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## The Effects of Population Growth on Land Use and Land Cover Changes in Ganta Afeshum District, Eastern Tigray Zone, Ethiopia during 2000 to 2014

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**Abstract:** Land use and land cover change is associated with the overwhelming proportion of the Ethiopian population lives in rural areas (85%) and about 90% lives in the Ethiopian highlands and directly depends on subsistence agriculture which is entirely dependent on natural resources. In the country, land use and cover changes have been particularly dynamic in the 20<sup>th</sup> Century. This is due to increasing population, expansion of the agricultural sector and the low economic standard of living in Ethiopia has brought in their awake numerous consequences to land cover and use changes. This initiates to assessing the impacts of population growth on land use and land cover change. To do this, the study analyzes the Effects of Population Growth on Land Use and Land Cover Changes in Ganta Afeshum district, Eastern Tigray Zone, Ethiopia between 2000 and 2014. For this study, two LANDSAT images covering over a period of 2000 (Landsat-7 ETM+) and 2014 (Landsat-8 OLI\_TIRS) were used and analyzed using Arc GIS 10.1 and Erdas Imagine 13. Supervised classification system was used to classify the images of different land use categories. In this study, to understand the effect of population growth on LULC, both primary and secondary data sources were required. From the two broad research approaches, quantitative and qualitative research, the research focused on the former because of the fact that the data is more or less engaged with quantitative data. In data analysis section, the LULC distribution maps, LULC change, the LULC transformation and its alteration due to population growth are presented and discussed. The acquired data is analyzed using statistical calculations such as percentage, growth rate. To present clearer understanding, tables, charts and graphs was used. The result shows that during the span of 14 years (2000-2014, the population of Ganta Afeshum was increased rapidly. This increase raised the demand for additional settlement areas and the accompanying demand for more agricultural lands. Consequently, in 2014, the settlement areas doubled and the agriculture land came close to doubling; that is it expands from 12.6% to 22.3%. However, settlement and agricultural lands expanded at the cost of bush and grass land as well as bare and rocky lands. On the contrary, forest land has significantly increased from 16.9% to 23.4% due to effective forest conservation measures.

**Keywords:** Population Growth, Land Use Change, GIS, Landsat Image.

### I. INTRODUCTION

#### A. Background of the Study

Land is a key resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, water catchment and storage, and so on. It is a fundamental factor of production, and through much of the course of human history, it has been tightly coupled with economic growth. The world population doubled from 3 billion to 6 billion between 1960 and 2000, and it currently stands at 7 billion (Amare, 2013). Consequently, global improper utilization of land is causing various forms of environmental degradation such as depletion of pasture land, agricultural land, mineral and water resources, vegetation and habitat which happen to be the most important elements of vitality for human beings, animals and other organisms (Gete, 2006). Several regions around the world are currently undergoing rapid, wide-ranging changes in land cover (Mas, 1999). Although other elements such as tectonic activities, volcanoes, flooding and drought contribute to the deterioration of LULC, the effect of population growth on LULC is becoming more serious because the effect of populations and their activities is continuous while natural hazards show up once in a while. The world population is still growing especially in the developing countries such as Ethiopia. The Ethiopian population doubled (from its 1900 size) in sixty years (rather than 140 years) to reach 23.5 million in 1965; it doubled again in just 25 years to reach 48 million in 1990 (Gete, 2010). The phenomenal growth was fueled by the combined impacts of increased fertility and declining mortality. The total fertility reached a high of 7.7 births in the early 1990s before coming down to 5.9 by the year 2000. Infant mortality dropped from 155 in 1970 to 97 in 2000 (Haile and Assefa, 2012).

The proportion of land with forest cover has been diminishing at alarming rates because fourth fifths of the population is engaged in agriculture. The land area covered by forests has gone down from approximately 40.0% at the turn of the century to approximately 3.0% at the present time, and the annual rate of deforestation is estimated at 88,000 hectares per year while the rate at which this loss is being replaced through afforestation is estimated at 6,000 hectares a year (Deneke, 2007). The soil has been and

continues to be eroded in the absence of coherent and sustained conservation efforts.

**B. Statement of the Problem**

In the 21st century, global environmental changes are increasingly on top of the international scientific and political agenda (Efrem, 2010) in doing of this, the Ethiopian government and international donors have initiated a number of programs that promote yield-enhancing and dissemination of soil and water conservation technologies (Mahmud and Kohlin, 2009). For sustainable LULC, it is essential to know its major characteristics, such as location, area, quality, productivity, suitability and the various limitations. LULC is a product of interactions between a society's various needs on the one hand, and the natural potential of land on the other hand (Kamper, 2001). In order to improve the economic condition of the area without further deteriorating the bio-environment, every bit of the available land has to be used in the most organized and harmonious way. This requires the present and the past LULC data of the area to be evaluated carefully. Based on this, this research will compare and contrast population and LULC data of 1994 and 2014 in order to demonstrate the population growth and its impact on LULC over the last twenty years. Theoretically, it is possible to choose a more recent bench mark, for instance the year 2011. But an interval of five years will not display a meaningful difference neither on population growth nor on change of LULC (Lillesand, et al 2004).

Ganta Afeshum is already one of the very few most densely populated provinces of Tigray region having population density ranging 206 – 361 persons per km<sup>2</sup> (CSA, 2007). With it, its population is still growing steadily which is making the threat of LULC change even more imminent. In addition to this, area under cultivation and urbanization is increasing; even sensitive areas (steep sloped lands) or areas which are not suitable for cultivation in general are cultivated to increase crop production, which further aggravates environmental degradation. This trend is greatly causing the available land to shrink considerably (Hellmers, 2010). If this trend is not suitably managed in time, it will go out of control and as a result, animals and other organisms will lose their habitat, people will suffer from shortage of land for beneficial activities such as agriculture, pasture, settlement area, and others in the near future. Therefore, there is a growing concern to balance population growth and the carrying capacity of the total land under study. On this ground, this research strives to identify the effects of population growth on LULC in Ganta Afeshum. It will also recommend feasible recommendations.

**C. Objectives of the Study**

**Main (General) Objective Of The Study:** The main objective of this study is to assess the “Effects of Population Growth on Land Use and Land Cover Changes in Ganta Afeshum Province, Eastern Tigray Zone, Ethiopia” between 1984 and 2014.

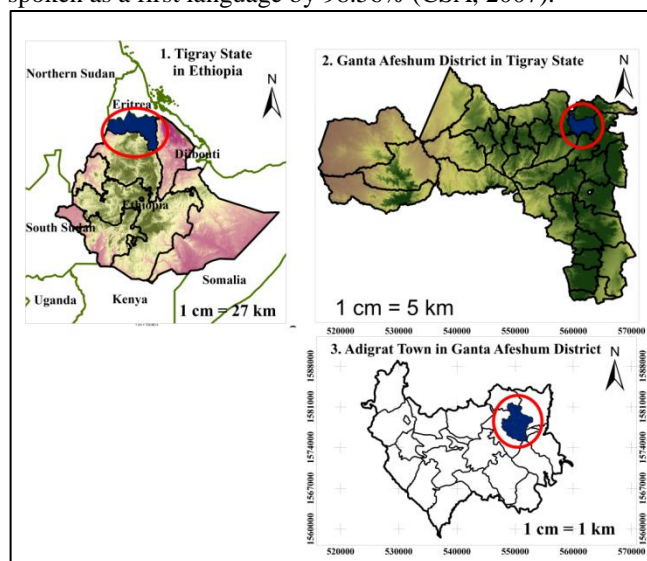
**Specific Objectives of The Study:**

The specific objectives of this study are to:

- Investigate the major land use land cover types
- Identify the impacts of population growth on LULC in the study area.
- Quantify the extent of change in LULC due to population growth in the study area using remote sensing and GIS techniques.

**II. SITE DESCRIPTION (LOCATION)**

One of the 36 districts in the Tigray Region of Ethiopia and part of the Eastern Zone, Ganta Afeshum is bordered on the south by Hawzen, on the west by the Central Zone, on the north by Gulo-mMekada and on the east by Saesi Tsaeda-Emba as shown in Fig.1. Towns in Ganta Afeshum include Adigrat and Bizet. The 1994 national census reported a total population for this district was 122,827; of whom 58,398 were men and 64,429 were women. Moreover, 39,561 or 32.21% of its population were urban dwellers. The largest ethnic group reported in Ganta Afeshum was the Tigrayan (98.07%), and Tigrinya was spoken as a first language by 98.56% (CSA, 2007).



**Fig.1. Location map of Ganta-Afeshum district.**

**III. MATERIALS AND METHODS**

**TABLE I: Source and Satellite Images Data Collection Processing**

Satellite/Spacecraft ID	Sensor ID	Path/Row	Date of acquisition	Spatial resolution/ Grid Cell Size (m)	Sun Elevation	Cloud Cover
Landsat-7	ETM+	169/050	2000-01-27	30m	45.8008678	0
Landsat-8	OLI_TIRS	169/50	2014-03-30	30m	62.39484780	0.48

Source: Earth Explorer, USGS.

In this study, to understand the effect of population growth on LULC, Census or survey or similar data will be used for the years between 2000 and 2014. Both are the most suitable available sources of data which cannot be gathered by individuals. For the study of land use and land cover change, data will be generated from the analysis of satellite images. For the study of this, Ground Control Points (GCP's) will be identified before interpretation of the satellite images. At each GCP location, GPS measurements would be taken during a field work. Three Satellite imagery

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covering the period 2000 (Landsat-7 ETM+) and 2014 (Landsat-8 OLI\_TIRS) would be used. Typically in Landsat ETM+, Bands 4, 3 and 2 are combined to make false-color composite images and Bands 3, 2 and 1 are combined to make true-color composite images. But for landsat image 8, Bands 5, 4 and 3 are combined to make false-color composite images and Bands 4, 3 and 2 are combined to make true-color composite images. The comparison of the land use land cover statistics assisted in identifying the percentage change, trend and rate of change between 1984 and 2014. In achieving this, the first task was to develop a table showing the area in hectares and the percentage change for each year (1984, 2000 and 2014) measured against each land use land cover type. Percentage change to determine the trend of change can then be calculated by dividing observed change by sum of changes multiplied by 100.

$$\text{Percentage change (trend)} = \frac{\text{Observed Change}}{\text{Sum of change}} * 100 \quad (1)$$

$$\text{Area of Each LULC in Km}^2 = \frac{\text{Count value} * 30\text{m} * 30\text{m}}{1,000,000} \quad (2)$$

Or

$$\text{Area of Each LULC in Hectare} = \frac{\text{Count value} * 30\text{m} * 30\text{m}}{1,000,000} * 100 \quad (3)$$

$$\text{Coverage of the area for each LULC type} = \frac{\text{Area of Individual type}}{\text{Sum of the area}} \quad (4)$$

Coefficient of variation (CV) was used to measure the reliability of the experiment as shown in Fig.2. The theoretical framework is that if an attempt is made to compare two experiments based on mean value then the comparison may be biased since measurements may be done on same scale.

$$\text{Coefficient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} * 100 \quad (5)$$

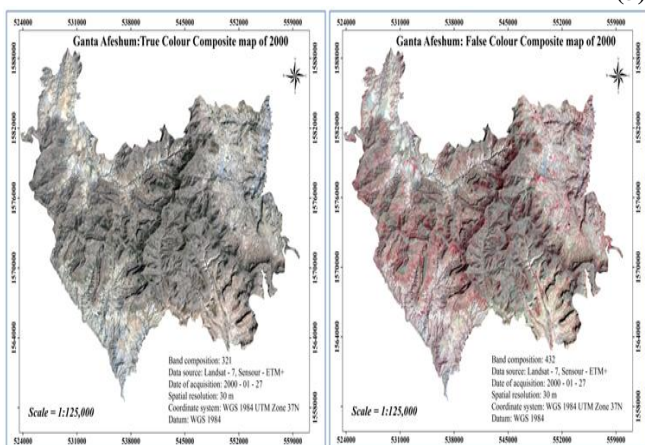


Fig.2. True color (left) and false color (right) composite maps of Ganta Afeshum 2000.

Thus, the CV states how large the Standard Deviation is in comparison to the mean in percentage terms. The CV of 100 percent indicates that Standard Deviation and the mean are equal. In that case, the data are highly variable and the mean is not a useful measure of the center of distribution as shown in Fig.3. The smaller the value of the CV, the better

the mean represent the data set. The distribution with the lowest CV has the least variability.

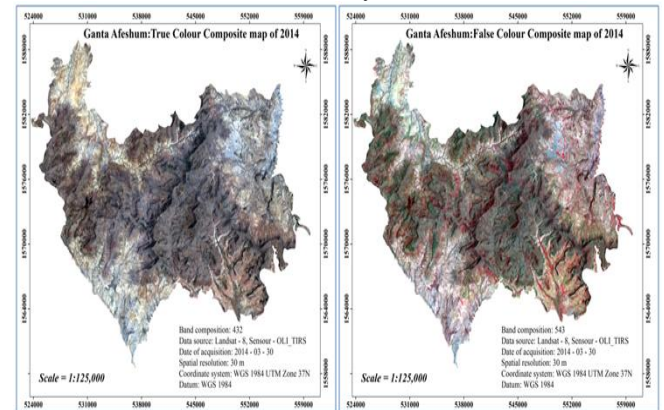


Fig.3. True color (left) and false color (right) composite maps of Ganta Afeshum 2014.

### A. Software Used

The following software's are used for the processing and analysis of data/images for this study.

- Arc GIS 10.1: This was used to compliment the display and processing of the data, Preparation of Location of the project area and for data base generation
- Google Earth for creating KML files for verifying of the land use land cover types
- Quantum GIS 2.6 for changing Digital Number (DN) values to reflectance
- Microsoft word – was used basically for the presentation of the research.

## IV. RESULTS AND DISCUSSION

### A. Land Use Land Cover Classification

Based on the prior knowledge collected from the peoples who lived in the study area and through observation of the current situation a classification scheme was developed for the study area. Using the application of image classification methods, six major land uses and land cover types were identified in Ganta-Afeshum district. These include forest land, bush land, agricultural land, bare land, settlement and available water based on the characteristics of Landsat satellite images of the year 2000 and 2014.

### B. Land Use Land Cover Classification for 2000

The study area has been categorized to six land use land cover categories, which were: Settlement, Forest, Agriculture, Bush land, Bare land and water. As indicated in the land use land cover map of the year 2000 (Fig. 4), the district is characterized by a rough terrain, especially the central part which hosts the majority of the forest land and bush/grass land. This portion of the land is devoid of major settlements because of its ruggedness, making it inconvenient for human settlement. The existing settlements are very tiny and sparsely populated. The land use land cover classification for 2000 from MSS satellite image (table 2) showed that majority of the study area was covered

by bush land 20480.5hectares (ha), contributes 33.6 % of the total area followed by bare or rocky land which constitute a total land area of 14009.04 ha (23%). Forest land and agriculture land cover an aerial size of 10296.36ha (16.9 %) and 7667.19ha (12.6 %) respectively, whereas the aerial coverage of Settlement land as well as available water (artificial lake) is very much insignificant which covers a total area of 430.56 ha (0.71%) and 2.16 ha (0.4%) respectively as shown in Fig.4. This shows that 63.7 % of the total area of the district was covered by bush land and forest land in 2000, which indicates that much of the area was covered by green vegetation. In addition the area categorized as bare land is also very much significant accounting about 23%.

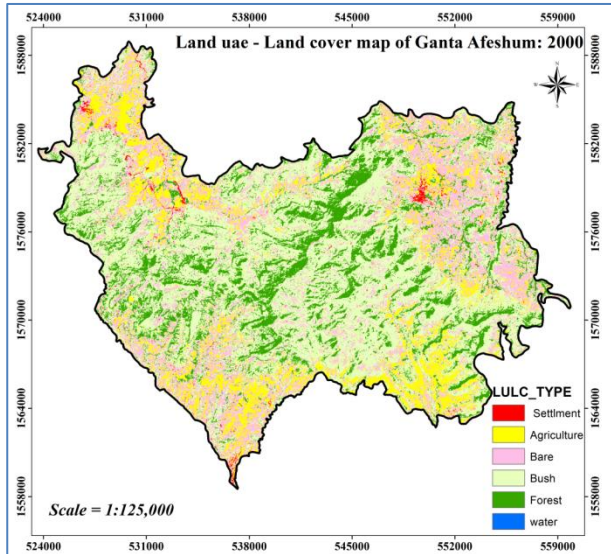


Fig.4. Land use and land cover map of Ganta Afeshum district in 2000.

TABLE II: GantaAfeshum Districtland Use Land Cover Types

Land use land cover type	2000		2014	
	In Hectare	In %	In Hectare	In %
Settlement Land	430.56	0.71	864.9	1.4
Forest Land	10296.36	16.9	14250.06	23.4
Agriculture Land	7667.19	12.6	13598.54	22.3
Bush Land	28497.06	46.8	20480.5	33.6
Bare Land	14009.04	23	11706.93	19.2
Artificial Water	2.16	0.4	1.44	0.002
Total	60902.37	100	60902.37	100

Source: Study

C. Land Use Land Cover Classification for 2014

As indicated in the land use land cover map of the year 2014 (Fig. 5), the central part of the district is still dominated by forest land and bush/grass land. This portion of the land is still devoid of major concentrated settlements because of its ruggedness, making it inconvenient for human settlement as well as for agricultural practices. The land use land cover classification for 2014 from ETM+ satellite image (table 2) showed that even though bush land is declined from 1972 to 1984 to 2000, the greatest share of land use/land cover from all classes is still bush land, which covers an area of 20,480.5 ha (33.6%). Forest land and agriculture land cover an aerial size of 14,250.06 ha (23.4%) and 13598.54 ha (22.3%) respectively, whereas the aerial

coverage of rocky/bare and settlement land is 11,706.93 ha (19.2%) and 864.9 ha (1.4%) from the total area of the district respectively. The aerial size coverage from water is declining as shown in Fig.5. There is decline of 13.2% bush land as well as 3.8 % bare land and converted to agricultural land, forestry and settlement. In other words, there was an increase of agriculture, forestry and settlement from 2000 to 2014 (Table2).

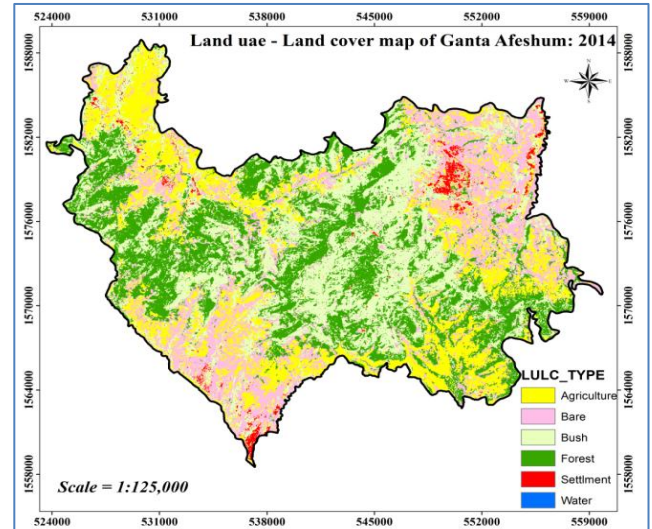


Fig.5. Land use and land cover map of Ganta Afeshum district in 2014.

D. Land Use Land Cover Change Detection from 2000 to 2014

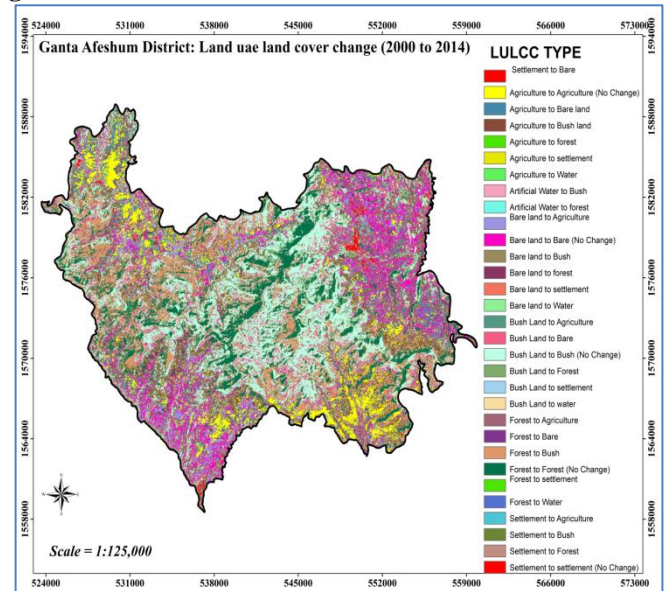
In the time period from 2000 to 2014 the change detection shows that there is an increase in area coverage/proportion of settlement, forest and Agriculture; and there is a decline of bush land and bare land. In the time period from 2000 to 2014 the change detection shows that there is an increase in area coverage/proportion of settlement, agriculture, and forestry; and there is a decline of artificial water, bush land and rocky/bare land areal coverage. When we see the contributing factors for this land use land cover change, population pressure takes the leading share. The population of the country in general and the province (Tigray state) in particular is growing rapidly. The first and foremost reason is that growing number of population increases the demand for additional cultivable land. Farmers have no option other than cultivating bare areas and bush lands. Secondly, when population pressure increases there is a demand for settlements. This has a two way effect on the environment. On one hand there is a need for settlement area on barren areas as well as through burning of bush lands and on the other hand there is a need for housing construction material particularly wood.

Even though the trees had cut down for construction and for fuel, there was an increasing in the coverage of the forest land. Thirdly, when population pressure increases there is a demand for additional source of water. This is mainly due to the fact that the land is degraded and farmers have large livestock population, and hence water for animals drink is needed. From the above discussion we can

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conclude that population pressure in the province particularly in the study area results in an increase of proportion of agricultural land, settlement and forest areas. Moreover, it is the policy of the present government to give emphasis for soil and water conservation activities, especially on hill areas of the country. In the province, since the early 1980's soil and water conservation activities had become one of the major preoccupations of the people and the authorities. This has involved mass mobilization of labor during the dry season, as well as food-for-work and cash-for-work programmes. Thus, the farmers in Tigray state were mobilized to treat catchments by building stone bunds over entire catchments, starting with higher level fields for more than the months. This required the equivalent of 2.5 to 5 months of part-time work per hectare of terracing work for a farmer and his family if tools were supplied. Each family was expected to give 90-180 man-days per year spread over 90-120 days of the year. This had a serious cost implication to the household.

After critical assessment, the present government substantially reduced the number of days allocated for "voluntary" unpaid involvement in soil and water conservation activities, to twenty days. Food-for-work and cash-for-work programmes are used to mobilize additional labor for such activities as shown in Fig.6. The conservation strategy focuses mainly on the construction of physical structures, depending on the topography and land use pattern. For steep uncultivated lands, contour stone bunds, cut-off ditches and contour furrows are used. For cultivated lands, contour stone bunds, soil bunds, or grass strips, complemented by check dams for gully control are used. To complement these physical structures, biological measures, such as tree planting and enclosures for natural regeneration are used. Since 2001/2002 about 600,000 ha of land has been terraced and 4,600 km of gullies treated. An average of 7-8 million person-days/year of labor was utilized both through food for work and as unpaid voluntarily. As a result of this the percentage/coverage of rocky/bare lands in the study area diminishes.



**Fig. 6. LULC change detection during 2000 to 2014 of Ganta-Afeshum district.**

### V. CONCLUSION

The results of this study showed that there was a change in land use land cover between the years 2000 and 2014 in Ganta Afeshum district. The change detection clearly depicts that population growth has significantly contributed in the expansion of agricultural land and settlement land. The three interrelated aspects: population, settlement and agriculture have grown simultaneously. Despite the positive developments that the population growth has brought in agriculture and settlement expansion, it has reduced the coverage of bush and grass lands. However, two major positive developments in environmental conservation have occurred in Ganta Afeshum district in the last fourteen years. First, the revival and expansion of forest cover which has never been affected by the rapid population growth. This indicates that the environmental policies and their meticulous enforcements have been integrated into the society's attitude. The second positive development is the partial expansion of the settlements and agriculture into the bare and rocky lands despite their harshness and inconvenience. The population pressure resulted in the settlement and cultivation of inconvenient and uncultivable lands respectively. But, on the other hand, these efforts have considerably reduced the pressure on bush or grass lands.

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**TABLE III: Ganta Afeshum District: Land use land Cover Types Determined Using Measures Of Central Tendency**

Land use land cover types	2000	2014	Standard Deviation (S)	Mean or average (M)	Coefficient of Variance (CV)= (S/M)*100	Change for 2014 to 2000
Settlement Land	430.56	864.9	307.1247593	647.73	47.41555	100.8779264
Forest Land	10296.36	14250.06	2795.688081	12273.21	22.77878	38.39900703
Agriculture	7667.19	13598.54	4194.097807	10632.865	39.44466	77.36015411
Bush Land	28497.06	20480.5	5668.563938	24488.78	23.1476	-28.13118266
Bare Land	14009.04	11706.93	1627.837592	12857.985	12.66013	-16.43303181
Artificial Water	2.16	1.44	0.509116882	1.8	28.28427	-33.33333333
Total	60902.37	60902.37				

Source: Study

National Park, Oromia National Regional State, Ethiopia.  
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