Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.1, 2015

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

(Ande, 2011).

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 agroecological 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.

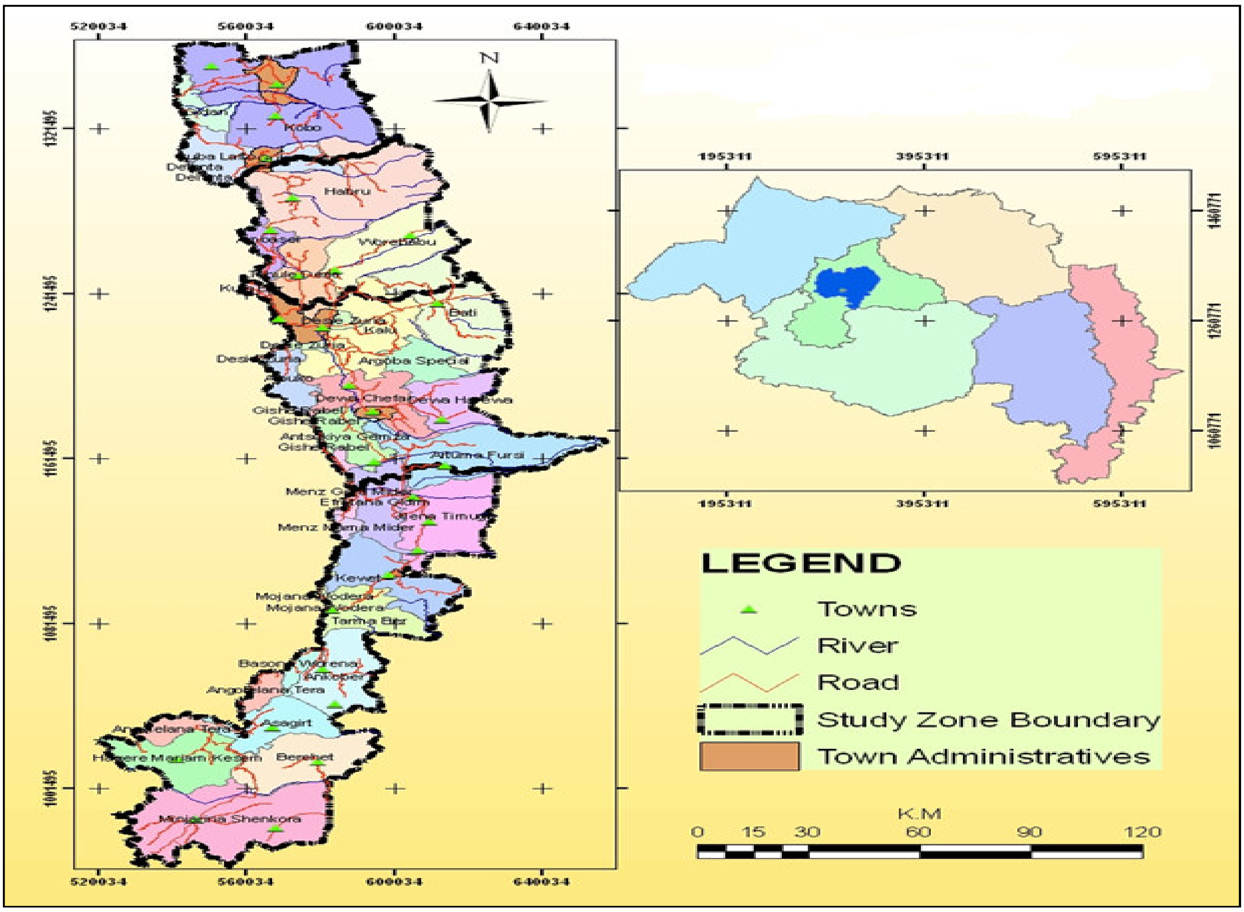

Figure 5: Location of east Amhara region

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 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.

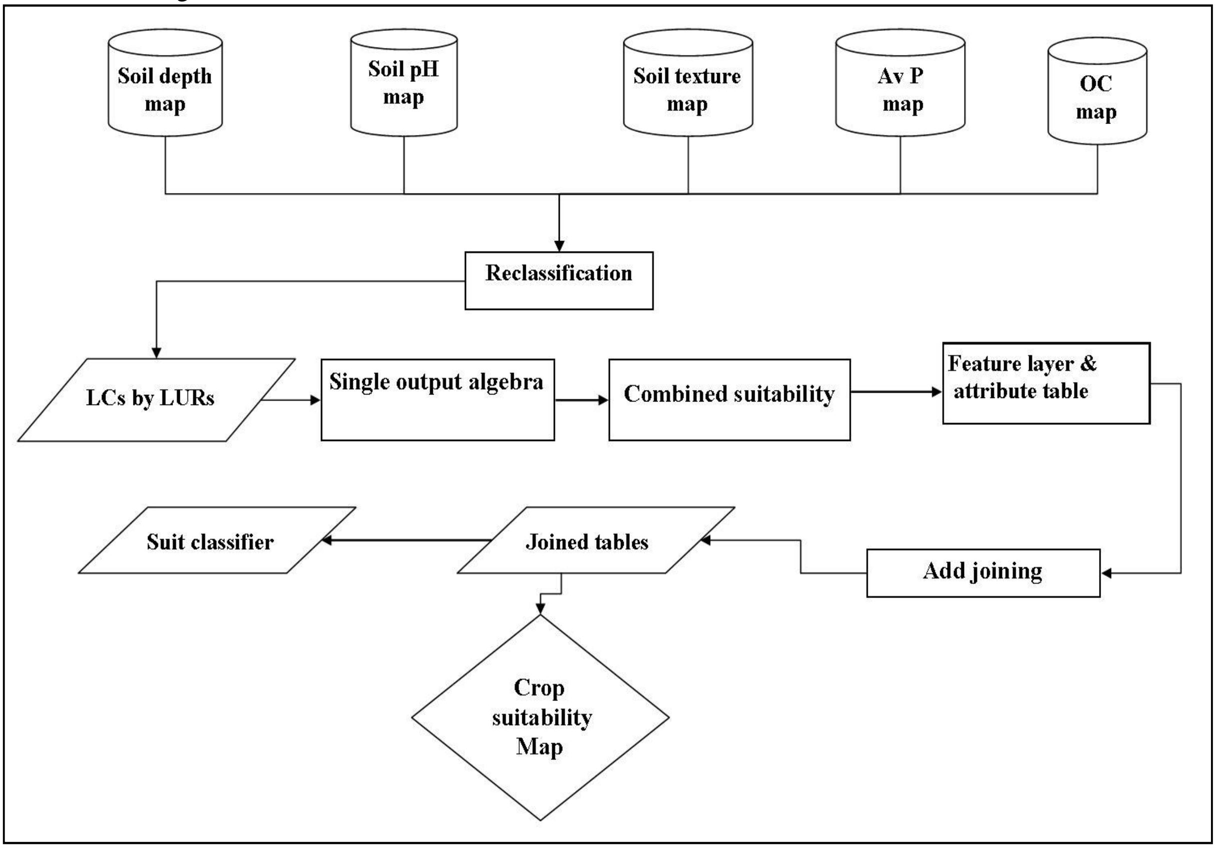

Figure 6: Model used in the study

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 sweat potato and their limitations

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

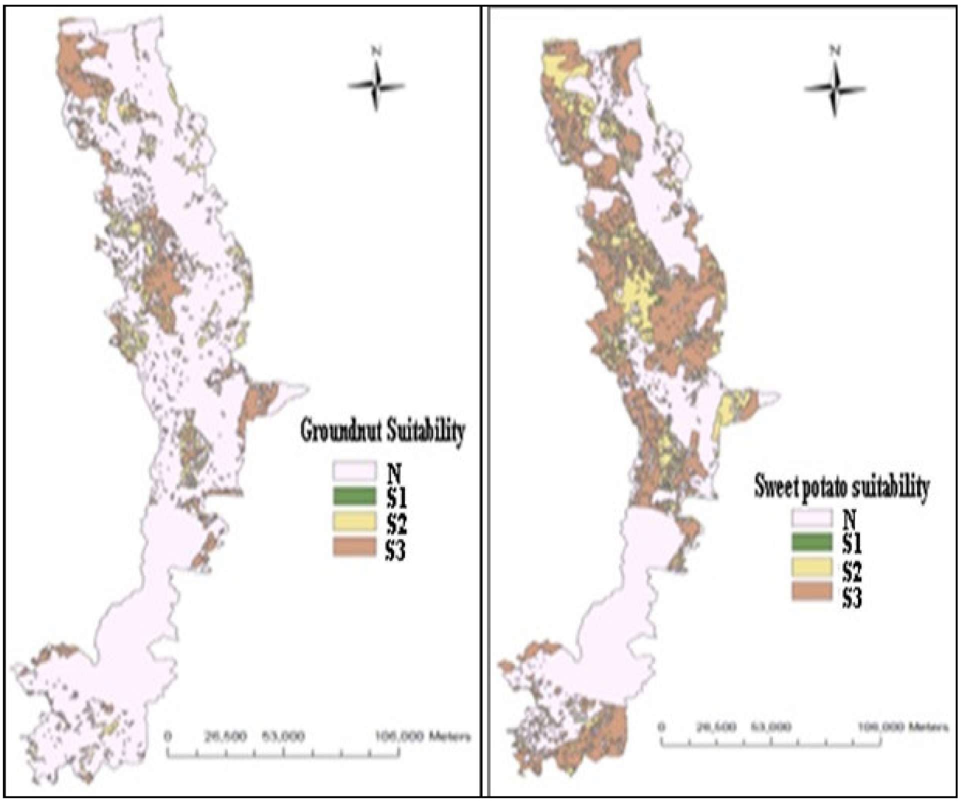

Figure 7: Groundnut (left) and sweat potato (right) suitability Map
Note: N for unsuitable; S1 for highly suitable; S2 for moderately suitable and S3 for marginally suitable

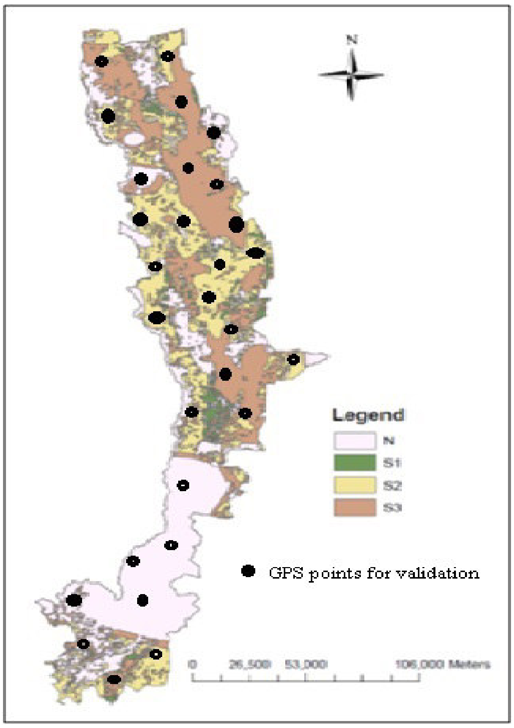

Figure 8: GPS points used to validate against for all crop suitability results

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

Addeo, G., Guastadisegni, G., Pisante, M. (2001). Land and water quality for sustainable and precision farming. I World Congress on Conservation Agriculture, Madrid

Ande, O. T (2011). Soil Suitability Evaluation and Management for Cassava Production in the Derived Savanna Area of Southwestern Nigeria. International Journal of Soil Science, 6, pp. 142-149.

Chiu Y. J., Borghuis A. M., Lee H. Y., Change K. T., and Chao J. H. (2007). Estimation of soil erosion in a reservoir watershed using 137cs fallout radionuclide. International Journal of Sediment Research, 22, pp. 304–317.

Davidson, D. A. (1992). *The Evaluation of Land Resources*. Stirling University press, USA, NewYork.

Development Studies Associates (DSA) & Shawel Consult International (SCI) (2006). *Potential Survey, Identification of Opportunities and Preparations of Projects Profiles and Feasibility Studies*. Addis Ababa, Ethiopia.

Ethiopian Central Agricultural Census Commission (ECACC) (2002). A Report on Preliminary Results of Area, Production and Yield of Temporary Crops (Meher Season Private Peasant Holding), Part II, on Ethiopian Agricultural Sample Enumeration, Addis Ababa, Ethiopia.

El-Swaify, S. A. (1994). State-of-the-art for assessing soil and water conservation needs and technologies, in: Napier, T. L., Camboni S. M., El-Swaify, S. A., (Eds.), Adopting conservation on the farm. Ankeny, IA: Soil and Water Conservation Society of America, pp. 13-27.

FAO (1976). *Framework for Land Evaluation* (pp. 17-21). FAO Soil Bulletin No.32, *FAO,* Rome.

FAO (1983). *Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soils Bulletin no. 52*, FAO, Rome.

FAO (1998). *Guidelines on Land Evaluation for Rainfed Agriculture*. Soils Bulletin No.52, FAO, Rome, Italy.

Fasil, K. (2002). *Analysis of Yield Gap for Wheat Cultivation in the Highlands of North Ethiopia.* Ph.D. Thesis, Gent University, Belgium.

Fischer, G., Velthuizen, H.V., Shah M., & Nachtergaele, F. (2002). *Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results.* International Institute for Applied Laxenburg in Australia.

Fresco, L.O., Huizing, H.G.J., Van Keulen, H., Luning, H.A., and Schipper, R.A. (1992). Land evaluation and farming systems analysis for land-use planning. FAO guidelines: Working document, ITC and Wageningen Agricultural University, Wageningen, the Netherlands.

Hurni, H. (1993). Land degradation, famine and land resource scenarios in Ethiopia. In: Pimentel D (ed) World soil erosion and conservation. Cambridge University Press, Cambridge, pp. 27-62.

Lal, R. (1994). Sustainable land use systems and soil resilience. In D. J. Greenland & I. Szabolcs (Eds.), *Soil Resilience and Sustainable Land Use*, pp. 41-67. UK: CAB International.Mongkolsawat, C., Thirangoon, P., & Kuptawutinan, P., (1997). A Physical Evaluation of Land Suitability For Rice: A Methodological Study using GIS. Proceedings of the 18th Asian Conference on Remote Sensing. Malaysia.

Mongkolsawat, C., Thirangoon, P., & Kuptawutiana, P. (1999). Land Evaluation for Combining Economic Crops using GIS and Remotely Sensed Data. Proceedings of the 2nd Asia Pacific Conference on Sustainable Agriculture, Pitsanulok, October 18-20.

Nisar Ahamed, T.R., Gopal Rao, K., and Murthy, J.S.R. (2000). GIS-based fuzzy membership model for crop-land suitability analysis. Agr Syst 63(2):75-95.

Ouyang, D., and Bartholic, J., (1997). Predicting sediment delivery ratio in Saginaw Bay watershed. Proceedings of the 22nd National Association of Environmental Professionals Conference. May 19-23, 1997, Orlando, FL, pp. 659-671.

Rossiter, G. D., (1996). A theoretical frame work for land evaluation. *Goederma*, 72, 165-190.

Sys, I., Van Ranst, E., & Debaveye, J. (1991). Part II Methods in Land Evaluation. *Agriculture Publication No.7, General Administration for Development Cooperation,* pp. 70-76. Brussels, Belgium.

Thavone, I., (1999). The Use of Geographic Information Systems for Soil Survey and Land Evaluation. Paper presented at the Application of Resource Information Technologies (GIS/GPS/RS) in Forest Land and Resources Management Workshop, Hanoi, Vietnam.

Van, Diepen, C. A., Van Keulen, H., Wolf, J., & Berkhout, J. A. A. (1999). Land Evaluation: From Intuition to Quantification. In B. A. Stewart (Ed.), *Advances in Soil Science,* pp. 139-204. New York: Springer.

Yamamoto, Y., & Sukchan, S. (2003). Land Suitability Analysis Concerning Water Resource and Soil Property. JIRCAS Working Report No.30. (pp. 25-31). Thailand.

Zhou, P., Luukkanen, O., Tokola, and T., Nieminen, J. (2008). Effect of vegetation cover on soil erosion in a mountainous watershed.Catena 75:319-325.