

Agricultural Land suitability Analysis for Four Major Crops Using Satellite Imagery and GIS Techniques

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ABSTRACT

Rural areas in India got a greater need to increase the agricultural production in a sustainable manner, with the finite land resource available. The yield of the crop depends upon the resources available, the climate of the area and its growth. Land suitability study is the holistic approach for sustainability. With the help of land suitability approach farmers can maximize the crop production by adapting the crop that is best suited for their land. Land suitability classes mirrors the extent of suitability within the orders. There are 3 land suitability classes within the order suitable. They are recognized as highly suitable S1, moderately suitable S2 and marginally suitable S3. There are 2 land suitability classes under the order not suitable N. They are recognized as currently not suitable N1 and permanently not suitable as N2. The parameter that are considered for land suitability study for agriculture as a whole are soil texture, land use land cover, macro nutrients of soil, slope, aspect, ground water prospects condition. Soil in the study area is classified into 5 categories viz., clayey, clayey mixed, clayey skeletal, loamy skeletal and rocky land. Soil texture has a vital role to play in plants growth; it's indirectly related to the fertility of the soil, water holding capacity of the soil, availability of oxygen to the roots and drainage condition of the soil. Land use/land cover map level 1 classification, study area is classified into agricultural land, water bodies, forestry, wastelands and built-ups. These layers were overlaid by using weighted overlay tool and the final land suitability map is generated. The spatial variation maps along with other inputs layers like aspect, slope, soil texture, ground water prospects and rainfall data were overlaid to obtain land suitability models for agriculture as a whole and particularly for major crops namely rice, maize, groundnut and grapes. The land suitability map for agriculture shows that the highly suitable regions are found in some parts of Gauribidanur and Chintamani villages of Chickballapur District of Karnataka where the study was conducted. There is no highly suitable class found in maps of individual crops, because there might not be highly suitable condition prevailing in the site.

Keywords: Land Suitability, Weighted Overlay, Major crops

1. INTRODUCTION

Agricultural land suitability analysis for major crops using satellite imagery and GIS techniques involves steps as follows:

1. Data Collection: Gather satellite imagery data, soil data, climate data, and other relevant datasets for the area of interest.

2. Pre-processing: Pre-process the satellite imagery to correct for errors, remove noise, and ensure uniformity across datasets.

3. Land Classification: Use GIS techniques to classify the land cover into different classes such as forest, water bodies, agricultural land, etc.

4. Soil Analysis: Analyze soil data to determine soil properties such as texture, pH, nutrient content, etc., which are important for crop growth.

5. Crop Selection: Based on the soil and climate analysis, select the major crops that are suitable for the area. Land Suitability Analysis carried out using GIS techniques to overlay the soil and climate data with the land cover data to determine the suitability of the land for each selected crop.

6. Mapping: Create maps that show the suitability of the land for each crop, highlighting areas that are highly suitable, moderately suitable, and unsuitable for cultivation. By following these steps, agricultural

land suitability analysis can help farmers and land managers make informed decisions about crop selection and land use planning, leading to improved agricultural productivity and sustainability.

Food and Agricultural Organization (FAO) has given the guide lines for land suitability study in the year 1976. This was adapted by National Bureau for Soil Survey (NBSS) and Land use planning in India and published manual titled "Soil site suitability criteria for the major crops". This manual is an effort made, to match the guidelines provided by FAO to meet the Indian scenario.

Land suitability is basically the extent to which a particular land area is fit for an intended use. In this case the intended use is for agriculture. There are two structures for land suitability classification one is land suitability order and the other is land suitability classes. The land suitability order reflects, whether the land is suitable or not for the intended purpose. Land suitability order S means that the land is suitable for the intended purpose and is expected to result in benefits within acceptable risk of damage to land resources. Land suitability order N means that the land is not fit for the intended purpose. Class Highly suitable (S1) is the one which has no or has very less limitation for the purpose under consideration which will neither reduce the yield nor rise the intakes above the acceptable level. Class Moderately suitable (S2) is the one which has certain limitation that are moderate for the purpose under consideration which will reduce the productivity and increases the intakes but overall gains are still attractive, but are at a lower scale than S1. Class Marginally suitable (S3) is the one which has vast limitations for the intended use and will reduce the yield and increases the input of resources and making the overall gains marginally justified. Class Currently not suitable (N1) is the land which has huge limitation which cannot be corrected using the existing knowledge or any other resource that are contemporary. Class permanently not suitable (N2) is the land that has unamend able limitation making it unfit for cultivation permanently.

2. Study Area

Chickballapur District in Karnataka, India, is known for its agricultural activities, particularly in horticulture and floriculture. It covers an area of approximately 4,480 square kilometers (1,730 square miles). is primarily dependent on surface water sources and groundwater for its water supply. Some of the key water sources in the district include: Arkavathy River is one of the major rivers in the region. It originates in the Nandi Hills of Chickballapur District and flows through the district, providing water for irrigation and drinking purposes. Ponnaiyar River also known as the Palar River, flows through the eastern part of Chickballapur District. It is a seasonal river that provides water for irrigation and other purposes during the monsoon season. Chickballapur District has a significant amount of groundwater resources, which are mainly recharged by rainfall. Groundwater is extracted through borewells and open wells for irrigation and domestic use. agriculture plays a significant role in the economy of Chickballapur District, with a focus on high-value crops such as Rice, maize, mango, silk, and fruits like Grapes etc. Efforts are ongoing to improve productivity, sustainability, and market access for farmers in the district.

3. Methodology

Currently there might not be scope for agriculture in the regions of water bodies, forests, wastelands and hence they were ranked accordingly. Soil nutrients play a major role in nourishing the crops. NPK are the three important macro nutrients and are required to all plants in appropriate amount for their growth irrespective of their species. Hence for this study only macro nutrients and other soil properties like pH, electrical conductivity, and organic carbon were considered. Slope and aspect have a lesser influence on plant growth so least weightage is adopted. Slope affects the agriculture production, drainage problem and diversity of plant species. Plain areas were assigned high ranking and as the slope increases ranking is low has the species cultivated are highly limited in steep slopes. The hours of sun light exposure to the plants depends on aspect. Plants in North facing slopes are the best, because they are exposed to the sun for a longer period. The ranks for soil texture, soil property and LULC were based on FAO (Food and Agricultural Organization) standards and ranks for slope and aspect were based on literatures. The weightage and ranks assigned to each of the thematic layers were as shown in Table 1. These layers were overlaid by using weighted overlay tool and the final land suitability map is shown in the figure 1.

Table 1. Weightages assigned for land suitability study of agriculture

| Layers | Group Weightage | Divisions | Rank |
|--------------|-----------------|-----------------|------|
| Soil texture | 20 | Clayey | 5 |
| | | Clayey mixed | 4 |
| | | Clayey skeletal | 3 |
| | | Loamy skeletal | 2 |

| | | | |
|-----------------------|----|-------------------------|---|
| | | Rock land | 1 |
| Land use/ land cover | 20 | Water bodies | 2 |
| | | Agricultural land | 5 |
| | | Waste land | 4 |
| | | Built up | 1 |
| | | Forest | 3 |
| Soil properties | 30 | Nitrogen | 5 |
| | | Phosphorus | 5 |
| | | Potassium | 5 |
| | | pH | 5 |
| | | Electrical conductivity | 5 |
| Slope | 5 | < 1 % | 5 |
| | | 1 % to 5% | 4 |
| | | 5% to 10% | 3 |
| | | 10% to 15% | 2 |
| | | > 15% | 1 |
| Aspect | 5 | North | 5 |
| | | South | 4 |
| | | Flat | 3 |
| | | East | 2 |
| | | West | 1 |
| Groundwater Prospects | 20 | Nil | 1 |
| | | Poor | 2 |
| | | Moderate | 3 |
| | | Good | 4 |
| | | Very Good | 5 |

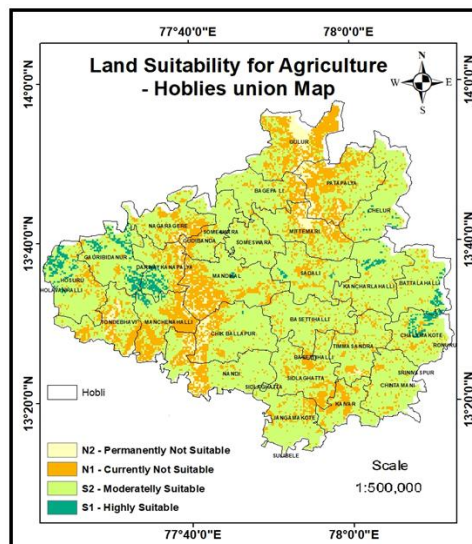


Figure 1. Land Suitability Map for Agriculture

3.1.Land Suitability Analysis for Principal Crops Grown

3.1.1. Rice Suitability Study

The commonly grown rice in study area belongs to the grass family. Rice crop is adapted in tropical climate and is the staple food for large population of the world. Rice belongs to crop group which demands

huge amount of water. The crop period is 120 days and delta (depth of water required to raise a crop in unit area) is 1200 mm. The variety of rice crop that is grown in the study area was Netravathi, Phalguna, M.O and genus of the rice Oryza. Soil and climate suitability criteria for rice crop are based on the manual “Soil site suitability criteria for the major crops” shown in the Table 2. The land suitability map generated for rice cultivation is as shown in figure 2.

Table 2. Site requirement for growing rice

| Layer | Highly suitable | Moderately suitable | Marginally suitable | Not suitable |
|------------------------------|---------------------|---------------------|---------------------|---------------------|
| Rainfall (mm) | 1110 - 1250 | 900 - 1110 | 750 - 900 | < 750 |
| Soil drainage class | Imperfectly drained | Moderately drained | Well drained | Excessively drained |
| Texture | Clayey | Clayey mixed | Loamy | Rocky land |
| pH | 5.5 to 6.5 | 6.6 to 7.5 | 7.6 to 8.5 | > 8.5 |
| Electrical conductivity ds/m | < 3 | 3 to 6 | 6 to 10 | > 10 |
| Slope % | 0 to 1 | 1 to 5 | 5 to 10 | > 10 |

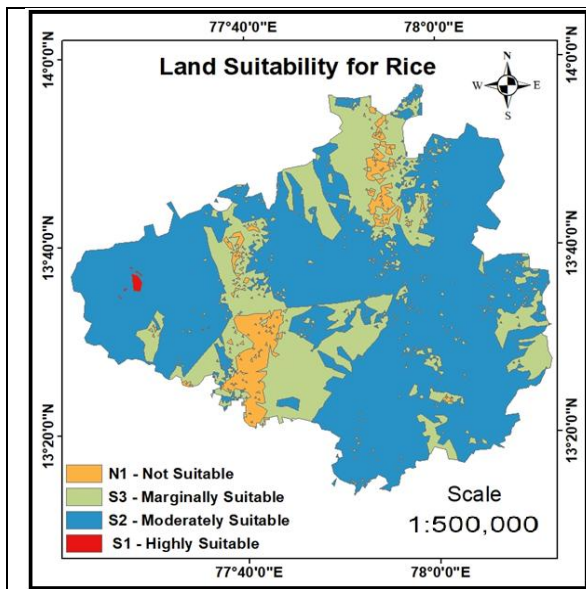


Figure 2. Land Suitability Map for Rice

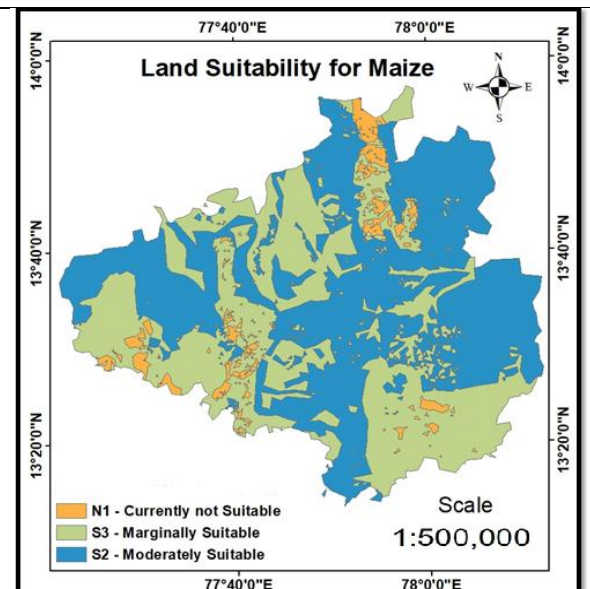


Figure 3. Land Suitability Map for Maize

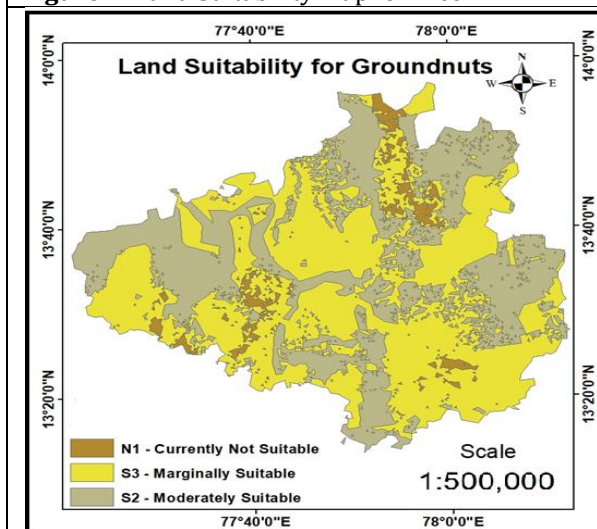


Figure 4. Land Suitability Map for Groundnut

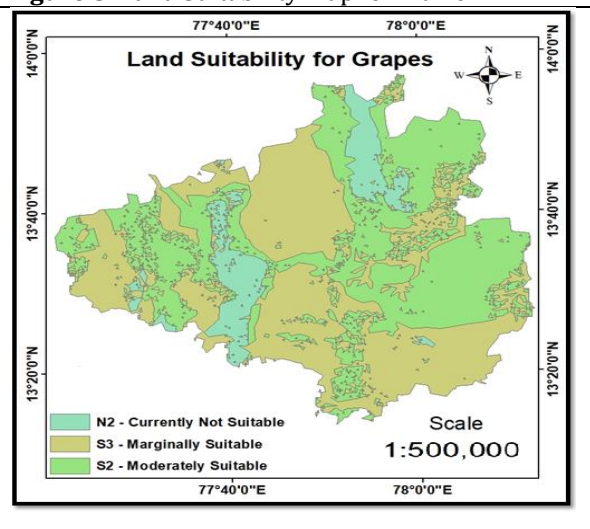


Figure 5. Land Suitability Map for Grape

3.1.2 Maize Suitability Study

The scientific name of maize is *Zea mays*. This crop is one of the vital cereals consumed by the people all over the world in fact it is called as “queen of the cereals”. Total depth of water required for maize crop is 400 mm. The crop period is 100 days. The common variety of crop grown in study area is Muskinujola. It requires a mean temperature of 22°C to 30°C. Soil and climate suitability criteria for maize crop are shown in the Table 3. This criterion is discussed in detail in “Soil site suitability criteria for the major crops” manual. The land suitability map generated for maize cultivation is as shown in figure 3.

3.1.3 Groundnut Suitability Study

Groundnut also called as Peanut or earthnut is one of the major oil seeds grown across India. Groundnut belongs to Leguminosae family and with *Arachis hypogaea* as a scientific name. The depth of water required for groundnut is 400 – 600 mm and requires a mean temperature of around 18°C. The crop period for this crop is 90– 120 days. Being a leguminous plant it requires lesser nitrogen. The common variety of groundnuts that are grown in the study area is Pish improved and TMV. Soil and climate suitability criteria for groundnut crop are shown in the Table 4. This criterion is discussed in detail in “Soil site suitability criteria for the major crops” manual. The land suitability map generated for groundnut cultivation is as shown in figure 4.

Table 3. Site requirement for growing maize

| Layer | Highly suitable | Moderately suitable | Marginally suitable | Not suitable |
|------------------------------|-----------------|---------------------|---------------------|---------------------|
| Rainfall (mm) | 900 – 1000 | 750 – 900 | 500 – 750 | < 500 |
| Soil drainage class | Well drained | Moderately drained | Imperfectly drained | Imperfectly drained |
| Texture | Loamy | Clayey mixed | Clayey | Rocky land |
| PH | 5.5 to 7.5 | 6.6 to 8.5 | 8.6 to 9 | > 9 |
| Electrical conductivity ds/m | Non saline | 1 to 2 | 2 to 4 | |
| Organic carbon | High | Medium | Low | |
| Slope % | 0 to 1 | 1 to 5 | 5 to 10 | > 10 |

Table 4. Site requirement for growing groundnut

| Layer | Highly suitable | Moderately suitable | Marginally suitable | Not suitable |
|------------------------------|-----------------|---------------------|---------------------|---------------------|
| Rainfall (mm) | 700 – 1000 | 500 – 700 | 350 – 500 | < 350 |
| Soil drainage class | Well drained | Moderately drained | Imperfectly drained | Imperfectly drained |
| Texture | Loamy | Clayey mixed | Clayey | Rocky land |
| pH | 6 to 8 | 8.1 to 8.5 | > 8.5 | - |
| Electrical conductivity ds/m | < 2 | 2 to 4 | 4 to 8 | - |
| Slope % | 0 to 1 | 1 to 5 | 5 to 10 | > 10 |

3.1.4 Grape Suitability Study

Grapes are adapted to sub-tropical climate, which has got short winter and long dry summer. The scientific name of grape is *Vitis vinifera*. The delta for grape is 900 – 1200 mm and requires a mean temperature of around 18°C. The crop period is 120 – 145 days. The common varieties of grapes that are grown in the study area are Dilkush, Sharath, red and blue [108]. Soil and climate suitability criteria for grape crop are shown in the Table 5 below. This criterion is discussed in “Soil site suitability criteria for the major crops” manual. The land suitability map generated for grape cultivation is as shown in figure 5.

Table 5. Site requirement for growing grape

| Layer | Highly suitable | Moderately suitable | Marginally suitable | Not suitable |
|------------------------------|-----------------|---------------------|---------------------|---------------------|
| Rainfall in mm | 50 – 60 | 60 – 80 | > 80 | - |
| Soil drainage class | Well drained | Moderately drained | Imperfectly drained | Imperfectly drained |
| Texture | Loamy | Clayey mixed | Clayey | Rocky land |
| PH | 6.5 to 7.5 | 6 to 6.4 | 4 to 5.9 | - |
| N, P, K status in mg/L | > 30 | 30 -15 | < 15 | - |
| Electrical conductivity ds/m | Non saline | < 1 | 1 to 2.5 | > 2.5 |
| Slope % | 0 to 1 | 1 to 5 | 5 to 10 | > 10 |

3.2 Hoblie wise Land Suitability Analysis for Major Crops

Rice is highly suitable to grow in Gauribidanur compared to all other hoblies. Growing rice crops are moderately suitable for 95% of the agricultural areas in the hoblies; Chelur, kancharahalli, Holavanhalli, Sidlaghatta, Chintamani Jangamakote. In Gulur, chickballapur and Nandi 70% of the area comes in marginally suitable category for growing rice crop. Areas not suitable for growing rice crop are spread over Tondebhavi, Mitemari and Patapalya. Battalahalli, Chelur and Gauribidanur have 80 % of its area moderately suitable for growing maize. Chintamani, Kaivar, Tondebhavi and Manchenahallih 75% of area marginally suitable for growing maize.

Kaivar, Chintamani hoblies on a whole and 50% area of Hosuru, Chelur, Mandikal, Chickballapur and Nagaragere are marginally suitable for growing groundnuts and the remaining area of the district falls under moderately suitable category.

Someshwara, Chintamani, Kaivar and Nandi are marginally suitable for cultivating grapes, whereas Battalahalli and patapalya are moderately suitable for growing grapes. Nagaragere, Holavanhalli, Tondebhavi, Manchenahalli, Basettihalli, Timmasandra and Sadali have 30 - 50% of area on both moderately and marginally suitable for growing grapes. The Table 6 gives the status of land suitability for agriculture and for individual crops.

Table 6. Land Suitability Status in the study area

| | S1 | | S2 | | S3 | | N1 | | N2 | |
|-------------|----------------------|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|-----------------|----------------------|-----------------|
| | Area km ² | Percentage area | Area km ² | Percentage area | Area km ² | Percentage area | Area km ² | Percentage area | Area km ² | Percentage area |
| Agriculture | 92.95 | 2.31 | 2873.33 | 71.06 | - | - | 912.72 | 22.57 | 164.24 | 4.06 |
| Rice | 194.95 | 4.76 | 1079.71 | 26.41 | 2806.74 | 68.66 | 6.12 | 0.14 | - | - |
| Maize | - | - | 2174.37 | 55.47 | 1746.02 | 42.68 | 170.37 | 4.16 | - | - |
| Groundnuts | - | - | 1656.30 | 40.50 | 2278.65 | 55.71 | 155.02 | 3.79 | - | - |
| Grapes | - | - | 1751.03 | 42.81 | 1946.10 | 47.58 | - | - | 392.87 | 9.61 |

4. RESULTS AND DISCUSSION

studied, to illustrate the degree of land suitability for agricultural purpose and to prepare the land suitability map for cultivation of rice, maize, groundnut and grapes in the study area. Land suitability analysis was carried out for categorizing the areas as most suitable, moderately suitable, marginally suitable and not suitable for agriculture and for growing rice, maize, groundnut and grapes. In Chickballapur district majority (71%) of area is moderately suitable for agriculture purpose. Rice is highly suitable to grow in Gauribidanur and areas not suitable for growing rice crop are spread over Tondebhavi, Mitemari and Patapalya. Battalahalli and Chelur have 80 % of its area moderately suitable for growing maize. Kaivar and Chintamani Hobli are marginally suitable for growing groundnuts. Battalahalli and patapalya are moderately suitable for growing grapes. The area of land most suitable for growing rice is found to be very less (195 km²) than the moderately suitable (1079 km²) and marginally suitable (2806 km²) areas, which was concluded based on the parameters; rainfall, drainage condition, soil texture, pH, electrical conductivity and slope of the area. It is evident from the study that, cultivation of rice can be

increased by 40% if the water supply for agriculture is augmented from other source without depending on rainfall and ground water. So it is proposed to supply the treated waste water from constructed wetlands for growing rice in the study area.

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