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Land suitability for major crops in Varathuru watershed in Andhra Pradesh using RS and GIS

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ABSTRACT

Agriculture is a dominant sector in Andhra Pradesh. It contributes 34 percent to the Gross domestic production, employs nearly 55 percent of the total labour force and generates the bulk of market exchange. Poor performance of the agricultural sector in relation to the fast-growing population, intensification of agriculture is the critical aim of the study to find land suitability for major crops of Varathuru watershed using remote sensing and GIS techniques. The objective is to assess the land suitability for major crops based on soil characteristics of Varathuru watershed. The depth-wise soil characteristics at soil series level used to arrive at site-soil characteristics for assessing crop suitability.The site-soil properties of soil series from the study area were matched with soil site suitability criteria for groundnut, redgram, sugarcane and rice crops that are grown in Varathuru watershed area and maps were generated by using *Arc*GIS V 10.3. Fifteen (15) soil mapping units at phase level were identified and were mapped into ten (10) soil series. The soil series VRT3 was highly suitable for growing groundnut, VRT1, VRT4, VRT5 and VRT8 soil series were moderately suitable for growing groundnut crop. VRT1, VRT3, VRT4, VRT5, VRT6, VRT7 and VRT8 soil series were moderately suitable for growing of redgram and VRT2 and VRT9 series were marginally suitable for growing of redgram crop. VRT1, VRT3, VRT4, VRT5 and VRT8 soil series were moderately suitable and VRT2, VRT6 and VRT7 soil series were marginally suitable for sugarcane growing. Whereas the soils of study area were not suitable for growing of rice crop.

Key words: *Crop suitability classification, Groundnut, Redgram, Sugarcane, Rice, Soil series, Maps*

Introduction

Projections to 2050 recommended the emergence of growing scarcities of natural resources for agriculture. Intensified competition for these resources could lead to their overexploitation and unsustainable use, degrading the environment and creating a destructive loop whereby resource degradation leads to ever-increasing competition for the remaining available resources. The world's population would reach 9.73 billion in 2050. To meet demand, agriculture in 2050 will need to produce almost 50 percent more food and feed than it did in 2012 (FAO, 2017). At the same time, modern intensive agriculture accounted for aquantum increase in crop production and ensures food security, which has also resulted in the over-exploitation and degradation of natural resources such as soil, air and water

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in India. The declining scenario in agricultural land andthe growing food demand needattention to optimized use of soil resources. Intensive and formidableland use needs a goodlevel of knowledge of soil resources to designsuitable soil management practices (Akpan-Idiok *et al*. 2016).

Timely and reliable information about soil resources is very essential regarding their nature, spatial distribution, potential and constraints. The land resource inventory process provides insight into the potentialities and constraints for efficient management of resources. It also offers to develop appropriate information on different landform distribution, cropping patterns and soil characteristics that can be used in the management and proper utilization of land resources.

The increased necessity for food production and the limited resources stimulatea need for sophisticated methods of land evaluation to aid decision-makers in their role to both preserve highly suitable lands and satisfy producer's demands for enhanced profits.

Knowledge of soil resources with respect to their spatial distribution, characteristics, potentials, limitations and suitability for alternate land uses helps in formulating strategies to obtain higher productivity on a sustained basis. The rapid evolution of satellite remote sensing and Geographic Information System (GIS) has made possible the development of new techniques for facilitating the mapping of natural resources. Remote sensing and GIS application in soil resource mapping enable the study of soils in the spatial domain, in time and cost-effective manner. Hence, to achieve sustainable crop yields the investigation was taken to know the land suitability for major crops in Varathuru watershed in Chittoor district of Andhra Pradesh using remote sensing and GIS techniques.

Materials and Methods

The study area

The study was conducted in 2018-2019 in Varathuru watershed of Chittoor district in Andhra Pradesh situated between 13° 16´ to 13° 12´ N latitudes and 79°15´ to 79° 19´ E longitudes, with an average elevation ranging from 324 to 356 m msl. The total geographical area of the watershed is about 2695.62 ha. The mean annual soil temperature was about 33.37ºC. The average rainfall in the watershed was 923.48 m. (Fig. 1)

Study method

After preliminary traversing of the entire watershed using 1:10,000 scale base map and satellite imagery based on geology, drainage pattern, surface features, slope characteristics and land use, landforms and physiographic divisions, twenty-one (21) soil profiles were selected and studied for evaluationand their morphometriccharacteristics were studied. Physical and chemical properties were estimated using standard procedures. A detailed soil resource inventory of the Varathuru watershed was carried out and a total of 15 mapping units were identified and mapped into 10 mapping series. After a detailed soil survey, crop suitability maps for major crops growing in Varathuru watershed area at soil series level were prepared by using the platform of *Arc* GIS. Their suitability was assessed using the limitation method regarding the number and intensity of limitations (Naidu *et al.*, 2006). This evaluation procedure consists of three phases.

In phase I, the data was collected in terms of characteristics as in Table 1. The following landscape and soil characteristics were used to evaluate soil

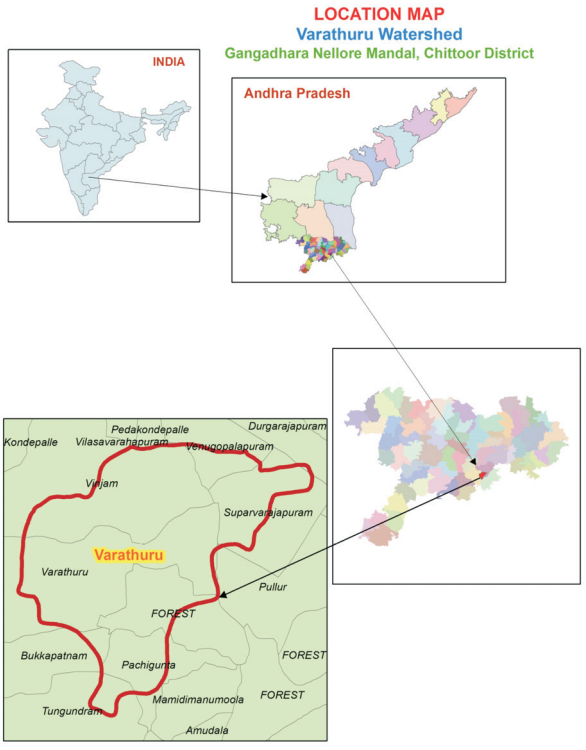

Fig. 1. Location map of Varathuru watershed in Chottoor district, Andhra Pradesh

Table 1. Site and soil characteristics of soil series for crop suitability classification

Soil series	Soil	Land form	Parent material	Wetness (W) Drainage	Physical soil characteristics (s)					Soil fertility characteristics (f)				Salinity and Alkalinity (n)	
					Texture	Coarse fragments volume (%)	Depth to solid rock or hardpan (m)	Lime content (%)	Apparent CEC [cmol (p+) kg^{-1} soil	BS (%)	Sum of basis cations [cmol (p+) kg^{-1} soil]	pH (1:2.5 H_2O)	OC (%)	EC (dS m^{-1})	ESP
VRT1	Fine loamy, mixed, iso hyperthermic, **Typic Haplustepts**	Upland	Granite - gneiss	Well drained	sc	None	0.54	3.69	23.85	81.88	24.31	6.97	0.45	0.18	1.09
VRT2	Fine loamy, mixed, iso hyperthermic, **Typic Haplustalfs**	Plains	Granite - gneiss	Well drained	scl	None	1.19	5.23	16.15	84.33	15.23	8.23	0.27	0.25	9.37
VRT3	Fine loamy, mixed, iso hyperthermic, **Typic Haplustepts**	Plains	Granite - gneiss	Well drained	sl	None	0.86	2.98	12.94	83.97	9.73	6.32	0.41	0.10	2.38
VRT4	Fine loamy, mixed, iso hyperthermic, **Typic Haplustalfs**	Upland	Granite - gneiss	Well drained	sl	None	0.57	6.06	11.20	74.48	6.09	6.30	0.32	0.29	3.83
VRT5	Fine loamy, mixed, iso hyperthermic, **Typic Haplustalfs**	Plains	Granite - gneiss	Well drained	sl	None	0.85	2.34	12.89	61.89	5.70	5.81	0.27	0.13	2.69
VRT6	Fine loamy, mixed, iso hyperthermic, **Fluventic Haplustalfs**	Plains	Granite - gneiss	Well drained	sl	None	1.41	6.06	8.35	83.57	8.22	8.15	0.27	0.23	1.40
VRT7	Fine loamy, mixed, iso hyperthermic, **Typic Ustorthents**	Upland	Granite - gneiss	Well drained	scl	None	0.52	4.64	13.92	83.43	10.69	8.23	0.42	0.40	4.29
VRT8	Fine loamy, mixed, iso hyperthermic, **Typic Ustorthents**	Upland	Granite - gneiss	Well drained	sl	None	0.70	4.72	13.10	83.06	11.76	7.85	0.33	0.25	1.88
VRT9	Skeletal, mixed, iso hyperthermic, **Lithic Ustorthents**	Slope	Hard Granite Gneiss	Well drained	gscl	35-60%	0.21	1.55	10.26	54.10	5.55	5.91	0.31	0.34	0.49
VRT10	Skeletal, mixed, iso hyperthermic, Lithic Ustorthents	Slope	Hard Granite Gneiss	Well drained	gsl	35-60%	0.18	1.55	7.01	55.19	3.87	5.94	0.23	0.22	0.39

suitability: topography (% slope), wetness (flooding and drainage), physical soil characteristics (texture/structure, % coarse fragments by volume, soil depth in cm, $CaCO_3$), soil fertility characteristics (apparent CEC (cmol (p^+) kg^{-1} clay), % base saturation, sum of basic cations (cmol (p^+) kg^{-1} soil), pH (H_2O), % organic carbon, salinity (EC, dSm^{-1}) and alkalinity (ESP). The study locations were nearly level to moderately steep sloping and had never been flooded (F0). The drainage conditions were compared with regards to texture: (a) fine and medium textured soils, and (b) coarse textured soils as per the guidelines given by FAO (1976). Soil characteristics were evaluated as suggested by FAO (1976).

In phase II, the landscape and soil requirements for these four crops were taken from Naidu *et al.* (2006) as described by Sehgal (2005).

In phase III, the land suitability under rainfed conditions has been assessed by comparing the landscape and soil characteristics with crop requirements at different limitations levels: no (0), slight (1) moderate (2), severe (3) and very severe (4) (Table 2). Limitations are deviations from the optimal conditions of a land characteristic, land quality, which adversely affect kind of land use. If a land characteristic is optimal for plant growth, it has no limitation. On the other hand, when the same characteristic is unfavorable for plant growth, it has severe limitations for land evaluation type. Thus, the evaluation was done by comparing the land characteristics with the limitation levels of the crop requirement given by Naidu *et al.* (2006) as described by Seghal (2005). The number and degrees of limitations suggested the suitability class of each soil series for a particular crop given by FAO (1976)

Results and Discussion

Groundnut crop requires an annual rainfall of 400 - 750 mm, drainage, well aeration, deep soil (80 cm) with fine sandy to

Table 2. Limitation levels of the land characteristics and land suitability classes at series level

Tentative series	Crop	Wetness (w)	Physical soil characteristic(s)			$CaCO_3$ (%)	Soil fertility characteristics (f)			Alkalinity (n)	Actual land suitability sub-class	Potential land suitability sub-class
		drainage	Texture	Coarse fragments (vol. %)	Soil depth (cm)		Sum basic cations [cmol (p+) kg^{-1} soil]	pH (1:2.5 H_2O)	OC (%)	ESP		
VRT1	Groundnut	0	1	0	2	0	0	0	1	0	S2sf	S2s
	Redgram	0	1	0	2	0	0	0	3	0	S3sf	S2s
	Sugarcane	0	1	0	2	0	0	0	1	0	S2sf	S2s
	Paddy	4	1	0	2	0	0	0	1	0	Nwsf	S2s
VRT2	Groundnut	0	0	0	0	0	0	4	2	1	Nf	S1
	Redgram	0	1	0	1	0	0	3	3	0	S3sf	S1s
	Sugarcane	0	1	0	1	0	0	3	2	1	S3sf	S1s
	Paddy	4	2	0	0	0	0	3	2	0	Nwsf	S2s
VRT3	Groundnut	0	0	0	1	0	0	1	1	0	S1sf	S1s
	Redgram	0	2	0	2	0	0	0	3	0	S3sf	S2s
	Sugarcane	0	2	0	1	0	0	0	1	0	S2sf	S2s
	Paddy	4	2	0	2	0	0	0	1	0	Nwsf	S2s
VRT4	Groundnut	0	0	0	2	0	0	1	2	0	S2sf	S2s
	Redgram	0	2	0	2	0	0	0	2	0	S2sf	S2s
	Sugarcane	0	2	0	2	0	0	0	2	0	S2sf	S2s
	Paddy	4	2	0	2	0	0	0	2	0	Nwsf	S2s
VRT5	Groundnut	0	0	0	1	0	0	0	2	0	S2sf	S1s
	Redgram	0	2	0	2	0	0	0	2	0	S2sf	S2s
	Sugarcane	0	2	0	1	0	0	0	2	0	S2sf	S2s
	Paddy	4	2	0	1	0	0	1	2	0	Nwsf	S2s

loamy texture and pH 6.5 to 9.2. Based on the criteria and degree of limitation, the overall suitability class for groundnut showed that the soil series VRT3 was very suitable (S1) with slight limitations of soil depth, pH and low organic carbon (Table 3) whereas the soil series of VRT1, VRT4, VRT5 AND VRT8 were moderately suitable (S2) with moderate limitations of soil texture, soil depth, soil pH and low organic carbon and soil series VRT6 was marginally suitable (S3) with severe limitations of soil pH and low organic carbon. The soil series VRT2, VRT9 and VRT10 were not suitable with very severe limitations of soil pH and low organic carbon. Similar results were observed by Leelavathi*et al*. (2010) and Meena *et al*. (2017).

As per analysis in the GIS environment, groundnut crop representing 119.96 ha (4.45 % of TGA) of watershed (Fig. 2) is very suitable (S1sf) with slight limitations of slope (s) and fertility (f). Furthermore, groundnut crop accounting for 922.50 ha (34.22 % of TGA) of the watershed is under moderately suitable (S2sf) class with limitations of soil such as soil depth (s), soil physical characters and fertility (f) and groundnut crop accounting 51.85 ha (1.92 % of TGA) of watershed is under marginally suitable (S3f) with severe limitations of soil fertility. Furthermore, about 1521.21 ha (56.43 % of TGA) of watershed is under not suitable (N) with very severe limitations of slope and soil physical characters. Similar results were reported by Kumar and Naidu (2012), who categorized groundnut growing soils of Vadamalapeta mandal in Chittoor district into marginally suitable category.

Redgram requires of 550-1200 mm annual rainfall, drainage, well aeration, deep soil (20 - 125 cm) with sandy to fine clay texture and pH 7.0 to 8.5. Based on the criteria and Devidegree of limitation, the overall suitability class for redgram revealed that all the soil series except VRT9 and VRT10 were moderately suitable (S2) with moderate limitations of soil texture, soil depth, pH and low organic carbon (Table 3). In contrast, the soil series of VRT9 was marginally suitable (S3) with limitations of slope, erosion, soil texture, soil depth, soil pH, low organic carbon and poor nutrient status. The soil series of VRT10 was not suitable (N) for growing redgram crop because of very severe limitations of slope, erosion, shallow rooting zone, texture, pH, low organic carbon and poor nutrient status.

As per analysis in the GIS environment, redgram crop representing about 1556.22 ha (57.73 % of TGA) of watershed (Fig. 3) is moderately suitable (S2sf) with slight limitations of soil texture, soil depth and fertility (f) followed by 836.79 ha (31.04 % of TGA) of watershed is under marginally suitable (S3sf) with severe limitations of slope (s), erosion, soil texture, soil depth and fertility (f). However, about 222.52 ha (8.25 % of TGA) of the watershed was not suitable (N) with limitations of slope (s), soil texture, gravelliness, soil depth (s) and fertility (f). Similar

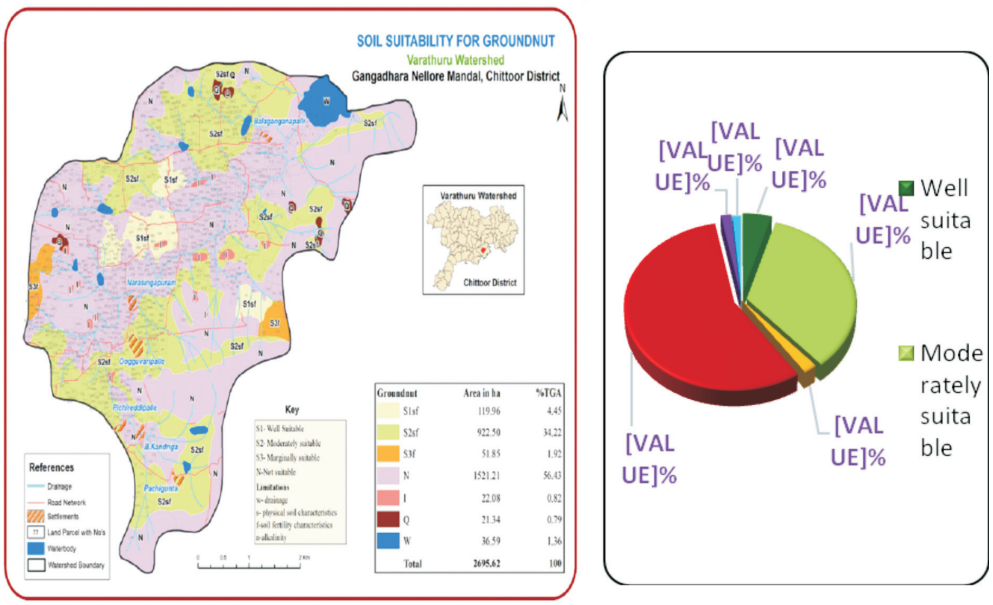

Fig. 2. Land suitability map of Groundnut in Varathuru watershed

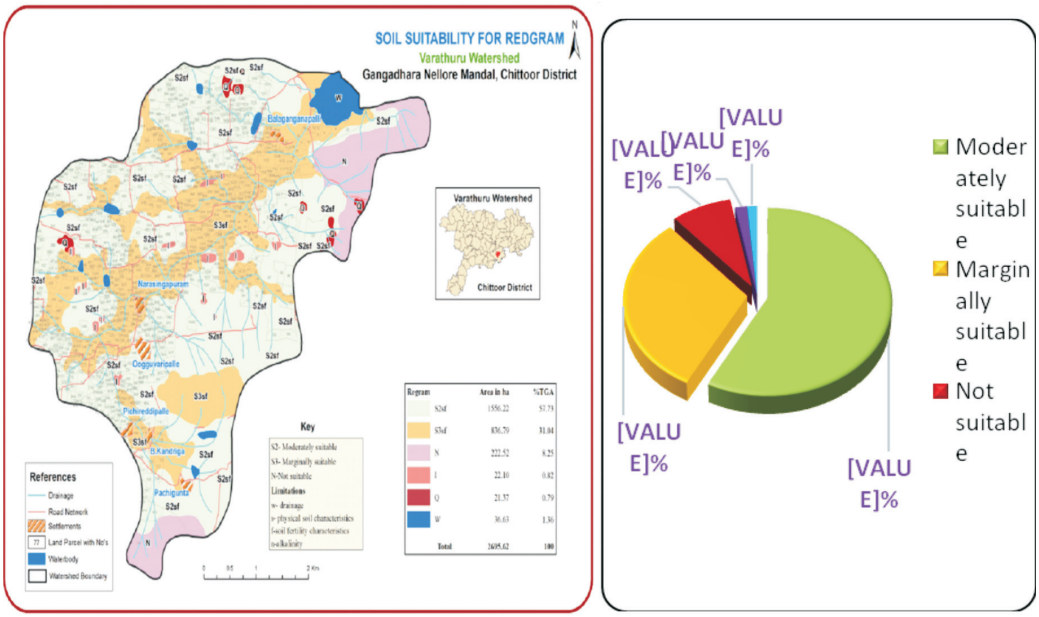

Fig. 3. Land suitability map of redgram in Varathuru watershed

findings were reported by Anilkumar *et al.* (2017), who reported that about 107 ha of Bantanahalli micro watershed, Karnataka was highly suitable and 434 ha was moderately suitable for growing redgram with limitations of gravelliness.

Sugarcane crop requires an annual rainfall of 900-1000 mm, soil depth of more than 75 cm with sandy clay loam to clay loam texture, free of salinity, alkalinity and well-drained soils. Based on the criteria and degree of limitations, the overall suitability class for growing sugarcane crop indicated that, the soil series VRT1, VRT3, VRT4, VRT5 and VRT8 are moderately suitable (S2) with limitations of texture, pH and low organic carbon, whereas VRT2, VRT6 and VRT7 were marginally suitable (S3) with severe limitations of soil texture, Soil pH and low organic carbon (Table 3). The soil series VRT9 and VRT10 were not suitable (N) for growing sugarcane crop with very severe limitations of topography, erosion, texture, gravelliness, rooting zone, pH, low organic carbon and low nutrient holding capacity.

As per analysis in the GIS platform, sugarcane crop accounts for about 1042.47 ha (38.67% of TGA) of watershed area (Fig. 4) is moderately suitable (S2sf) with limitations of texture and fertility (f), followed by about 1256.33 ha (46.61% of TGA) area is marginally suitable (S3sf) with limitations of slope (s), soil depth and fertility(f) and about 316.72 ha (11.75% of TGA) area is not suitable (N) with limitations of slope (s), texture, soil depth and fertility (f). Similarly, Abishek *et al*. (2018) reported that the sugarcane growing soils of Bharuch Taluka in Bharuch

Table 3. Crop-suitability evalution for different soil series in Varathuru watershed

Tentative soil series	Groundnut	Redgram	Sugarcane	Paddy
VRT1	S2sf	S2sf	S2sf	N
VRT2	N	S3sf	S3sf	N
VRT3	S1sf	S2sf	S2sf	N
VRT4	S2sf	S2sf	S2sf	N
VRT5	S2sf	S2sf	S2sf	N
VRT6	S3f	S2sf	S3sf	N
VRT7	N	S2sf	S3sf	N
VRT8	S2sf	S2sf	S2sf	N
VRT9	N	S3sf	N	N
VRT10	N	N	N	N

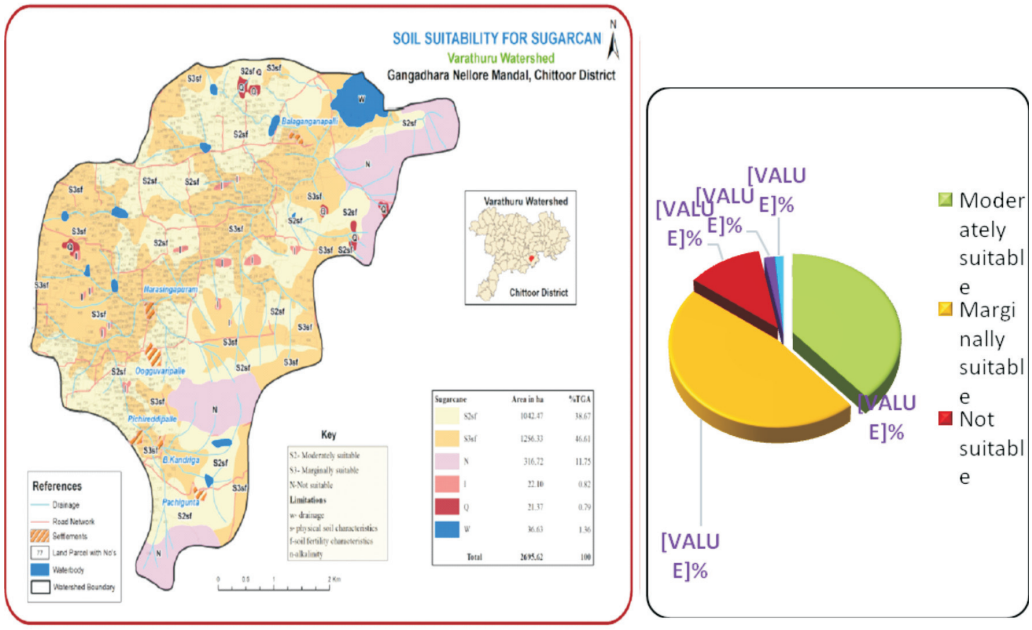

Fig. 4. Land suitability map of sugarcane in Varathuru watershed

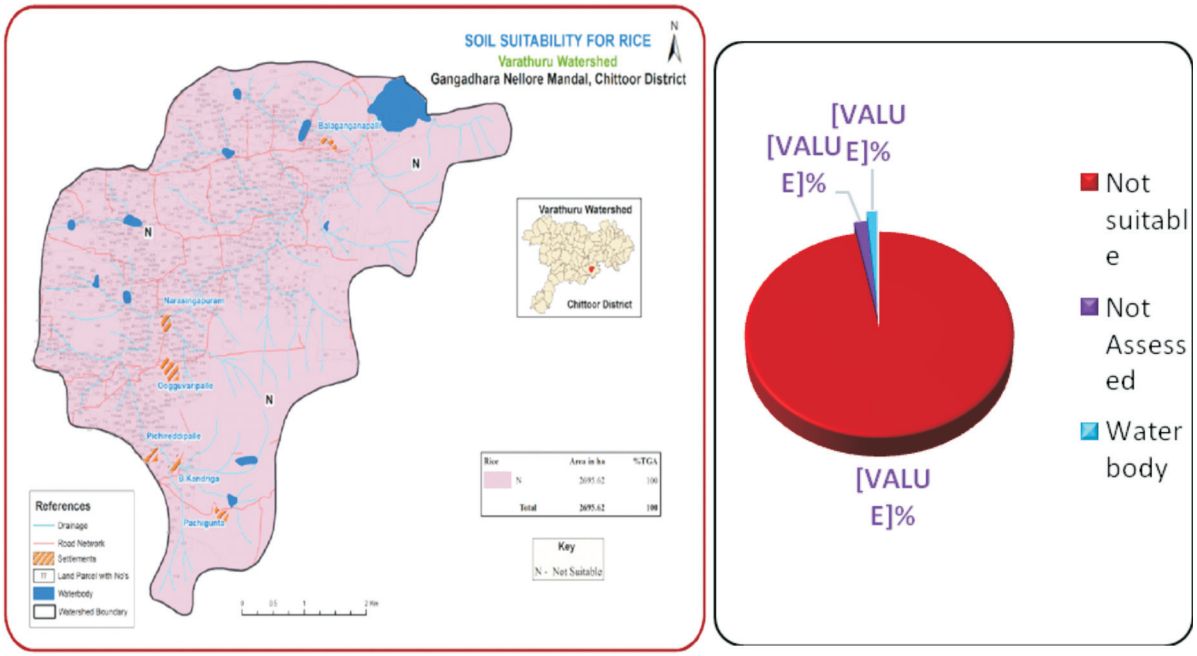

Fig.5. Land suitability map of rice in Varathuru watershed

District of Gujarat were highly variable and the major limitations were basically related to soil fertility.

The various factors that influence rice yield are texture, infiltration and permeability rate of soil which greatly influence in the selection of this crop. As it requires standing water, structureless soil after puddling is required with high clay and silt content.

Based on the criteria and degree of limitation, the soil-site suitability of soil series for rice has been worked out. All the soil series in the study area were not suitable (N) for growing rice crop (Table 3) but the soil series differ in degree and kind of limitations among these soil series. Furthermore, the soil series exhibited very severe limitations of soil texture,

drainage, slope, erosion, soil depth, low organic carbon and poor nutrient status. As per analysis in the GIS platform, rice crop representing 2695.62 ha (100 % of TGA) of watershed area (Fig. 5) is not suitable (N) with very severe limitations of slope (s), erosion, soil texture and fertility(f). Similarly, Sujatha *et al.* (2020) reported that soils of the Jammalamadugu, Proddutur tract of Pennar river basin in YSR Kadapa district in Andhra Pradesh were marginally suitable (S3) for rice cultivation with severe limitations of wetness (w), slope (s) and fertility (f).

It is concluded that the soils of watershed showed different degrees of suitability for growing groundnut, redgram, sugarcane and were not suitable for growing rice crop.The main limitations in all the soil series found to be areshallow soil depth, slope, texture, pH, poor nutrient status and low organic carbon. However, the degree of these limitations in all these soil series are varied from slight to severe. Further, integrated use of organic manures and inorganic fertilizers not only paves the way to achieve sustainable yields of crops but also sustains the soil health to future generations without undergoing deterioration and also helps in doubling the farmers income.

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