	18.14	0.36
Cotton	15.48	41.76	38.37	0.73
Groundnut	-	3.64	92.34	0.36
Bajra	-	4.43	91.55	0.36
Amla	22.19	55.65	17.77	0.73
Custard apple	22.19	55.65	17.77	0.73
Guava	-	1.64	76.20	18.50
Lime	15.48	38.70	23.66	18.50
Musambi	15.48	38.70	23.66	18.50
Sapota	-	21.09	56.75	18.50
Pomegranate	-	47.98	30.23	18.13

Note: S1-Highly suitable, S2-Moderately suitable, S3-marginally suitable and N-Currently not suitable

Table 4. Weightage ranking of crop suitability input criteria

Soil depth		LCC		Slope		Gravel		Erosion		Crop suitability	
Classes (cm)	Ranking	Classes	Ranking	Classes (%)	Ranking	Classes (%)	Ranking	Classes	Ranking	Classes	Ranking
<25	1	I	8	0-1	6	<15	4	Slight	3	S1	4
25-50	2	II	7	1-3	5	15-35	3	Moderate	2	S2	3
50-75	3	III	6	3-5	4	35-60	2	Severe	1	S3	2
75-100	4	IV	5	5-10	3	60-80	1	-	-	N/N1	1
100-150	5	V	4	10-15	2	-	-	-	-	-	-
>150	6	VI	3	15-25	1	-	-	-	-	-	-
-	-	VII	2	-	-	-	-	-	-	-	-
-	-	VIII	1	-	-	-	-	-	-	-	-

Note: S1-Highly suitable, S2-Moderately suitable, S3-marginally suitable and N-Currently not suitable

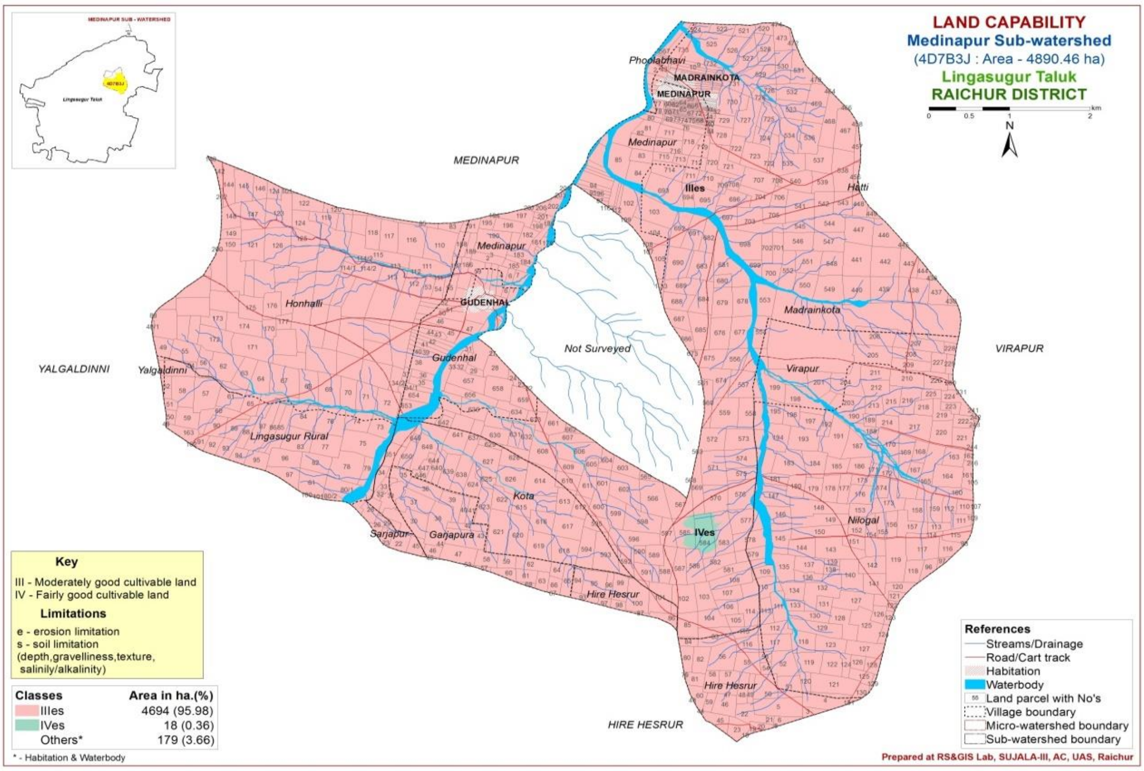

Fig. 5. Land capability classes of Medinapur Sub-watershed

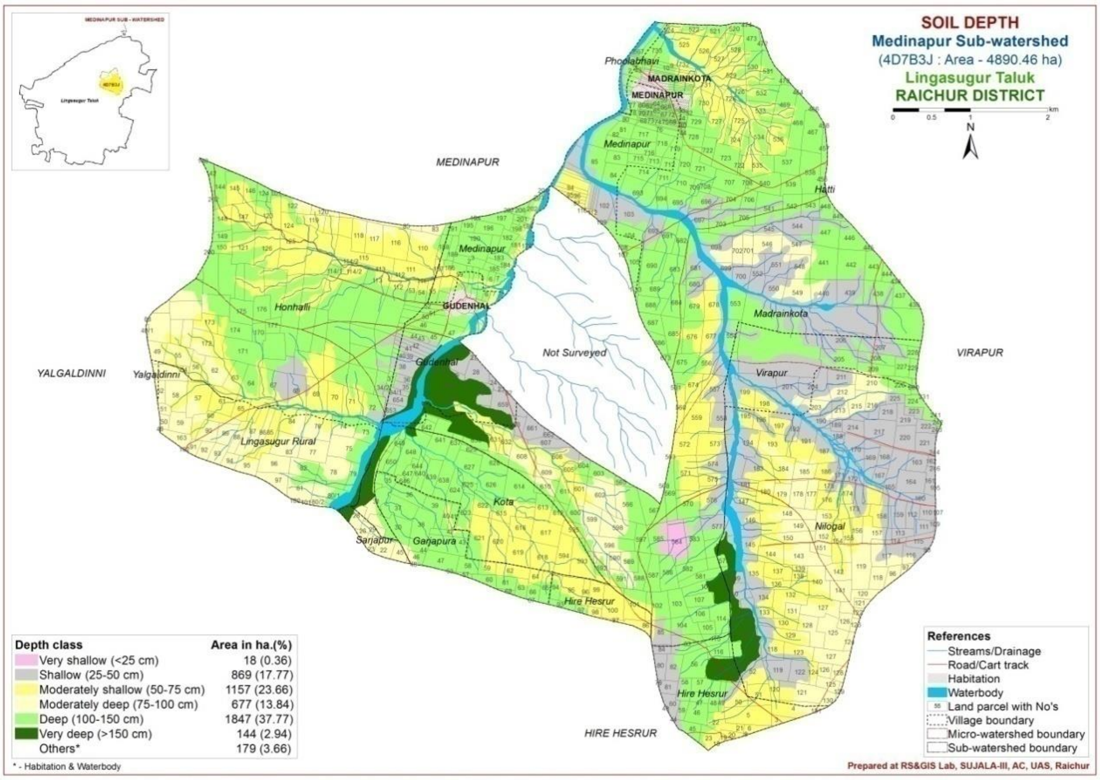

Fig. 6. Soil depth classes of Medinapur Sub-watershed

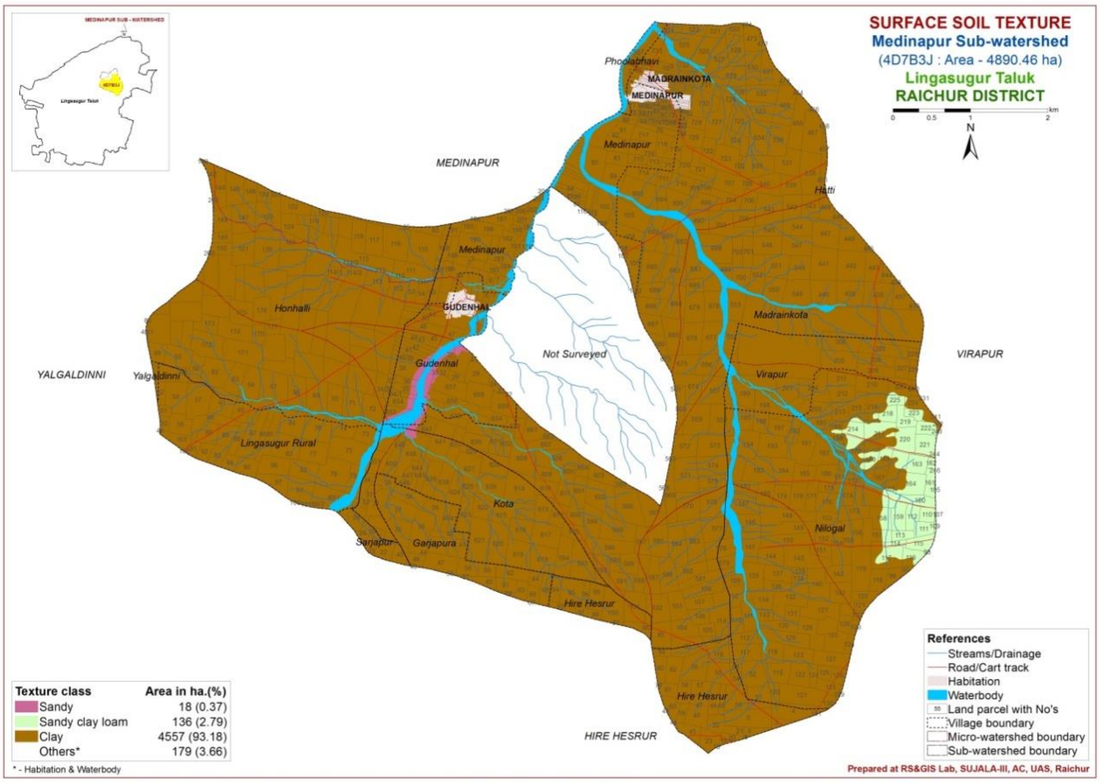

Fig. 7. Surface soil texture classes of Medinapur Sub-watershed

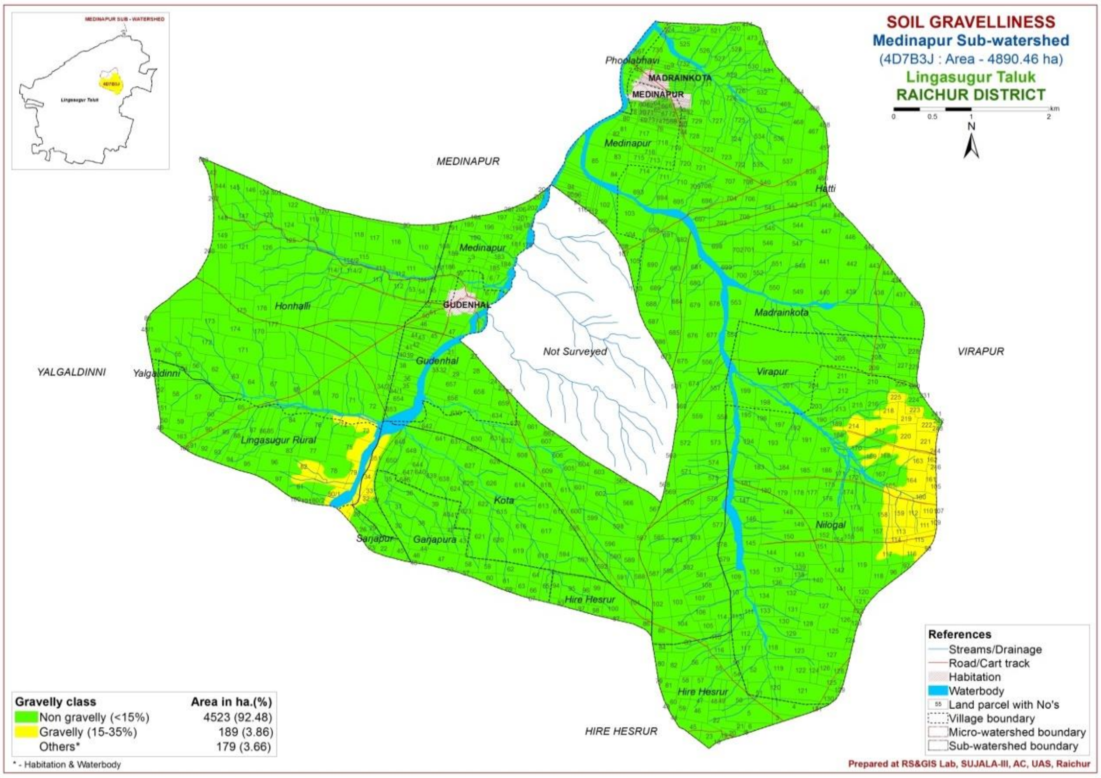

Fig. 8. Soil gravel classes of Medinapur Sub-watershed

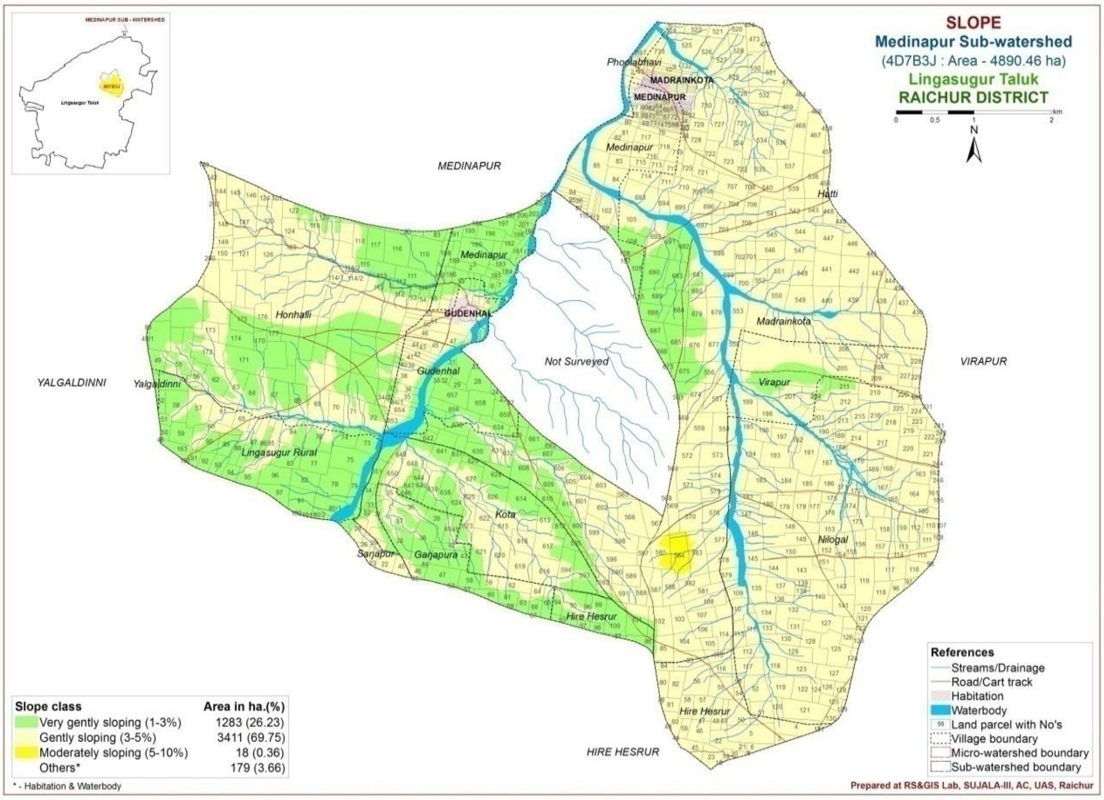

Fig. 9. Slope classes of Medinapur Sub-watershed

3.1 Land Capability Classification

Suryawanshi et al. [18] defined land capability classification as an interpretive classification of soils based mostly on the inherent soil features and external land attributes. The soils of the Medinapur sub-watershed of the Lingasugur taluk have been divided into two land capacity classes, namely IIIes and IVes, based on properties of the soil. Ajaykumar et al*.* [19] classified land capability class Based on soil properties in the soils of Malli-1 micro watershed of Kalaburagi district and they observed three land capability classes for better land management, *i.e.,* III, IV and VI. Under land capability class IIIes the Aidabhavi, Heggapur, Gudenhal, Guntagola, Jantapur, Kalamali, Kamarkhed Tanda, Krishna, Nagalapur, and Yerdhal soil series were categorized. Due to severe constraints in erosion, slope, texture and soil depth these soils were classified as marginally cultivable lands. However, a portion of the Hirehusrur soil series was categorized as IVes which is moderately cultivable land with restrictions on soil depth, erosion, slope, and texture. The area which covers IIIes and IVes LCC were 4694 ha and 18 ha, respectively (Fig. 5). Rajesh et al. [20] observed the II*es*, III*es* and IV*es* Land capability classes in Kalmali North-1 micro watershed with limitations of soil erosion, texture, soil drainage, soil fertility and topography. Rajendra-Hegde et al. [17] also stated that the soils of yaadhalli-1 micro watershed of Yadgir District of Karnataka were grouped into land capability class II (87%) and IV (2%) with limitations of soil characteristics and erosion.

3.2 Land Suitability Classification of Field and Horticultural Crops

The soil phase units of Medinapur sub-watershed were evaluated for its suitability for production of various crops (Table 3). In order to determine the suitability of the land for various field and horticulture crops based on the current land use, the soil-site characteristics from the study region were matched with criteria of land suitability of different crops as defined by Sehgal, (1966). The land suitability of field crops such as Bajra and Groundnut showed that 217 ha (4.43%) was moderately suitable (S3), 4478 ha (91.54%) was marginally suitable (S2) and 18 ha (0.34%) was presently not suitable (N1) because texture, slope and depth of soil act as limiting factor. Whereas, Chickpea and Cotton were highly suitable (S1) to an area of 815 ha (16.67%), about 3859 ha (79.26%) was moderately suitable (S2), 18 ha (0.36%) was marginally suitable (S3) and about 18 ha (0.36%) was currently not suitable (N1) with productive constraints of rooting depth, topography and erosion in Medinapur sub watershed. Basavaraj et al. [16] conducted similar type of study in Dabarabad subwatershed in Karnataka state and they concluded that most of the area (36.10%) was marginally suitable (S3l) followed by moderately suitable (S2l) in (19.83%) for agriculture crops (sorghum, redgram, blackgram, bengalgram and sugarcane) due to slight to moderate limitation of topography and an area of 34.91% was currently not suitable (N1rl) with severe limitations of rooting depth condition and topography.

Land suitability to horticultural crops showed that Amla, Custard apple, Lime and Musambi were highly suitable (S1) to an area of 1085 ha (22.19%), 2772 ha (55.65%) was moderately suitable (S2), 869 ha (17.77%) was marginally suitable (S3) and 36 ha (0.73%) was presently not suitable (N1) as texture, slope and rooting condition act as limiting factors. Whereas, Guava, Sapota and Pomogranate occupied about 80 ha (1.64%) as moderately suitable (S2), about 3727 ha (74.21%) was marginally suitable (S3) and 904 ha (18.50%) was currently not suitable (N1) with limitations of rooting depth, slope and erosion in the sub watershed. Geetha et al*.* [21] in Giddadapalya Micro-watershed concluded that major horticulture crops such as Mango, Sapota, Guava are highly suitable for major part of the micro watershed. Mango and Sapota were suitable for 69.09 % area. Rajendra-Hegde et al. [17] also conducted the land suitability evaluation and they found that a maximum area is under highly suitable (S1) land for growing horticultural (brinjal, onion, Bhendi, musambi, lime and custard apple) crops followed by moderately suitable (Class S2) land with minor limitations of texture, rooting depth, drainage and calcareousness. The marginally suitable (Class S3) land covers a minimum area with major limitations of rooting depth, gravelliness, texture and calcareousness. Currently not suitable (Class N1) land covers a negligible area with severe limitations of rooting depth and gravelliness.

The major cultivable crops in Medinapur sub-watershed was Sorghum (*Sorghum bicolar L.*) and Redgram (*Cajanus cajan L.*) covering an area of 896 ha (18.86%) and 2832 ha (59.64%) respectively (Fig. 10). Sorghum is a medium to long duration crop, The factors that influence sorghum yield are rainfall, temperature, slope, and texture [22]. Redgram is long duration crop

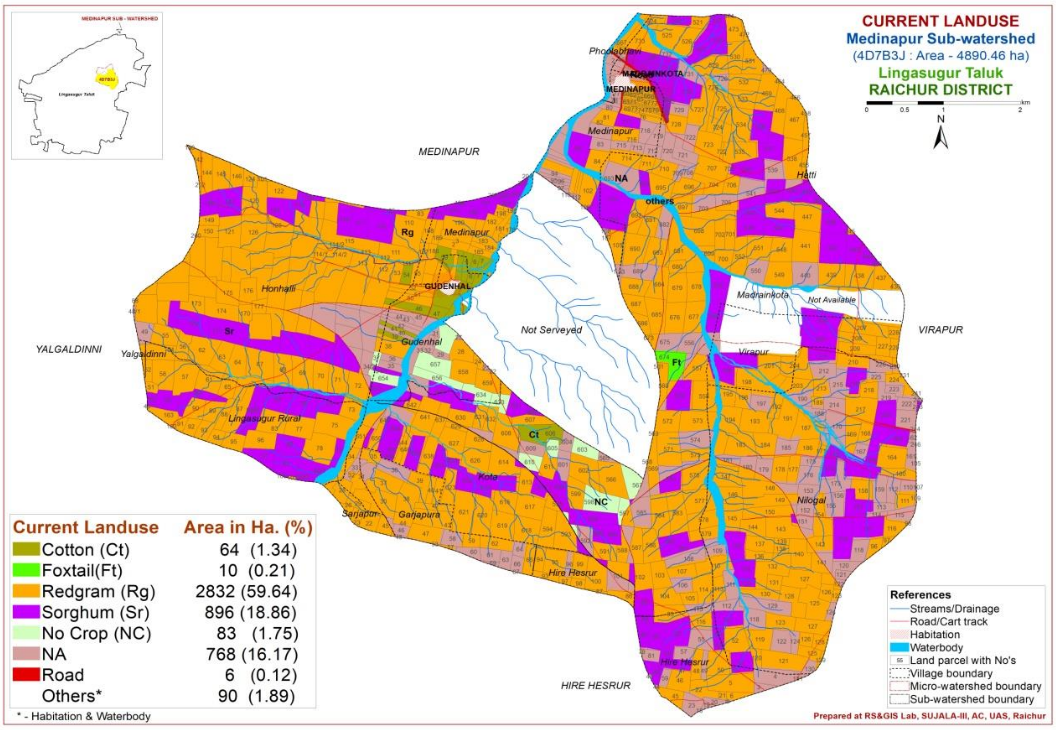

Fig. 10. Current land use of Medinapur Sub-watershed

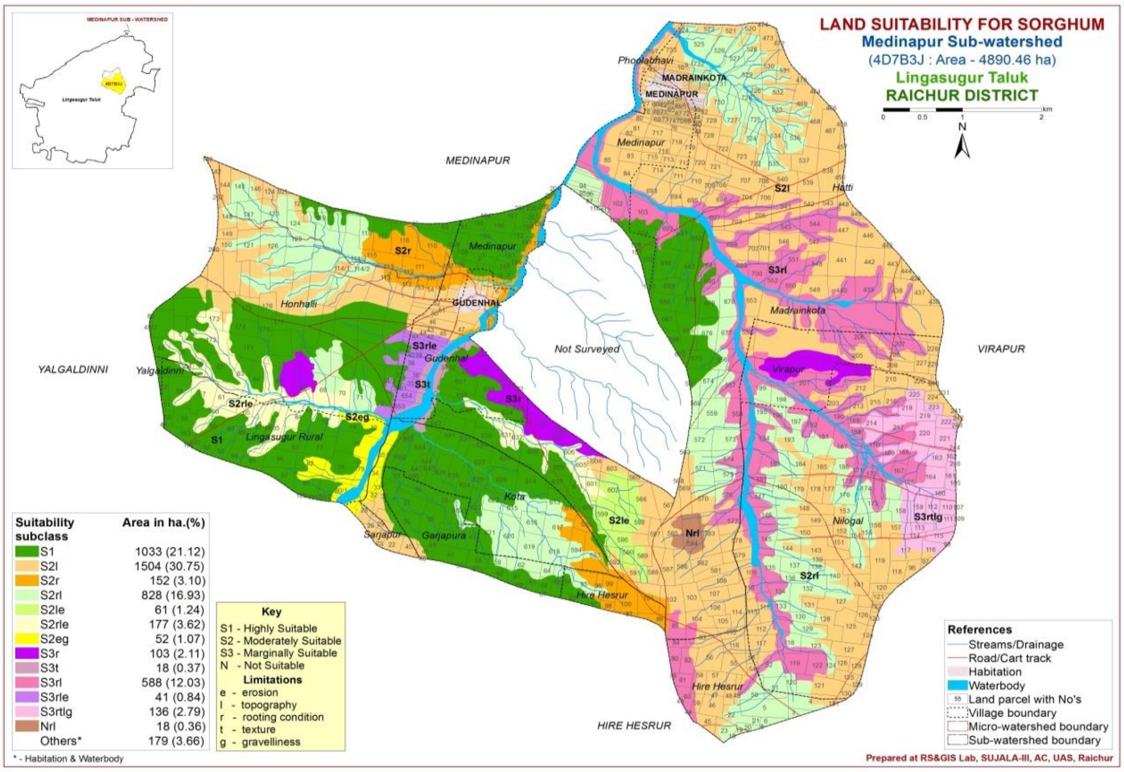

Fig. 11. Land suitability map for Sorghum in Medinapur sub-watershed

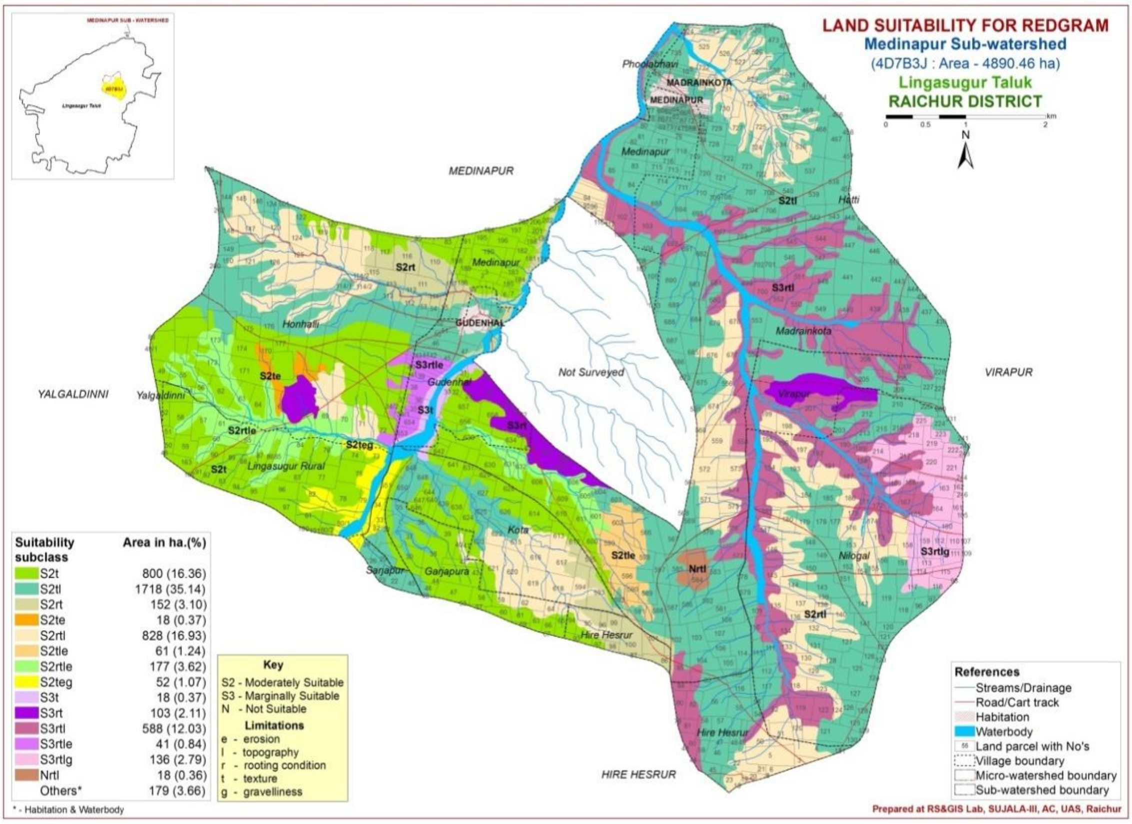

Fig. 12. Land suitability map for Redgram in Medinapur sub-watershed

Table 5. Linear regression parameters of Medinapur sub-watershed

Crops	Independent variables	Dependent variable	Linear Regression parameters					
			Variables	Constant	Co-efficient	t	F	R^2
Sorghum	Physic-chemical properties	$Y_{Suitablity}$ (df=22)	Depth		0.302	2.951*	2.932*	0.746
			LCC	10.880	-1.247	-1.496		
			Slope		-0.173	-0.531		
			Erosion		0.529	1.473		
			Gravel		0.756	1.724		
			pH		-0.923	-3.095**		
			EC		0.362	0.414		
			OC		1.410	0.711		
			N		0.003	0.272		
			P		0.014	0.400		
			K		0.003	0.813		
Redgram	Physic-chemical properties	$Y_{Suitability}$ (df=22)	Depth		0.207	2.883*	2.91*	0.744
			LCC	3.325	-0.206	-0.353		
			Slope		-0.366	-1.601		
			Erosion		0.312	1.242		
			Gravel		0.474	1.543		
			pH		-0.388	-1.856		
			EC		0.621	1.013		
			OC		0.701	0.505		
			N		0.001	0.158		
			P		0.016	0.677		
			K		0.003	1.190		

Table 6. Proposed crop plan for Medinapur Sub-watershed based on soil site crop suitability assessment

Proposed Land Use Class	Soil Map Units	Survey Number	Field Crops	Horticulture Crops	Suitable Interventions
LMU-1	ADBmD3	**Madrainkota:** 584	**Sole crop**; Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower,	Custard apple, Tamarind, Amla, Ber, and Aonla **Veg:** Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, cury leaf, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	Deep and wider size pit, Drip irrigation with suitable soil and water conservation measures, Cultivation on raised bunds with mulches and drip. Soil and land manage needs with Crescent bunds.
LMU-2	JNTmB2 JNTmC2 JNTmC3 KMThC2g1 YRDmB2 YRDmC3	**Honhalli:** 68,34/2,72. **Gudenal:**43,42,41,39,10,38,36,35,34/1,654,653,27,28,24,23,22,659. **Madrainkota:**633,661,662,607,85,103,692,697,698,545,544,547,551,699,700,552,550,548,440,439,681,680,677,557,553,574,576,577. **Virapur:**206,207,201,204,199.211,190,189,214,217,218,255,223,219,222,221,244,162,188,170,169,168,65,163,162,246,105,160,158,159,113,114,116,115,109,107,117,116,98,192,191,187,17,172,175,195,194,188,187,147,145,135,134,133,134,118,119,122. **Hire Hesrur:** 84,80,82,79,81,60,43,44,59.	**Sole crop**; Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, ground nut , maize	Custard apple, Tamarind, jamun, Ber, Sapota, Aonla, **Veg:** Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, cury leaf, Tomato, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	Laser land leveling to 2% slope to reduce soil erosion and facilitate uniform distribution of applied nutrients and soil moisture. Drip irrigation with suitable soil and water conservation measures Cultivation on raised beds with mulches.
LMU-3	HEGmB2 HEGmC2 HEGmC3	**Madrainkota:**524,522,25,526,527,529,726,581,726,725,533,536,722,539,725,724,727,730,731,732,679,678,677,676,556,674,556,674,	**Sole crop**; Sorghum, Bajra, Navni, Red gram, Green gram,	Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate,	Application of FYM, Biofertilizers and micronutrients, Deep and wider size pit, Drip irrigation

Proposed Land Use Class	Soil Map Units	Survey Number	Field Crops	Horticulture Crops	Suitable Interventions
		560,559,572,573,563571,575,101,601,605,606,632,631. **Kota:**622,615,616,617,595,594,953,618,620,621. **Hire Hesrur:** 95,96,99,98,100,87,86. **Lingasugur Rural:** 57,61,60,65,86,84,85. **Honhalli:**71,70,69,63,172,173,56,55,172,173,145,147,148,124,125,126,121,119,118,117,116,115,114/2,113,112,111,113,112,52,54,55,110,185,187. **Medinapu:**186,187,55,59,6,7,184,178,199,203.	Cotton, Maize, Sun flower, black gram, bengal gram, ground nut , maize	**Veg:** Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, cury leaf, Tomato, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	with suitable soil and water conservation measures Cultivation on raised beds with mulches and drip. Graded bunds and strengthening of field bunds.
LMU-4	NAGmB2 NAGmC2 NAGmC3	**Honhalli:**120,117,85,83,88,48/1,49,55,62. **Lingasugur Rural:**52,58,51,52,48,59,163,162,90,88,77,83,96,97,75,78,81,100,101,180/2. **Sarjapur:**26,28,29,23,22,45. **Madrainkota:**608,609,610,602,599,598,596,590,590,702,701,546,547,549,440. **Nilogal:**210,212,215,213,203,193,184,185,179,178,177,148,149,150,143,144,139,142,156,157,119,118,96,97,120,121,122,141,126,123,131,128,127,128,125,129,121. **Hire Hesrur:**131.	**Sole crop**; Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, ground nut , maize	Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, **Veg:** Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, cury leaf, Tomato, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	Laser land leveling to 2% slope to reduce soil erosion and facilitate uniform distribution of applied nutrients and soil moisture. Drip irrigation with suitable soil and water conservation measures Cultivation on raised beds with mulches and drip.
LMU-5	KMLmB2	**Honhalli:**140,142,144,202,200,15	**Sole crop**;	**Fruit crops:**Sapota, Jamun,	Application of FYM,

Proposed Land Use Class	Soil Map Units	Survey Number	Field Crops	Horticulture Crops	Suitable Interventions
	KMLmB3 KMLmB3g1 KMLmC2 KMLmC3	0,149,148,146,124,101,122,175,176,174,170,177,171,64,67,34,72,37. **Medinapur:**194,207,204,208,292,206,197,191,195,196,182,198182,183,185,6,7,133,105,107,108,84,85,83,715,716,82,81,717,718,76,72,82,81,80,78,66,65,67,76,62,64,59,61,77. **Gudenhal:**52,50,51,46,44,45,47. **Kota:**649,648,644,650,647,639,638,624,625,627,626,614,641,637,629,628,614,623. **Garjapur:**35,36,37,39,404,30,38,44,47,58,57,60,61,63,69,65. **Madrainkota:**642,630,604,603,565,566,567,597,585,588,587,586,582,584,108,107,106,114,105,102,569,568,581,675,673,686,687,684,688,684,683,690,683,691,682691,694,693,714,711,170,171,722,723,722,707,708,540,539,539,538,537,457,457,468,466,469,464,470,472,473,474,703,705,541,542,543,448,447,446,441,442,443,444,436,437,430,553. **Poolabhavi:**567,2. **Virapur:**205,208,209,227,229. **Nilogal:**226,290,224,241,242,243. **HireHesrur:**115,116,53,56,58,57,47,46,45,59,48,49.	Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango **Veg:**Solanaceous, Cucurbits, Drumstick and curry,Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, curry leaf, Tomato, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	Biofertilizers and micronutrients, Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds

Proposed Land Use Class	Soil Map Units	Survey Number	Field Crops	Horticulture Crops	Suitable Interventions
LMU-6	GDNmB2 GDNmB3g1 GDNmC2 GNTmC2 KRIaB2	**Gudenal:**33,32,29,657,656,658,636,634**.** **Kota:** 651,34, 33,32. **Madrainkota:**94,95,96,97,108,55,54,112. **Nilogal:**578,109,110,113,117.	**Sole crop**; Sorghum, Bajra, Navni, Red gram, Green gram, Cotton, Maize, Sun flower, black gram, bengal gram, maize, ground nut.	**Fruit crops:** Sapota, Jamun, Guava, Tamarind, Lime, Musambhi, Custard apple, Jackfruit, Amla, pomegranate, Mango **Veg:**Solanaceous, Cucurbits, Drumstick and curry, Onion, Tomato, Brinjal, Chilli, Bhendi, Green leaf, curry leaf, Tomato, **Flowers**-Gaillardia, marigold, Chrysanthemum, lilly	Use of short duration varieties, sowing across the slope, drip irrigation and mulching is recommended Cultivation on raised beds with mulches and drip irrigation system. Drip irrigation with suitable soil and water conservation measures. Graded bunds and strengthening of field bunds

with deep root system, making it the perfect choice for the study region. Suitability evaluation for Sorghum, revealed that an area of 1033 ha (21.12%) was highly suitable (S1), 2774 ha (56.71%) area was moderately suitable (S2), 886 ha (18.15%) area was marginally suitable (S3) and 18 ha (0.36%) area was currently not suitable (N1) for sorghum, due to the severe constraints of rooting condition, erosion and texture in the sub-watershed, (Fig. 11).

Redgram is a long day crop, the Redgram suitability assessment in Medinapur sub watershed revealed that 3806 ha (77.84%) area was moderately suitable (S2) and an area covers 886 ha (18.14%) was marginally suitable (S3) and 18 ha (0.36%) area was currently not suitable (N1) due to the severe limitations of soil erosion, texture and very shallow soil depth, in sub-watershed (Fig. 12). Similar works on soil-site suitability carried out in 48A distributary of Malaprabha right bank command by Ravikumar et al*.* [23] they observed that Cotton, Wheat, Maize, Soybean, Sorghum were moderately suitable.

3.3 Estimation of Suitability of Sorghum and Redgram Using Linear Regression

Suitability criteria namely soil-depth, slope, LCC, gravelliness, and erosion for Sorghum and Redgram were subjected to linear regression with derived suitability classes. It explained the variance with R^2 = 0.746 and 0.744 for sorghum and redgram respectively. For both crops, the F test was significant at the 5% level. Therefore, the variables such as depth and pH are significantly contributing to suitability of sorghum (Equation 1, Table 5). Whereas, soil depth alone was significant at 5 per cent level for Redgram crop (Equation 2, Table 5) suitability. In common soil depth was significantly contributing to the suitability of sorghum and redgram, as increase in soil depth supports root system and increases the availability of moisture and nutrients required for crop growth [24]. Soil pH with neutral to moderately alkaline to strongly alkaline may reduce the availability of micronutrients, therefore it makes crop moderate to marginally suitable [25].

$$Y_{Sorghum} = 10.880 + 0.302^{*}depth - 0.923pH, \text{ Total DF} = 22, F = 2.93^{*}, R^2 = 0.745 \quad \text{----- Equation 1}$$

$$Y_{Redgram} = 3.325 + 0.207^{*}depth, \text{ Total DF} = 22, F = 2.91^{*}, R^2 = 0.744 \quad \text{----- Equation 2}$$

The planning and adoption of site-specific soil and water conservation practices in different soil phases will help to control the runoff, soil loss, and nutrient loss from agricultural land, therefore minimizing the land degradation. Singh et al. [26] concluded that adoption of in situ interventions such as ridge and furrow, BBF, contour cultivation, compartmental bunding and conservation furrow decreases the runoff velocity, enhances soil moisture, and recharges the groundwater. A crop plan module was proposed in this study for field and horticulture crops suitable to the soil phase units *viz*., GDNmB2, KMLmB2, KMLmB3, KMLmB3g1, KMLmC2, KMLmC3, GDNmB3g1, GDNmC2, GNTmC2 and KRIaB2. These soil-phase units require intervention using soil or land management techniques, such as mulched raised bed cultivation, drip irrigation, the construction of graded bunds, and the strengthening of existing field bunds. Remaining soil-phases namely ADBmD3, JNTmB2, JNTmC2,JNTmC3, KMThC2g1, YRDmB2 and YRDmC3 have must adopt deep and wider size pits, drip irrigation, and appropriate soil and water conservation techniques, including cultivation on raised beds with mulches, graded bunds, and strengthening of field bunds, application of FYM, bio-fertilizers, and micronutrients, as well as cultivating (Table 6). Milkias et al. [27] reported that adoption of ridge and furrow, contour ridge, and tied ridge increased the soil moisture by 134.5%, 128.5% and 121.8% and the grain yield of maize by 143.1/5, 131.4% and 121.1%, respectively, over the control treatment at Ethiopia.

4. CONCLUSION

In the Medinapur SWS the land capability classifications identified were IIIes and IVes, with restrictions on soil erosivity, texture, drainage, fertility and topography. These limitations can be taken care site specifically referring to spatial maps developed. Therefore, land evaluation using remote sensing and GIS tool eases to adopt site specific land management and also facilitate future data updation, and allows spatial analysis. Redgram and sorghum covered maximum area under current land use. Estimation of suitability criteria of sorghum and redgram showed significant F test model with R^2= 0.746 and R^2= 0.744 respectively. The result indicated that soil depth is an inextricable factor for any digital multi-criteria land suitability assessment. Soil-phase unit specific crop plan (field and horticultural crops, millets and pulses) with suitable interventions, maximize the yield and sustain the land suitability for cultivation of crops.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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