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Evaluation of Land Use Patterns across Agro-Ecological and Slope Classes using GIS and Remote Sensing: The Case of Gedeo Zone, Southern Ethiopia

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Abstract This study was aimed to identify and evaluate the land use (LU) / land cover (LC) classes as a function of slope categories by analyzing the current satellite image and Digital Elevation Model (DEM) /SRTM. In order to achieve the objectives of the study various data sources and methods were used. Very recent land sat image in combination with the ground truth data were used as the principal data source for the classification of the LU/LC and the DEM was used for the classification of the slope classes. The ground truth data of the different LU/LC and the slope data were collected through field survey using GPS and clinometer, respectively. The ground truth data was used as a reference for interpretation and the classification of the image. Supervised classification method and the Gaussian maximum likelihood classification algorithm were used and the study area was classified in to eight LU/LC classes. Similarly, ten slope categories were produced by using DEM. Finally, the classified satellite image was superimposed with the classified DEM for land use pattern evaluation, and it was found that more than 69% of the study area including very steep slopes is covered with agro-forestry system.

Keywords *Agroforestry; DEM; Gedeo; Land Use/Land Cover; Slope Classes; Supervised Classification*

1. Introduction

Up to date and accurate land use (hereafter LU) information forms an essential component of local and regional economic planning to ensure that various activities are positioned on the landscape in a rational manner [1]. Thus, knowledge of LU and land cover (hereafter LC) is important for many planning and management activities and it is considered as an essential element for modeling and understanding the earth as a system [2].

Land cover refers to the physical description of space observed, bio (physical) cover on the earth's surface. LC is concerned with social, cultural, and economic behavior that involves human actors and actions as they affect, shape, and organize the environment [3]. On the other hand, LU is

characterized by the arrangements, activities and inputs people undertake in a certain LC type to produce, change or maintain it [4, 5]. Thus, the definition of land use establishes a direct link between LC and the actions of people in their environment. When LU is defined in economic context, it refers to land use for agricultural, residential or other purposes, etc. [1]. Therefore, LC is about the biophysical aspect of land whereas LU is about the functional aspect of land. Many of the LU operations lead to the change in LC, which is the consequence of the interactions between the natural environment and the use. As a result, the knowledge of the current LU is essential to support the analysis and management of land, vegetation, water resources, and the conservation of biodiversity [1].

Land uses and land covers change over time in response to evolving economic, social, and biophysical conditions [6]. Africa is said to have the fastest rate of deforestation in the world as a result of over-dependence on primary resources with direct effect on the bio-diversity. One of the impacts of population growth can be seen in the reduction of available land per individual [7, 8]. The rapid population growth has resulted in fragmentation and reduction of farm size which has adversely affected production and productivity. This in turn has also changed the LU system. In terms of the total population engaged in various agricultural systems in Ethiopia, the seed-based temporary agricultural systems come first followed by ensete-based permanent systems. The Gedeo indigenous agro forestry system is one of the ensete-based permanent systems which carry the highest population density in Africa [9].

Agroforestry is regarded as a dynamic, ecologically based, natural resources management system that integrates trees on farms and agricultural landscapes, diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels [10]. The home garden agro forests of Gedeo are among the most structurally complex and diverse forms, consists of closely growing trees, shrubs, and annual crops that form seemingly unbroken vegetation cover [7]. Permanent tree cover protects and improves the soil, while increasing soil carbon stocks [9].

Investigating the land use dynamics is indispensable in order to examine various ecological and developmental consequences of land use change over a space of time [8]. The loss of soil fertility, along with drought and unusually high rainfall at the wrong time, fall in the coffee productivity due to disease and pests, and unprecedented increase in population pressure were suggested to influence the existing agroforestry systems [7]. However, despite its crucial ecological and economic importance, there is no up-to-date scientific information which shows the specific locations, spatial distribution, and spatial extent of various land use/ LC classes in the study area. Similarly, there is no current information about the relationship between LU and slope classes of the study area. Therefore, LU/ LC mapping and evaluation of the LU in relation to slope and agro-ecological classes are essential to design appropriate policies and strategies in order to promote sustainable land management. Therefore, this study is aimed to identify and map the LU/ LC types and slope classes, and to evaluate the land use pattern across the slope and agroecological classes.

2. Materials and Methods

2.1. Description of the Study Area

Gedeo zone is found 369 kms south of Addis Ababa and 90 kms south of Hawassa along the Addis Ababa-Moyale international road [11]. Geographically, it is located at 6^{o} to $6^{o}31'50''$ N and 38^{o} to $38^{o}27'$ E (Figure 1). The land area of the Zone was estimated at 1352.4 Km^2 [12]. The altitude of the study area ranges from 1,350 to 3000m [11]. The Zone has sub-humid tropical climate which receives annual rainfall that ranges from 1200 to 1800 mm whereas the mean monthly temperature is $21.5^{o}C$ with mean monthly maximum and minimum temperature of $25^{o}C$ and $18^{o}C$, respectively.

The Gedeo Zone has a total population of 975,506, of which 486,996 were males and 488,510 were females [13]. This Zone is one of the most densely populated regions in the country (769 persons /Km^2), the national average being 70 whereas the average farmland size is about 0.3 hectares [13]. About 80, 6, 4 and 5 % of the study area is cultivated land, forest and shrub land, uncultivated land, and the land occupied by other components such as cemetery, respectively [11].

Agriculture provides an employment for an estimated 89% of the population, and the coffee constitutes 30% of the Zonal export. However, the productivity of agricultural sector is constrained by factors such as rapid population growth, traditional farming methods, and a limited use of modern technologies [7].

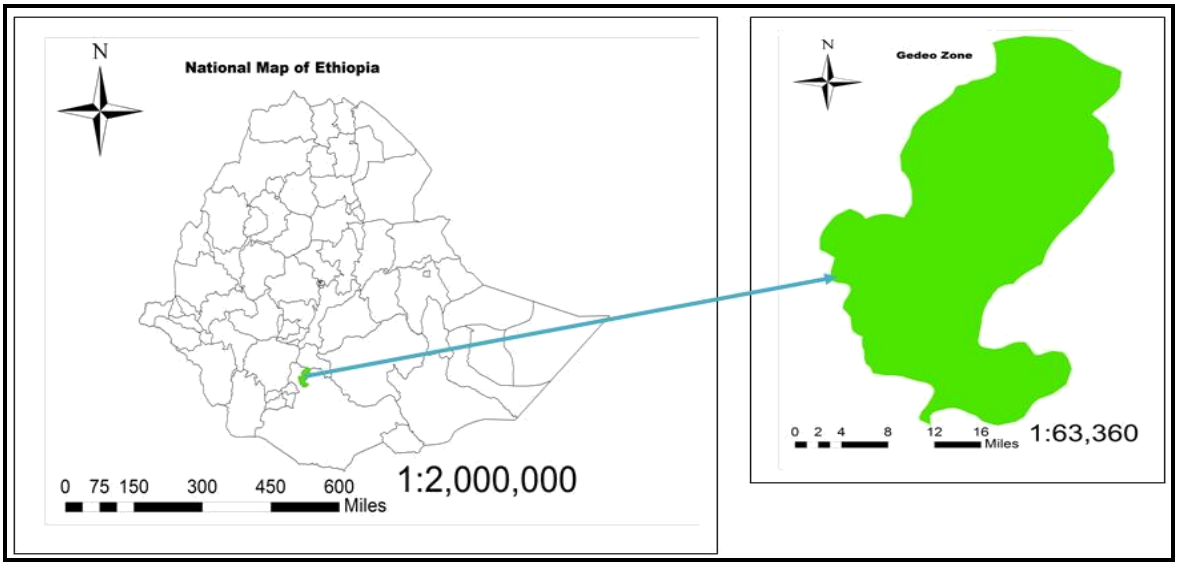

Figure 1: *Geographic Location of the Study Area* [12]

2.2. Methods of Data Collection

Topographic maps with the scale of 1:50,000 and 1:250,000 which cover the whole study area were purchased from the Ethiopian Mapping Agency (EMA). In addition, SPOT satellite image (*Systeme Pour l'Observation de la Terre*) with spatial resolution of 5m x 5m was obtained from the same office. The topographic maps were intended to be used as base maps or reference maps in order to extract accurate spatial data and use it as a basic framework to integrate spatial data from different sources such as field and remotely sensed data.

The SPOT image which was acquired in 2006 was expected to be used as the principal data sources for LU/ LC study. However, due to heavy cloud cover during the image acquisition larger part of the study area was masked with clouds. For this reason, cloud free and current orthorectified multispectral land sat 8 image which was acquired in January 2015 was downloaded and used for the LU/LC classification.

In order to enhance the satellite image interpretation and accuracy of LU/LC classification, a detailed field survey was conducted so as to take representative ground truths, and the location of each ground truth data was recorded using Global Positioning System (GPS). Furthermore, the biophysical data such as the location and types of LC, slope, altitude, and aspect of the sample sites have been recorded. The slope data was collected using Clino Master Clinometers.

2.3. Methods of Data Analysis

Multispectral Land Sat 8 Satellite image acquired in January 05/2015 was used as the base for LC/LC classification. The image was enhanced and processed in various ways such Normalized Difference Vegetation Index (NDVI), spectral ratio, and Principal Components Analysis (PCA), and it was interpreted visually by using the ground truth data as a reference. The detailed procedure of digital image interpretation and classification methods is indicated in Figure 2.

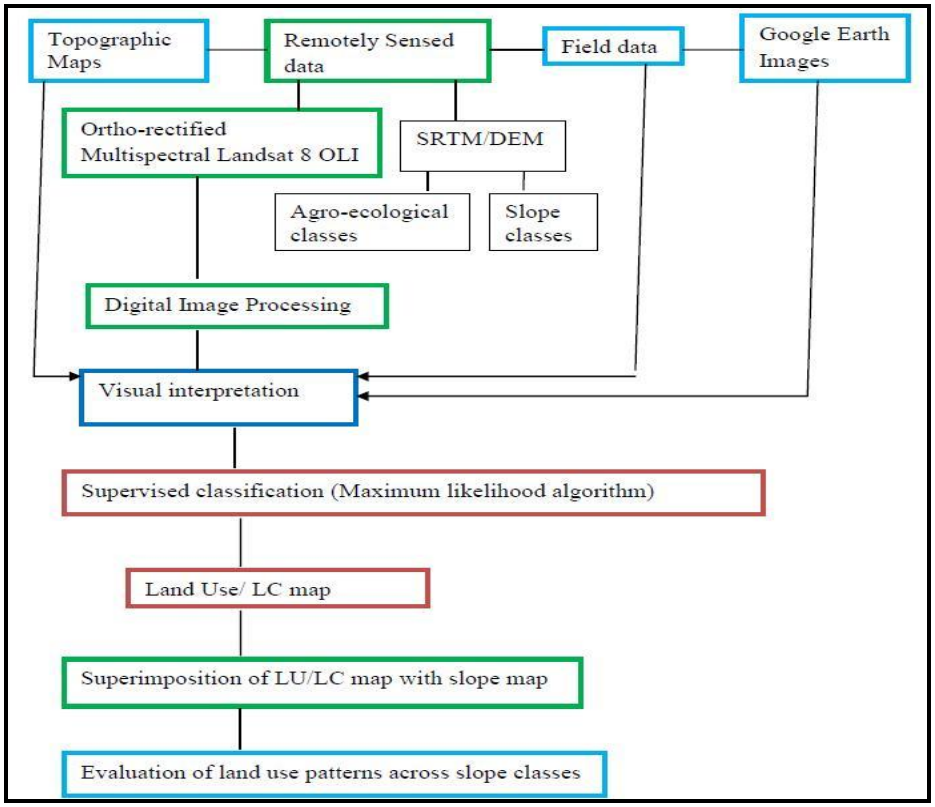

Figure 2: *Flow Chart of Digital Image Analysis, Interpretation, Classification, and Land Use Evaluation Methods Applied in the Study*

2.4. Training Stage

EARDAS IMAGINE 2013, ENVI 4.5, and ArcGIS 10.1 were used for digital processing, interpretation, and EARDAS IMAGINE 2013 was used to classify the satellite image. After full interpretation of the image digitally and visually, training areas were overlaid on the image as a region of interest so as to train the software. As the quality of the training process determines the success of the classification stage and the value of the information generated from the entire classification effort, representative and complete samples were taken carefully for all information classes or LC categories following [2].

2.5. Classification Stage

After adequate number and representative training areas were taken, the maximum likelihood classifier was adopted during the classification stage, which evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel [2].

2.6. Accuracy Assessment

Accuracy assessment is one of the most important post classification tasks performed after digital image classification where the accuracy of the classification was assessed using error matrix (confusion matrix) following [2].

3. Results and Discussion

3.1. Land Use/ Land Cover Classes of the Study Area

In the current study some parts of the satellite images were covered with cloud. Of the total 1352.4 km^2 of the study area, 1287.4 Km^2 (95%) was considered for the study. After the land sat 8 satellite image was processed, it was interpreted visually with the help of the ground truth data and other collateral information such as past topographic maps, google maps and other secondary documents. The supervised classification was applied to classify the image because ground truth data was collected before the interpretation and classification of the image. Moreover, the supervised classification is better in controlling the informational categories tailored to a specific purpose and geographic region [1]. Accordingly, the study area was classified into 8 (eight) LU/LC classes (Figure 3; Table 1) by taking its unique biophysical characteristics into account.

Table 1: *The Description of the Land Use Classes*

LU/LC Class	Description
Agroforestry	The complex land use pattern that includes natural and plantation trees where trees are found on the upper layer, enset in the middle, coffee in the lower layer, and other herbaceous plants at the ground layer. In some parts it is mixed with small parcel of cereals, pulses, vegetables, and root crops, and scattered rural settlements where it is absolutely impossible to map each layer separately.
Annual crops	Refer mainly to rain fed crops that complete their lifecycle within 3-4 months such as maize, teff, barley, and wheat fields that are found outside of the agro-forestry.
Urban	Refers to towns including residential area, infrastructures such as roads, various institutions, factories, and cemetery..
Grass land	Refers to area of the land covered with grass and mainly used for grazing purpose.
Juniper plantation	Plantation of juniperus tree (*Juniperus procera*).
Bare land	Devegetated land, particularly rock outcrops .
Dried bamboo	recently died bamboo forest found in the highland area.
Wetland	marsh lands where the local people use for grazing purpose during dry periods.

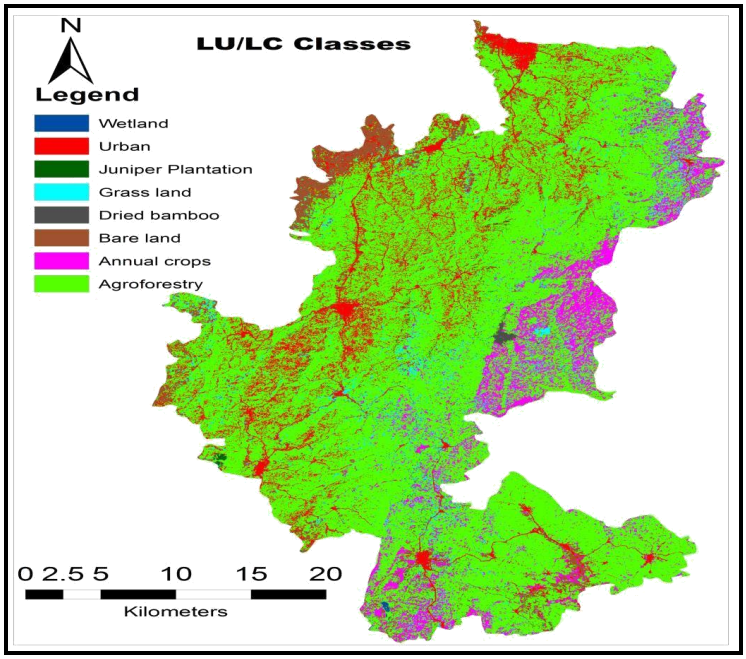

Figure 3: *Land Use/Cover Classes of the Study*

3.2. The Dominant LU/LC Components

The agroforestry class covers the largest surface area of the study area (Table 2), which consists of various LU layers or strata predominantly close to open coffee (*Coffea Arabica*) and enset (*Ensete ventricosum*) homegardens combined with close to open natural and plantation trees. This land use class is used primarily for production of farm commodities (e.g., food, fiber, and fuel). In this class, the upper layer contains different species of trees, the middle layer contains enset (*Ensete ventricosum*), and the lower layer contains coffee (*Coffea arabica*).

According to the [11], the LU/LC of the study area was categorized into four classes, namely cultivated land 80%, forest and shrub land 6%, uncultivated land 4%, and others 5%. Similarly, other researchers reported that the land use within the Gedeo Zone to be 80% cultivation, 19% grazing, and 1% natural forest and other uses [7]. The deviation from the current finding seems to be associated with the methodologies employed. The previous studies have used conventional methodologies that involved a rough estimation but the current study has applied remotely sensed data as a principal data source since land cover information can be visually interpreted more or less directly from the evidence visible on satellite images as reported by early workers [1].

Table 2: *Surface Area of the LU/LC classes*

No	LU/LC	Area	
		Hectares	**Percent**
1	Agroforestry	89239.77	69.3
2	Annual crops	10976.58	8.5
3	Bare land	6257.97	4.9
4	Dried bamboo	1156.41	0.9
5	Grass land	6222.96	4.8
6	Juniper plantation	323.28	0.25
7	Urban	14508.63	11.3
8	Wet land	100.98	0.07
	Total	**128786.58**	**1**

3.3. The Two Dominant Crops in Gedeo Agroforestry: Coffee and Enset

Both coffee and enset make up the largest proportion of the Gedeo agroforestry system (Figure 4). The two crops play a significant role in the livelihoods of the Gedeo people, as their economy and social life depend on them. One can hardly find the homegardens that do not host coffee and enset [14]. The enset and coffee homegarden agroforestry system in southern Ethiopia is a typical example of the integral homegardens [15].

In the current study area, coffee was commonly observed below an altitude of 2400 masl. It is dominantly found in the mid and low land areas, and the coffee coverage decreases as altitude increases to the highland, and it almost shrinks in the higher altitude of the study area whereas enset is found in all the three agroecological zones of the study area. But its quality decreases in the highland areas.

The other important components of Gedeo agroforestry include tree crops such as avocado (*Persea americana*) and mango (*Mangifera indica)*, and other common trees like *Cordia africana, Croton macrostachys, Erythrina brucei*, and *Milletia ferruginea*. Furthermore, there is a trend of planting eucalyptus trees around the boundaries of farm land, river sides and some degraded areas by the local people, particularly in the highland areas of Bule *Woreda* (district). This is because the Gedeo people believe that eucalyptus demands more water and nutrient, which may compete agricultural crops if grown together. Thus, The Gedeo farmers are able to comprehend the influence of eucalyptus on traditional agricultural biodiversity (agrobiodiversity). In the long run, eucalyptus, the exotic fast growing tree species should be treated with caution in order to limit its rapid expansion into the traditional agroforestry of the study area although there are now mounting evidences which support the relative importance of *Eucalyptus* trees [16, 17].

Figure 4: *Overview of Enset-Coffee Agroforestry System of Gedeo: Crops: A) Coffea Arabica, B) Ensete Ventricosum, and Shade Trees C) Millettia Ferruginea, and D) Cordia Africana*

Enset is growing across the three agroecological zones of the study area though it grows luxuriantly in the highland and midland area (Figure 5). It is the perennial herbaceous, multipurpose root crop, which is the main staple food of the Gedeo people. Every part of the enset plant is used by the Gedeo people, and they declare that “enset is our food, our clothes, our beds, our houses, cattle-feed, and our plate.” This shows the multipurpose use of the crop. Brandt et al. (1997) described both food and

nonfood uses of enset. The major foods obtained from enset are *kocho* and *bulla,* and *amicho*, which are processed from the pseudostem and leaf petioles, and the corm, respectively [18]. Enset is viewed as a food security crop since it produces higher yields under low input conditions compared to cereals [9] for about 20 million people living in the southern and southwestern parts of Ethiopian [19].

Enset agriculture integrate both crop production and animal husbandry in Gedeo Zone like anywhere in the south and south western parts of Ethiopia. Most enset plant parts serve as cattle feed [18] whereas livestock offer manure for soil fertility, particularly for enset, coffee and cabbage in the homegardens. Furthermore, enset culture is a polyculture where young enset plants are intercropped with annuals such as legumes whereas older enset plants are intercropped with perennials such as coffee.

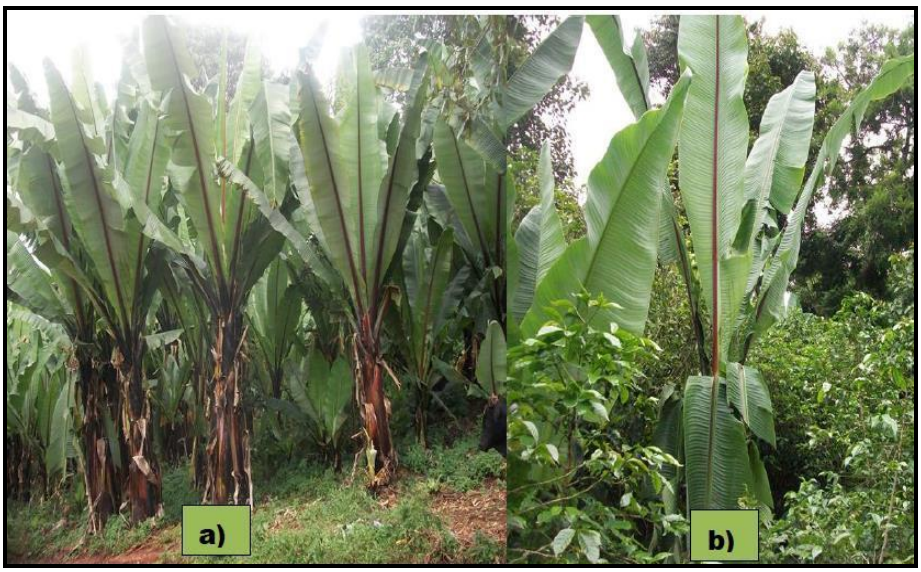

Figure 5: *Enset luxuriantly growing in the Midlands of the Study Area a) Monocultured enset, and b) enset growing together with coffee crop*

As to Admasu Tsegaye and Struik (2002) these crops are used to supplement the low protein and vitamin content of enset products and to generate cash from sales. Therefore, enset cultivation is suitable for sustainable agricultural systems due to its contribution to soil fertility, long storability of its produce, multipurpose use, its accessibility at any time, and the high productivity though it varies depending on edaphic factors, altitude, cultural practices and clonal differences [20]. In addition, in some parts of the agroforestry system there are also cereal crops such as maize, barley and wheat, pulses, vegetables, and grasses in small parcels of land.

Urban LU/LC includes areas of intensive use with much of the land covered by structures, which comprises town, strip developments along transportation roads, power, and communications facilities, and such isolated units as factories, shopping center, mills, and institutions. This land use class is the largest after agroforestry. Currently, due to the electrification of rural areas coupled with production, processing and trading of coffee, urban areas are rapidly expanding at the expense of Gedeo agroforestry system. Studies depicted urbanization as one of the causes for the loss of biodiversity [8].

The annual crop LU/LC class is used to produce crops such as small grains, predominantly found in the highlands and midlands of the study areas, respectively. Specifically, maize, wheat, teff, and barley are the major cereal crops constituting this class. Legumes such as broad bean and field pea are also included in this class which are grown extensively in the same agroecology, and contribute a lot to the soil fertility.

The bare land LU/LC category describes areas which are not vegetated, i.e., areas of exposed ground caused naturally, by construction, or by other cultural processes. These areas include mainly bare rock and the largest part of this class is located in the western lowlands of the study area**.** Another important LU category in this classification is the dried bamboo forest (Figure 6). The local people stated that bamboo has lived over eighty years. However, studies in the country showed that basically the highland bamboo (*Arundinaria alpina*) dies after its flowering periods, which takes about forty years [21]. A total area of about 1156.41 hectares of bamboo forest is currently dried. This is mainly due to the completion of its life cycle.

Figure 6: *The Dried (Dying) Bamboo in Bule highlands of Gedeo Zone*

4. Classification of Agroecological Classes

Agroecology is defined as the application of ecological concepts and principles to the design and management of sustainable agroecosystems, which provides a framework to assess the complexity of agroecosystems [22]. Agroecological zonation is usually used to improve the planning of agricultural development as ecological conditions frequently relate to climatic parameters such as rainfall amount and variability, and vegetation characteristics (types, composition, natural or plantation). In Ethiopia, traditional agroclimatic zones classified in relation to altitudinal ranges. Accordingly, the major agricultural zones in Ethiopia are categorized as *Kola* which means low land (500- 1800 m.a.s.l.), *Woyna Dega* which means mid land (1800-2400 m.a.s.l.), and *Dega* or highland (2400-3200 m.a.s.l.), and *Wurch* or cold and humid area (> 3800 m.a.s.l) [23, 24]. In the current work the study area was categorized into three agro-ecological classes using DEM with 90 meter spatial resolution (Figure 7).

According to GZAO [11] the Gedeo Zone was classified into 3 agroclimatic zones, namely *Dega* (30%), '*Woyna Dega* (67%) and *Kola* (3%). But our study shows that the *Kola* part of the study area covers 12079.53 hectares (9%), *Woyna Dega* covers 88017.84 (65%), and *Dega* covers 35158.05 (26%).

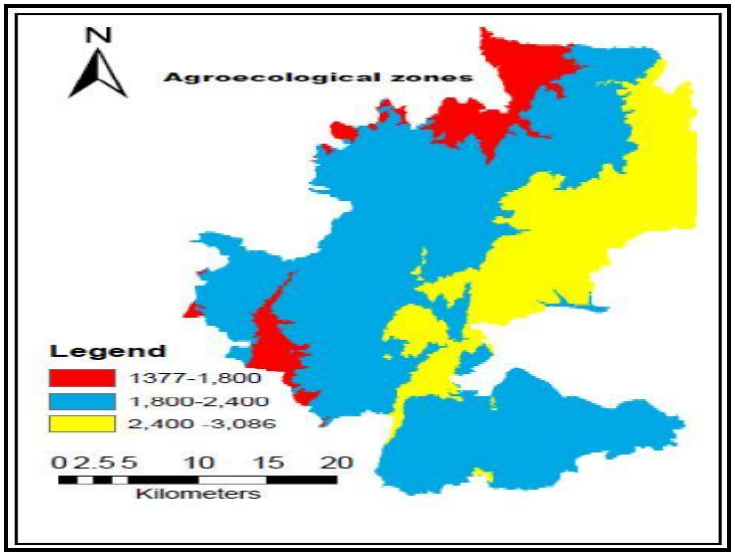

Figure 7: *Agroecological Zones of the Study Area*

These figures indicate that 65% of the study area is laid under the *Woyna Dega* agro-ecological zone which is dominantly covered by the indigenous agroforestry system (Figure 8). However, there is a slight difference in percent agroclimatic zone classification of the study area by the Gedeo Zone Administrative Office and the present study, which could be associated with the methodologies used.

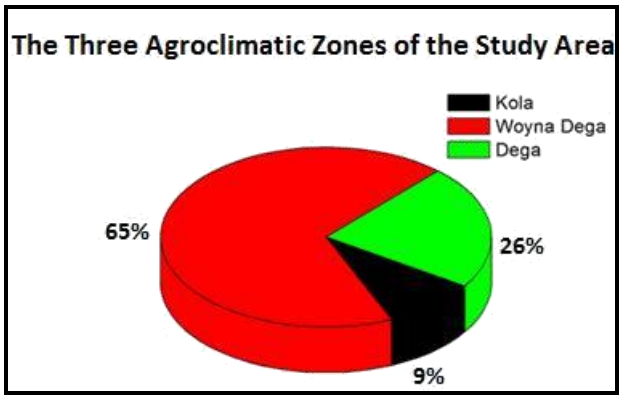

Figure 8: *The Proportion of the Agroclimatic Zones of the Study Area*

Woyna Dega is the most dominant Ethiopian agricultural belt where all major rain-fed crops can be grown including teff and maize. The highest average number of crop species in *Woyna Dega* was reported [25], which is in line with the concept of mid-altitudinal bulge in species richness [26]. Mid-elevations provide better environmental conditions that support the growth of different crop species [27]. The lower part of this belt is also suitable for cash crops such as coffee [28]. Consistently, coffee and enset are the most dominant crops in the *Woyna Dega* of the study area with very small patches of maize, wheat, barley, pulses, and vegetables in some parts. Based on our survey in the study area coffee is found predominantly at the altitude below 2400 m a.s.l. However, enset is found at all agro-ecological zones from the low lands to the high lands.

5. Classification of Slope Categories

Ninety meter spatial resolution DEM/SRTM was used to categorize the slope. Accordingly, ten slope classes (Figure 9) were identified in accordance with the FAO (2006) (Table 3).

Table 3: *Slope Percentage and Description*

No	Slope percentage	Description
1	0-0.2%	Flat
2	0.2-0.5%	Level
3	0.5-1%	Nearly level
4	1-2%	Very gently sloping
5	2-5%	Gently sloping
6	5-10%	Sloping
7	10-15%	Strongly sloping
8	15-30%	Moderately steep
9	30-60%	Steep
10	>60%	Very steep

Source: FAO (2006) [29]

Our result indicates that the slope classes of the study area range from level to very steep or from zero to greater than 107 % (>47^{o}) (Figure 9).

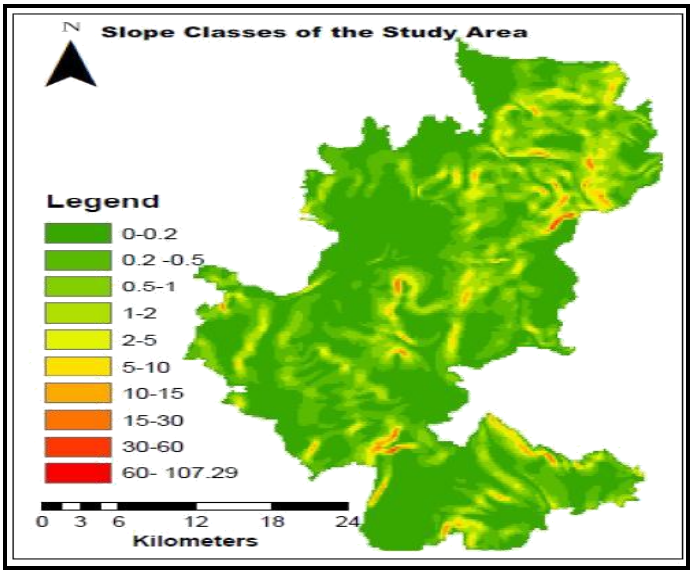

Figure 9: *Slope Classes of the Study Area*

6. Evaluation of LU Patterns across Slope Categories

In order to evaluate land capability as a function of slope categories, the LU / LC and the slope map were produced at the same scale and displayed side by side. Accordingly, the LU/ LC types on each slope class were identified to evaluate the land use as a function of slope classes (Figure 10).

A study by [30] suggested that the land with slope greater than 50% should be excluded from cultivation due to erosion hazards and economic factors. Likewise, Ethiopian proclamation on the rural land administration and land use states that the slope which is more than 60 percent shall not be used for farming and free grazing; they shall be used for development of trees, perennial plants and forage production [31].

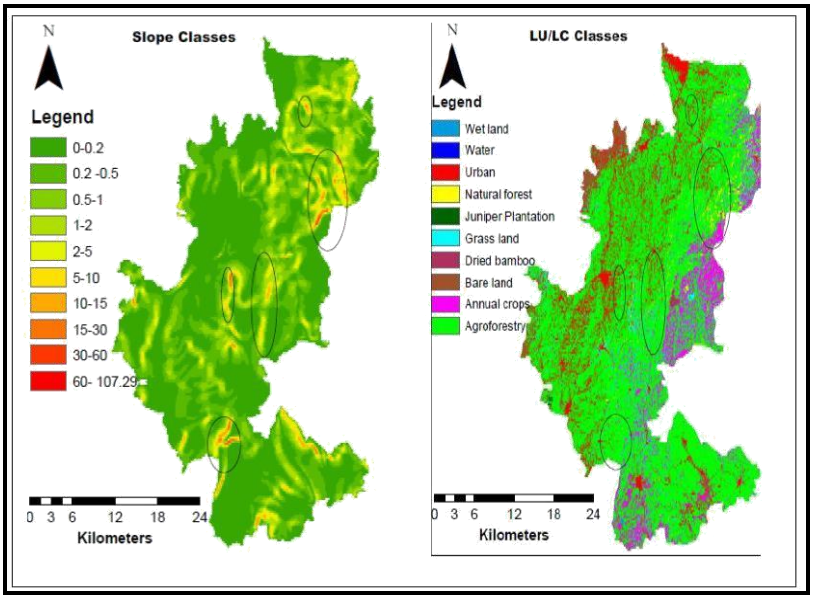

Figure 10: *Evaluation of Land Use as a Function of Slope Classes*

In the Gedeo indigenous agroforestry system, slopes with greater than 100% are covered with agricultural crops, mainly coffee and enset combined with natural and plantation trees. Although this slope is not recommended for agriculture, there is no evident problem of soil erosion in the study area (Figure 11). The sustainability of indigenous agroforestry on such a steep slope could also be due to the absence of free grazing by livestock and zero tillage, which is associated with the abundance of woody plants that function as soil stabilizers [32].

Thus, they stated that traditional agroforestry should be integrated or further developed and adapted to the special local conditions. Therefore, the Gedeo farmers have a unique experience and indigenous knowledge in conserving their environment that should be assisted scientifically and adopted to other regions in the country.

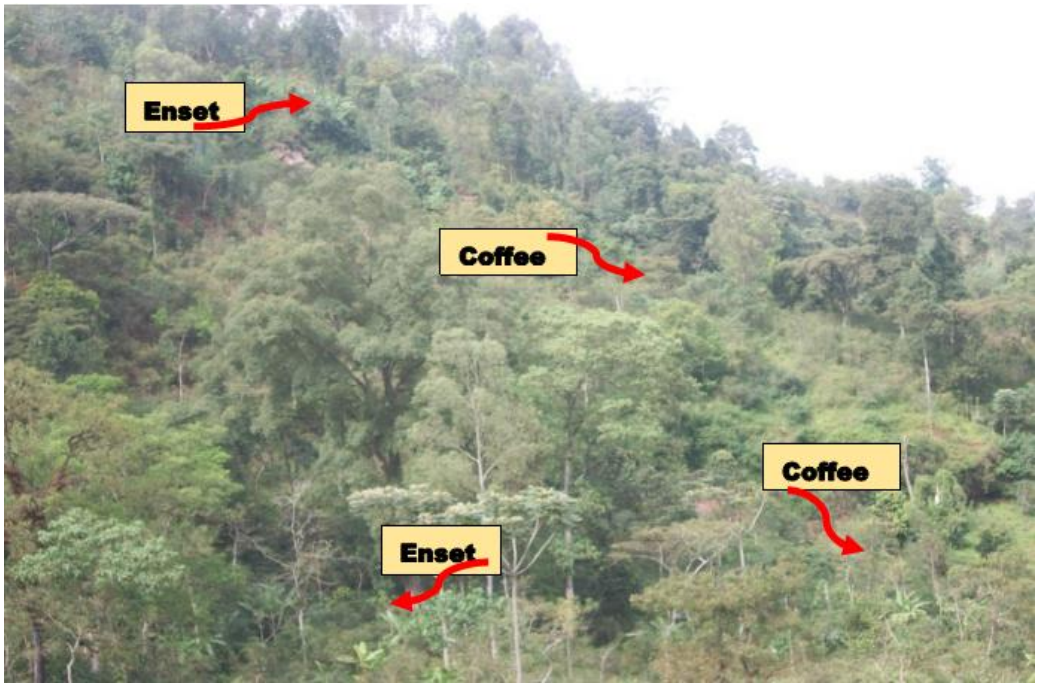

Figure 11: *Enset and Coffee in the Gedeo Agroforestry System where the Slope is above 100%*

One study in the Gedeo Zone argued that farming in the Gedeo highlands is constrained by rainwater erosion, which is not averted by the use of physical soil conservation structures such as terracing, but by the use of water-stocking ensete plants. Funnel-like ensete leaves collect rainwater towards a barrellike pseudo-stem, where it is stored and slowly distributed, via the roots, following moisture gradient, avoiding erosion due to direct impact of rainwater. Being one of the most ancient ensete peoples, the Gedeo manage ensete behavior and use it as an internal biotic pacemaker of very complex multiple rotations [9].

The indigenous knowledge of the natural resource conservation practices is common in many indigenous peoples of the world, including Africa. The indigenous/ traditional knowledge of the Gedeo people has enabled them to conserve their environment (agroforestry LU system) where there is the highest population density in Africa [9]. It demands especial acknowledgement and recognition for such resource conservation strategy. However, in some parts of the study area one can observe the allocation of tree crop production in very steep slopes without any physical conservation structures. Hence, such steep slope areas should be supported by physical conservation practices meant for sustainable land management.

7. Conclusion

The classified image depicted that the dominant LU of the study area is agro forestry mainly in the low and midlands. This class consists of perennial crops primarily coffee and enset combined with natural and plantation trees. In some parts of the study area, even very steep slopes with > 100% are covered with perennial crops without applying any physical conservation measures. However, there is no obvious erosion problem in the area, which could be due to the close cover of perennial crops, particularly the enset and coffee combined with woody plants. This has also been happened because of the long experience of the indigenous people in agroforestry farming where the system is highly aggregated to maintain the agro-ecostyem. Furthermore, there is no tillage and free grazing in the area. Bamboo forest which covers greater than 1,156 hectares has been completely dried. It is advisable to the local people to enclose the dried bamboo forest so that the bamboo can regenerate from the seeds produced by the plant. Similarly, the plantation of bamboo should be carried out by collecting planting materials or suckers from other highland areas. Planting eucalyptus around farm land is not recommended but eucalyptus trees were planted as hedges around the boundary of farm lands in many highland and some midland areas. Therefore, awareness creation and supportive lessons should be delivered to peasant meant to conserve the rich biodiversity of Gedeo agroforestry.

Acknowledgments

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References

[1] Campbell, B.J., and Randolph, H.W., 2011: *Introduction to Remote Sensing.* Fifth Edition. New York: The Guilford Press.

[2] Lillesand, T.M., and Kiefer, R.W., 2004: *Remote Sensing and Image Interpretation.* Fifth Edition. USA: John Wiley and Sons.

[3] Wood, C.H., Porro, R. (Eds.) 2002: *Deforestation and Land Use in the Amazon.* Korea: University Press of Florida.

[4] Di Gregorio, A., and Jansen, L.J.M., 1998: Land Cover Classification System (LCCS): Classification Concepts and User Manual, Environment and Natural Resources Service (SDRN) GCP/ RAF /287/ITA Africover– East Africa Project Soil Resources, Management and Conservation Service (AGLS), cooperation Italiana, UNDP, Food and Agriculture Organization of the United Nations, Rome.

[5] European Communities, 2001: *Manual of Concepts on Land Cover and Land Use Information Systems.* Luxembourg: Office for Official Publications of the European Communities.

[6] Lebow, B., Patel-Weynand, T., Loveland, T., and Cantral, R., 2012: *Land Use and Land Cover National Stakeholder Workshop Technical Report.* Report prepared for 2013 National Climate Assessment, 73. Available online at http://downloads.usgcrp.gov/NCA/Activities/final_nca_lulc_workshop_report.pdf.

[7] Abdu Abdelkadir and Tewodros Assefa, 2013: Gedeo: Highland Home Garden Agroforestry System. In: *Farmers' Strategies for Adapting to and Mitigating Climate Variability and Change through Agroforestry in Ethiopia and Kenya; Oregon State University, Corvallis, Oregon*: Davis C.M., Bernart B., and Dmitriev A. (Eds.) Forestry Communications Group. 45-50.

[8] Ademiluyi, I.A., Okude, A.S., and Akanni, C.O. *An Appraisal of Landuse and Landcover Mapping in Nigeria.* African Journal of Agricultural Research. 2008. 3 (9) 581-586.

[9] Tadesse Kippie., 2002: *Five Thousand Years of Sustainability? A Case Study on Gedeo Land Use (Southern Ethiopia).* Heelsum, The Netherlands: Treemail Publishers.

[10] ICRAF, 2000: Paths to Prosperity through Agroforestry: ICRAFs corporate strategy 2001-2010. Nairobi, Kenya: ICRAF. 43.

[11] GZAO (Gedeo Zone Administrative Office) 2006: General facts about Gedeo Zone. http://www.gedeozone.gov.et/about%20us.html.

[12] CSA, 2007: Administrative boundary of Ethiopia based on CSA Census data of 1994.

[13] Central Statistical Authority: The 2007 Population and Housing Census of Ethiopia: Statistical Report for Southern Nations, Nationalities and Peoples' Region. Addis Ababa: CSA.

[14] Abiyot Legesse, Bogale Teferi, and Axel Baudouin, 2013: Indigenous Agroforestry Knowledge Transmission and Young People's Participation in Agroforestry Practices: The Case of Wonago Woreda, Gedeo Zone, Southern Ethiopia.

[15] Tesfaye Abebe, Wiersum, K.F., Bongers, F., and Sterck, F., 2006*: Diversity and Dynamics in Homegardens of Southern Ethiopia.* In: Tropical Homegardens A Time-Tested Example of Sustainable Agroforestry. Kumar, B.M., and Nair, P.K.R. (Eds.) Netherlands: Springer. 123-142.

[16] Desalegn Tadele and Demel Teketay, 2010: *Effects of extracts from leaves of Eucalyptus globulus Labill. On Seed Germination and Early Growth of Olea europaea L. subsp.* cuspidata. In: Eucalyptus Species Management, History, Status and Trends in Ethiopia Proceedings from the Congress held in Addis Ababa, September 15th-17th. Gil L., Wubalem Tadesse, Tolosana E., and López R. (Eds.) 81-90.

[17] Edwards S (ed.): Ethiopian Environment Review No. 1. Forum for Environment: Addis Ababa; 2010.

[18] Melesse Maryo, Sileshi Nemomissa, and Tamrat Bekele. *Diversity and Distribution of Enset (Ensete ventricosum (Welw.) Cheesman) Landraces IN Kembatta Tembaro Zone, S. Ethiopia*. In: *Proceedings of 4th National Conference on Environment and Development; Dilla*: Alemayehu Paulos, Melesse Maryo, Habte Dulla, Tagel Elias (Eds.) Dilla University. 2014. 104-130.

[19] Welde Micheal, G., Bobosha, K., Blomme, G., Addis, T., Mengesha, T., and Mekonnen, S. *Evaluation of Enset Clones against Enset Bacterial wilt.* African Crop Science Journal. 2008. 16 (1) 89-95.

[20] Genet Birmeta. *Genetic Variability and Biotechnological Studies for the Conservation and Improvement of Ensete ventricosum*. PhD Thesis. 2004.

[21] Bekele, A., Birne, A., and Tegrias, B., 1993: Useful Trees and Shrubs for Ethiopia. Regional Soil Conservation Unit (RSCU). Swedish International Development Authority Technical Handbook No. 5. Nairobi, Kenya.

[22] Altieri, M.A., and Nicholls, C.I., 2005: *Agroecology and the Search for a Truly Sustainable Agriculture 1st edition.* Basic Textbooks for Environmental Training. In. Mexico: United Nations Environment Programme. 290.

[23] Daniel Gamachu, 1977: *Aspects of Climate and Water Budget in Ethiopia.* Addis Ababa: Addis Ababa University Press.

[24] CBDC, 2009: *Agro-biodiversity feeds the World. Status Report on Agro-biodiversity in Africa.* In.: Community Biodiversity Development and Conservation (CBDC). 133.

[25] Melesse Maryo. 2013: *Enset- Based Agrobiodiversity in the Agricultural Landscape of Kambatta Tembaro, Southern Ethiopia.* A Thesis Submitted to the Department of Plant Biology and Biodiversity Management Presented in Fulfillment of the Requirements for the Degree of Doctor of Philosophy (Biology: Botanical Science). Addis Ababa University, Ethiopia.

[26] Rahbek, C. *The Role of Spatial Scale and the Perception of Large-Scale Species-Richness Patterns.* Ecology Letters. 2005. 8; 224-239.

[27] Kluge, J., Kessler, M., and Dunn, R.R. *What Drives Elevational Patterns of Diversity? A Test of Geometric Constraints, Climate and Species Pool Effects for Pteridophytes on an Elevational Gradient in Costa Rica.* Global Ecol Biogeogr. 2006. 15; 358-371.

[28] Mitiku, Haile, Herweg, K., and Stillhardt, B., 2006: *Sustainable Land Management –A New Approach to Soil and Water Conservation in Ethiopia*. Land Resources Management and Environmental Protection Department, Mekelle University, Ethiopia, and Swiss Centre for Development and Environment, National Centre of Competence in Research (NCCR) North-South University of Bern, Switzerland.

[29] FAO, 2006: *Guideline for Soil Description.* Fourth Edition. Rome, Italy.

[30] Grosskopf, T. and Hindle, J., 2002: *Agricultural Land Classification.* Therese Hulme, Agricultural Environment, New South Wales, Ag fact AC. 25.

[31] FDRE: Federal Democratic Republic of Ethiopia (FDRE) Rural Land Administration and Land use Proclamation No 456/2005. 2005.

[32] Amler, B., Betke, D., Eger, H., Ehrich, C., Hoesle, U., Kohler, A., Küsel, C., Lossau, A.V., Lutz, W., Müller, U. et al., 1999: Working Group on Integrated Land Use Planning. Land Use Planning Methods, Strategies and Tools, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany.