Geographical Information System (GIS) Based Land Capability Classification of East Amhara Region, Ethiopia

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Abstract
The objective of this study was to spatially classify lands of East Amhara Region, Ethiopia based on their capability for sustainable use by USDA criteria. Evaluation criteria for capability analysis were soil depth, soil texture, soil drainage, organic carbon and slope. Surface soil samples at 0-30cm depth from different soil types were collected and analyzed in the soil laboratory of Amhara Design and Supervision Works Enterprise (ADSWE). Geographical Information System (GIS) was used to develop land capability map. Digital Elevation Model (DEM) data of 30 m resolution was used to derive slope. Surface soil samples at 0-30cm depth from different soil types were collected and analyzed in the soil laboratory of Amhara Design and Supervision Works Enterprise (ADSWE). Intersect overlay analysis method was applied to obtain the spatial and attribute information of all the input parameters using Geographical Information System (GIS) 10.1 soft ware. The study demonstrates that GIS provide advantage to analyze multi-layer of data spatially and classify land based on its capability. The study revealed that 1192.36 ha (29.81%), 24.24 ha (0.61%), 3.81% (152.44 ha), 50.76 ha (1.27 %), 507.32 ha (12.68 %), 1833.72 ha (45.84 %), 0.16 ha (0.004%) and 2072.96 ha (51.82%) of the region was categorized in the range of land classes I, II, III, IV, V, VI, VII and VIII, respectively.
Keywords: Ethiopia; GIS; highlands; land capability classification

1. Introduction

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, air and water resources (Sonter and Lawrie 2007). Failure to manage land in accordance with its capability risks degradation of resources on- and off-site, leading to a decline in natural ecosystem values, agricultural productivity and infrastructure functionality. Natural resources should be managed in a sustainable manner so that the changes proposed to meet the needs of development are brought without diminishing the potential for their future use (Kanwar, 1994). It has been essential in a country like Ethiopia where majority of the population depends on agriculture. The increase in the number of people makes a pressure rate on land resources inevitable that causes an impact on the land degradation and environmental pollution.

United State Department of Agriculture (1973) guidelines have been applied to determine land capability with eight classes designated with Roman number I to VIII. The criteria for placing an area in a particular class involve the landscape location, slope, depth; texture and land use/land cover. The final aim of LCC is to predict the agricultural capability of the land development units in function of the land resources (Sys *et al*, 1991). Agriculture is the mainstay of the Ethiopia's economy where its production is highly dependent on natural resources (Akililu and Graaff, 2007). However, land degradation is a major cause of poverty in country and the farming populations have experienced a decline in real income due to demographic, economic, social, and environmental changes (Mitiku *et al,* 2002).

Sustainable land management is inevitable to minimizing land degradation, rehabilitating degraded areas and ensuring the optimal use of land resources for the benefit of present and future generations (FAO, 1998, 2008). Despite the aggravation of land degradation and its consequences in the country in general and the study region in particular, there have been few studies to classify lands based on their capability at region level. Therefore, this study was initiated to spatially classify lands of East Amhara Region based on their capability for sustainable use.

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.

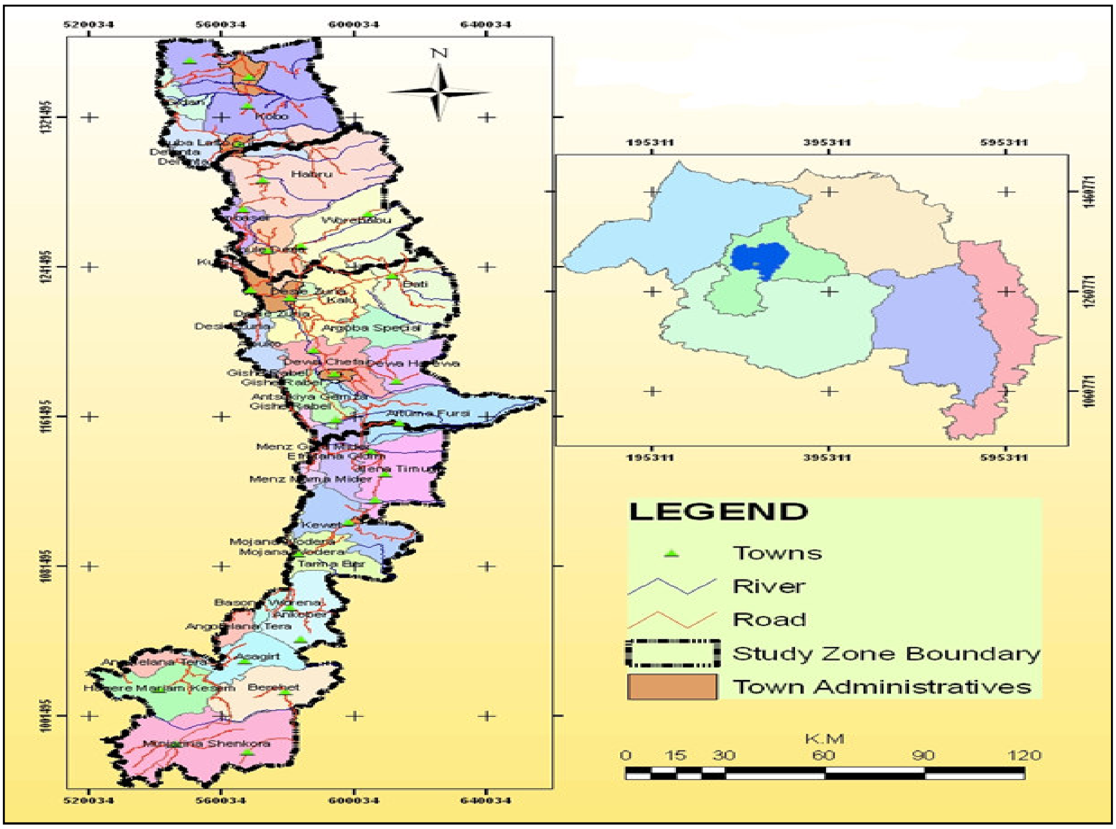

Figure 7: Location map of East Amhara Region

2.2 Data Sources

The 30 m spatial resolution DEM (digital elevation model) was used to generate slope by using "Spatial Analyst Tool Surface Slope" in ArcGIS environment. "Tools Overlay Intersect" in GIS environment was used to map LCC using USDA (1973) LCC method in ArcGIS at scale of 1:25,000. Ground truth data were used to validate the results.

2.3 Surface Soil Sampling

The region was stratified into six slope classes as there is strong relation between slope and soil types and their characteristics (FAO, 1998). Based on soil color, texture and slope, major soil types and their boundaries were identified and delineated by auguring by intensive traversing. Several auger observations were taken by Edelman auger at surface layer (0-30cm) and bulked into 10 composite soil samples for surface soil characterization and crop suitability evaluation purposes (Figure 2). Spatial soil characterization was made at scale of 1:25,000 based on the information obtained from field soil surface description and laboratory analysis result. Surface soil samples from different soil types were collected and analyzed in the soil laboratory of Amhara Design and Supervision Works Enterprise (ADSWE).

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.1, 2015

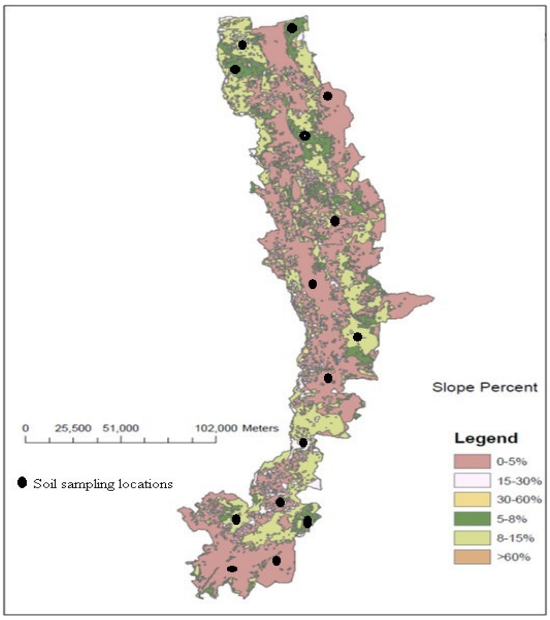

Figure 8: Soil sample locations along slope category

2.4 Soil Analysis

The soil samples collected from surface were air dried at room temperature and ground to pass through sieves. Soil texture was determined by the hydrometer method as described in Bouyoucos (1962) where hydrogen peroxide was used to destroy OM and using sodium hexa-metaphosphate as dispersing agent. Then, hydrometer readings after 40 seconds and 2 hours were used to determine the silt plus clay and clay particles in suspension, respectively, whereas the percent of silt was calculated from the difference. Soil textural classes were determined following the textural triangle of USDA system as described by Rowell (1997). The OC content was analyzed following the Walkley and Black wet digestion method (Nelson & Sommers, 1982).

Table 1: Soil physicochemical Analysis

Soil depth (cm)	Texture class	OC (%)
>150	Heavy clay	1.05
>150	Silty clay	112.58
>150	Clay loam	133.47
>150	Heavy clay	66.78
>150	Clay loam	172.94
>150	Clay loam	83.76
>150	Clay loam	66.5
>150	Loam	102.32
>150	Clay	130.62
>150	Clay	55.46

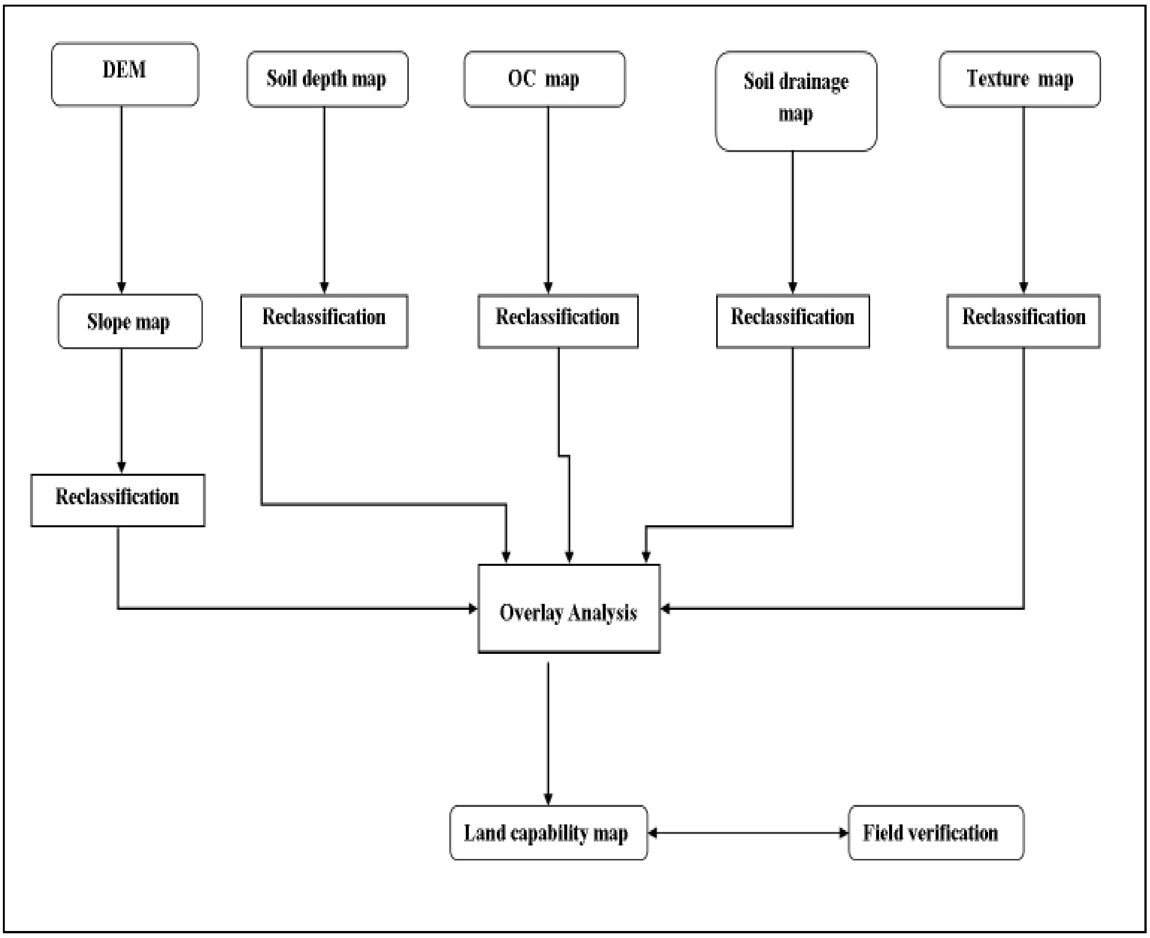

Figure 3: Land capability classification (LCC) method performed in GIS environment

3. Results and Discussions

LCC I to III occupied 1369.04 ha (34.23%) of the region can be termed as the land suitable for agriculture. Class I covered 1192.36 ha of land and accounts 29.81% of the study area. The soils do not have limitations or hazards that restrict their use and suitable for a wide range of crops. They can be cropped very intensively, used for pasture, range, woodlands and wildlife reserves. The soils are deep, well drained, and the land is flat to gently sloping and generally fertile. They hold water well and are either fairly well supplied with plant nutrients or highly responsive to input of fertilizer. Their texture indicates that they have a higher water-holding capacity. They are suitable for irrigated crop cultivation. The sites are level and climate is favorable.The soils need only commonly used crop management practices such as land preparation, manure and fertilizer application and weeding to maintain their productivity. Land management, however, is linked to farm size, level of capitalization considered economically justified by the farmers. The level of yield is considered relatively high in these soils.
As shown in table2 and figure 3, land capability class II occupied 24.24 ha of land accounted 0.61%. Soils in class II have limitations that reduce the choice of plants or require moderate conservation practices. Soils in this class require careful soil management and conservation practices to prevent deterioration or to improve air and water relations when the soils are cultivated. The limitations are few and easy to apply. Class III consists of 3.81% of the study area occupied 152.44 ha of land. The major limitations of this class include erosion, slope, soil depth and drainage. It is, therefore, obvious that the soils in Class III have combinations of limitations that reduce the choice of plants or require special conservation practices.

The soils and climatic conditions in class IV can be used for cultivation, but there are very severe limitations on the choice of crops. Also, very careful management is required. This class covers 50.76 ha which is 1.27 % of the land area of the region. The most limiting factor of soils in class V is poor drainage. Soils in classes V to VIII are generally not suited for cultivation. In some waterlogged areas of this class, drainage is not feasible. Often water loving crops such as rice, dry season grazing or pasture development is feasible on this class of land. The class occupies only 507.32 ha that counts for 12.68 % of the study area. Soils in class VI have extreme limitations that restrict their use other than grazing, forestry and wildlife. This class covers about 1833.72 ha which is 45.84 % of the study area. The major limitations in the class VII are soil depth, slope, and erosion. Soils in this class have very severe limitations which restrict their use to grazing. It can be used for

Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.1, 2015

limited forestry and wildlife. This land capability class occupies 0.16 ha. It is 0.004% of the study area. The major limitations of the class VIII are soil depth, and slope. This land capability class occupies relatively a vast area in the study area which is 2072.96 ha that accounts for 51.82%.

Table 2: Land capability class and area

No	Land Capability Class	Limitaions	Area (ha)	Cover (%)
1	CLASS I	-	1192.36	29.81
2	CLASS II	Organic matter	1.36	0.03
3	CLASS II	Soil depth	1.16	0.03
4	CLASS II	slope	1.68	0.04
5	CLASS II	Soil drainage	20.04	0.50
Sub total for class II			24.24	0.61
6	CLASS III	Organic matter	112.44	2.81
7	CLASS III	texture	30.64	0.77
8	CLASS III	slope	1.96	0.05
9	CLASS III	Soil dainage	7.4	0.19
Sub total for class III			152.44	3.81
10	CLASS IV	texture	8.56	0.21
11	CLASS IV	slope	42.2	1.052
Sub total for class IV			50.76	1.27
12	CLASS V	texture	88.96	2.22
13	CLASS V	slope	418.36	10.46
Sub total for class V			507.32	12.683
14	CLASS VI	Soil depth	745.16	18.63
15	CLASS VI	slope	1088.56	27.22
Sub total for class VI			1833.72	45.84
16	CLASS VII	Slope	0.16	0.004
Sub total for class VI			1833.88	45.85
17	CLASS VIII	Soil depth	45.8	1.15
18	CLASS VIII	slope	16.2	0.41
19	CLASS VIII	Soil drainage	177.08	4.43
Sub total for class VIII			2072.96	51.82
Grand total			4000	100

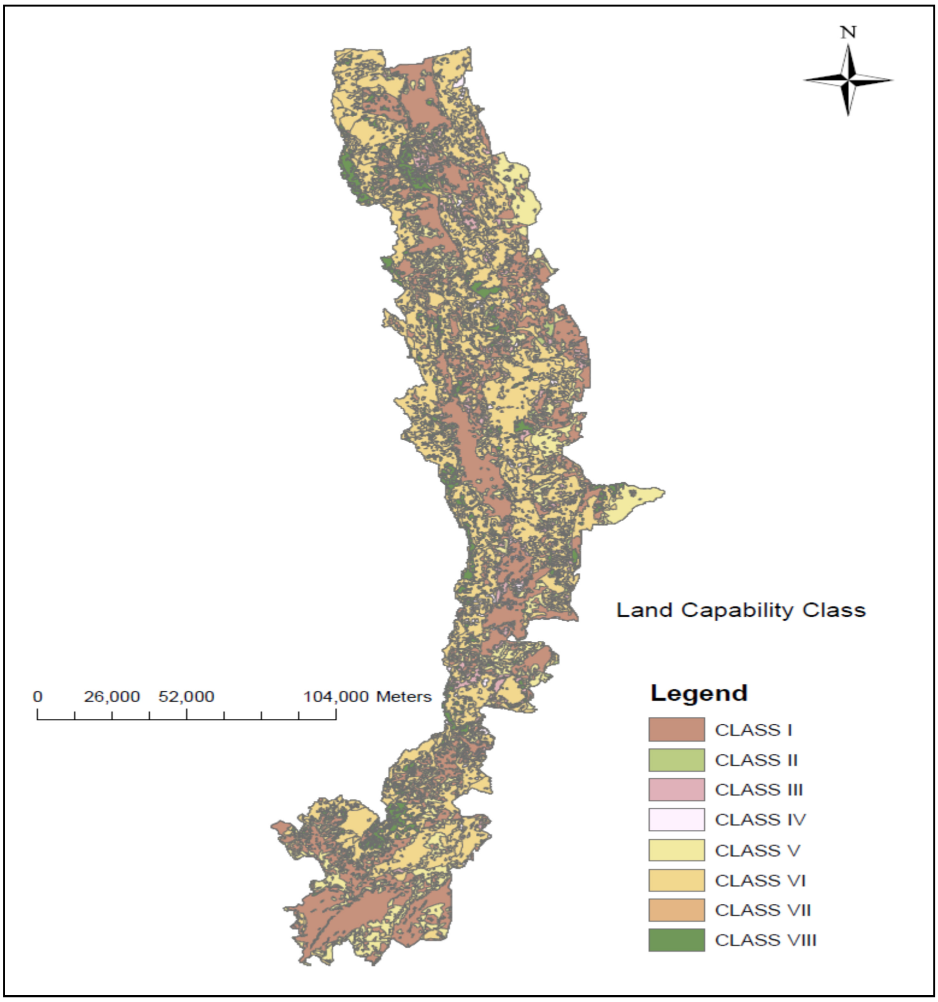

Figure 4: Capability map of the study region

4. Conclusions

The study demonstrates that GIS provide great advantage to analyze multi-layer of data spatially and classify land based on its capability. The LCC procedure described would be instrumental to identify land capability classes for decision-making process. Land capability classes ranging I to III are suitable for a wide range of uses. However, they require some soil conservation actions. Classes IV and VI are most susceptible to land degradation. Hence, the land use pattern need to be modified according to identified land capability classes to conserve and sustainably use of the land resources of the region.

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