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LAND SUITABILITY ASSESSMENT FOR CHILLI USING GIS AND SATELLITE REMOTE SENSING DATA

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Abstract

Land suitability assessment is important to identify environmental limitations that affect growth, development, and chilli production. A study on land suitability assessment of chilli for the Sylhet district of Bangladesh was performed to measure suitable lands for its higher productivity. The maps for the Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) were generated from Landsat-8 satellite images. Other vector layers for soil and climate were transformed into raster datasets. Finally, ArcGIS software used a weighted overlay spatial analysis to identify and measure lands under different suitability classes. The study results showed that the lands for highly suitable, moderately suitable, marginally suitable, and not suitable categories were 15,187; 93,909; 207,908; and 3,396 hectares which accounted for 4.74, 29.31, 64.89, and 1.06 percent, respectively. The developed land suitability assessment model for chilli would be a valuable tool for scientists, agricultural extension workers, and land policymakers to take further initiatives to increase the production and sustainable management of agricultural lands in the study area.

Keywords: Land suitability, Chilli, GIS and remote sensing data.

Introduction

Chilli (*Capsicum frutescens*) is an important spice, and one of the valuable cash crops belonging to the family Solanaceae originated in Mexico (Bose *et al.* 2002). Both the green and ripened chillies are used as spices. It is a good source of vitamin A and C, phosphorus, and an inevitable part of daily cuisine in many parts of the world. In addition, pickles, sauces, and curry powder are prepared from dry chillies (Naidu *et al.* 2006). Chilli plays an important role in food and nutrition security as an alternate crop. The production of chilli may be lesser in quantity as compared to the major crops but offer much-needed nutritional value and variety in the diet. In Bangladesh, the crop is cultivated in an area of 75,535 hectares, and the production is around 119,781 metric tons with an average yield of 1.58 tons/hectare (Anonymous, 2020). There are some high-yielding varieties of chilli developed by the Bangladesh Agricultural Research Institute (BARI). Some local varieties such as Balijuri, Bain, Bona, Dhani, Halda, Paba, Patnai, Saita, Suryamukhi, and Shikarpuri are also cultivated all over the country. It can be grown in both the summer and winter seasons. The crop is mostly grown in Bogura, Noakhali, Cumilla, Patuakhali, Faridpur, and Barisal districts. The crop is cultivated in Bangladesh as a winter crop; however, the demand for chilli exists all the year-round. The demand of chilli is always higher than its supply in the Sylhet region. Moreover, chilli production is affected by wilt disease in the rainy season, and the price grows up several times higher than its usual price.

The rapidly growing population and decreasing trend of agricultural land in Bangladesh is a major constraint to ensure food and nutrition security. Due to the adverse effect of global warming and climate change, changes in the pattern of rainfall and flash flood cause enormous loss of crops. Sustainable agricultural land management is crucial to face the challenges of increased productivity of crops, especially alternate crops. Therefore, it is important to assess land suitability for important spice crops such as chilli to enrich the economy of the country.

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Land suitability assessment is essential for sustainable land management and other natural resources like water. With advances in Information and Communication Technology (ICT), the uses of geospatial technology such as Geographic Information Systems (GIS) and satellite remote sensing data are being used to assess the land suitability of crops (Bandyopadhyay *et al.* 2009). Nowadays, the GIS and remote sensing technology are being considered valuable tools for land suitability assessment of crops (Habibie *et al.* 20019). GIS and satellite remote sensing are robust tools to evaluate lands for crops on a large scale considering various soil physicochemical and vegetative parameters. As of today, no studies regarding land suitability assessment for cultivating chilli in the Sylhet region incorporating the remote sensing technology have been performed yet to increase production. Therefore, a comprehensive study utilizing soil physicochemical and vegetative parameters for sustainable land use planning and higher productivity of chilli was undertaken. This study has attempted to develop a land suitability assessment model that could help the agricultural extension workers and chilli growers of the Sylhet region to take the necessary steps to increase production and to develop an appropriate policy for sustainable management of agricultural lands in the study area. The present study specifically aimed:

i. to identify the suitable lands in the study area with respect to environmental factors for chilli production using the GIS and remote sensing data.
ii. to measure the suitability classes of lands of chilli for inventory planning as well as for sustainable management of agricultural lands.

Materials and Methods

Study area: The study area is located between the latitude and longitude of 24°36′ and 25°11′ north, and 91°38′ and 92°30′ east, respectively. The land of the study area is 3,20,400 hectares. The Indian states of Meghalaya surround this area to the north, Assam to the east, the district of Moulvibazar to the south, and Sunamganj and Habiganj to the west (**Figure 1**).

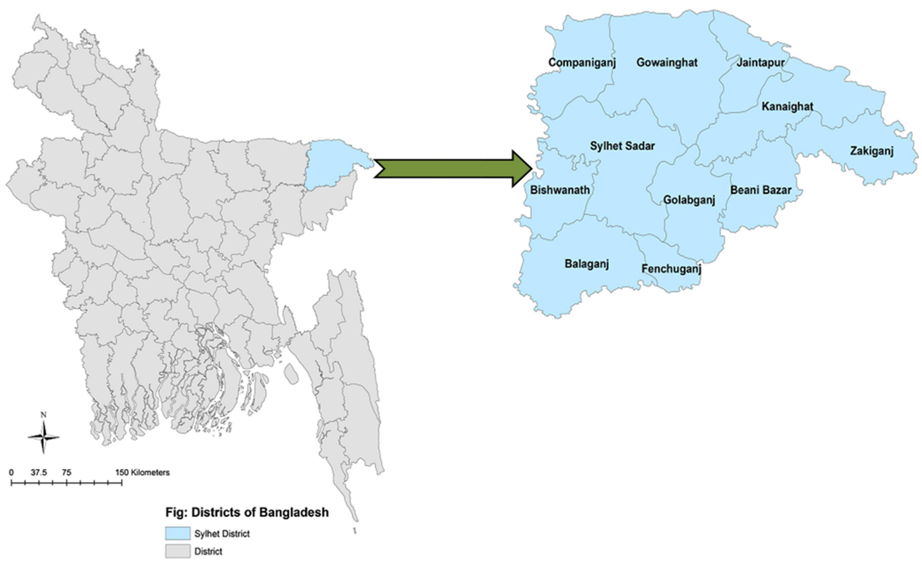

Figure1. The study area is the Sylhet District of Bangladesh

Method: The study was performed using Landsat-8 images gathered from the USGS (United States Geological Survey) websites over the entire area on the date of December 31, 2018 to determine Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) using ArcGIS 10.4® software. Other vector data for different parameters were collected from the Bangladesh Country Almanac (BCA) and transformed into raster datasets for reclassification. Finally, suitability classification was performed using weighted overlay spatial analysis in the ArcGIS environment (**Figure 2**).

Criteria for suitability assessment

Normalized Difference Vegetation Index (NDVI): The NDVI is a vegetation parameter correlated with various biophysical parameters and crop indices (Rouse et al. 1973). The proportion of green biomass sensed or captured in satellites is important for vegetation monitoring. Apart from this, the NDVI measures the phenological variations in vegetation. This study calculated the NDVI for chilli using Landsat-8 satellite images (**Figure 3a**). The map for the NDVI was developed using extraction by masking the acquired images to distinguish the vegetation status of this area.

$$\mathrm{NDVI} = \frac{\mathrm{R_{NIR}} - \mathrm{R_{RED}}}{\mathrm{R_{NIR}} + \mathrm{R_{RED}}}$$

Here, R_{NIR} refers to the near-infrared bands, and R_{RED} represents red bands.

Soil Adjusted Vegetation Index (SAVI): The SAVI is a vegetation index that attempts to minimize the effect of soil brightness, referring to a soil-brightness correction factor.

$$\mathrm{SAVI} = \frac{(1+\mathrm{L})(\mathrm{R_{NIR}}\text{-}\mathrm{R_{RED}})}{(\mathrm{R_{NIR}}+\mathrm{R_{RED}}+\mathrm{L})}$$

Here, L is a canopy background adjustment factor. The value of L is 0.5.

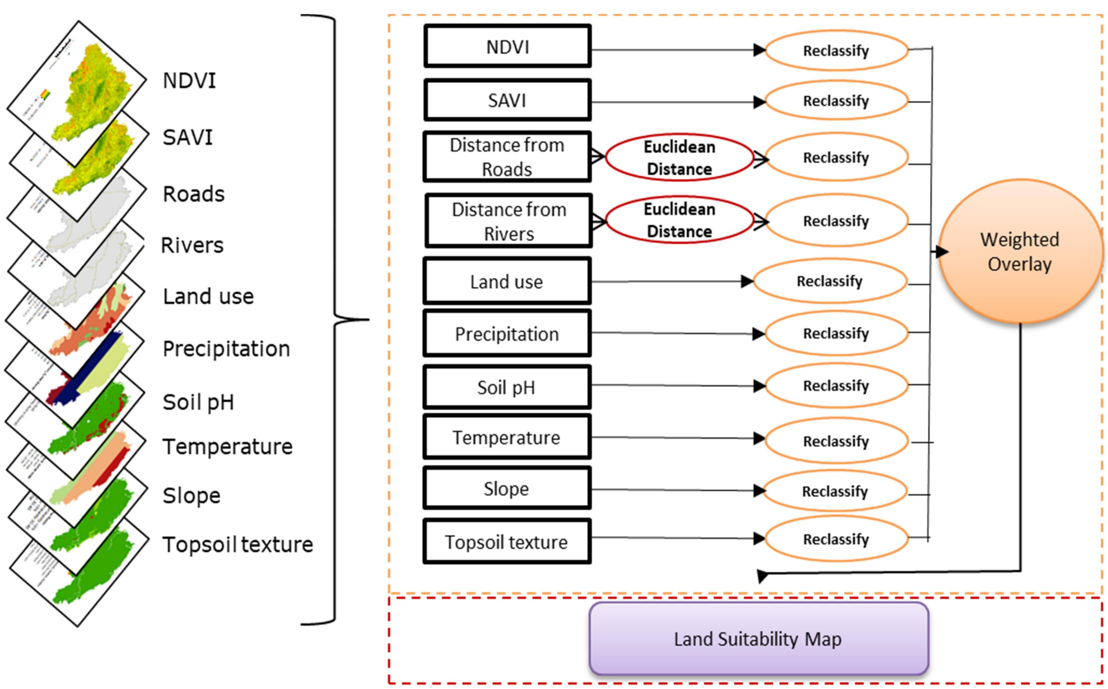

Figure 2. A conceptual research framework for land suitability assessment of chili

Distance from roads

The study area is crossed by three types of roads: highways, district roads, and local roads. Distance from roads is an important accessibility parameter that was considered to minimize the transportation costs associated with the cultivation of crops. Minimum distances between fields and roads enhance the transport of inputs and harvested crops. Data for distance from roads were retrieved in polyline vector form and then converted into a raster. Spatial analysis was performed to measure the distances using the Euclidean distance.

Distance from rivers

The study area is crossed by a large number of small and big rivers, which are part of the watershed in this area. Distances from rivers may also facilitate transportation. In addition, it may be the source of irrigation water during the winter season. The data for distances from rivers were retrieved as a polyline vector and then converted into raster data. Once the vector data were converted to raster form, they were analyzed using Euclidean distance to calculate the distance from rivers. The study area concerning distance from rivers was extracted by masking followed by reclassification according to the shortest distances.

Land use

Land use data collected from the Bangladesh Country Almanac (BCA) were utilized to evaluate the lands for different suitability classes. The land use map classified the lands into highly suitable, moderately suitable, marginally suitable, and not suitable categories for chilli production. Land use data were reclassified, followed by the transformation into raster files.

Precipitation

Chilli prefers 750 to 1000mm precipitation per year (Naidu *et al.* 2006). High precipitation is detrimental for chilli cultivation, although it is also susceptible to water stress. The study area is characterized by higher rainfall, which is an adverse factor in chilli production. Rainfall data were collected from the Bangladesh Country Almanac (BCA) and converted to a raster file.

Soil pH

Chilli usually grows in soils with pH ranging from 5 to 9. However, the optimum pH is 6-7 (Hosmani 1982; Bose *et al.* 2002). Classification concerning soil pH was performed according to the guidelines of the Bangladesh Agricultural Research Council (Hussain *et al.* 2012).

Temperature

Chilli plants can grow well in a wide range of temperatures. The optimum temperature ranges between less than 10°C and 20-30°C (Hosmani 1982). Temperature regimes below 10°C and above 30°C have been observed as detrimental to plants' growth and development. Temperature data were collected from the Bangladesh Country Almanac (BCA) and converted from a vector to a raster dataset.

Slope

Land slope affects erosion and surface runoff due to the microclimate variation. Slope also influences other soil properties, such as the percentage of soil moisture, clay materials, and the availability of other nutrient elements, such as nitrogen, calcium, and magnesium (Khormali *et al.* 2012). Land with a minimum slope is suitable for chilli cultivation. On the other hand, a flattened slope is also unsuitable for chilli cultivation, as it may cause waterlogged conditions. Slope data were obtained from the Bangladesh Country Almanac (BCA) and transformed from vector to raster files.

Topsoil texture

Soil texture is considered an important criterion due to its influences on other soil properties such as bulk density, water holding capacity, and hydraulic conductivity. Chilli plants grow well in fairly light fertile soils that provide adequate soil nutrients, optimum microbial activities, and nitrogen to the plants. Soils with higher clay and sand contents are worse than loamy soils in terms of moisture and nutrient holding capacity, along with favorable microbial activities (Zhang *et al.* 2017). Topsoil texture data were collected in vector form and finally transformed into raster files, followed by reclassification.

Land Suitability Assessment

The land suitability assessment for chilli was conducted considering the classification guidelines proposed by the FAO, 1976. The guidelines for the land suitability classification were utilized to assess the suitability of each land unit for a particular purpose. According to the FAO's guidelines for land suitability assessment, it was initially determined whether the land was suitable (S) or not suitable (N). The suitable class (S) was further divided as required. In practice, three classes—S1, S2, and S3—were used to evaluate the lands for chilli cultivation. Thus, the land suitability evaluation was performed for the prioritized criteria that were reclassified into four categories. Finally, the suitability classes for chilli were determined considering equal influences of the criteria and using the weighted overlay spatial analysis in ArcGIS environment.

Results & Discussion

Reclassification of the criteria: The raster layers of all criteria were reclassified according to different suitability levels such as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) classes **(Figure 3a-j)**.

Weighted overlay: The suitability map for chilli was generated using weighted overlay spatial analysis. The results of the weighted overlay demonstrated that 4.74% (15,187 ha) were highly suitable, 29.31% (93,909 ha) were moderately suitable, 64.89% (2,07,908 ha) were marginally suitable, and 1.06% (3,396 ha) were not suitable (**Figure 4 & Table 1**).

Table 1. Land suitability classification for chilli

Suitability level	Pixel value	Area (%)	Area (hectares)
Not suitable (N)	466	1.06	3,396
Moderately suitable (S3)	28514	64.89	2,07,908
Marginally suitable (S2)	12880	29.31	93,909
Highly suitable (S1)	2083	4.74	15,187

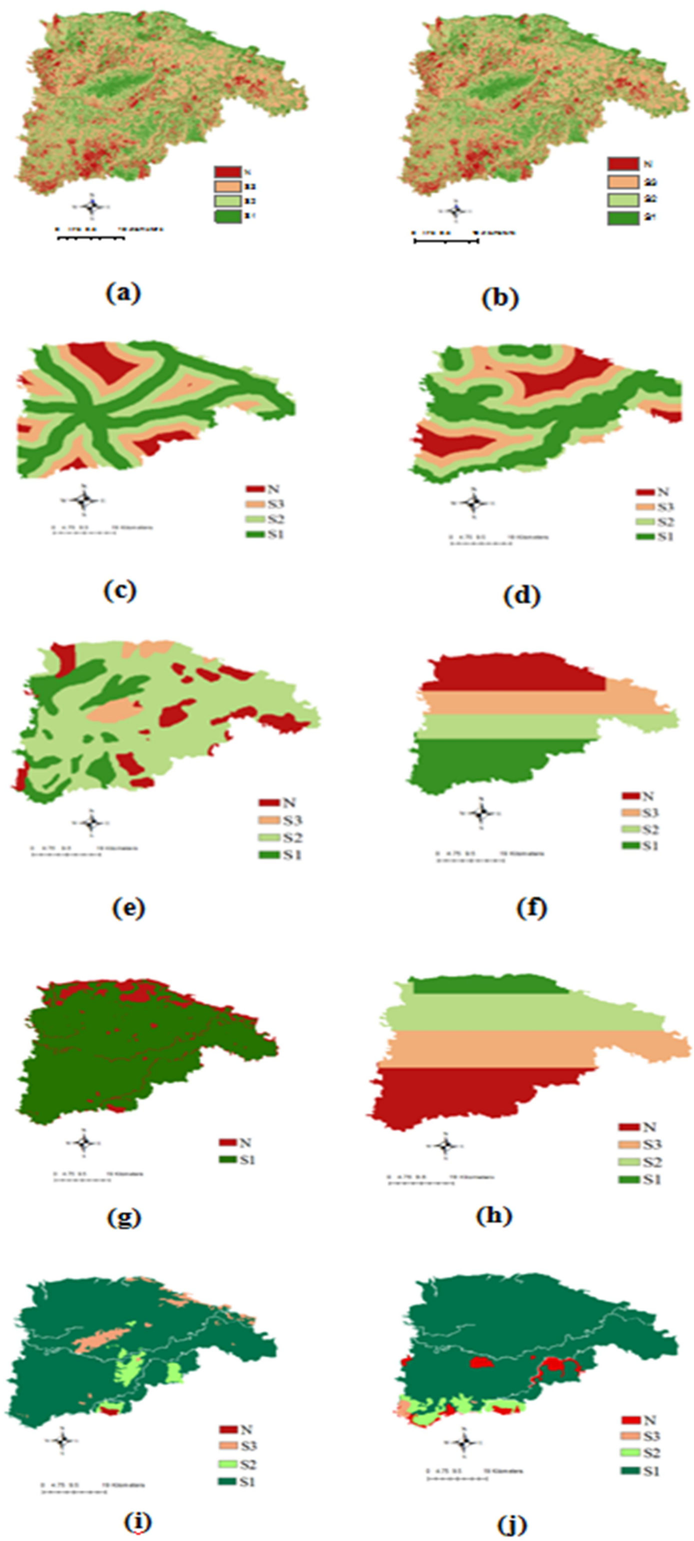

Figure 3. Reclassification map of the criteria (a) NDVI, (b) SAVI, (c) Distance from roads, (d) Distance from rivers, (e) Land use, (f) Precipitation, (g) Soil pH, (h) Temperature, (i) Slope, and (j) Topsoil texture

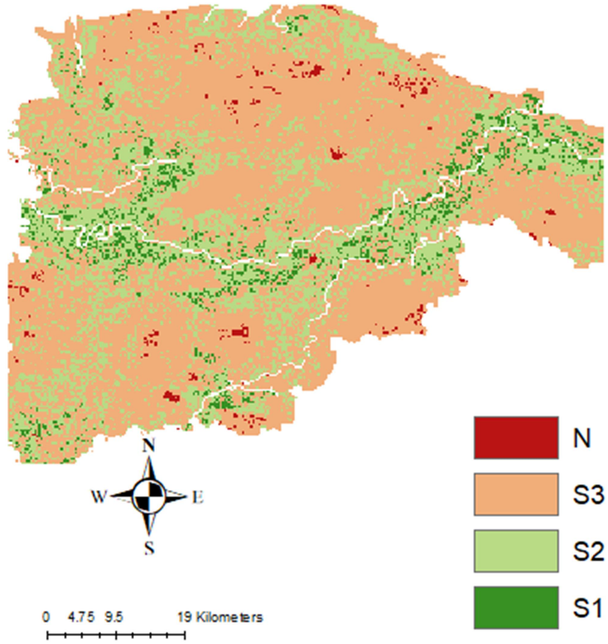

Figure 4. Suitability map of chilli

The incorporation of Landsat-8 images as remote sensing data and other geospatial datasets was important in this study to evaluate environmental limitations and to assess land suitability for chilli production. Various climatic, edaphic, topographic, and accessibility factors are critical and important for sustainable chilli production (Amarathunga *et al.* 2008). Distance from roads and rivers are important accessibility parameters concerning transportation facilities of input and harvested crops. The distance from rivers also facilitates the advantages of irrigation.

Most of the lands (64.89%) are marginally suitable for chilli cultivation, followed by 29.31% moderately suitable, 4.74% highly suitable, and only 1.06% not suitable categories. The maps of land suitability for chilli in the study area would be a valuable tool for scientists, agricultural extension workers, policy planners, and large farmers for its commercial production. The result of the present study would ensure better utilization of land and water resources along with food and nutrition security of the study area. Thus, it would also improve the livelihood of rural farmers. Suitability for growing a crop is not only determined by bio-physical potentiality but also by socio-economic suitability. Therefore, future research should be undertaken considering the factors of socio-economic suitability, including marketing and pricing of the product, which also depends on the government policy. Future horticultural research should also be carried out to validate the results of the present research.

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