IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Geoinformatics for Agricultural Land Suitability Assessment for Sustainable Land Management in Thanjavur District, South India

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ABSTRACT

Agricultural crop land suitability assessment of Thanjavur District is the primary objective of this study. In the present study, the remote sensing and geographic information system (GIS) techniques are utilized to assess the land type suitable for crops production. The various land capability parameters are chosen such as topographic wetness index (TWI), land use and land cover (LULC), soil, drainage density, slope, aspect and geology. All these factors determine the suitability of a given area for a particular type of crop cultivation. The various agricultural crop produce in Thanjavur district are paddy, maize, wheat, potato, and oilseed etc. All the parameters were prepared and integrated with the help of weighted overlay analysis in ArcGIS software. The final suitability maps are categorized into five classes such as not suitable zone, poorly suitable zone, moderate suitable zone, highly suitable zone and Very high suitable zone. The not suitable zone cover 27 sq.km (1%), poorly suitable zone covers 292 sq.km (8%), moderately suitable zone covers 1196 sq.km (32%), highly suitable zone covers 1596 sq.km (43%) and very high suitable zone covers 624 sq.km (17%). The result revealed that only 17% of Thanjavur district falls under very high suitability class, so it is necessary to improve the soil quality parameters to sustainable agricultural practices in the study area.

Keywords: Land capability, TWI, sustainable agriculture, Weightage Overlay, Thanjavur district

1. INTRODUCTION

Land consists of physical environments such as soil, relief, climate, vegetation and hydrology that have direct effect on land use potential (FAO, 1977). Site suitability assessment of agricultural development includes the assessment of a large amount and variety of physiographic data, climatic characteristics (rainfall and temperature), internal soil condition (depth, moisture, texture, salinity and natural fertility), and external soil conditions (slope, accessibility and flooding) (Wang 1994). Perveen et al. (2007) used the parameters of soil texture, soil moisture, soil consistency, soil pH, soil drainage, organic matter content and slope in agricultural land suitability analysis. The use of the AHP method for determination of land suitability has gained popularity recently. There are different studies discussing the uses of AHP in the literature. Among them, there are studies on the land use suitability for different crops (Mustafa et al. 2011).The World Commission on Environment and Development associated land suitability with sustainable development and defined sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs (Feizizadeh and Blaschke, 2012). Geographical information system (GIS) is a useful technique to investigate the multiple geospatial data with precision and higher flexibility in land suitability analysis (Mokarram and Aminzadeh, 2010; Mendas and Delali, 2012).

Akinci et al (2013) studied the agricultural land use suitability analysis is using GIS and AHP technique in the Yusufeli district of Artvin city (Turkey). The parameters of great soil group, land use capability class, land use capability sub-class, soil depth, slope, aspect, elevation, erosion degree and other soil properties were used. In determining the weights of the parameters, experts' opinions were consulted, and the agricultural land suitability map generated was divided into 5 categories according to the land suitability classification of the United Nations Food and Agriculture Organization (FAO, 1977).The development of agriculture will not only improve the rural economy but also promote the diversification of poor farmers and rural tourism that can prevent the migration activity of poor people from hilly areas to the plain lands (Boori et al. 2014). Moreover, the very small land is available for agricultural development in the study area because of high variation in elevation and abundance of natural resources. Pramanik (2016) have analyzed site suitability for agricultural land use of Darjeeling district using AHP and GIS techniques. Bera et al (2017) discussed the land suitability analysis for agricultural crop using remote sensing and GIS in Purulia District.

The world population is constantly increasing, from 1.6 billion in the early 1900s to 7.6 billion nowadays (PRB, 2018). With the increase in population, people have started to use lands more and more for their basic needs. So, agricultural, pasture and forest lands are constantly degraded. For this reason, land use types are being changed due to misuse of land. Everest et al (2021) determined the agricultural land suitability with a multiple criteria decision making method in Northwestern Turkey. The identification of suitable lands which is having the highest productivity as well as highest net profit on lesser input is expected and prioritized in the plain areas. So, the suitability analysis of agricultural land is an appropriate and strong method for the plain areas. The main objectives of the study are to identify the suitable lands for the agricultural development using GIS and weighted overlay process in the study area.

2. STUDY AREA

Thanjavur district is located between 9º 50' and 11º 25' North latitude and 78º 45' and 79º 25' East longitude (**Fig.1).** It is bordered by Tiruchirapalli and Cuddalore districts on the North, and Tiruvarur and Nagapattinam districts on the East, Palk Strait and Pudukottai district on the South, Pudukkottai and Tiruchirapalli districts on the West. The total geographical area of the district is 3,602.86 sq.km. This is only 2.77 % of the area of Tamil Nadu.

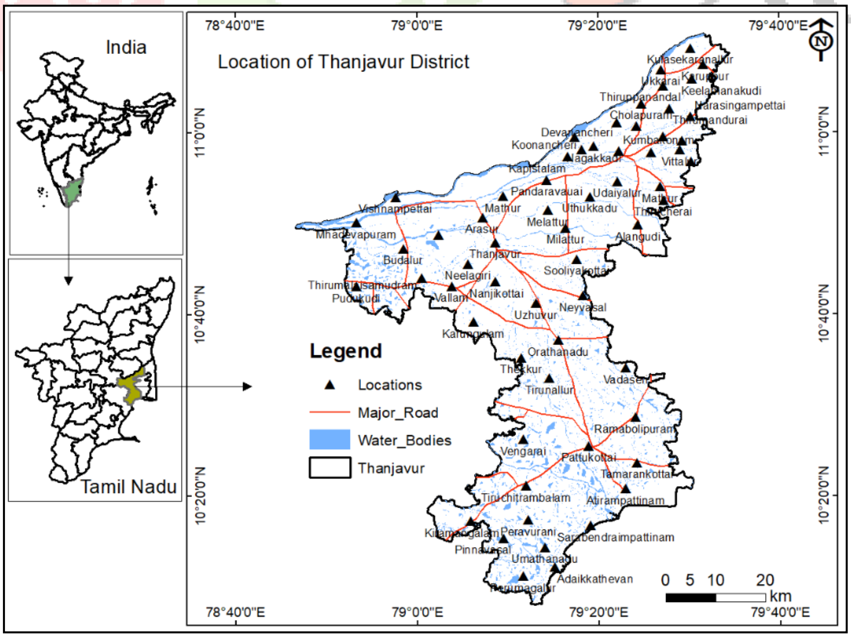


Fig. 1: Location of Thanjavur District

3. METHODOLOGY

In the present study multi-criterion, site suitability modeling was developed to establish appropriate and potential locations for agricultural development based on a group of constraints and criteria. Depending on their significance and importance in the agriculture seven different constraints and criteria were selected. The identification of different criteria depended on maximum limitation method that influences the product yield of agriculture which includes topographic wetness index (TWI), land use and land cover (LULC), soil, drainage density, slope, aspect and geology. The IRS P6 LISS III satellite data were utilized to generate land use land cover. Geology map prepared using GSI report. Soil order map were developed using soil survey information. Topographic parameters were examined in three categories. These are slope, elevation and aspect. Slope and aspect were derived from the SRTM data with 30 m spatial resolution. The methodology adopted in the present study is shown in **Figure 2.**

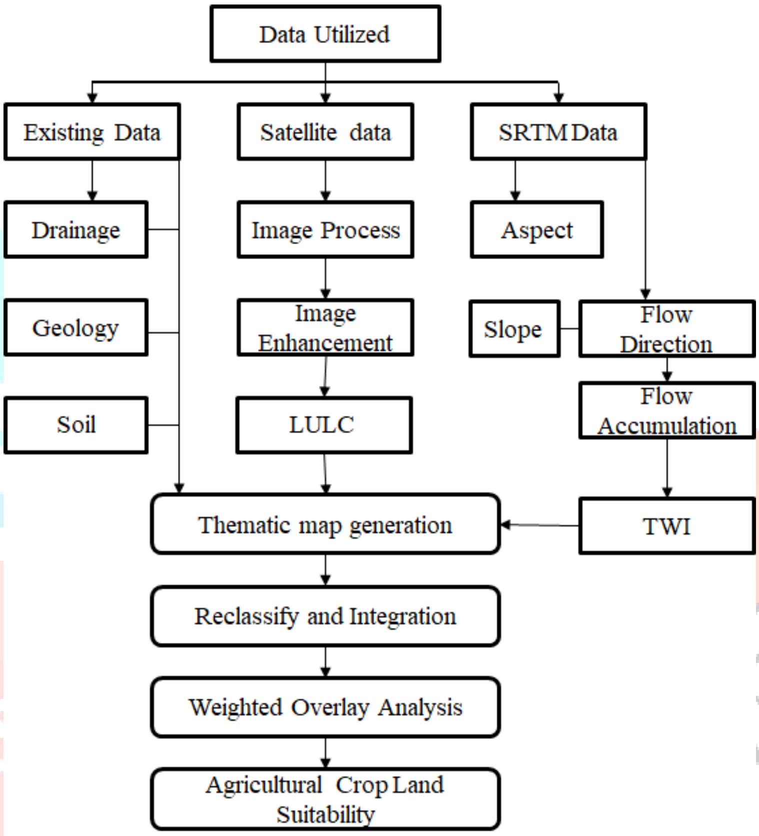


Fig. 2: Methodology adopted in the present study

3.1 Calculation of Weighted Value

The weighted value computed help of multi influence factor (MIF) method, with assigning the distinctive parameters, topographic wetness index (TWI), land use and land cover (LULC), soil, drainage density, slope, aspect and geology **(Fig.3).** The impact of each major and minor factor is assigned a weighted of 1.0 and 0.5 separately as appeared in (Table 1). The combined weighted of both major and minor impacts are considered for calculate the relative rates. This rate is additionally used to calculate the value of each impacting factor. The proposed score for each influencing variable is calculated by utilizing the formula;

$$Wt = \frac{(A+B)}{\sum(A+B)} \; x\, 100 \qquad (1)$$

Where, A is the major interrelationship between two elements and B is the minor interrelationship between two variables. The concerned score for each affecting component was partitioned similarly and allocated to each reclassified factor.

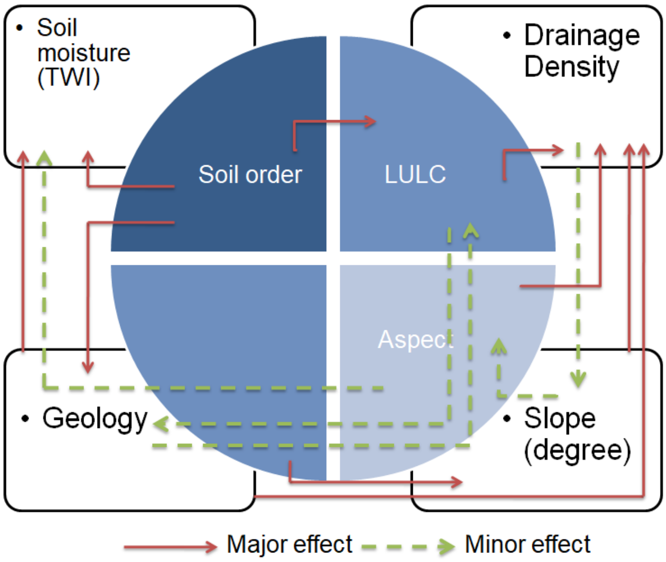


Fig.3 Interrelationship between the multi-influencing factors concerning the land capability

Table 1: Effect of influencing factor, relative rates and score for each Potential factor (Magesh et al. 2012)

Factor	Major effect (a)	Minor effect (b)	Proposed relative rates (a + b)	Proposed score of each influencing factor
Topographic wetness index (TWI)	2	0	2	13
Land use and Land cover (LULC)	2	1.5	3.5	22
Soil Order (SO)	4	0	4	25
Drainage Density (DD) (km/sq.km)	1	0.5	1.5	9
Slope (Degree) (SL)	2	0.5	2.5	16
Aspect (AS)	1	0.5	1.5	9
Geology	1	0.5	1	6
		Total	**16**	**100**

3.2 Factors influencing Land capability

3.2.1 Topographic Witness Index (TWI)

Topographic Witness Index (TWI) has been widely used to explain the impact of topography conditions on the location and size of saturated source zones of surface runoff generation. Recently, TWI has been used for groundwater potential mapping (Davoodi Moghaddam et al. 2013; Nampak et al. 2014) and describing spatial wetness patterns (Pourghasemi et al. 2012a; Pourtaghi and Pourghasemi 2014). It is defined as (Moore et al. 1991):

$$TWI = In\left(\frac{A_s}{tan\beta}\right) \quad (1)$$

where, A_S is the cumulative upslope area draining through a point (per unit contour length) and β is the slope gradient (in degree).

In this study, TWI map is grouped into four classes using quantile classification scheme (Tehrany et al. 2014) **(Fig.4).** The tendency of water to accumulate at any point in the catchment (in terms of α) and the tendency of gravitational forces to move that water down slope (indicated in terms of tan b as an approximate hydraulic gradient) are considered by the ln β tanα index. Primarily, the water infiltration depends upon material properties such as permeability and pours water pressure on the soil strength.

3.2.2 Land Use/Land Cover

Land use capability classification is a fundamental argument which shows the agricultural production suitability of lands. In other words, land uses capability classification allows easier comprehension of a land survey (Everest et al., 2017). The five class of LU/LC presence in this study area in particular, agricultural land, water bodies, built-up land, current fallow land and grass land **(Fig.5).**

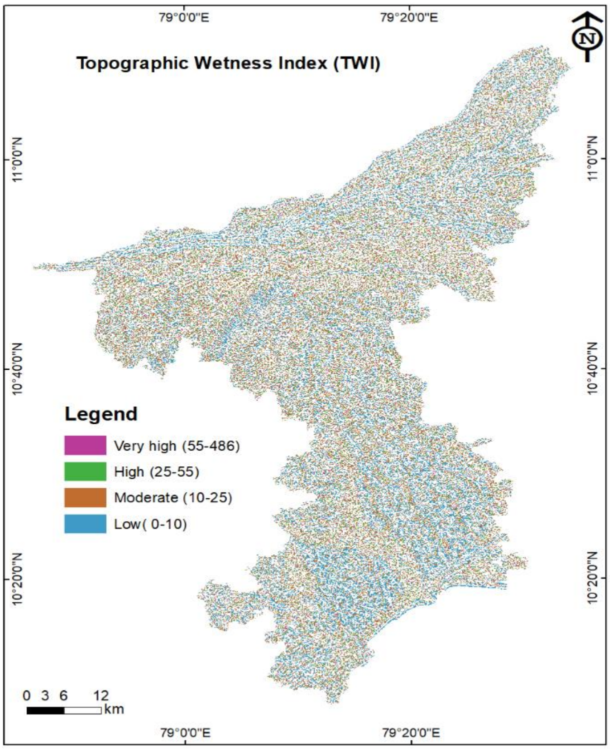


Fig.4: Topographic Wetness Index (TWI) in the study area

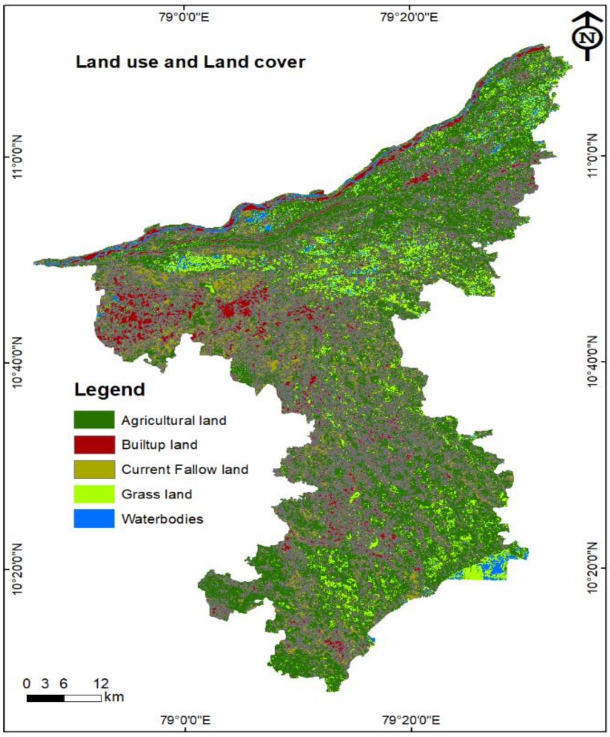


Fig.5 Land use and Land cover in the study area

3.2.3 Soil

The normal development of soil is closely related to the topography of the area–in other words, with geomorphological properties. The thickness of the soil layer decreases with increasing slope and increases with decreasing slope (Atalay, 2006). The soil map found seven major soil types found in the district, they are alfisols, vertisols, entisols, inceptisol, reserved forest and swamp **(Fig.6).** The alfisols is most appropriate for agricultural crop. The crops grown are rice, wheat, maize etc. Wheat is the major Rabi crop become both as flooded and rain encouraged conditions.

3.2.4 Drainage

Drainages are very important for agricultural practices. Drainage density map is developed using drainage map in GIS platform using density line tool. The drainage density output map were classified into five groups such as very low to very high density **(Fig.7).** Up to 1 km from the river is extremely positive for growing crops in view of the presence of irrigational water.

3.2.5 Slope

Slope is an important factor for agriculture. Slope degree has a direct effect on soil depth, susceptibility to erosion, soil tillage, use of agricultural machines, irrigation, plant adaptation, etc. The 0-0.35 degree of the slope demonstrates the flat zone which is reasonable land for developing agriculture. 0.35-1.05 degree of the slope has some Steepness and is respectably reasonable for growing crop. 7.03-90 degree range of slope is the higher slope where upon it is not appropriate to develop growing crop because of surface run off of the rainfall water **(Fig.8).** Slope degree is the main factor determining erosion control (Koulouri and Giourga, 2007). The amount of materials carried away with erosion increases with the increasing degree of slope. Accordingly, with an increase in slope degree, the development of soils occurs slowly (Atalay, 2006), and soil depth and fertility decrease.

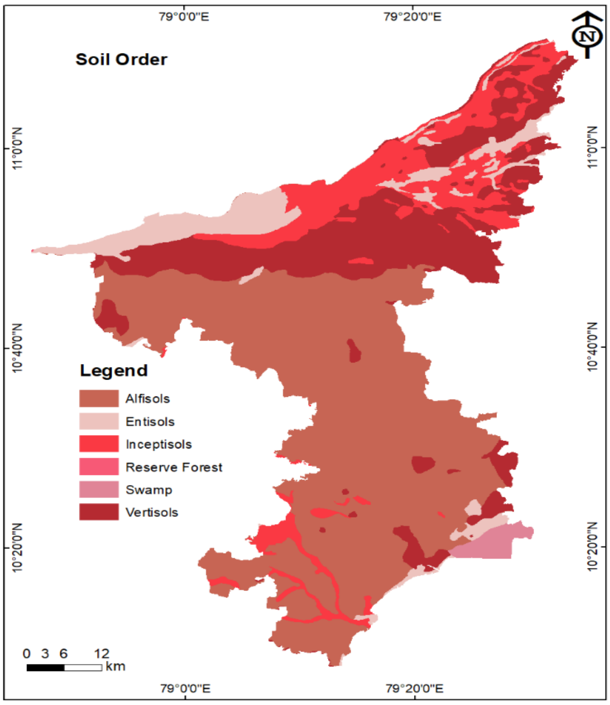


Fig.6: Soil Order in the study area

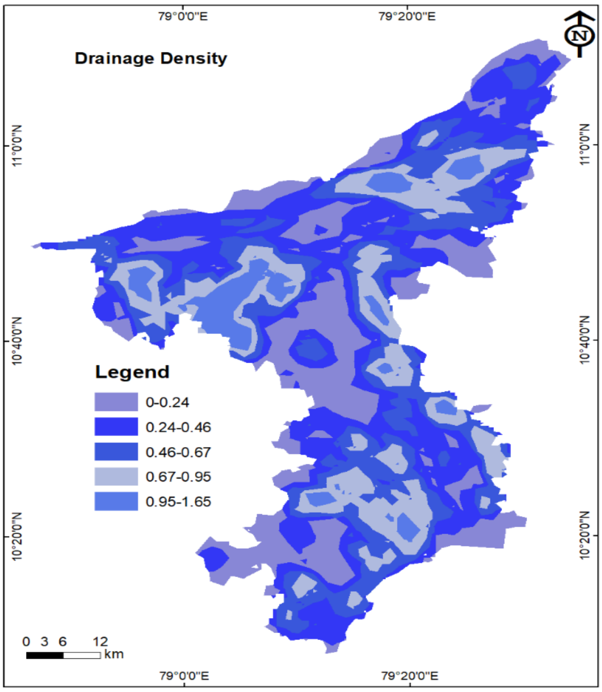
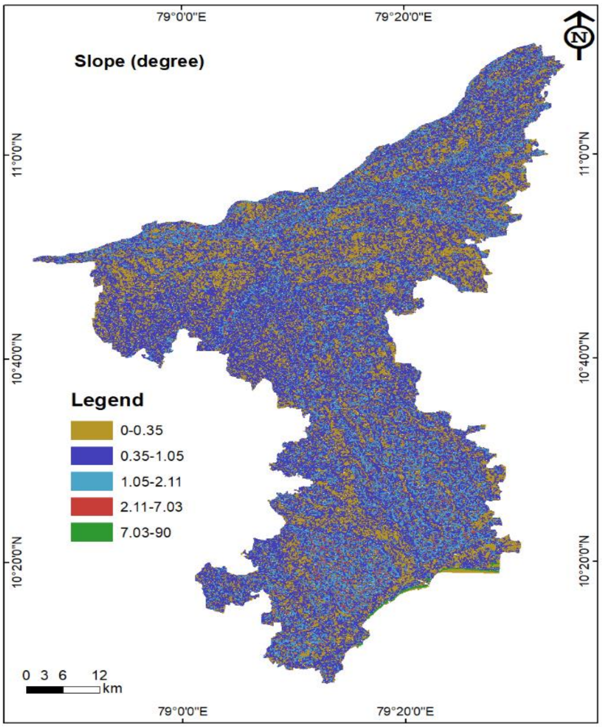


Fig.7: Drainage Density in the study area

3.2.6 Aspect

Aspect is one of major elements in crop production. Aspect causes ecosystem changes. It is associated with plant variety, distribution of plant species, vegetation period and crop yield. Plants need sunlight, so they can perform their physical and metabolic activities. When plants benefit from sunlight, they germinate, develop their organs and give fruit (Bale et al. 1998; Yimer et al. 2006). The data based on the aspect in the study area are presented in Table 2.The overall part of the region is mostly in the southwest direction, while the western part of the Thanjavur district has mainly northwest direction in terms of aspect. The northern part of the study area has essentially has northeast direction **(Fig.9).**



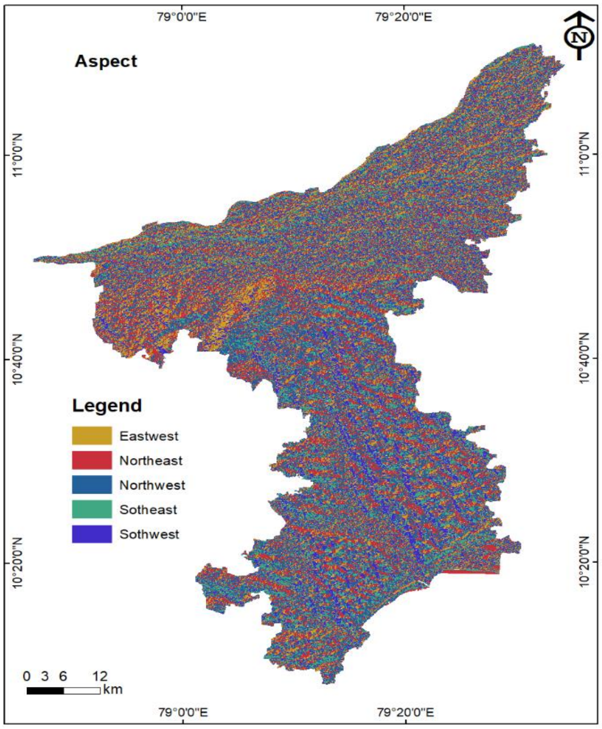


Fig.8: Slope (degree) in the study area **Fig.9: Aspect of the study area**

3.2.7 Geology

The district is covered by mostly sedimentary and alluvial rocks. The minor rocks of widespread occurrence in the district are granites and granite. The geology map of Thanjavur district is shown in **(Fig.10).**

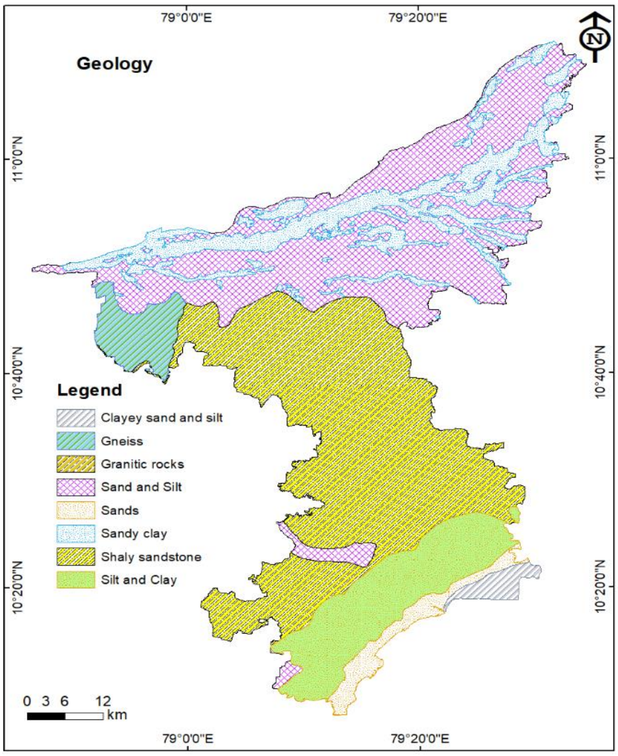


Fig. 10 Geological features of the study area

3.3 Calculation of agricultural land suitability

Vector weighted overlay analysis model were used in the calculation of agricultural land suitability. A model was created in the model builder on ArcGIS to perform overlay analysis. The vector maps and resulting scores were imported into the model. By combining the suitability and weighted values of the criteria in GIS, the suitability values for each class were calculated. Agricultural land suitability analysis was calculated with the equation given below (Zhang et al. 2015).

$$S = \sum_{i=1}^{n} (Wi.Xi) \quad (2)$$

In this formulation, S is total land suitability score; Wi is the weighted value of the land suitability criteria; for the sub-criteria score of Xi i is land suitability criteria; and n is the total number of land suitability criteria. The final land suitability map was created by means of weighted overlay analysis. The resulting map was reclassified for FAO (1977) based on the suitability analyses. The final suitability map was classified into five classes. In this classification, S1 indicates land which is highly suitable for agriculture with no limiting factors, S2 indicates land which is moderately suitable for agriculture with some limiting factors, S3 indicates land which is marginally suitable for agriculture with severe limiting factors, and N indicates land which is not suitable for agriculture. The agricultural crop land suitability delineate utilizing weighted overlay analysis in the wake of allocating weighted an incentive through MIF technique **(Table 2).**

Table 2: Effect of land influencing Factor, Relative Rates and Score for each factor

Sl.No.	Theme	Sub-class	Rank	Weight	Score
1	Topographic Wetness Index (TWI)	Very high (55-486)	4	13	52
		High (25-55)	3		39
		Moderate (10-25)	2		26
		Low (0-10)	1		13
2	Land use and Land cover (LULC)	Agricultural land	5	22	110
		Built-up land	1		22
		Current fallow land	4		88
		Grass land	3		66
		water bodies	4		88
3	Soil Order (SO)	Alfisols	5	25	125
		Entisols	4		100
		Inceptisols	3		75
		Reserve Forest	1		25
		Swamp	1		25
		Vertisols	2		50
4	Drainage Density (DD) (km/sq.km)	Very low (0-0.24)	1	9	9
		Low (0.24-0.46)	2		18
		Moderate (0.46-0.67)	3		27
		High (0.67-0.95)	4		32
		Very high (0.67-1.65)	5		45
5	Slope (Degree) (SL)	0-0.35°	5	16	80
		0.35-1.05°	4		64
		1.05-2.11°	3		48
		2.11-7.03°	2		32
		7.03-90°	1		16
6	Aspect (AS)	East west	1	9	9
		Northeast	3		27
		Northwest	1		9
		Southeast	4		32
		Southwest	3		27
7	Geology (GL)	Clayey sand and silt	5	6	30
		Gneiss	1		6
		Granitic rocks	2		12
		Sand and silt	4		24

		Sands	3		18
		Sandy clay	4		24
		Shaly sandstone	5		30
		Silt and clay	4		24

4. RESULT AND DISCUSSION

The land suitability zones of this study area can be classified into five classes, specifically, not suitable, poor suitable, moderately suitable, highly suitable, and very high suitable zones **(Fig.11).** The Not suitable zone cover 27 sq.km (1%) found in Budalur, Pudukudi, and Thirumalaisamudram, poorly suitable zone covers 292 sq. km (8%) found in near Atirampattinam, Mattur, Devamakuruchi, Moderately suitable zone covers 1192 sq.km (36%) found in northern part of Thanjavur block, southern parts of Pattukkottai block, Highly suitable zone covers 1596 sq.km (43%) found in northern and central part of the study area and Very high suitable zone covers 624 sq.km (17%) found in Central and southern part of the total study area (Table 3). Paddy crop is useful for developing in the highly suitable zone. The oilseed is the better decision to develop in the moderately suitable zone of the study area. In the low suitable region of Thanjavur district, it is preferable to grow wheat.

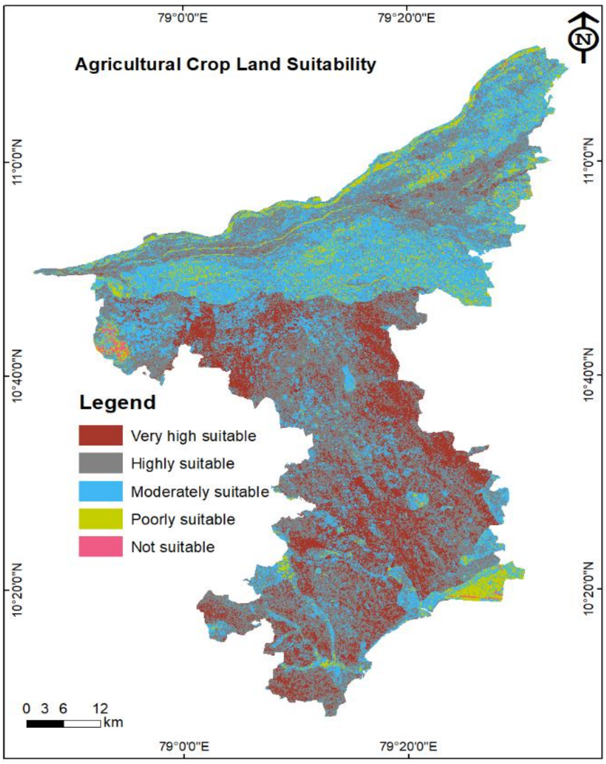


Fig. 11 Agricultural Crop Land Suitability of the Thanjavur District

In addition, the extent to which the present agricultural lands correspond with the suitability map and how they will be affected by the drainages were determined in this study. Examining the agricultural management plan of the study area shows that only 17% of the area is currently used for agricultural activities. Highly suitable lands for agriculture are the most suitable lands for agricultural production. These lands have the highest potential for agricultural production. Urbanization is the major problem with these lands. Many researchers pointed out that agricultural areas are destroyed due to urbanization (Ricketts and Imhoff 2003; Chen 2007; Everest 2017).

Table 3: Land suitability level and their land characteristics

Sl. No.	Suitability class	Area (Sq.km)	Area in %	Land qualities/characteristics	Remarks
1	Not suitable (N1)	27	1	Flat slope, with reserved forest and swamp, barren land no drainage availability	The land is not suitable for agriculture, areas under dense vegetation, barren rocks, open rocks are not suitable for agriculture
2	Poorly suitable (N2)	292	8	Less slope, less soil moisture with low elevation entisols low drainage density	Less suitable land for agriculture with careful farm management, necessary protection from drainage and intensive erosion
3	Moderately suitable (S3)	1196	32	Gentle to stiff slopes, with micro terracing, medium soil moisture with lower elevation, vertisols, moderate drainage capacity	Suitable for agriculture, favorable area for agriculture if irrigation facilities are available
4	Highly suitable (S2)	1596	43	Gentle to steep slopes with gullies, high soil moisture with lower elevation, entisol soil good drainage capacity	Favorable for agriculture if irrigation facilities are available
5	Very high suitable (S1)	624	17	Gentle slopes with gullies, high soil moisture with lower elevation, alfisol soil good drainage capacity	Most suitable for agriculture, favorable area for intensive agriculture if irrigation facilities are available
Total		**3735**	**100**		

5. CONCLUSION

The aim of this study was to determine to find alternative areas suitable for agriculture using remote sensing and GIS. The point of this study was primarily focused on the identification of the suitable land for agriculture crop in the Thanjavur district which is mostly covered by vegetation cover. Geographic information system (GIS) is used for the assessment in which seven distinct parameters were chosen. The MIF technique was built up for the recognizable proof of their reasonable site for agricultural crop. At the end of the evaluation, it was computed that 17% of the area sis suitable for agriculture crop production. In any case, the problems of the low production caused by land use characteristics, such as very low elevation, a high degree of slope, less soil moisture, the presence of bare rocks, and low availability of the irrigation system. The outcomes can be more exact by basically dissecting the strategies and methods used. The study likewise involves the physical properties only and need to incorporate the financial and social criteria for the farming generation. The use of high resolution satellite image will help in assessing better area. Additionally, the distinguished area must be reported on ground level with some other neighborhood and territorial parameter before the last usage. In the study,1% of the not suitable land is used for agricultural practice. It would not be an economically wise decision to perform agricultural production in these lands due to improper management techniques causing erosion. Fruit orchards are widespread in the areas both marginally suitable and not suitable for agriculture.

6. Acknowledgement

The author would like to thank Professor and Head, Department of Industries and Earth Sciences for supporting to complete this work.

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