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# Geographical Information System (GIS) based Land Suitability Evaluation for Cash and Perennial Crops in East Amhara Region, Ethiopia

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**Abstract**
The objective of this study was to spatially evaluate land suitability for sesame (*Sesamum indicum* L.), cotton ( *Gossypium hirsutum* L.), Enset (*Ensete ventricosum* L.) and Mango (*Mangifera indica* L.) crops in the East Amhara Region, Ethiopia based on FAO guidelines. Geographical Information System (GIS) was used to develop land suitability map. Land characteristics (LCs) and crop requirements used as criteria for crop suitability analysis were soil (soil depth, soil texture and pH), topographic (slope) and climatic (temperature) factors. Crop suitability map was made by matching between reclassified LCs with crop LURs using GIS model builder. The results indicated that the largest portion of the region (1649.8 ha (41.2%), 2760 ha (69 %), 2974 ha (74.35%) and 3852 ha (96.3%)) due to soil depth) were unsuitable due to soil depth for sesame, cotton, Enset and mango production, respectively. The map assists decision makers in the suitability of the crops' production.
**Keywords:** land suitability evaluation; crop; GIS; Amhara, Ethiopia

## 1. INTRODUCTION

Agriculture is the basis for the economy of Ethiopia. It accounts for the employment of 90% of its population, over 50% of the country's gross domestic product (GDP) and over 90% of foreign exchange earnings (ECACC, 2002). Irrespective of this fact, production system is dominated by small-scale subsistence farming system largely based on low-input and low-output rain-fed agriculture. As the result farm output lags behind the food requirement of the fast growing population. The high dependency on rain-fed farming in the dry lands of Ethiopia and the erratic rainfall require alternative ways of improving agricultural production.

Ethiopian agricultural sector has a proven potential to increase food supplies faster than the growth of the population (Davidson, 1992). Crop production plays a vital role in generating surplus capital to speed up the overall socio-economic conditions of the farmers. However, the country is unable to feed its people.

Sustainable agriculture would be achieved if lands be categorized and utilized based upon their capacity (FAO, 1983). Thus, land evaluation is essential to assess the potential and constraints of a given land parcel for agricultural purposes (Rossiter, G. D., 1996) using satellite data. The GIS system contains a set of procedures that facilitate the data input, storage, manipulation and analysis, and data output to support decision making activities (Grimshaw, 1994). To date, the FAO guidelines on the land evaluation system (FAO, 1976, 1983) are widely accepted for the evaluation. The value of land quality is the function of the assessment and grouping of land types into orders and classes in the framework of their fitness. Generally, land suitability is categorized as suitable (S) and not suitable (N). Whereas, S features lands suitable for use with good benefits, N denotes land qualities which do not allow considered type of use, or are not enough for suitable outcomes (FAO, 1993, 1985). Under the present situation, where land is a limiting factor, it is impractical to bring more area under cultivation to satisfy the ever growing food demand (Fischer *et al*., 2002). In other hand, the rapid population growth has caused increased demands for food while soil erosion and extensive deforestation continue (Fresco, 1992). Therefore, successful agriculture is required for sustainable use of soils that significantly determine the agricultural potential of an area. Land suitability evaluation for sesame (*Sesamum indicum* L.), cotton, Enset (*Ensete ventricosum* L.) and Mango (*Mangifera indica* L.) crops were not yet done in the region. This calls for a need to conduct detailed studies at region level for use in crop suitability analysis. Hence, the main objective of the study were to spatially evaluate the suitability of the selected crops using GIS tools thereby identify the potential to expand the selected cereal and pulse crops cultivation in East Amhara Region, Ethiopia.

## 2. MATERIALS AND METHODS

### *2.1 Description of the Study Region*

The present study region, East Amhara, with total area of 4,000 hectares (ha) is geographically located between 963873 and 1363639 north and 519535 to 656864 m east UTM (figure 1). The altitude is ranging from 580 to 3960 m.a.s.l. The study region has mean annual rainfall varying from 476 to 1930 mm. The major agro climatic zones (ACZ) categorized in to four traditional agro ecological zones as *Wurch, Dega, Woynadega* and *Kola* with 0.64, 16.25, 46.28 and 36.83%, respectively. The major farming system is mixed mode of production. However, the living standard of the farming community is still at subsistence level meanwhile the productivity of land is

 

seriously declining due to miss and under utilization of natural resources.

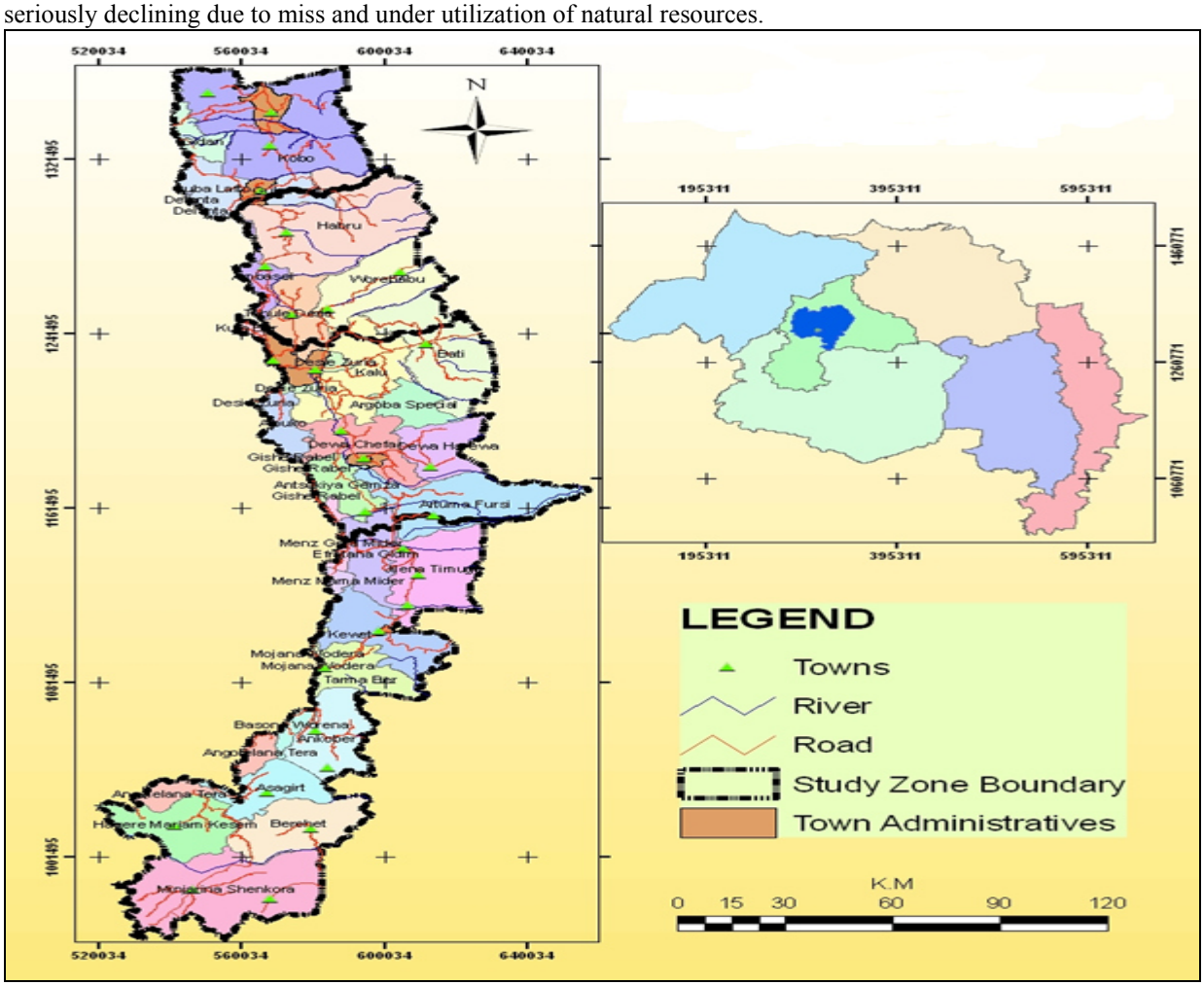


**Figure 1: Location map of East Amhara Region**

### *2.2 Data Sources*

The data sources consisted of different sets of primary, secondary and integrated database of the study region. Soil and climate database was obtained from the Amhara Regional soil and climate maps developed by DSA and CSA (2006) and established in excel computer program with the database file format. Crop environmental requirements database established in excel computer program with the database file format as classifier tables arranged from to values against the suitability classes. The 30 m spatial resolution DEM (digital elevation model) was used to generate slope by using "Spatial Analyst Tool Surface Slope" in ArcGIS environment.

### *2.3 Land Suitability Evaluation and Classification*

The crop land utilization types (sesame (*Sesamum indicum* L.), cotton, Enset (*Ensete ventricosum* L.) and Mango (*Mangifera indica* L.)) were selected through discussion with the key informant farmers and development agents. When crop selection was carried out, area coverage, importance of the crops in the livelihood of the concerned community, suitability of soils and agro-climatic conditions of the study region were considered. The crop land use requirements (LURs) were also selected based on agronomic knowledge of local experts and FAO (1998) guideline. Digital data of selected land characteristics (LCs) of the region and classifier tables for crop LURs were properly encoded to the Microsoft Office Excel sheet as database file to be used in ArcGIS for spatial analysis. The LCs were reclassified based on crop LURs.

The evaluation criteria used to address the suitability of the selected crop LUTs in the study region were soil (texture, pH and available P), topographic (slope), and climatic (temperature) factors were rated based on FAO land evaluation system using (FAO, 1976, 1983) guidelines. Individual land suitability classifications at present condition was then made in an area of about 4000 ha by matching between reclassified LCs of the region with crop LURs using GIS model builder (Figure 3). The model builder uses maximum limitation method so that the most limiting climatic or soil parameter dictates the final level of suitability (Sys *et al*., 1991; Van Diepen *et al*., 1999). Ground truth data collected by GPS were used for checking and validation of results.

 

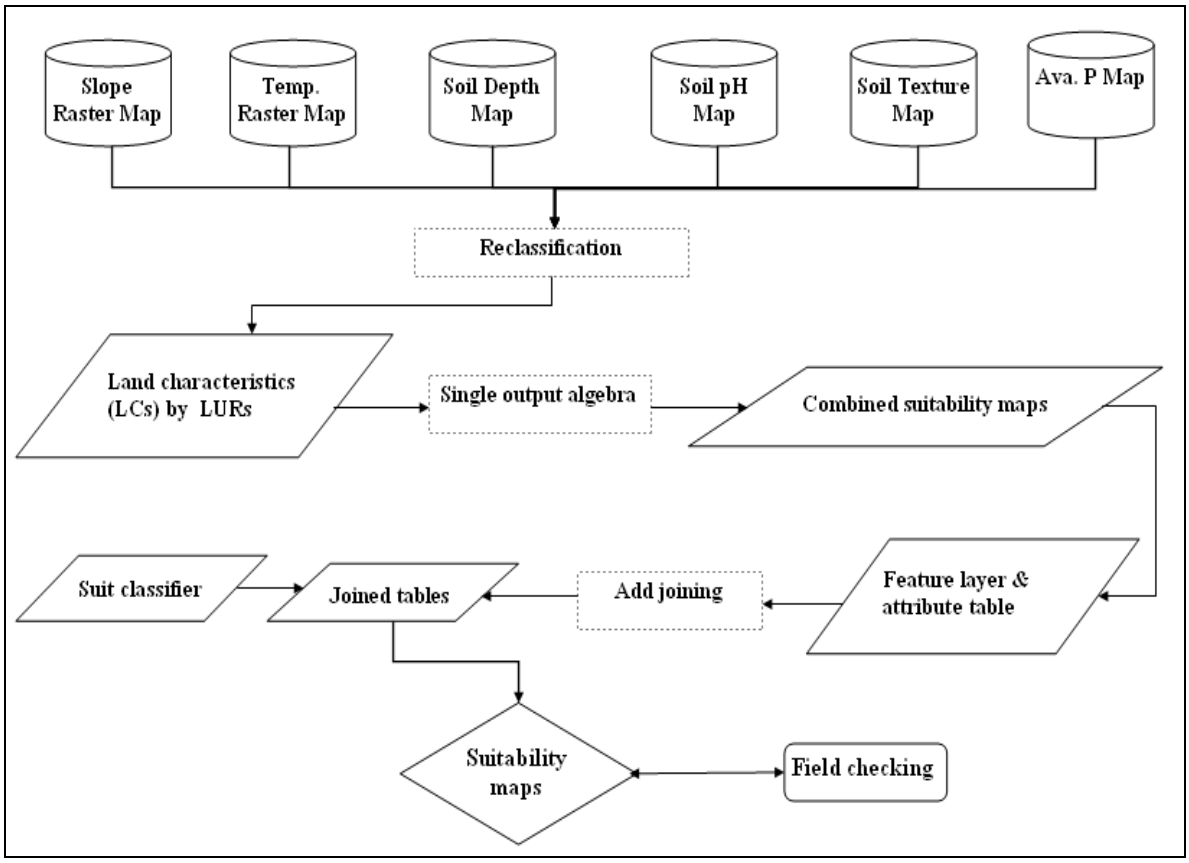


**Figure 2: Overall methodology followed and outputs produced in ArcGIS environment**

## 3. RESULTS AND DISCUSSION

The factors influencing sesame and cotton yields and their suitability are slope, temperature, soil depth, texture, pH, available phosphorus, etc (FAO, 1998). The study has produced potential land suitability map of the East Amhara Region that will allow growing the right cash and perennial crops at the right site for optimum yield and optimum return to investment for each crops. Table 1-2 and figure 3-4 showed that the land use suitability analysis indicated that the largest portion of the region (1649.8 ha (41.2%), 2760 ha (69 %), 2974 ha (74.35%) and 3852 ha (96.3%)) due to soil depth for) were unsuitable due to soil depth for sesame, cotton, Enset and mango production, respectively. In addition, 1036.3 ha (25.9%), 630.4 ha (15.76%) land areas were moderately suitable (S2) for sesame and cotton crop production, respectively.

**Table 1: Sesame and Cotton Suitability, Areas and their Limitations**

| | Sesame | | Cotton | |
|---|---|---|---|---|
| Suitability class | Area (ha) | Cover (%) | Area (ha) | Cover (%) |
| Nr | 1649.8 | 41.2 | 2760 | 69 |
| S1 | 228.2 | 5.7 | 281 | 7.03 |
| S2k | 160.5 | 4 | 116.1 | 2.9 |
| S2r | 264.3 | 6.6 | 180.1 | 4.5 |
| S2t | 611.5 | 15.3 | 334.2 | 8.36 |
| Sub-total for S2 | 1036.3 | 25.9 | 630.4 | 15.76 |
| S3r | 313.2 | 7.8 | 238.5 | 5.96 |
| S3k | 772.2 | 19.3 | 90.5 | 2.26 |
| Sub-total for S3 | 1085.4 | 27.1 | 329 | 8.22 |

 

**Table 2: Enset and Mango Suitability, Areas and their Limitations**

| Suitability class | Enset | | Mango | |
|---|---|---|---|---|
| | Area (ha) | Cover (%) | Area (ha) | Cover (%) |
| Nr | 2974 | 74.35 | 3852 | 96.3 |
| S1 | 92.12 | 2.3 | 24 | 0.6 |
| S2k | 82.4 | 2.06 | 16 | 0.4 |
| S2r | 137.28 | 3.43 | 28.4 | 0.71 |
| S2t | 219.68 | 5.49 | 44.4 | 1.11 |
| Sub-total for S2 | 119.56 | 2.99 | 22 | 0.55 |
| S3r | 82.4 | 2.06 | 25.2 | 0.63 |
| S3k | 512.12 | 12.8 | 32.4 | 0.81 |
| Sub-total for S3 | 714.08 | 17.85 | 79.6 | 1.99 |

The study revealed that GIS technique was found to be most essential tool for the crop land suitability evaluation of the Region. It was clear that the same parcel of land was suitable for all crops bringing competing nature of crop LUTs. To validate the variations observed in the spatial analysis, other empirical research need to be carried out. The current limiting factors for all crop suitability were soil texture (k), soil depth (r) and temperature (t) limitations. Decision-making regarding selection of crop LUTs and mitigation measures to alleviate the identified crop production limitations could also be include socio-economic evaluation (Ceballos-Silva and Lopez-Blanco, 2002).

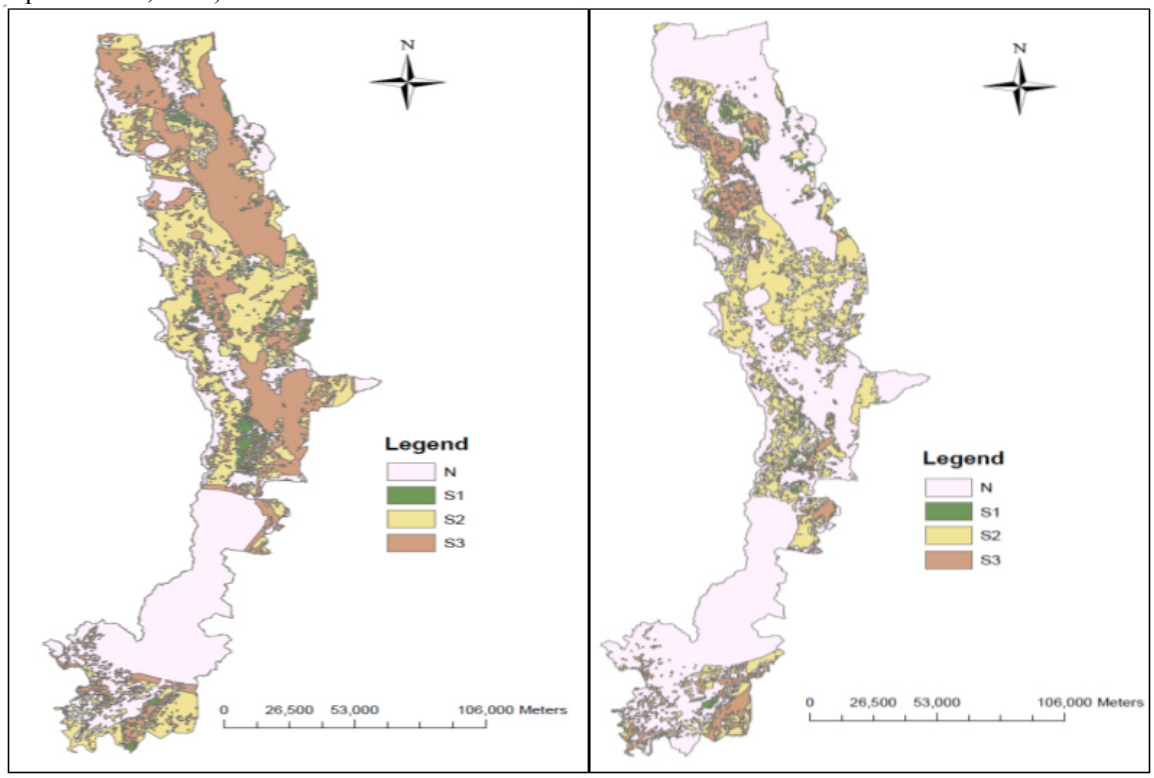


**Figure 3: Sesame (left) and Cotton (right) Suitability Maps**

 

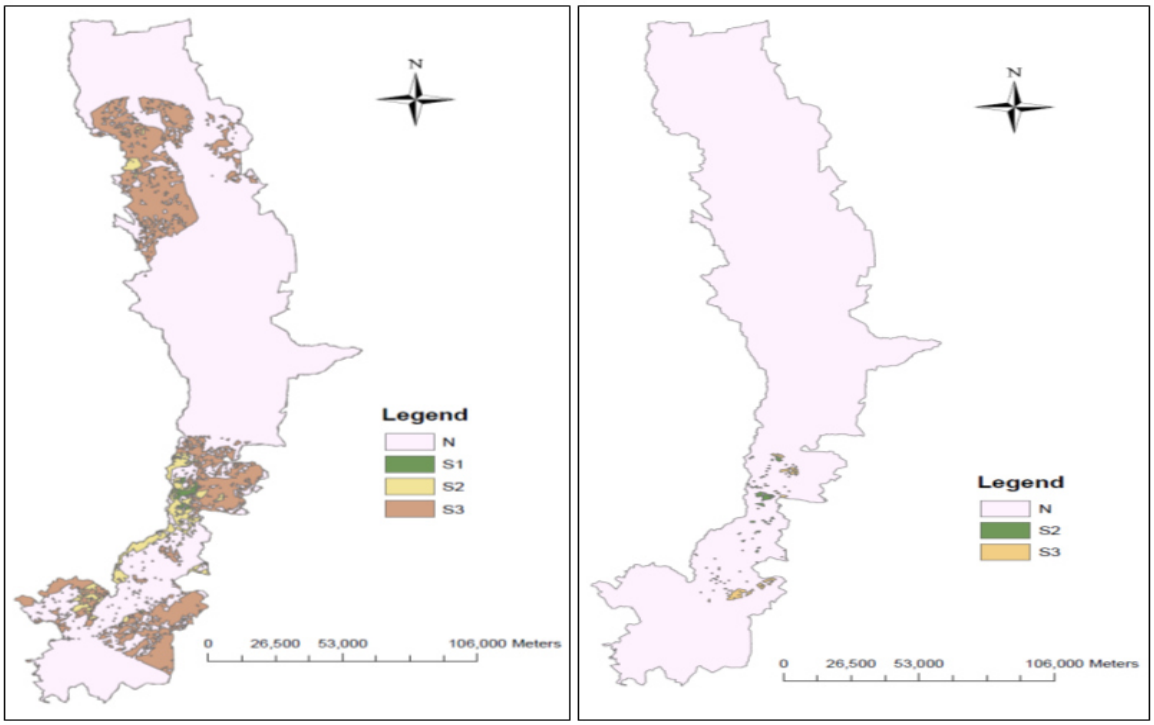


**Figure 3: Enset (left) and Mango (right) suitability Map**

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