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Monitoring Deforestation in South Western Ethiopia Using Geospatial Technologies

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Abstract

Maize Deforestation is one among the major environmental problems of our planet earth contributing to land degradation and climate change. Ethiopia had been a home of varied flora and fauna species. However, since recent time most endemic animals and indigenous tree species have dwindled although efforts are there to regain the forest resource through mass mobilization. The study used Landsat image along with institute field survey to monitor the spatio-temporal dynamics of deforestation in the south western parts of Ethiopia. A Supervised maximum likelihood classification algorithm was used along with visual interpretation of the satellite image. According to the result obtained, agricultural land, shrub and woodland and grazing lands were increased by 3715, 511 and 229 hectares respectively at the expense of forest in between 1987 and 2015. In contrast, forest land was reduced by 4455 hectares between the same years and the rate of deforestation is found to be 0.75, 1.48 and 1.119% for the three forest monitoring periods (1987-2001, 2001-2015 and 1987-2015) respectively. The major drivers behind these changes are found to be farmland expansion, biomass fuel, grazing land e and land fragmentation. Population growth and lack of awareness about the long-term consequences of deforestations are also underlying causes. The logistic regression model proposed that deforestation is a function of slope, elevation, and distance to roads, forest edge and aspects. The coefficients for the explanatory variables indicated that the probability of deforestation is negatively related to slope, elevation, and distance from roads, forest edge and aspects. The overall results showed that providing alternative economical access, alternative cook stove technology, creating awareness about the long term impacts of deforestation to rural people; require the attention of government institutions and NGOs.

Keywords: Deforestation; Forest monitoring; Drivers of deforestation; Spatio-temporal; South western parts of Ethiopia

Introduction

Globally, forests are key components of biodiversity that represent the foundation of ecosystems, through the services they provide and affect human well-being. These include provisioning services, environmental and ecological regeneration and cultural service [1,2].

Regardless of all these importance, forest resources are mal-treated and deforested unwisely. Increasing pressures from a growing human population, encroachment and conversion for agricultural land expansion, illegal logging and poaching of wild animals, overgrazing leading are among the factors leading to loss of vegetation cover globally [3].

Moreover forest resources in developing countries have been under tremendous pressure for a longer time resulting in loss of biomass and biodiversity, soil degradation and erosion FAO [4]. This is due to an alarming increment of population and their need for larger areas for agricultural production, fuel wood collection and repetitive drought [5].

Deforestation is most prominent in tropical regions such as Africa. Africa accounted for a net loss of 4.0 million hectares per year (which equals about the size of Belgium and is equivalent to 0.3% of the entire African forest cover) which suffered the second largest net loss in forests per annum and an average annual negative change rate of -0.62% from 2000 to 2005 [4]. Lepers et al. [6] also showed that the large majority of households in sub-Saharan Africa, rural and urban, still depend on biomass in the form of wood or charcoal for their energy needs and many depend on wood and fiber for their shelter and household items, and for income generation.

Ethiopia has been facing rapid deforestation and land degradation that has been principally fueled by increase of population [7-11]. This in turn resulted in extensive forest clearing for agricultural use, overgrazing, exploitation of existing forests for fuel wood, fodder and construction materials, setting of fire to create pastureland and expansion of settlements.

To cover energy needs, most households in Ethiopia resort to freely gathered biomass fuels. More than 85% of Ethiopian population lives in rural areas. The vast majority of these populations are dependent on the traditional fuels of wood, cow dung and crop. According to Addiyo woreda Agriculture and Rural Development Office (AWA RDO) annual report 2015 most of the forests are depleting in alarming rate and this leads to various environmental and social problems among local inhabitants. In order to rehabilitate the degraded areas and to maintain the remaining forests the local government has introduced a tree planting campaign every year in which every person is encouraged to plant trees, with significant influence on the attitude of the population on trees, additionally, NGO, like Naturschutzbundler

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(NABU) is pioneering varieties of forest management strategies such as Biosphere Reserves.

Despite the facts that all these auspicious remedial actions were taken, deforestation is to cause environmental degradation, which involves land degradation, water resources depilation and loss of biodiversity; still today there is a fast removal of those forests that are aged, non-replicable indigenous tree species which have different economic, cultural, ecological, medical and other purposes. Most importantly the loss of forest area is resulting in habitat disturbance, land degradation which decline soil productivity and water availability from time to time. For instance, many of local ponds and wetlands such as Hana chafe in Alarigeta, Ejibachwaallo in Bokaand Iinoo in Medwuta which supported as communal grazing land and interns the source of drinking water for each kebeles cattle population, are now drying up and totally dry in hard winter season.

Therefore; the episodes of such forest depletion and degradation snatched the attention and interest of researchers. Hence, this study was initiated to be conducted on deforestation with the major objective of monitoring deforestation in south western parts of Ethiopia particularly in Addiyo woreda, Kaffa Zone SNNPRS.

Description of Study Area

The study area lies between 7°8' to 7°26'N latitude and 36°15' to 36°50'E longitude (Figure 1). It shares boundaries with Oromia region of Jimma Zone in the North and North east, Tello Woreda in the South, Gimbo Woreda in the West, Decha Woreda in the Southwest and Konta special Woreda in the South East. The total study area is 12586 hectar/ha while the total population of the study area is 1718 male 1374 and female 344 kaffa Zone Finance and Economic Departments [12].

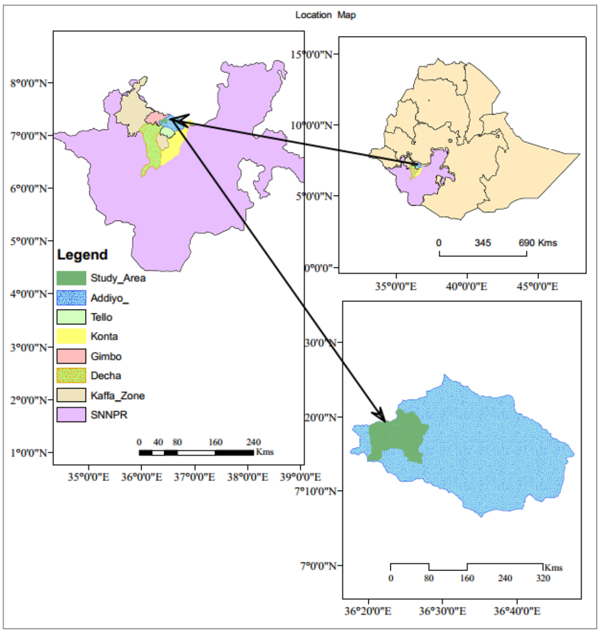

Figure 1: Study area.

The area is characterized by relatively moderate air condition with mean annual rainfall ranging between 1400 and 2000 mm and average annual temperature varying from 12°C to 26°C [12].

The study area has three traditional agro-ecological zones such as cold ecological zone (Dega) between 2500-3000 meters above sea level, semi cold zone (Woina Dega) between 1500-2500 m.a.s.l, and hot zone (Kolla) between 500-1500 m.a.s.l [12]. Predominantly the area is highland with undulating landscape consisting of mountains and rivers valleys with altitude varying from 1360-3200 m.a.s.l. As data obtained from soil map produced by WBISPP [13], shows that the dominating soil units in the study area are Pellic Vertisols, fluvisol, cambosols with clay soil texture as a dominant figure.

Data Sources and Methods of Data Collection

Both primary and secondary data sources were used. Primary data were collected from household heads, government officials and experts, experts, community leaders and elders, development agents, NGO and religion leaders by using tools like structured questionnaires, interview, and focus group discussion. Three focus group discussions were conducted, each group having 10 participants chosen from the local people.

Cloud free Satellite imageries (Landsat5 TM of 1987, Landsat 7 ETM+ on of 2001 and Landsat 8 OLI of 2015 imagery) with 30 m by 30 m spatial resolution were downloaded from http://glovis.usgs.gov/ for the dry season of January to February. Field visit was carried out to get an overview of the study area, to identify and to record GPS readings concerning various land use/cover features and forest cover types. These data were used for designing the final image classification, verifying sample sites and for land cover map validation. In addition, photographs were taken from the four land use and land cover of the study area and other essential information were generated, which helped to support in the identification and quantifying of forest cover change and mapping.

Methods of Data Analysis

Image classification

Land sat images downloaded from United States Geological Survey (USGS) glovis website s were first rectified, geometrically corrected and geo-referenced to UTM 1984 projection. For land cover classification supervised classification was employed on ERDAS Imagine version 10 software using the decision rule of maximum likelihood classifier algorithm. During the fieldwork, various land cover classes were taken and recorded based on systematic sampling using GARMIN 64 GPS devise. These samples were used as representative signatures for the various lands cover types identified and 20 GCPs were taken for each land use types. Based on these sample training signature prepared from the GCPs collected data classification of land cover classes including Agricultural land, forest, grazing land, shrub-land and woodland land cover classes were undertaken (See Table 1).

Post classification

To examine the forest cover change and the rate of its changes, post classification comparison change detection method was employed. Four aspects of forest cover change detection characteristics are identified such as; detecting the changes, identifying the nature of the

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changes, measuring the temporal and areal extent of the changes, and assessing the spatial pattern of the change.

No	Land use land cover Classes	Description of land covers
1	Forest	Areas covered by trees forming closed or nearly closed canopies; Forest; Plantation forest; Dense (50-80% crown cover) predominant species like Wanza (*Cordials Africana*), Weira (*Olean Africana*), Bamboo (Arundineria) Grawa (*Vernonia specious*), Kosso (*Hygenia Abyssinica*), Shola (*Ficus Sychmorise*), Geteme(*Schefflera abyssinica*).
2	Wood land and Shrub	Areas covered with Wood and shrub canopy mixed with yamesho, Bissana (*Croton Macrostochys*), Grawa (*Vernonia specious*), Wanza (*Cordials Africana*) etc. are among species classified as shrubs and woodland.
3	Agricultural land	Areas of land ploughed/prepared for growing rain fed crops. This category includes areas currently under crop; fallow, and land under preparation were classified as agricultural lands.
4	Grazing land	Land area covered grasses were consider as grazing land

Table 1: Description of land use and land cover classes identified and detected based on field observation data.

Accuracy of 2015 land use and land cover classification was tested and verified using historical Google earth imagery and ground trothing field collected data. Based on error matrix produced overall accuracy is 90% where 90% of Land-sat derived map for the study area was correctly classified with reference to reference data.

Qualitative methods of the study

The survey generated through qualitative and quantitative data were summarized, categorized and coded into numeric values and entered in to StatIC12. The information that were obtained from structured and unstructured interviews and focus group discussion in the study area were narrated and qualitative in nature and were used to support the coded qualitative and quantitative data. Correlation (Comparative) analysis between forest area from Land sat images and mean NDVI values of dry season from Ground Survey data were analyzed to examine the consistency between Land sat images and dataset from field survey. Logistic Regressions models were developed for physiographic and locational factor (driver) analysis. Variables were described as Dependent variable: The spatial occurrence or non-occurrence of deforestation in between 1987 and 2015 years in the study area. While independent variables: were physiographic and Location variables such as elevation, slope, aspect, distance to forest edge and distance to roads.

Per class, cross-referenced user accuracy ranges from 85% (Grazing land) to 95% (Forest land). This user's accuracy indicates the probability that a sample from both classes, most importantly from grazing and forest cover map actually matches the real world observation from reference dataset. As an example, a user's accuracy of forest land category in Land sat imagery would indicate that 95% probability of correctly detecting and classifying forest land areas from the total category of sample points assigned to this class. On the other hand, the producer's accuracy estimated for this dataset ranges from 85% representing grazing land class to about 95% both forest land followed by agriculture and shrub and wood land accounting 90% producer accuracy.

Results and Discussion

Based on the analysis of land sat images of 1987, 2001 and 2015, four land use/cover types, agricultural land, forest, grazing land and bush and woodland were identified and mapped. Each land use has shown a remarkable change between 1987 and 2015 and significant change was observed between 2001 and 2015, a conversion from forest to other land uses taking the largest share.

The result showed that forest cover accounted for 8146 ha (65%) and 3709 ha (29.47%) of the total area in the year 1987 and 2015 respectively (Figure 2). Between 1987 and 2001, 22% from total forest area were deforested, which accounts 14.5% of total study area (12,586 ha); whereas from 2001 to 2015, about 33% of total forests were deforested and this accounts 20.94% the study area. From 1987-2015, 55% of the forests were lost out of total forest cover and this accounts 35.53% of the total study area. Currently, only 45% of forests remain, out of the total forest land and that accounts 29.5% of the total study area.

Land use and land cover change between 1987 and 2015

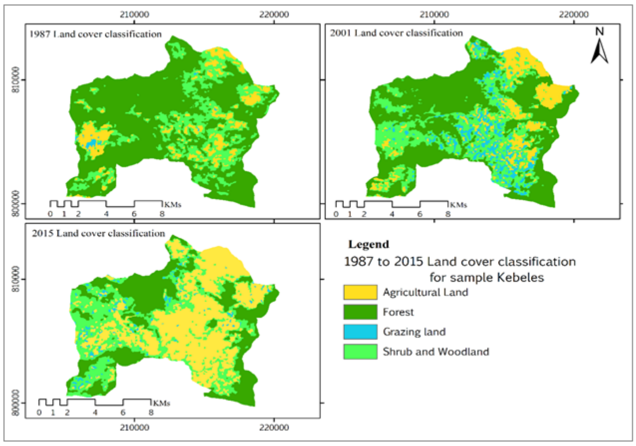

Figure 2: Land use land cover classification map of the study area.

Year	Land use/cover type					
	Forest to agricultural land (ha)	%	Forest to shrub land (ha)	%	Forest to grazing land (ha)	%
1987-2001	426	3.4	488	3.9	906	7.2
2001-2015	2612	20.8	23	0.2	0	0
1987-2015	3038	24.1	511	4	229	1.8

Table 2: Change Detected from Forest Land to other forms of Land Use Types. Source: Land sat image.

The change from forest land to agricultural land is increasing from time to time and the conversion from forest land to agricultural land is 426 ha, 2612 ha and 3038 ha from 1987-2001, 2001-2015 and 1987-2015 respectively. In line with the present work study conducted on dynamics land use land cover change in Arsi Zone Dera District revealed considerable reduction of natural forest and shrubs, while

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agricultural land is expanding between 1985 and 2011 [14]. The most significant historical change in land cover has been the expansion of agricultural lands. Farmers/villagers clear the forest to obtain more land for agricultural production and in search of fuel wood for cooking and lightning (Table 2). This is followed by grazing land 906 ha, 0 ha, 229 hectare for the same periods respectively. Similarly, the conversion of forest land to shrub land is 488 ha, 23 ha and 511 ha in these time periods. The same result was observed in Ameleke watershed where shrubs were expanding from 2000 to 2006 and simultaneous to this, an increase of shrub land cover was found in Afar range lands from 1972 to 2007 [15].

Rate of forest cover change since 1987

The temporal dynamics of deforestation was easily understood from the rate of deforestation calculations considering deforestation estimate made for the two monitoring periods (1987 to 2001 and 2001 to 2015). The result showed that the rate of deforestation was increased from 0.76% during the first monitoring period (1987-2001) to 1.48% during the second monitoring period (2001-2015). Moreover, since 1987 to 2015 the average rate of deforestation was found to be 1.1%, which is the highest one in the world. According to FAO [4] Africa accounts -0.18% of forest loss per annum while in Latin America the rate of deforestation is -0.23% per year and in the World the rate of deforestation accounts -0.07% per year. In connection to this, the study conducted by Temesgen [14], revealed that forest cover had shown remarkable spatial and temporal change in Dera. Similarly, deforestation in South area caused significant forest cover dynamics between 1972 and 1985 [16]. Therefore, the rate of deforestation in the study area is high because most land use land cover type is drastically changing and harms natural forests of the area.

Spatial dynamics of forest cover change

As obtained from land sat imageries among three periods and household survey, forest cover shows dynamics along temporal and spatial perspectives. The dynamics clearly showed that there were deforestation among the selected kebeles but the degree and intensities of deforestation was not similar in spatiotemporal perspectives.

In 1987 most of the forest, cover was intensively found in Olarefeta that accounts 3398 ha followed by Boka kebele, which has 2948 ha, and Medwuta, which has 1817.56 ha. These forests were dramatically changed in to other forms of land use. For instance from 1987-2001; 978 ha (33.18%) of the total forest cover of the sample kebeles, 331.56 ha (18.24%), 510 ha (15%) forest lands were changed to other forms of land use from Boka, Medwuta and Alarigeta kebele respectively. While from 2001-2015 deforestation in Alarigeta is takes the leading position with 1249 hectares (36.76%) of forests followed by Medwuta, 559 ha (30.76) and lastly Boka, 827 ha (28%) of forests were devastated. The result was consistent with that of Gebrekidan et al. [15], who also found a reduction of forest along watershed in different kebeles or spatially and temporally at Ameleke watershed (Figure 3).

Major drivers of deforestation

Most of the scholars argued that in most parts of sub Saharan Africa the dominant cause of deforestation is the need of cropland expansion. Concomitant to Land sat evidence, household survey response calculated by Stat 12, also asserted that agricultural expansion occupied the leading position being strongly agreed by 113 (88.3) of the total respondents and demand of grazing land 84 (65.63%) has got the third position next to need of biomass fuel 109 (85.16%).

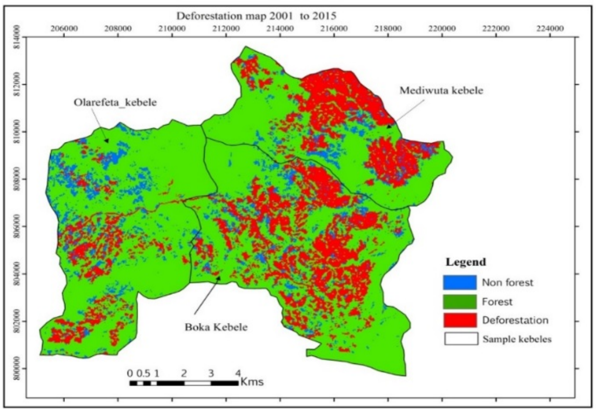

Figure 3: Deforestation map of the study area in between 1987-2015.

The remaining impacts like natural resource competition, lack of awareness, new opportunity to market and infrastructural development like road construction were considered by 83 (64.84%), 79 (61.72%) 59 (46.09%) and 34 (34.38%) of the respondents as human induced impacts of deforestation. They were driven by increasing population growth in the study area. In line with this, AWARDo [17] Strategic Plan Management (SPM) 2011–2015 reported that, before 20 to 30 years ago, 30 to 40 percent area of the Woreda was covered by forest. Now, it is reported that, mainly because of agricultural expansion, fire wood consumption and grazing land expansion the remaining forest and woodland of the study area is less than 20% of the total area of the Woreda. The logistic regression model proposed that deforestation is a function of slope, elevation, and distance to roads, forest edge and aspects. The coefficients for the explanatory variables indicated that the probability of deforestation is negatively related to slope, elevation, and distance from roads, forest edge and aspects.

Conclusion

This paper has verified that the recent progress in remote sensing image analysis are powerful tool for assessing land use and land cover changes at micro levels. The study is carried out in south western parts of Ethiopia specifically at kaffa zone of SNNPR using satellite images in conjunction with focused group discussion, household survey, and interview and field observations. The finding from satellite image showed that forest cover of the study area accounted for 8146 ha (65%) and 3709 ha (29.47%) of the total area under study in the year 1987 and 2015 respectively. From 1987 up to 2001, 22% from total forest area were deforested which accounts 14.5% of total study area. Whereas from year 2001-2015 about 33% of total forests were deforested this account 20.94% the study area. Totally from 1987-2015 around 55% of the forests were lost out of total forest cover and the evidence that found from FGDs, HH survey, interview and field observation accreted that the forest cover is declining from time to time and place to place in the study area. Caused by different interrelated socio-economic and political drivers. The major drivers are: rising demand for forest products like fuel, construction wood, fodder, etc. Conversion of forest land to agricultural land, shifting cultivation, urbanization, etc., additionally expanding population, resulting in actual human and animal population exceeding the carrying capacity of the land also has a great impact on forest resource.

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