ORIGINAL ARTICLE

GIS Based Land Capability Classification for Agriculture: the case of Gumay District, Jimma Zone, Southwest Ethiopia

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ABSTRACT

The study was conducted in Gumay district of Jimma zone, in Oromia region, which is found in southwestern Ethiopia. The objective of the study was to develop GIS based land capability classification for agriculture which will assist land managers and land use planners in identifying land capability and areas with physical constraints for a range of nominated land uses for agriculture. Due to over exploitation and mismanagement of natural resources coupled with socio-economic factors, the problem of land degradation is on the rise. Accordingly, Gumay district selected through purposive sampling technique. GIS application has been used to match the land capability classification and different land quality parameters, like soil texture, depth, drainage, slope and stoniness under various land units were evaluated. Subsequently, all of them were integrated using ArcGIS10.1 application to generate land capability classification maps. Land capability maps for each land use were developed to illustrate the capability degrees and displayed the spatial representation of soil suitable for agriculture. Based on the result obtained from land capability classification; out of 40976 ha, 33.77% of the land in the district fall under class I; 39.67% categorized under class II; 7.65% fall under class III; 18.86% fall under class IV and only 0.05% of the land classified under class VI, which is not suitable for annual crop cultivation, and hence, should be under pasture, bush or tree cover. Accordingly, the land resource of Gumay district is more capable for annual crops cultivation.

Keywords*:* Agriculture, GIS, Gumay, Land Capability Classification, Southwestern Ethiopia

INTRODUCTION

Land is the major natural resource that economic, social, infrastructure and other human activities have been undertaking on (Lambin et al., 2003; Moser, 1996). It comprises the physical environment, including climate, relief, soils, hydrology and vegetation; to the extent that these influence potential for land use (FAO, Soils Bulletin No.32, 1976).The most important aspects of land are its role in providing anchorage space to all resources, and the fact that most human activities take place on land.

Land is limited in supply and there is completion for its use. In the light of increasing population, the demand is also increasing, thus optimum use of land has become a necessity. Land is also unevenly distributed in terms of its qualities. It has its limitations for different uses. Land can be improved for particular use by certain measures, it can also be improved by a certain kind of land use or at least sustained production can be assured. Land can deteriorate by its mismanagement, wrong land use or by certain cultivation practices.

According to Sonter and Lawrie (2007) 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. The land capability evaluation characterizes and appraises land development units from a general point of view without taking into consideration the kind of its use. There are defined classes ranging from I to VIII (Landon, 1991). United State Department of Agriculture (1973) guidelines have been applied to determine land capability with eight classes designated with Roman number I to VIII. This classification is useful as some soils can be suitable for specific crops and unsuitable for another's; therefore precision of land utilization types is necessary. It cloud be expressed not only in terms of types of crop productions, but also how these specific crops are produced (Sys et al., 1991).

Precision of land utilization type is necessary for agricultural productivity and profitability. Hence, 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. So, 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, 2008).

Even though, researches on land capability classification in different part of Ethiopia are not more enough in number, there have been very few studies to classify lands based on their capability level. Simeneh and Getachew (2016) reported on evaluation of land use types and physical soil and water conservation structures in Wyebla Watershed, Northwest Ethiopia. Gizachew (2015) showed a GIS based land capability classification of East Amhara Region, Ethiopia. Gizachew (2015) also reported on land capability classification using geographical information system in shinfa watershed, highlands of Ethiopia. As written evidences shows, most of the studies have been conducted in the northern part of the country. As result, still there is lack of information on the status and classification of land use capability in southwest Ethiopia particularly in the targeted area. Accordingly, this study was initiated to classify the land of Gumay district based on their capability for sustainable use.

Therefore, evaluating land use capability for agriculture is most important for selecting optimum land use types which would bring sustainable agricultural production. Moreover, recommending different level treatments according to the limitations of land capability that fulfills the existing gaps would be very crucial for land use sustainability, productivity and improved livelihood of the study area. So, this study would have a remarkable piece of work which clearly portrays the prevailing situation.

Objectives

- The main aim of this study was to identify land-use capability classifications for agriculture in Gumay district, Jimma zone, Southwest Ethiopia by integrating GIS techniques. More specifically, the study intended to achieve the following objectives:To identify the required evaluation criteria's in order to classify the land capability for agricultural production in Gumay district.
- To identify areas with physical constraints and the maximum limiting factors of land use capability in the study area.
- To develop land use capability classification map and recommend the possible management requirements for better land use capability in Gumay district.

Significance of the Study

Land capability classification is the most important issue to be done for every country particularly for developing world; in order to make the area more profitable. About 85 % of the Ethiopian people are highly dependent on rain fed agriculture with fragmented agricultural land. As a result, production of crops does not much with the growth of population of the country. So capability of the land should be studied in order to make the fragmented land more productive and profitable. In light of the situation and profile of the study area, analyzing land use capability would have some paramount importance on account of the following reasons.

- ✓ Assessing the land use capability and knowing the capable growing land areas for agriculture would have a vital importance for better land productivity, food security and profitability.
- ✓ Secondly it may knock the mind of the concerned bodies to take the necessary action for the better land use planning and agricultural productivity according to the capability of the land.
- ✓ Moreover; as far as the knowledge of the researchers very little was done on land-use capability in the region particularly in the study area. Thus, this study could be used as a benchmark for further studies.

MATERIALS AND METHODS

Description of the Study Area

Gumay district, located in Jimma zone of Oromia region, which is found in the southwestern part of Ethiopia stretching from 7^{o} 50′ N-8^{o}5′N and 36^{o} 15′E-36^{o} 40′E (Figure1). It covers an area of 40976 ha and about 416 kms far from the capital city, Addis Ababa. Its average altitude approximately ranges between 1800-2000 meter above mean sea level and characterized by undulating topography with isolated hills, plateaus, and plains.

The climate of the study area is characterized by moderate climate condition; the mean annual temperature of Gumay district varies between15^{o}C-22.5^{o}C and the rain fall varies between 1500-2000mm. Soil types are associated with parent materials and are outcomes of the past geological phenomena. Cambisols, nitososls, lithosols, acrisols, & vertisols are the dominant soil types in the study area (Geological Map of Ethiopia, 1996). The dominant source of livelihood of the study area is agriculture. The farming system of the study area is one of the typical smallholders and subsistence rain fed-based agriculture activities. The smallholders farmers cultivate variety of crops (maize, and Sorghum), and cash crops (coffee and chaat), fruits (banana, orange, mango, and guava) and vegetation. The area is well known by cash crop particularly coffee and it also known by its moist evergreen forest. In the area, cattle, sheep, got, poultry are the livestock types kept by the smallholder farmers. Crop production and livestock rearing are equally important activities in the study area (Central Agricultural Census Commission [CACC], 2003).

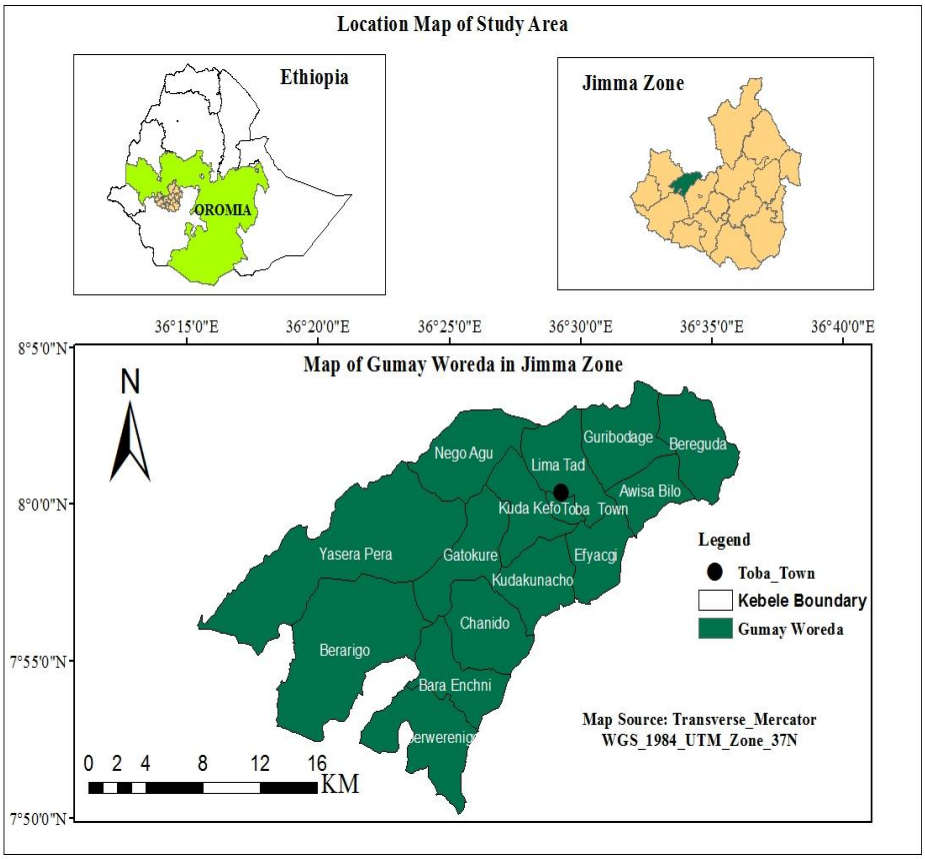

Figure 1: Location map of the study area

METHODOLOGY

Data Types and Sources

The materials used to investigate land use capability analysis in Gumay district were: ArcGIS10.1 Software, Aster DEM, Meteorological data, land use and soil data. The main sources of the data were both primary and secondary sources. Accordingly, the primary data for this study was DEM. DEM is a grid of cells in some coordinate system having land surface elevation as the value stored in each cell. Simultaneously, different secondary source of data were employed to derive the required information for the study. These includes pertinent documents like; available recorded documents, previous literatures, and review of relevant published and unpublished documents, journals, and reports which are written on the subject under investigation have been taken and included for the study.

Selection of Evaluation Criteria

Evaluation criteria, objectives and attributes, should be identified with respect to the problem situation. A set of criteria selected should adequately represent the decision making environment and must contribute towards the final goal. It is known that set of attributes or criteria depends upon the system that is being analyzed. The process of selecting the criteria is iterative in nature. Literature survey, analytical study and the opinion survey are tools that aid in the selection of evaluation criteria. So based on available data the following evaluation criteria are considered to address the assessment of land capability decision-making.

1. Soil- Texture, Drainage and Depth
2. Topographic- Slope
3. Land use- Stoniness/Rockiness

After, the selection of the evaluation criteria and description of kinds of land use, the criteria for land classification or the

requirements are determined for land use capability for agricultural use. It is clear that each kind of land use needs different environmental conditions as result of these different conditions have been identified if it is to be practiced on a sustained and economically viable basis. Correspondingly the limitations for each type of land use have been determined. These requirements and limitations indicate the types of data which are required for evaluation of land capability, and thus condition the nature of the study needed. Accordingly, the following criteria's were adapted for land capability classifications.

Table 1: Classes of the Limiting factors, Range of values, and Coding for Slope.

Slope Classes	Range in %	Code
Flat or almost flat	0-3	L1
Gently sloping	3-8	L2
Sloping	8-15	L3
Moderately steep	15-30	L4
Steep	30-50	L5
Very steep	>50	L6

Source: Adapted from USDA, 1973; Tana-Beles WME, 2012

Table 2: Classes of the Limiting factors, Range of values, and Coding for Soil depth.

Soil Depth Classes (D)	Range in CM	Code
Very deep	>150	D1
Deep	100 – 150	D2
Moderately deep	50 – 100	D3
Shallow	25 – 50	D4
Very Shallow	< 25	D5

Source: Adapted from USDA, 1973; Tana-Beles WME, 2012

Table 3: Classes of the Limiting factors, Range of values, and Coding for Texture.

Soil Texture Classes (T)	Common Name	Code
Sand	Coarse	T1
Sandy Loam	Coarse	T2
Loam	Coarse	T3
Silt Loam	Medium	T4
Clay Loam	Medium	T5
Silt Clay Loam	Fine	T6
Heavy Clay	Fine	T7

Source: Adapted from USDA, 1973; Tana-Beles WME, 2012

Table 4: Classes of the Limiting factors, Range of values, and Coding for Water logging.

Water Logging Classes (W)	Code
None	W0
Intermittently Waterlogged	W1
Regularly Waterlogged	W2
Swamps	W3

Source: Adapted from USDA, 1973; Tana-Beles WME, 2012

Table 5: Classes of the Limiting factors, Range of values, and Coding for Surface Stoniness.

Stoniness or Rockiness (S)	Code
< 15%	S0
15 – 30%	S1
30 – 50%	S2
50 – 90%	S3
>90%	S4

Source: Adapted from USDA, 1973; Tana-Beles WME, 2012

Method of Data Analysis

In order to analyze the data the study has employed different methods and applications of Arc GIS10.1. The land evaluation was based on topography (Slope), soil conditions and land use. The soil characteristics included drainage, soil texture and soil depth. So based on all the available data and requirements the index for land capability was calculated and accordingly analysis was made.

RESULTS & DISCUSSION

For land capability classification, slope, soil depth/texture and land use conditions were assessed in remote sensing and GIS environment. As all of the parameters which are used in the study have a great influence on the capability of the land. Slope is a basic element for analyzing and visualizing landform characteristics. As Figure 3 reveals that slope was a limiting factor in the north and middle part of the district. The role of soil is also undeniable in LCC; meanwhile soil is the fundamental raw material for plant growth. Moreover, in order to classify land capability, it is necessary to have information on existing land use since it is considered as an essential element for modeling and understanding the earth as a system.

Land Capability Classification

Land utilized for multiple purposes. Thus, it is mainly used for agriculture, pastures and forestry. Based on the capability or limitations, the land is grouped into eight classes. Among them, the first four classes of lands are used for agriculture or cultivation of crops. These four classes are differentiated based on the extent of soil slope, erosion, depth, structure, soil reaction and drainage. Classes from V to VIII are not capable of supporting cultivation of crops and hence, should be for growing grasses, forestry and supporting wild life. As it is shown in Table 6 below; different land capability classes were identified in the study area.

Table 6: Areas of land under different capability classes

Land Capability Classes	Area(ha)	Percentage
Class I	13 776	33.77
Class II	16181	39.67
Class III	3121	7.65
Class IV	7694	18.86
Class VI	24	0.05
Total	40796	100

The capability classification revealed (Table 6) that 99.95%, almost the entire district, falls under class I to class IV, i.e., land that can be cultivated with the appropriate conservation measures (Figure2 and Table 6). However, as one move from class I to class IV, the cultivable land becomes more and more vulnerable to erosion and therefore requires more and more conservation treatment.

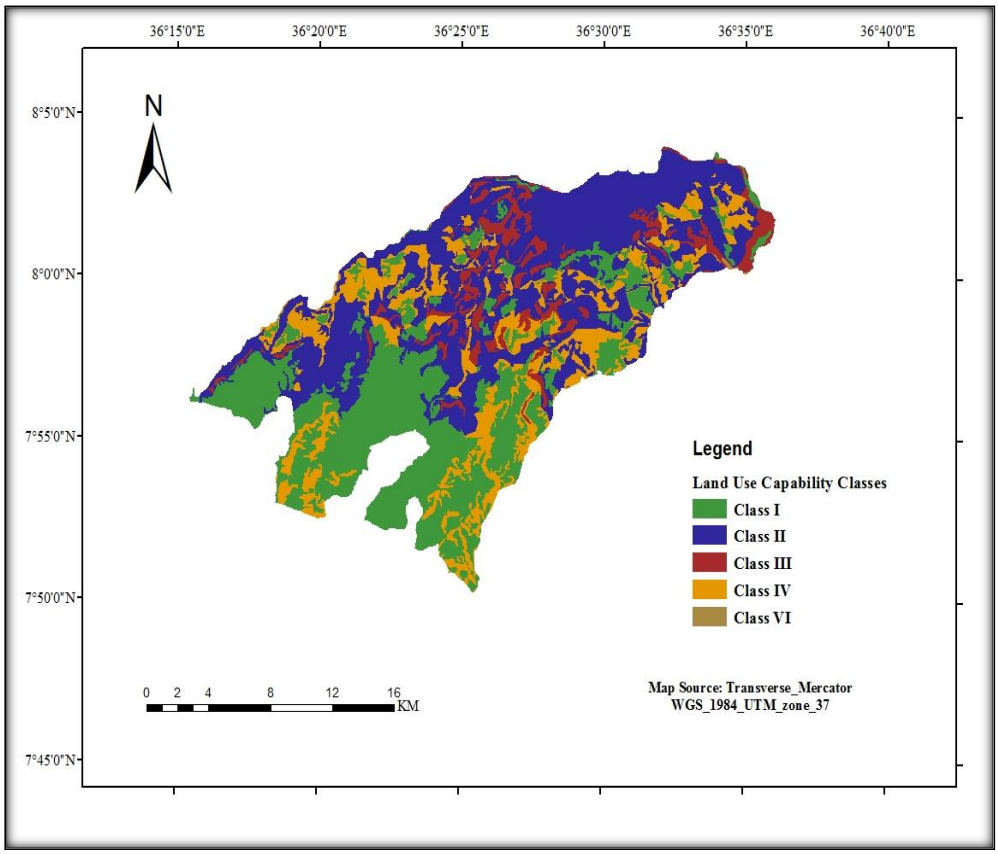

Figure 2: Land capability classification map

As it is shown in Table 6; 33.77 percent of the area in the district is very good cultivable land with no specific difficulty in farming. Relatively the grater percent which is 39.67% of the area falls under class II which is Good cultivable land which needs protection from erosion or floods, drainage improvement and conservation of irrigation water.

The marginally suitable lands (Class III) occupy only 7.65 % of the area in the district which is moderately good cultivable land where special attention has to be paid to erosion control, conservation irrigation water, intensive drainage and protection from floods. On the other hand, class IV covers 18.86 percent of the land which is fairly good land suited for occasional or limited cultivation, needs intensive erosion control, intensive drainage and very intensive treatment to overcome soil limitations.

Surprisingly only 0.05 percent (very insignificant) of the land is not at all suitable for annual crop cultivation, and hence, should be under pasture, bush or tree cover. So, it is possible to say large part of the area in the district suitable for annual crop cultivation with different level treatment according to the class's limitations.

Land Use Capability Subclasses

Land use capability sub-classes and limiting factors of each mapping unit has been identified. These were done to find out areas that need more management practice and the limiting factors that hinder the productivity of the land. Accordingly the capability sub class and limiting factors as been identified and map out by using the application of GIS. So, as the result indicated in the map (Figure3) below, topography and soil conditions are the major limitations; which needs more capital and effort to improve and to be more productive in the area.

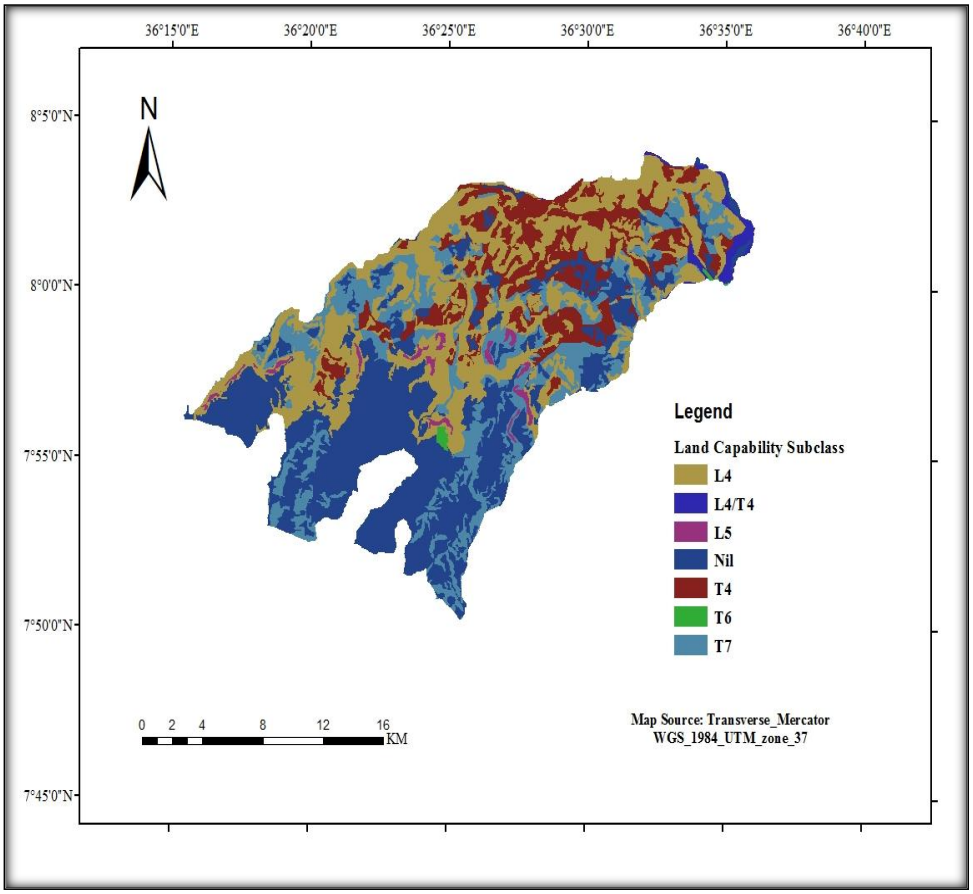

Figure 3: Land capability classification subclasses map

CONCLUSIONS

Land-use capability classification is grouping or classifying of areas with the "same" capability to support sustainable agriculture. It is important for soil conservation i.e. to analyze biophysical conditions. Moreover, to develop the culture of appropriate land use and increase land resource productivity, it is essential to harness the land according to its potential.

Most of the parameters used in this study were essential but soil condition has high influence in determining the land capability of the area rather than the others. Based on the result obtained from land capability classification analysis; out of the 40976ha, 99.95 percent of the areas in the district fall under classI to class IV which is suitable for annual crop cultivation with different level of treatment according to the limitations. Conversely, as compared to the other four classes, very insignificant percent of the land in the district fall under class VI, which is not suitable for annual crop cultivation. Almost 85 % of Ethiopian people highly dependent on agriculture but most of the farmers have small plots of land with poor management and investment level. As a result, the growth of production doesn't much with the growth of population. So, land capability and suitability analysis becomes more important in order to avoid poverty and improving the quality of life for rural populations and the economy for the country in general.

In this study only physical characteristics of the parameters are used to analyze the land capability classification of the study area. But it is necessary to take in consideration the socio-economic issues to make land capability more efficient. Therefore, further research should be conducted on the evaluation of land capability by considering the socio economic aspects in the study area.

The result of the study has to be conveyed to local farmers and the concerned bodies to make them understand about capacity and limitation in range of suitability of their farm holding. Accordingly they are advised to make use of research results to cultivate crops according to its land capability.

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