



Site Suitability Analysis for Agricultural land using Spatial Information Techniques; A Case Study of Sankrail and Gopiballavpur II Block, Jhargram District, West Bengal, India

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Abstract

Agricultural land suitability analysis is a prerequisite for sustainable agriculture. In that process geo environmental parameters and the expertise of computer scientist to analyze and interpret the information is required. It involves evaluation criteria, ranging from soil fertility, communication, infrastructure, irrigation facility, agricultural land etc. The inappropriate use of land without suitability analysis may lead to ecological, economic and social problem. Multi-criteria decision making techniques like ranking and rating are used for suitability analysis with the help of Remote Sensing (RS) and GIS techniques. In this work using the high resolution Sentinel 2B optical data and also used Google Earth Engine (GEE) for extract agriculture land. The present study highlights the land suitability analysis and socio economic status of some places of Sankrail block and Gopiballavpur-II block, Jhargram District, West Bengal, India. Its main feature was to support of GIS capabilities that converted the map on digital format. Different Geo-environmental, socio economic development and infrastructural criteria like agricultural land, road, infrastructure (market, bank), fertility map, and irrigation were considered to match the local environmental conditions for land suitability analysis. The support of expert knowledge through on spatial tools to derive criteria weights with the use of their relative importance by using pair-wise comparison method technique was also used. Then the weighting sum techniques were applied to analyze the suitable land for agriculture.

Keywords: Multi-criteria decision making, Sentinel 2B, Google Earth Engine (GEE), Socio-economic development and Geo-environmental.

1. Introduction

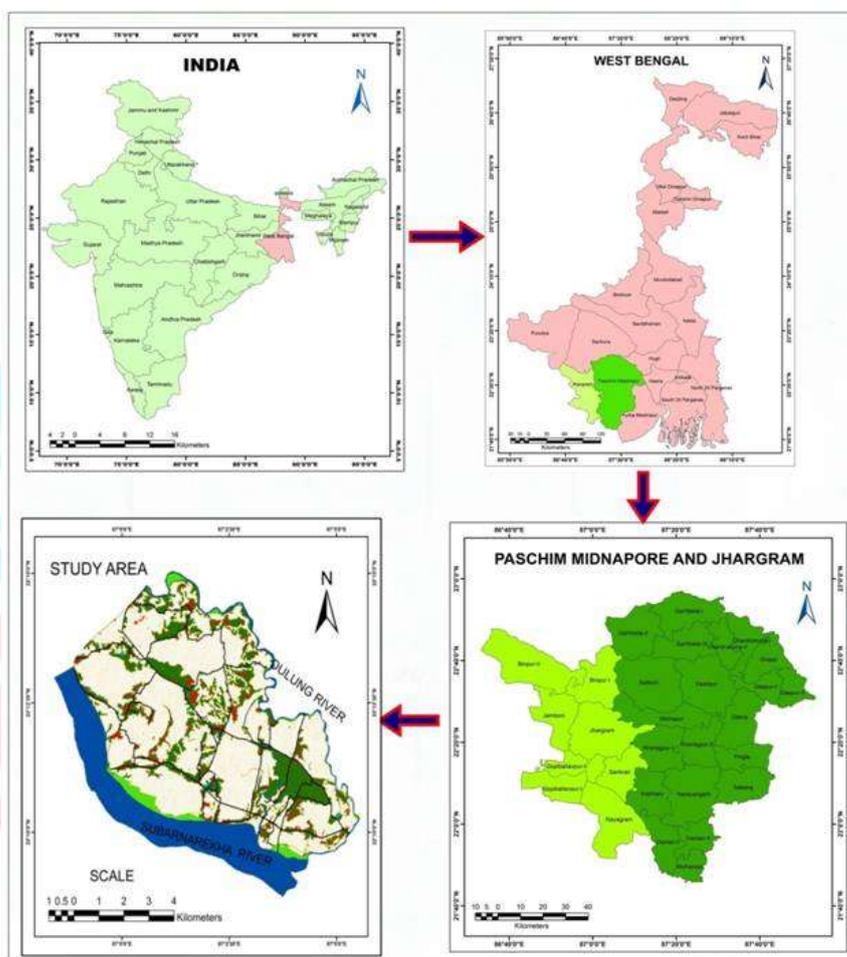
Agriculture, being the most primitive occupation of the civilized man, started its development starting from shifting cultivation to advance precision farming (Chacón, 2015; Rosa, 2004). With the advancement of the civilization and technology man came to know more crops needed and started to cultivate many crops. Now a day's agriculture becomes a profession commercial agriculture and precision agriculture. In recent decades sustainable agriculture started to save the environment and to save the world (Bazgeer, 2007).

Nowadays, demand of food increases and the farmer produces more and more crops. But it is impossible to bring more area under cultivation so farming community try to produce more crops to available land of cultivation (Rosa, 2009). The farmers also use more pesticide, fungicide and chemical fertilizer to produce more crops in a small piece of land. To produce more and good quality of food man has to concern about sustainable farming and organic farming because it balanced nutrition quality of land, good productivity and also mankind health. In land suitability analysis GIS and Multi criteria decision analysis (MCDA) technique used by expert system (He, 2011). This tool was required for spatial database management. Geographical Information system or GIS, which is a tool for collecting, storing and retrieving at will transforming and displaying spatial data for particular set of purposes can provide all desirable requirements (Elsheikh, 2013). For the land site suitability analysis

environmental, social and economic criteria is needed. Aim of the study based on the agricultural site suitability analysis using GIS and MCDA (Malczewski, 1996). As this process incorporates expert knowledge and judgment of decision makers at various levels, this process varies with the experts' knowledge and environment of study (Johnson, 1991).

2. Location

The study area presented the inter-fluvial region of Subarnarekha River and Dulung River, which presented some areas of Sankrail Block and Gopiballavpur-II Block in the district of Paschim Medinipur, West Bengal, India. The total area of the study area is 80.0670107 Sq. km. The study area bounded between 22°09'57.84"N to 22°14'6.95"N Latitude and 87°05'18.46"E to 86°59'51.02"E Longitude. This presented study area spread over the places of Rohini, Rogra, Bahradanri, Kukhrakhupi, Andhari, Mahapal and Goalmara.



3. Materials and Methods

To execute the present study and to fulfil the objectives and goals different data sets are used. This project uses Google Earth from Google, Cartosat DEM data from Bhuvan, NRSC, India, Sentinel 2B from ESA, and also using Google Earth Engine for extract agriculture land. In this Present study project mainly based on the field survey data.

This project based on the field data collection. Random sampling techniques are used to complete data collection in a short period of time. Field visits are continued to 30 days. During field survey used GPS, pH meter instruments. Socio economic data lift irrigation point data, presents of Bank and Market point data, Soil sample data etc are collected during field survey.

Methodology is the systematic and theoretical analysis of the methods applied to a field of study. The methodology is the general research strategy that outlines in which way research to be undertaken and in which method is to be used. It also describes various stages and steps involved for collecting data or information. Methodology of this dissertation involved various steps that are listed below-

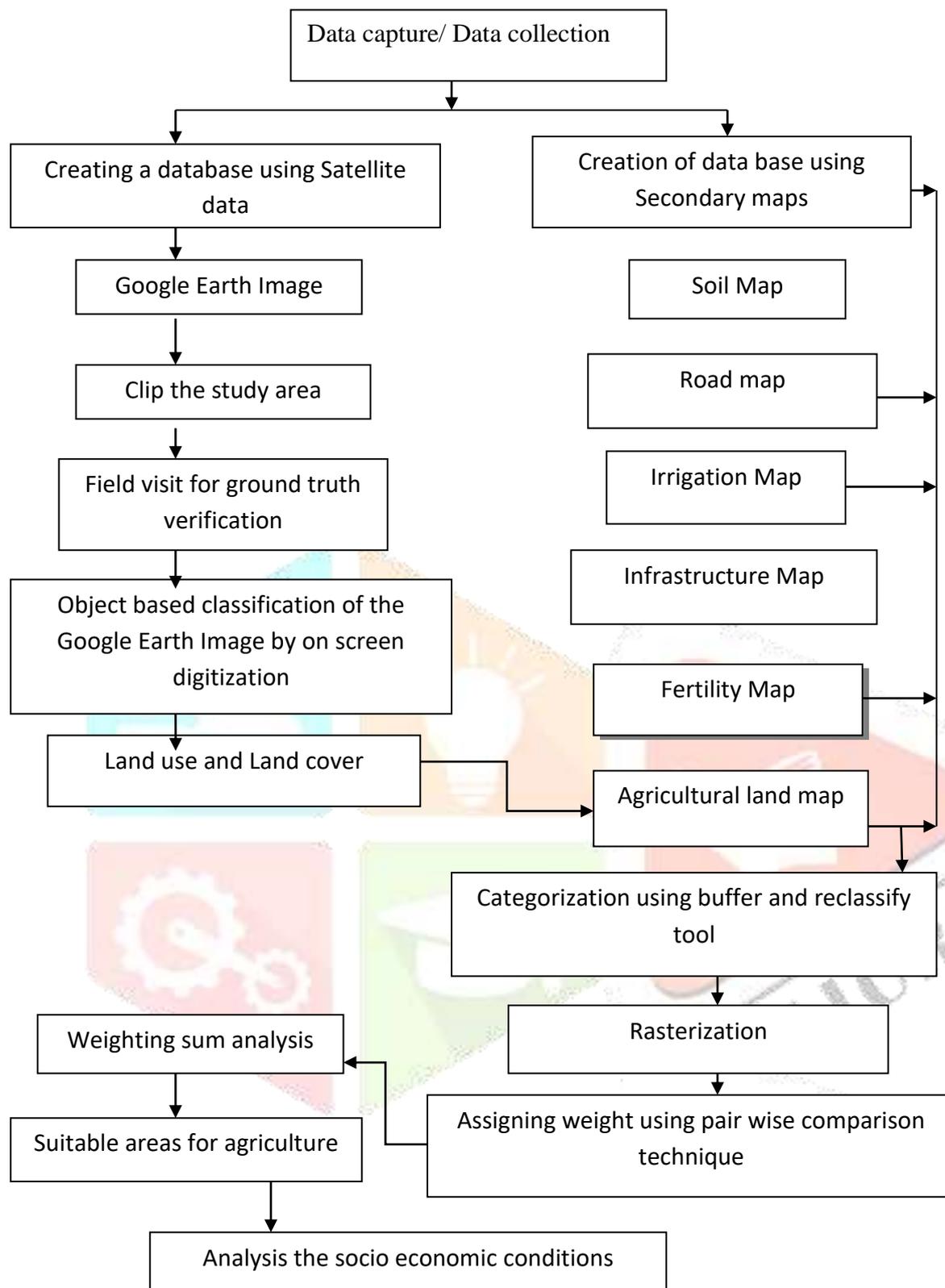


Fig 2: Flow chart of the work

4. Classification technique

In this study classification of land use and land cover are required to know the present status of land. In Remote Sensing and GIS many classification technique are used like Maximum likelihood, support vector machine, neural network analysis, object based classification technique etc. Here in this study applied object based classification technique (Adeel, 2010). In the time of object based classification used Google earth image data by on screen digitization technique. In this classification technique required ground truth verification to proper identification of objects (Marinoni, 2004). In this study area 7 types of land use feature found these are agricultural land, vegetation, Scrub vegetation, settlement, River, Water body and industry.

5. Spatial multi criteria decision making (SMDM)

The spatial multi criteria decision making (SMDM) and GIS spatial decision problems typically involved and large set of alternatives and multiple conflicting evaluation criteria. The increasing trend of spatial decision problems give opportunity to GIS based spatial multi criteria decision analysis (Bojorquez, 2001). In spatial multi criteria decision making both GIS and Multi criteria decision making acts as inseparable component, where GIS techniques and procedure have an important role in analyzing decision problems (Store, 2001). On the other hand Multi criteria decision making provides a rich collection of techniques and procedure for structuring decision problems and designing, evaluating, and prioritizing alternative decision. Spatial multi criteria decision making can be thought of as a process that transforms and combine geographical data and decision maker preference to obtain information for decision making (Mendas, 2012).

5.1. Selection of evaluation criteria

Evaluation criteria depend on goal and objectives of project. In GIS environment to analyze a multi criteria decision problem, a set of criteria selected for decision making to contribute the final goal (Butt, 2015). The development of possible location for good agricultural cultivated land depends on different factors. These factors include physical, environmental and socio economic parameter. First of all the data should be collected according to needed to meet all of the criteria. The evaluation criteria are selected to use for suitable agricultural land analysis. The evaluation criteria are must be related to geographical entities and relation between them that they can be easy to presented thematically (Prakash, 2003). The selection of evaluation criteria is iterative in nature. The following evaluation criteria are selected for land suitability analysis.

- a) Agricultural land
- b) Lift irrigation
- c) Transport facilities (Road)
- d) Infrastructure (Bank and Market)
- e) Fertility map

5.2. Multi criteria evaluation

The main process of decision making is to evaluation of the criteria. Criteria are evaluated according to the objectives. The both use of GIS and Multi criteria analysis method criteria are potentially analyzed and easy for obtaining agricultural land suitability analysis. Evaluation of multi criteria the decision maker used different framework. Here is one of this.

Table No. 1: Hierarchical organization of the criterion

Goal	Criteria	Alternatives
Multi criteria agricultural land suitability analysis	1. Agricultural land	1. Extreme suitable zone
	2. Infrastructure	2. Suitable zone
	3. Transport facilities (Road)	3. Moderately Suitable zone
	4. Lift Irrigation	4. Less suitable zone
	5. Fertility	5. Unsuitable zone

5.3. Assigning criteria weights

The weights of the decision making criteria are calculate in pair wise comparison technique. It is widely used in multi criteria decision making. It first established by Satty in 1960. In criteria analysis it's called analytical hierarchy process (AHP). This process the following operations

- Calculate sum value of each column.
- Normalization of the matrix by dividing each element of column row.
- Compute the mean of the elements in each row matrix.
- Then compute consistency ratio, $CR = \text{Consistency index}(CI) / \text{Random Index}(RI)$

$$CI = \frac{\lambda - n}{n - 1}$$

Where,

λ = Sum of the products between priority vectors and column total.

N = No of criteria

Random index or RI is fixed. Its calculate using no of criteria.

Table No. 2: Random consistency ratio

N (No of criteria)	Random index (RI)
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

5.4. Aggregating criteria weights and standardized criterion maps

In this study criteria weights and standardized criterion maps are calculate weighted linear combination technique. This technique applied by following formula

$$S = \sum W_i \times X_i$$

Where,
 S= composite suitability score
 W_i= weighted value
 X_i= factor score
 Σ= sum of weight

6. Results and Discussion

6.1. Land use and Land cover

The land use land cover is the representation of the human and natural effort. Man use the land according to his needs, due to the impact of man’s and nature land use and land cover of an area changed. Land use land cover of an area plays an important role to the development of economy (Gajbhiye, 2012).

Here the object based classification technique used to classify the area into different classes. The categories mainly include Agricultural land, Vegetation, Scrub vegetation, River, Water body and Industry etc. The land use and land cover map of the presented area is representing here.

Table No. 3: Area of Land use / Land cover

Class Name	Area(In Sq K.M)	Area in Percentage (%)
Vegetation	15.3183	23.78%
Scrub vegetation	1.68953	2.62%
Industry	0.0693677	0.11%
Water body	0.491843	0.76%
Settlement	2.32947	3.61%
Agricultural Land	44.5471	69.12%
TOTAL	64.4456107	100.00%

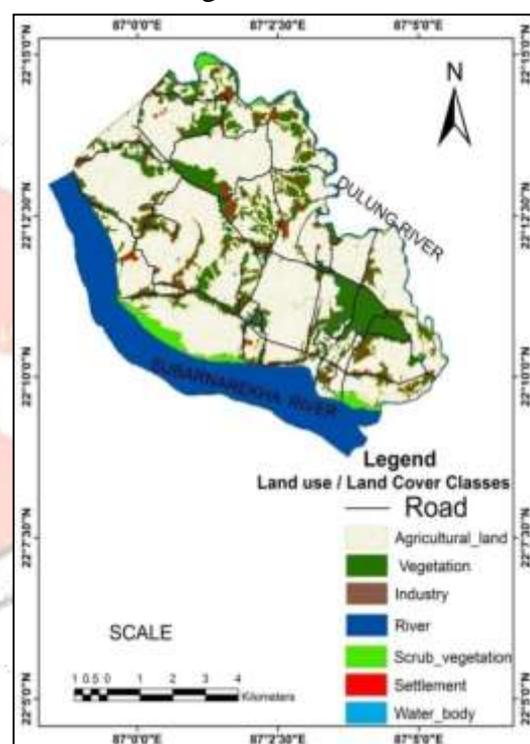
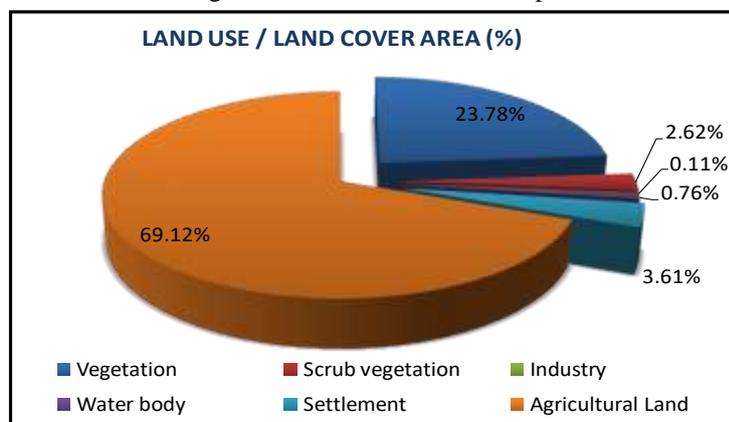


Fig 2: Land use / Land cover map



Graph No. 1: Area converge of Land use / Land cover types

6.2. Agriculture land

In suitable site for agriculture analysis agricultural land is the much needed criteria. Without evaluate agriculture land analysis of an area impossible. In this study project categorized the agriculture land according to used (Korolyuk, 2010). Here two types of agriculture land present.

a. Single crop land: - crop cultivated in this land only monsoon season. Which affect the economy of the area.

b. Double crop land: - people used this land regularly all the benefits and facility present there, especially irrigation facility.

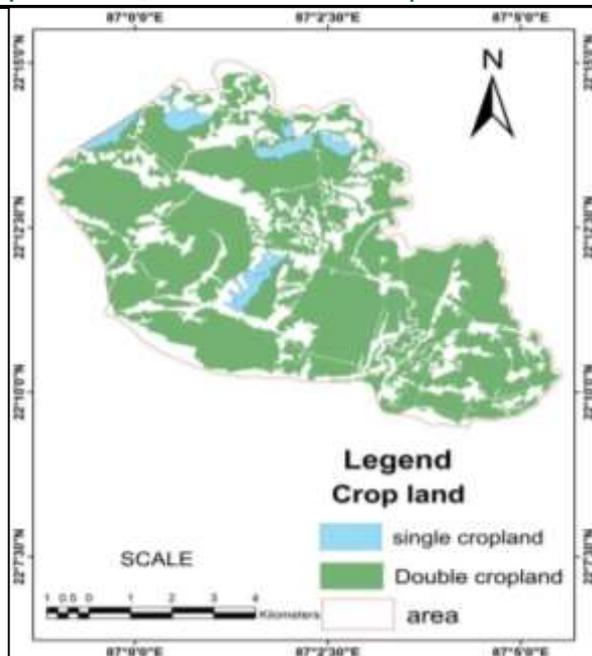


Fig 3: Types of Agriculture land

6.3. Infrastructure

Infrastructure is another important criterion that is used to analyze the suitable land for agriculture. Here in this area two types of infrastructure parameter used these are presents of Bank and Presents of market. Punjab bank is the only bank that spread all over the area. People used bank account for taking agricultural loan. There was present much local market where people sell their agricultural product. Due to the good transport facility people also sell their product in their existing market like Jhargram, Khargapur, Lodhasuli, Belda, Gopiballvpur etc. In the present of good infrastructure people are more interested to agriculture.

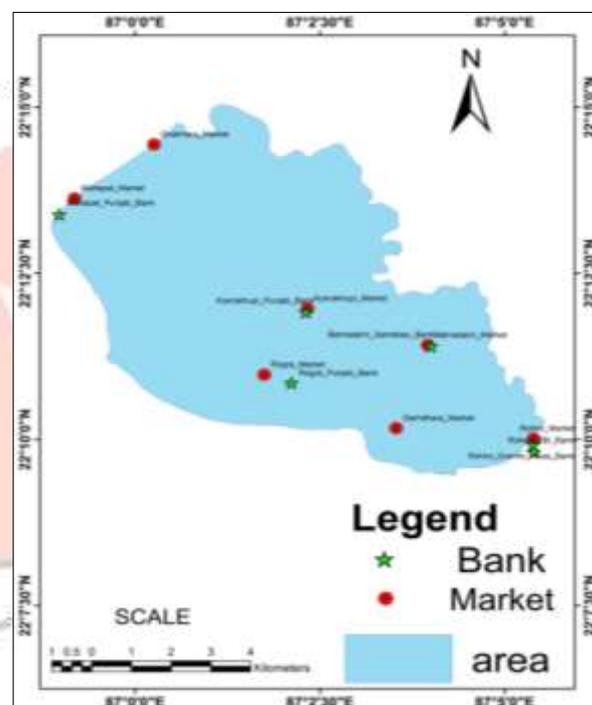


Fig 4: Infrastructure Map

7. Transport facility (Road)

The well connected road network is the key element of the development of an area. To identify the suitable place for agriculture land in the study area creates some criteria in secondary maps. Road is the one of the important criteria. Major road of this area extended through the heart of this area and extended towards Khargapur, Lodhasuli, and Belda town. In this area small minor road also present but this entire minor road are well connected with the major road. This place are connected with some high ways like S.H- 5, S.H- 9, N.H – 6 etc.

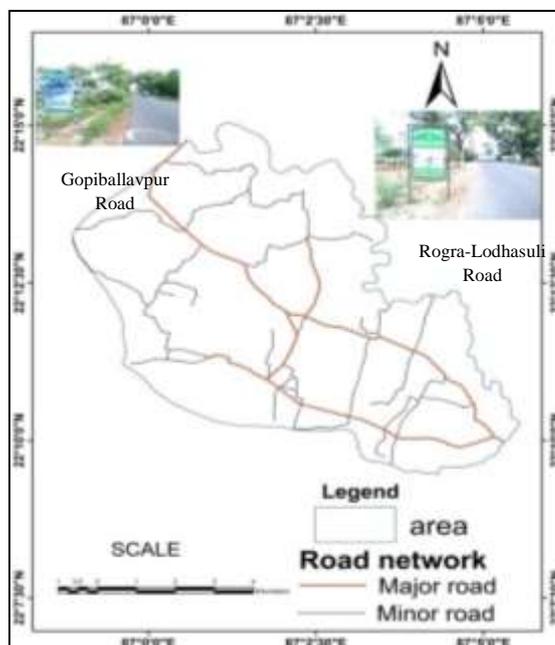


Fig 5: Transport Facility Map

8. Lift Irrigation

Irrigation is the one of the important criteria to analyze the land suitability analysis. In agriculture sector irrigation is much needed elements for crop cultivation. Economy of this area is mainly depending on agriculture. So people set up the lift irrigation pump according to his needs (Ashraf, 2013). Some government pump house also present in this area. But in recent time's government take initiative part in agricultural development and established some pump house in drought area. This area present good cultivated land and fertile land but due to lack of water land retain to the fallow land.

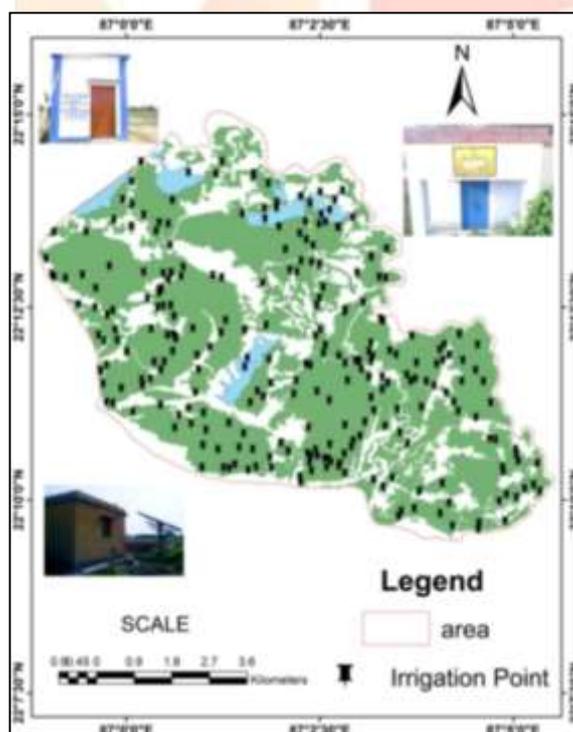


Fig 6: Lift Irrigation Map

9. Fertility

Fertility is the Characteristics of soil. Fertility depends on the soil pH, Organic carbon, micro nutrients, major nutrients etc. It is the most important factor of land suitability analysis of agriculture (Fall, 2014). Here in this study project fertility measured by the data of pH, organic carbon, Slope analysis, etc. Fertility map shows the zone of fertility like high fertile zone, Low fertile zone etc. Though this area must be a good fertile zone but it is less at rate of time by the expensive use chemical fertilizer. So people of this area are request to use organic fertilizer for sustainable farming and to save the environment (Ahmed, 1997).

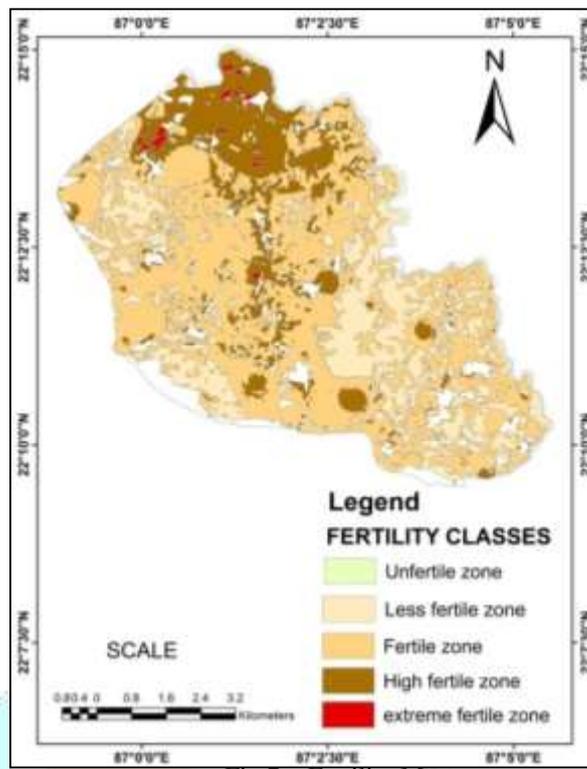


Fig 7: Fertility Map

Selected criterion for land suitability analysis in agriculture

Different factor are used to analyze the suitable land for agriculture. These factor maps are used in GIS environment and using spatial decision support system to make the decision of suitable site. In GIS environment create some boundary to divide zone of importance to analyze which zone is more suitable for agriculture. The criteria maps are describe below.

Agriculture land

This is the one of the important criteria of agriculture land suitability analysis. Economy of this area depends on agriculture and 69.12% of land covered by agriculture.

Table No. 4: Area of Agriculture land classes

Sl No	Agriculture Land types	Score	Class	Area in Sq. km
1	Single crop land	1	Less suitable	42.5471
2	Double crop land	2	Very suitable	2
			Total area	44.5471

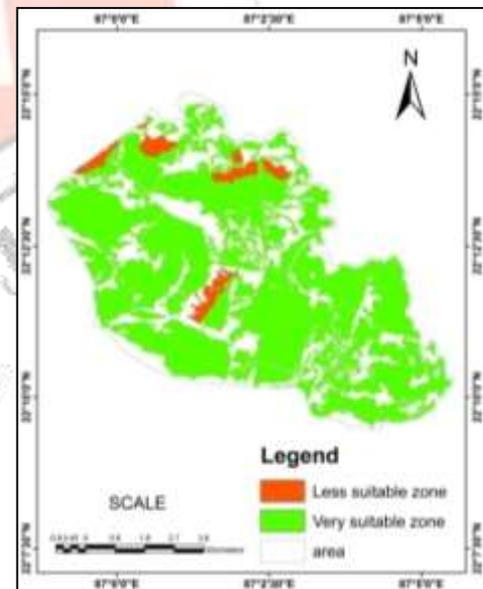


Fig 8: Suitable Zones of Agriculture land

Infrastructure

Here in infrastructure criteria represent the presents bank and market. Small local market spread all over the area, where people sell their productive goods. In which area is extreme suitable or less suitable present in diagram below.

Sl No	Rank	Distance in Meter	Class	Area in Sq. Km
1	1	3000-4500	Less suitable	5.50837
2	2	1500-3000	Moderate suitable	25.363
3	3	1000-1500	Suitable	16.2453
4	4	500-1000	Very suitable	13.422
5	5	0-500	Extreme suitable	5.37015
			Total	64.4456107

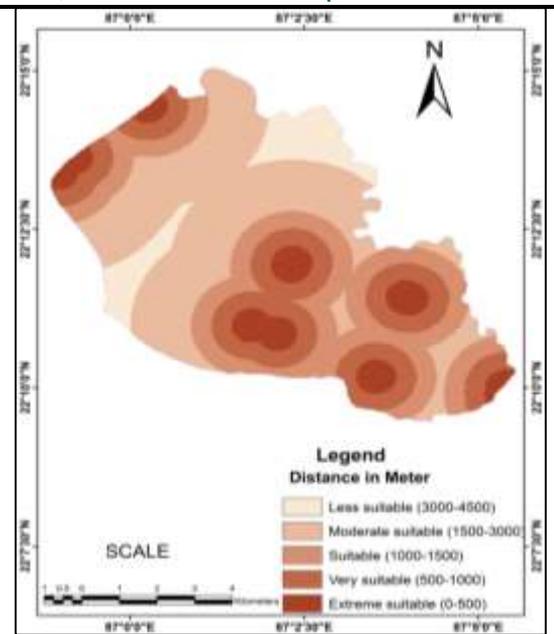


Fig 9: Criteria Map of Infrastructure

Transport Facility

Transport facility represents the road and networking communication of this area. In this area one major road Rohini- Lodhasuli road pass through the heart of this area. Also present some minor road which is connecting to major road. Here in this map present the distance of from the agriculture land.

Table No 6: Distance from Main Road

Sl No	Rank	Distance in Meter	Class	Area in Sq. Km
1	1	1000-1500	Unsuitable	1.8301
2	2	750-1000	Less suitable	4.13444
3	3	500-750	Moderate Suitable	10.0053
4	4	250-500	Suitable	18.5655
5	5	0-250	Extreme suitable	31.2699
			Total	64.4456107

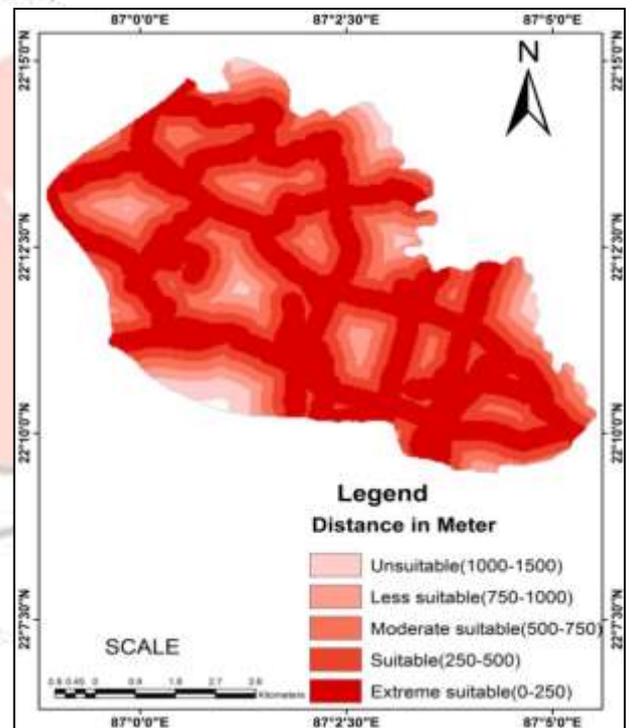


Fig 10: Criteria Map of Road

Fertility

Fertility is one of the important criterions of agriculture. Good fertility of land is good for agriculture. In recent time fertility of soil decreased due to the expensive used of chemical fertilizer. Soil fertility of this area is measured by the used of organic carbon, pH value of soil, elevation data, and soil data (Dent, 1995). Soil fertility map of this area is shown below:

Table No 6: Area under different Suitable land Fertility class

Sl No	Rank	Class	Area in Sq. Km
1	1	Unsuitable	0.00374311
2	2	Less suitable	14.4967
3	3	Suitable	32.8288
4	4	Very Suitable	10.555
5	5	Extreme suitable	0.46777
		Total	58.35201311

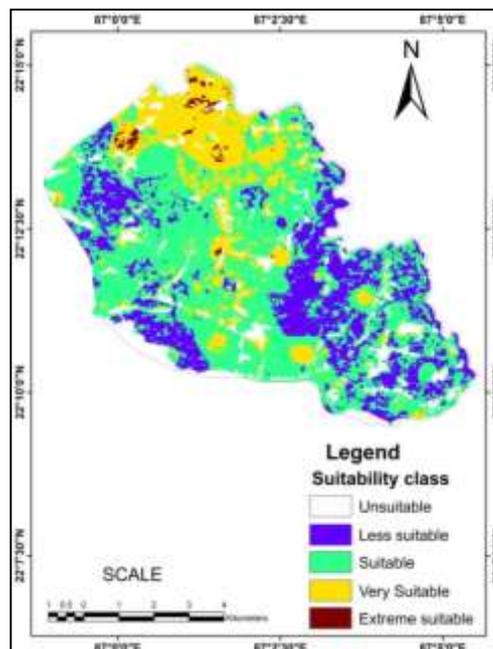


Fig 10: Criteria Map of Fertility

Criteria standardization

Criteria standardization is the standardized all the criteria using reclassify tool in GIS. In this method criteria are classified in different classes. Here in this project criteria are standardized into five classes like extreme suitable, very suitable, suitable, less suitable, unsuitable which represent the value of 1 to 5 and where 1 represent unsuitable zone and 5 represent extreme suitable zone. Some feature of this criteria evaluation not in range between them this time use another order of class. Every criteria of this project evaluated correctly to perfect land suitability analysis. Here in this study used different socio economic, environmental and physical criteria these are agriculture land, infrastructure, transport facility, Irrigation, fertility to perfect analyze of multi criteria decision analysis.

Assigning criterion weights

All the criteria of this project assigning weights using pair-wise comparison technique, which was first established by the (Satty and Vargas, 2001). These criterion weights are calculated using Microsoft excel. The weighted values of any criteria depend on the user preference.

Weighted value for different criterion derived from pair wise comparison technique

Table No 7: Weights for different criterion

Criteria	Agriculture land	Infrastructure	Transport facility	Irrigation	Fertility	Weight
Agriculture land	1	4	5	7	9	0.515127915
Infrastructure	0.25	1	6	3	7	0.259747347
Transport facility	0.2	0.166666667	1	2	3	0.099269235
Irrigation	0.142857143	0.333333333	0.5	1	5	0.091525652
Fertility	0.111111111	0.142857143	0.333333333	0.2	1	0.034329853
Total	1.703968254	5.642857143	12.833333333	13.2	25	1

Calculation for consistency ratio (CR)

$$\lambda \text{ max} = 5.472701$$

Consistency Index (CI) = $\lambda - n / n - 1$ where, n = number of criteria

$$= (5.472701 - 5) / (5 - 1)$$

$$= 0.118175$$

Consistency Ratio = CI / RI

$$= 0.118175 / 1.12$$

$$= 0.105514$$

When, the no of criteria is 5 then the Random index is 1.12

Suitable location for agriculture land

As per the output of the final map suitability of agricultural zone were analyzed. The map shows some place of extremely suitable zone around Cheriyaasingha, Birdahi, Ramanandapur, Bahradanri, Kukhrakhupi, Rogra, Baincha, and some portion of Mahapal and Goalmara. Also all the high suitability and suitability region present around all this area. Single crop cultivated area are shows as less suitable land for agriculture activity, lack of different type of facility like communication, infrastructure and unavailability of irrigation this area shows, less suitable. The suitability map of this area presented below.

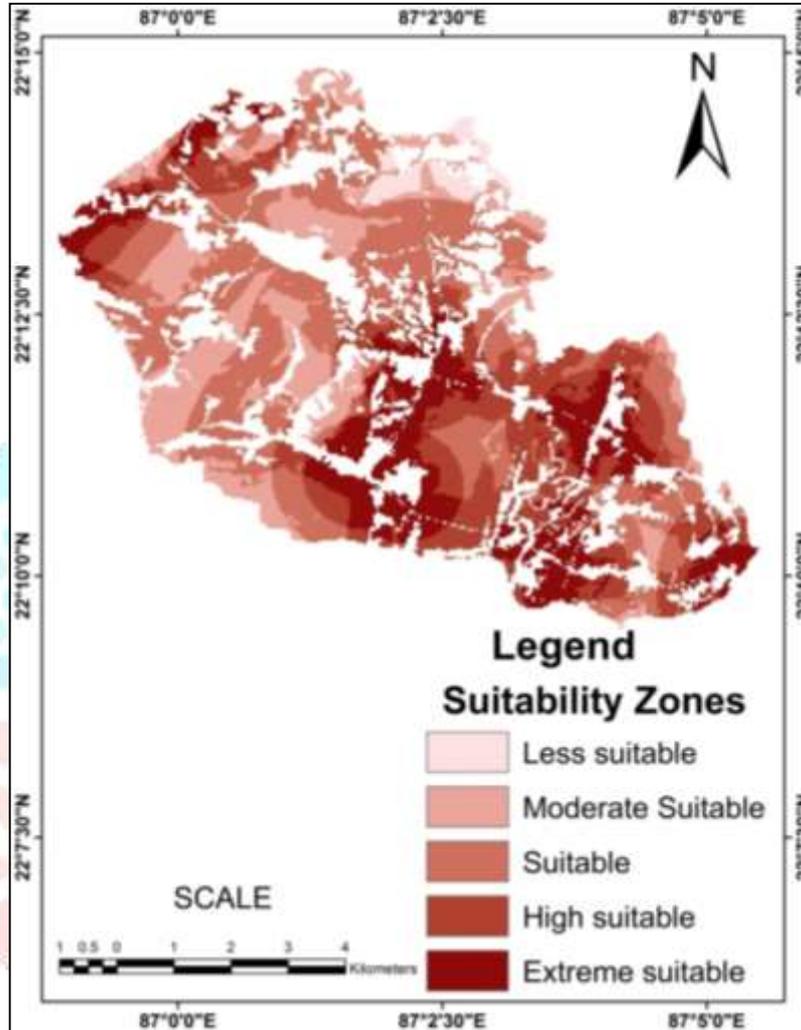


Fig 12: Suitability Map of agriculture land

Conclusions

This study based on the evaluation of land suitability analysis of agriculture land. Agriculture is the main occupation of this area. Most of the peoples are depend on agriculture. According to the land use land cover analysis 44.57% of area covered by agriculture land. So, need to attention to the development of agriculture. Here in this study all the facility and infrastructure are described to analyze, finding suitable place for agriculture. After complete all the discussion it conclude that agricultural parameter are needed to modify in this region. Unavailability of irrigation, markets, roads and infrastructure are affect on not only the agriculture also affect the economy of this region. In final suitability map of agriculture land identified the extreme suitable land or less suitable land. After the socio economic study it also clear that this area present low economic condition due to depend on agriculture and 75% of the farmers are marginal farmers. This area need to development of agriculture, for the development of society and economy.

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