A Geographic Information System Based Physical Land Suitability Evaluation to Groundnut and Sweet Potato in East Amhara, Highlands of Ethiopia

Gizachew Ayalew
Amhara Design and Supervision Works Enterprise (ADSWE), Bahir Dar, Ethiopia
E-mail: gizachewayalew75@yahoo.com

Abstract
Land suitability mapping and analysis is a prerequisite to achieving optimum utilization of the available land resources. The objective of this study was to spatially evaluate land suitability for groundnut (Arachis hypogaea L.) and sweet potato (Ipomoea pandurata L.) crops in the east Amhara region, Ethiopia based on FAO guidelines. Geographical Information System (GIS) was used to create land suitability map. The criteria for crop suitability analysis were soil depth, soil texture, pH, organic carbon and temperature. Crop suitability map was made by matching between reclassified land characteristics with crop requirements using GIS model builder. The land use suitability analysis indicated that the largest portion of the region 1562993 ha (83.26%) and 1039522 (55.37%) were unsuitable for groundnut and sweet potato crops production, respectively due to clay in soil texture (k), shallow root depth (r) available phosphorus (p) and low climatic temperature (t). The map could assist decision makers during land cultivation with studied crops.

Keywords: land, crop, suitability, GIS, Amhara

1. Introduction
Ethiopia has a considerable land resource for agriculture. About 73.6 million ha (66%) of the country’s area is potentially suitable for agriculture (Fasil, 2002) and the 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 due to various bio-physical and socio-economic constraints and policy disincentives.

Agriculture is the basis for the economy of Ethiopia. It accounts for the employment of 90 percent of its population, over 50 percent of the country’s gross domestic product (GDP) and over 90 percent 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 rainfed agriculture. As the result farm output lags behind the food requirement of the fast growing population. The high dependency on rainfed farming in the dry lands of Ethiopia and the erratic rainfall require alternative ways of improving agricultural production.

Soil erosion is becoming a major policy challenge in Ethiopia not only for increasing crop productivity but also for maintaining soil resource base for the future generation. It can pose a great concern to the environment because cultivated areas can act as a pathway for transporting nutrients, especially phosphorus attached to sediment particles, to river systems (Ouyang and Bartholic, 1997). Its effect is both on-site (decreased soil productivity) and off-site, with impacts on water quality that include increased sedimentation and probability of floods (El-Swaify, 1994; Zhou and Wu, 2008 and Chiu et al., 2007). The net soil loss from cultivated fields due to erosion ranged from 20 to 100 t/ha per year, with corresponding annual productivity loss of 0.1 to 2% of total production (Hurni, 1993). In other side, the potential of the land for crop production to sustainably satisfy the ever increasing food demand of the increasing population is declining as a result of severe soil degradation (Lal, 1994).

In order to produce products in an environmentally compassionate, socially acceptable and economically efficient and ensure optimum utilization of the available natural resource, land evaluation is required (Nisar Ahamed et al., 2000 and Addeo et al., 2001). Land evaluation is also essential to assess the potential and constraints of a given land parcel for agricultural purposes (Rossiter, G. D., 1996) using satellite data and GIS which have strong capacity in data integration and analysis (Yamamoto et al., 2003, Thavone et al., 1999, Quang Duc, 1999, Mongkolsawat et al., 1999 and Mongkolsawat et al. 1997). To date, the FAO guidelines on the land evaluation system (FAO, 1976, 1983) are widely accepted for the evaluation. The guidelines involve the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. Soil suitability evaluation, on the other hand, involves characterizing the soils in a given area for specific land use type. Certain groups of activities are common to all types of soil suitability evaluation and details of these activities which are carried out vary with circumstances. The suitability of a given piece of land is its natural ability to support a specific purpose and this may be major kind of land use, such as rain fed agriculture, livestock production, forestry

33
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 groundnut (*Arachis hypogaea* L.) and sweet potato (*Ipomoea pandurata* L.) crops were not yet done in the region. This calls for a need to conduct detailed studies at watershed 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, Ethiopia.

2. Materials and Methods
2.1 Description of the Study Watershed
2.1.1 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 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 consisting of crop production and animal rearing. It exists in many forms depending on climate conditions, market prices, technological developments, soil characteristics, composition of the family and farmers' initiative. Farmers can decide to choose for mixed farming when they want to save resources by interchanging them on the farm because they consider mixed systems closer to nature and allow diversification for better risk management. However, the living standard of the farming community is still at subsistence level meanwhile the productivity of land is seriously declining due to mess and unsuitable utilization of natural resources.
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 using “Spatial Analyst Tool Surface Slope” in ArcGIS environment.

2.3 Land Suitability Evaluation and Classification
The land suitability for groundnut and sweet potato crops were done based on the 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 depth, texture, pH, organic carbon, and climatic temperature factors were rated based on FAO land evaluation system using (FAO, 1976; 1983) guidelines and inserted in the GIS model. Individual land suitability classifications at present condition were then made in the region by matching between reclassified LCs of the region with crop LURs using GIS model builder (Figure 2). The model builder uses maximum limitation method based on each crop suitability rating classifier table 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.

![Diagram](Figure 6: Model used in the study)

3. Results and Discussion
Table 2 and Figure 3 showed that the land use suitability analysis indicated that the largest portion of the region 1562993 ha (83.26%) and 1039522 (55.37%) were unsuitable for groundnut and sweet potato crops production, respectively. In addition, 98616 ha (5.25%) and 217256 ha (11.57%) land areas were moderately suitable (S2) for groundnut (Arachis hypogaea L.) and sweet potato (Ipomoea pandurata L.) crop production, respectively.
due to clay in soil texture (k), shallow root depth (r), available phosphorus (p), and low climatic temperature (t). As Figure 4 showed several GPS points were used to validate all crop suitability results.

Soil degradation is also a major problem in the region as whole not only for increasing the crop productivity but also for maintaining soil productivity. Accordingly, the potential of the land for crop production to sustainably satisfy the ever-increasing food demand of the increasing population is declining (Lal, 1994) and annual crop productivity loss reached 0.1 to 2% of total production in the region (Hurni, 1993). The main factors (temperature, soil depth, texture, available phosphorus) influencing groundnut and sweet potato crops yields and their suitability (FAO, 1998) should be amended based on the crop land use requirements of the crops.

Table 1: Suitability of groundnut and sweet potato and their limitations

<table>
<thead>
<tr>
<th>No</th>
<th>Groundnut</th>
<th>Area (ha)</th>
<th>Cover (%)</th>
<th>sweet potato</th>
<th>Area (ha)</th>
<th>Cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N</td>
<td>1562993</td>
<td>83.258</td>
<td>N</td>
<td>1039522</td>
<td>55.374</td>
</tr>
<tr>
<td>2</td>
<td>S1</td>
<td>42</td>
<td>0.002</td>
<td>S1</td>
<td>5774</td>
<td>0.308</td>
</tr>
<tr>
<td>3</td>
<td>S2k</td>
<td>17869</td>
<td>0.952</td>
<td>S2k</td>
<td>55191</td>
<td>2.94</td>
</tr>
<tr>
<td>4</td>
<td>S2p</td>
<td>37918</td>
<td>2.02</td>
<td>S2n</td>
<td>15748</td>
<td>0.839</td>
</tr>
<tr>
<td>5</td>
<td>S2r</td>
<td>709</td>
<td>0.038</td>
<td>S2t</td>
<td>23510</td>
<td>1.252</td>
</tr>
<tr>
<td>6</td>
<td>S2t</td>
<td>42120</td>
<td>2.244</td>
<td>S2t</td>
<td>122807</td>
<td>6.542</td>
</tr>
<tr>
<td></td>
<td>Sub total</td>
<td>98616</td>
<td>5.25</td>
<td></td>
<td>217256</td>
<td>11.57</td>
</tr>
<tr>
<td>7</td>
<td>S3n</td>
<td>83169</td>
<td>4.43</td>
<td>S3n</td>
<td>146413</td>
<td>7.799</td>
</tr>
<tr>
<td>8</td>
<td>S3r</td>
<td>56009</td>
<td>2.984</td>
<td>S3r</td>
<td>4201</td>
<td>0.224</td>
</tr>
<tr>
<td>9</td>
<td>S3t</td>
<td>34741</td>
<td>1.851</td>
<td>S3t</td>
<td>70779</td>
<td>3.77</td>
</tr>
<tr>
<td></td>
<td>Sub total</td>
<td>173919</td>
<td>9.27</td>
<td></td>
<td>221393</td>
<td>11.79</td>
</tr>
</tbody>
</table>

Figure 7: Groundnut (left) and sweet potato (right) suitability Map
Note: N for unsuitable; S1 for highly suitable; S2 for moderately suitable and S3 for marginally suitable
4. CONCLUSIONS
The study revealed that GIS technique was found to be essential tool for the crop land suitability evaluation of the Region. 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 available phosphorus (p) limitations.

5. References
farming systems analysis for land-use planning. FAO guidelines: Working document, ITC and Wageningen Agricultural University, Wageingen, the Netherlands.


The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage: http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/  All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar