International Journal of Environmental Sciences Vol. 4 No. 3. 2015. Pp. 158-165

Full Length Research Paper

Mapping of Plantation Forest in the Upper Catchment of Addis Ababa

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Abstract

Monitoring deforestation and forest degradation is central to assessing changes in carbon storage, biodiversity, and many other ecological processes in tropical regions. Mapping of forest site in urban environments is critical since the resulting map not only helps us identify hot green spots and set up long term plan on how to preserve or restore green forest areas in urban environments, but also contribute to understand large scale carbon cycle studies. Among various remote sensing data types, Orto photo of Addis Ababa and sample of GPS point data were utilized to map vegetation volume in metropolitan area located within the upper catchment of Addis Ababa. Arc-GIS 9.3 software was used to digitize the plantation site and to calculate volume of vegetated area while SPSS 20 software was used for percentage analysis. The analysis of the selected area for the change detection of the forest cover showed that the area of Yeka plantation has been reduced from 15 Square kilometer to 14.9 Square kilometer within 2 years. This result has been found with the comparison of the sample GPS point with the digitized orto photo of Addis Ababa city 2011 from Yeka Sub-City. Based on the comparative analysis of the Addis Ababa City Orto photo 2011 with the GPS points for the reduction of forest covers in the upper catchment of sample area and field observations, the present study has identified existing forest areas and recommended major functional zones for forests development in Addis Ababa. The recommendation for the plan of the forest development is based on the slope and the contour maps. Forest degradation, plantation, mapping, Biodiversity, urban landscape

Keywords: *Addis ababa, Afforestation, Plantation forest, Ethiopia.*

Introduction

The word *'forestry'* has been derived from Latin word *'foris'* meaning outside the village boundary or away from habitat land and the 'forest' is referred to as an area occupied by different kinds of trees, shrubs and grasses maintained for productivity of wood and non-wood materials (Krishan 2011).

Plantation forests are defined by (FAO 1993) as forest stands established artificially by afforestation on land previously did not carry forests, or forest stands established artificially by reforestation on land which carried forests within previous 50 years or within living memory and involving the replacement of previous crop by new and essentially different crops. (Evans 1992) defines plantations simply as a forest crop or stand raised artificially either by sowing or planting (Yirdaw, 1996).

Global demand for wood products is increasing but the forest resources of the world are decreasing (FAO 2005). Total world round wood production is predicted to grow by 6.6 billion cubic meters by the year 2025 (Sohngen *et al*., 1997). Some of the demand will be met from managed natural forests but these resources will have diminished due to forest destruction and degradation in the tropics. Several countries have already invested heavily in forest plantations to meet the demand for some forest products especially timber, poles and fuel wood. Chile, New Zealand, Brazil, Spain and Portugal have forest plantations producing round wood for especially eucalypts poles. Plantations in Brazil and Argentina for instance, produce 60% of the country's industrial round wood but comprise only 2% of the forest area (Waggener 2001). In addition and Brazilian exports account for nearly 2.8% of the world market for pulp and paper (Sohngen *et al.,* 1997).

Plantations include industrial and peri-urban plantations established and operated by the government as well as community woodlots and catchment protection plantations. Peri-urban plantations are treated to supply urban centers with poles and wood fuel while community woodlots are established and managed by groups of farmers or a community for either protection or production of fuel wood. Catchment protection plantations are designed to prevent land degradations such as, area closures, planting of steep slopes and areas of badly degraded land. Poor management, encroachment and illegal cutting have reduced the growing stock below the desirable level. These shortcomings are rooted in weakness in the organization and staffing of the forest administration at all levels, and in the lack of funds to support the maintenance of plantations. The area of forest plantations established for industrial wood supply can not

help to compensate for the reduction in production from natural forests mainly due to the nature of the trees planted and poor past management practices

Urban forestry refers to any re-vegetation effort including the planting of trees and shrubs whose design is intended to improve the environmental quality, economic opportunity, or aesthetic value associated with a city's landscape. The perception that comes to mind regarding urban forest is street trees and ornamental woody plants. However, the urban forest is a complex system of trees and smaller plants, wildlife, associated organisms, soil, water and air quality in and around a city. According to (Hancock 1995), the upper catchments of urban afforestation efforts are particularly necessary because of the quality of the environment in urban landscapes. The urban environment is characterized by air and water pollution, settlement in fragile ecosystems and steep slopes, and loss of water catchments and floodplain surface areas (Hancock 1995).

According to (FAO 1985), in Ethiopia forest plantation have started by the turn of the 19th century, when Emperor Menelik requested his advisor to get him a fast growing tree species to overcome the fuel wood shortage he faced at the time. During the early 19th hundred, it was reported most of Addis Ababa was covered by forests and there were about 13,500 hectares of Eucalyptus plantation in 1964 (FAO 1985). There were about 162, 000 hectares of plantation forest and about 36, 000 hectares of per urban fuel wood plantation (FAO 1985). These were managed by the state, and Eucalyptus is the main plantation species (MOA 1991). Ethiopia's forest resource conservation, development and utilization was not the product of a long evolving process in which different land-use planning measures have been devised and used to meet changing needs and various ecological conditions of the country (MOA 1991). In Addis Ababa *Eucalyptus* species have been introduced since 1895 to satisfy the growing demand for wood and construction material and to reduce the pressure on the remaining natural vegetation. Without the successful introduction of *Eucalyptus* species under the reign of Emperor Menelik II, it is unlikely that Addis Ababa would have become the capital of Ethiopia and diplomatic centre of Africa (Hancock 1995). However, in recent years the urban forest of Addis Ababa including the upper catchments of the Entoto Mountain and other forest areas of Addis Ababa have been declining at an alarming rate.

Eucalyptus species are known to respond to several conducive and adverse environments, probably explaining their widespread distribution. This makes Eucalyptus a dominant hardwood plantation species (10-15 million ha worldwide; (Brown 2000). Since Eucalyptus sp. is widely used in exotic plantations, routine identification of superior clones has become increasingly important (Sekatuba *et al*., 2004).

Forests and the benefits they provide in the form of wood, food, income, and watershed protection have an important and critical role in enabling people to secure a stable and adequate food supply and sustainable ecosystem functions (Badege 2003). Deforestation and land degradation, however, are impairing the capacity of forests and the land to contribute to food security, and to provide other benefits, such as fuel wood and fodder in Ethiopia. Ethiopians are facing rapid deforestation and degradation of land resources. The increasing population has resulted in extensive forest clearing for agricultural use, overgrazing, and exploitation of existing forests for fuel wood, fodder, and construction materials. Forest areas of the country have been reduced from 40% a century ago to an estimated less than 3% today and the current rate of deforestation is estimated to be 160,000 to 200,000 ha per year. It is estimated that fertile topsoil is lost at a rate of one billion cubic meters per year (FAO, 1981; UNEP, 1983, Constable, 1985, Kuru, 1990, Yirdaw, 1996), resulting in massive environmental degradation and constituting a serious threat to sustainable agriculture and forestry ecosystem functions.

Ethiopian city are experiencing an influx of people from rural area on unknown scale, looking for work and a better quality life. because of this rapid growth on the urban-rural fringe, planners and policy maker lack accurate, timely and cost effective urban land use data which is most essential to make decision concerning land resource management.

Urban land is always modified by men's activity and today in the study area continuously agricultural land and forest land are converted in to urban built up area without considering its social, economic, physical and environmental impact. Addis Ababa is the capital and the most populated city of Ethiopia with a population of 1423111 (CSA, 1984), 2112737 and 2738248 in the years 1994 and 2007 respectively. A rapid and unplanned expansion and commercial development, along with population pressure, has meant the city environment is deteriorating with time. At present the forests of Addis Ababa are almost transformed to urban habitats accommodating an excessive population due to a high rate of rural–urban migration. In addition, industrialization within the urban areas and conversion of different land use within the city and the surrounding urban areas has caused the rapid depletion of existing tree cover during the previous years

This depletion of green resources has indicated that succeeding city governments had no proper long-term plans to keep the city green with the exception of intervening in some areas such as the establishment of a few parks and roadside plantations under a city beautification programme. These interventions also have diverse problems for sustainable management of the urban forest. Residents in general are not aware of the importance of existing tree cover in and around their living premises. With the rapid expansion of the city, wide roads replaced narrow and unpaved roads, leaving a host of disturbed areas. However, there are no plans to plant new trees along these roads and fill the space created by different development activities. No serious effort has been made to reclaim land in a well-planned manner to allow the city to have adequate space along with its growth. On the contrary, an alarming scenario observed is the reduction in forest areas over time especially in the upper catchment of the city. To ameliorate the existing conditions, there is an urgent need to identify the appropriate forest plantation sites within Addis Ababa upper catchment areas in order to formulate a

mapping of plantation forests using GIS software to suite for a sustainable plan and strategy of upper catchment forest development and management. This study aimed to identify the upper catchments of plantation forests of Addis Ababa and to locate the area using slope, elevation and contour map based on results of the identification and to indicate the forest development planning areas based on the slope and elevation criteria. Therefore, this study focuses on identifying plantation forest cover in upper catchment of Addis Ababa City; the plantation forest cover change in the upper catchment of Addis Ababa and mapping plantation forest in the upper catchment of Addis Ababa for sustainable planning of forest development.

Materials and Methods

Description of the study area

Addis Ababa is located in the central highlands of Ethiopia. Geographically, it is located at 9º 38' 0''N between 38º 42' 0''E, with the lowest elevation of 2020m above sea level, in the southern periphery, and the highest over 3000m above sea level, north of the city using GIS analysis fig 1

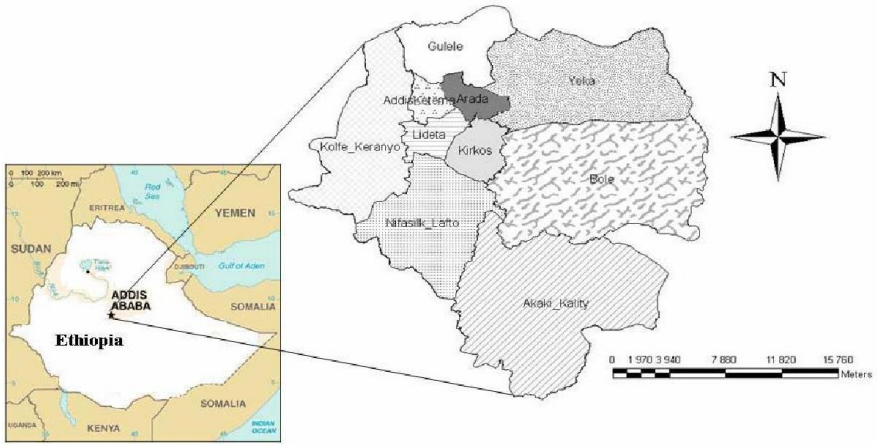

Fig 1: Map of Addis Ababa City

Sampling Methods

Site selection for GPS point data collection

The selected site for upper catchment plantation forest data collection was: Yeka mount plantation area where it is located above the British Embassy which has been selected for taking GPS point data for comparing with the current and previous forest coverage to indicate appropriate mapping of plantation site. The purpose of selection was based on the accessibility of the site.

Data collection and analysis methods

Methods of Data Collection

In order to obtain data about the amount of plantation forest cover, the forest cover change in upper catchment of Addis Ababa and related data were reviewed. Furthermore, data of CSA for the population of Addis Ababa and meteorological data were utilized and also the Addis Ababa Orto photo of 2011 was digitized to prepare maps. Moreover, few primary data was collected through interview of an expert and physical observation of the selected site.

Methods of Data Analysis

The data that was collected from the secondary source about the amount of plantation forest cover, the forest cover change in upper catchment of Addis Ababa and related data were reviewed. In addition for the study, the dataset was organized and used from aerial photo of 2011 (see figure 1 above). To use the aerial photo, the writer utilized ERDAS Imagine 9.2 and ArcGIS 9.3 software for image analysis and mapping purpose. Furthermore, the data collected using GPS from the sample study site were incorporated to see the changes of forest cover in the area using ArcGIS 9.3 and the chart were manipulated using SPSS 20 software for showing the identified forest cover share of the percent and qualitative explanation also used for the analysis of the data collected through interview.

Since the aerial photography is geo-referenced, projection type used was datum of Adindan UTM Zone 37 North are the spatial reference coordinate systems used in this study. The researcher mosaic the images of the 10 sub-cities using Erdas Imagine 9.2. Then, using ArcGIS 9.3 the forest plantation areas were digitized by using on screen digitization methods. After this the areas that were covered by the forested plantation was identified and mapped. Parallel to this, contours with 20 meter interval was generated Digital Elevation Model (DEM). Elevation, Contour and slope maps were derived from DEM data set using 3D Analyst extensions of Arc GIS 9.3 software. Moreover, the elevation of Addis Ababa City is also shown on 3D orientation by using Arc GIS 9.3. This helps to identify the upper catchment areas to plan and map the plantation forest easily.

Result and discussion

Plantation forest cover in upper catchment of Addis Ababa City

This study focuses on identifying the forest sites of the upper catchments of Addis Ababa City using GIS tools and amount of forest cover by digitization on orto photo of 2011 and mapping of plantation forest in the upper catchment of Addis Ababa for sustainable planning of forest development. This study has achieved results and outputs based upon well-defined objectives. A brief discussion on the findings of this study has been mentioned below.

An attempt has been made to identify forests in the upper catchment of Addis Ababa in different Sub-Cities. The amount of forest cover have been identified by digitizing the orto photo of 2011 in five Sub-Cities of Addis Ababa such as Yeka, Gulele, Kolefikeranyo, Akaki-kality and Bole Sub-Cities with different amount of areas in square kilometers 14.9, 10, 5, 0.42 and 4.84 respectively fig 2, whereas the other sub-cities of Addis Ababa such as Nefas selk lafeto, Kirkos, Ledeta, Addis Ketema and Arada did not have any forest cover.

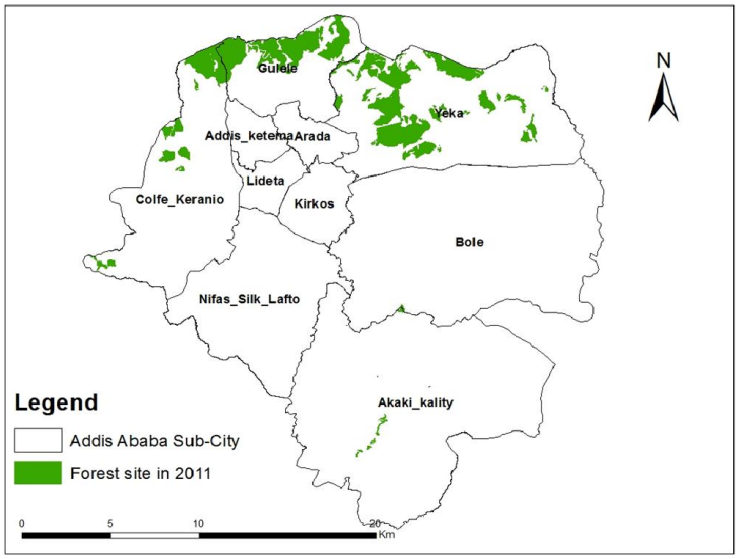

Fig 2: forest sites in Addis Ababa

The forest cover contribution of the above sub-cities in fig 3 has been analyzed using SPSS 20 software and the result of the analysis has been indicated in percentage. As can be seen from fig 3 below the percentage share of the identified forest coverage of the sub-city Addis Ababa such as Yeka, Gulele, Kolefikeranyo, Akaki-kality and Bole are 42.37, 28.45, 14.22, 1.2 and 13.76 percent respectively.

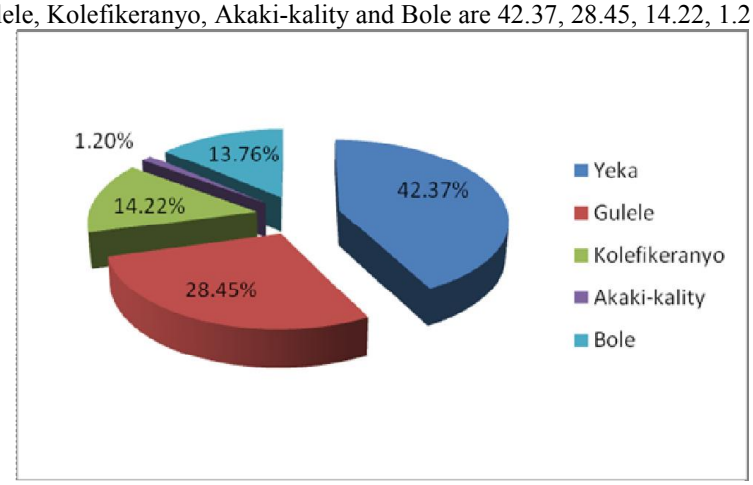

Fig 3 : Percentage share of areas covered by forest in squire kilometer

Plantation forest cover change in the upper catchment of Addis Ababa

The analysis of the selected area for the change detection of the forest cover showed that the area of Yeka plantation has been reduced from 15 square kilometer to 14.9 square kilometer within 2 years. According to the analysis fig 4, the amount of removed forest coverage from the sample sub-city was 0.12 square kilometer. This result has been found with the comparison of the sample GPS point with the digitized orto photo of Addis Ababa city 2011 from Yeka Sub-City (See GPS Point in table 1 and fig 4. In recent years the urban forest of Addis Ababa including the upper catchments of the Entoto Mountain and other forest areas of Addis Ababa have been declining at an alarming rate supported by (Hancock 1995). The influence of humans and their domestic animals has profoundly altered both the vegetation and the landscape, and little natural highland vegetation remains today. Ecological degradation, including deforestation and erosion, is widespread, particularly in the northern and central highlands witnessed by the author (Getahun 1988; Hurni 1990).

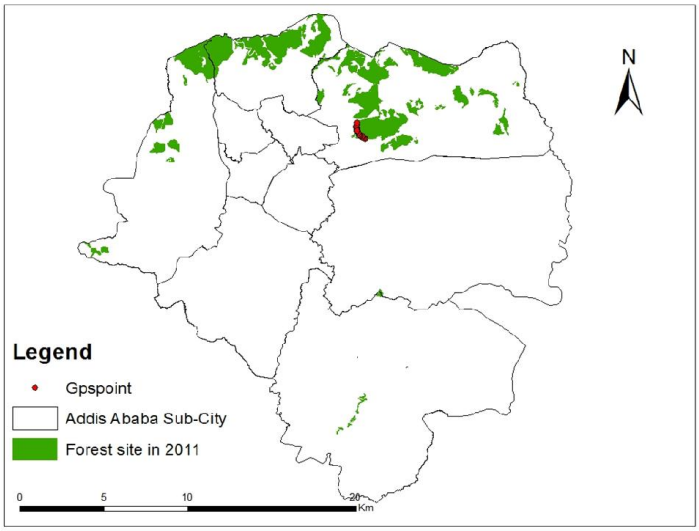

Fig 4: Yeka Sub-City indicated plantation forest with GPS Points

Table 1: GPS points from Yeka Sub-City Plantation Forest

Elevation	2466	2490	2493	2498	2506	2519	2496	2488
X	998095	998098	998154	998222	998222	998334	998427	998524
Y	477296	477216	477141	477121	477031	476944	476883	476819
Elevation	2494	2502	2503	2503	2502	2534	2538	2534
X	998565	998632	998685	998692	998758	998845	998929	999038
Y	476802	476817	476833	476808	476771	476798	476819	476802

Source: on field survey 2013 at Yeka Sub-city mount plantation area.

The reason for the change of forest cover is the expansion of built up areas to the forest areas and stepper slopes of the upper catchment which aggravates erosion and the occurrence of gully around the built up areas of the city fig 5. This is supported by (Berryman *et.al.,* 2008) that, as slopes become steeper, grading and the provision of infrastructure become more difficult and expensive. Further, the extent of site disturbance, loss of the aesthetic appeal of steep slopes, and environmental degradation become greater as well. Development of steep slopes, especially adjacent to stream corridors, can increase erosion of stream banks resulting in decreased water quality of slope instability. The greater the steepness of the slope, the more likely it is that rain will run off rather than infiltrate. In addition, the steeper the slope, the faster the water will travel. Water with more speed has greater erosive power. The upper catchments of urban afforestation efforts are particularly necessary because of the quality of the environment in urban landscapes. The urban environment is characterized by air and water pollution, settlement in fragile ecosystems and steep slopes, and loss of water catchments and floodplain surface areas and more erosion hazards (Hancock 1995).

Fig 5: Occurrence of gully in the upper catchment of Yeka Sub-City of Addis Ababa

From the physical field observation in the selected sub city of Addis Ababa, it was realized that deforestation because of looking for fuel wood, construction materials and encroaching of house construction in the upper part of the sloppy areas of Addis Ababa city and other environmental problems in the area were observed fig 6. This witnessed by the interviewed expert that the runoff today is a serious problem in surveyed area affecting every down settler of city in the form of clearly visible gully land and visible encroaching of the forest areas in the field of stepper slope land. This occurrence could be a burden for the downstream settler of the community which leads exposing to property damage and affects the ecosystem of the surrounding areas of the city.

The type of land cover, obviously, can affect both the rate of infiltration and runoff amount by following the coming of precipitation. Land cover is one of the factors that determine the rate of soil loss due to erosion. It influences both factors of erosivity of the eroding agents and erosibility of the eroding subject. Both surface and ground water flows are significantly affected by type of land cover. For example, forest canopy and leaf litter help to reduce the erosive action of rain drops. On the other hand, the formation of sheet, rill and/or gully erosion are common in areas where ground cover is insufficient. It is well understood that the outcome of this alteration is typically reflected in increases in the volume and rate of surface runoff and decreases in ground water recharge and base flow (Andersen, 1970), which eventually lead to larger and more frequent incidents of local flooding reduced residential and municipal water supplies, and decreased base flow into stream channels during dry weather (Harbor, 1994). Other impacts associated with change of discharge behavior due to urbanization include increased lake and wetlands water levels, modified watershed water balance and increased erosion of river channel beds and banks (Doyle *et al.,* 2000).

Fig 6: Photo taken from yeka sub city in the upper catchment of plantation area

Conclusion

Mapping of forest site in urban environments is critical since the resulting map not only helps us identify hot green spots and set up long term plan on how to preserve or restore green forest areas in urban environments, but also contribute to understand large scale carbon cycle studies. Among various remote sensing data types, Orto photo of Addis Ababa and sample of GPS point data were utilized to map vegetation volume in metropolitan area located within the upper catchment of Addis Ababa. ArcGIS were used to digitize the plantation site and to calculate volume of vegetated area and SPSS 20 software for percentage analysis.

Green infrastructure and forest increment in the urban areas is being increasingly acknowledged at all levels of planning policy, from regional down to site specific, as providing a multitude of benefits. There is a strong argument that it should be planned for and maintained in much the same way as green areas in the urban environment to realize return on investments and maximize the benefits, forest area and green infrastructure has the capacity to meet many different types of aspirations that a city or community may have, whether that could be addressing global issues like climate change and biodiversity, or very personal ones like the health and wellbeing of a community. A pre-condition to even understanding the benefits from forest area is to identify where this resource exists, understand what type of resources they are and assign the correct function or functions that they perform.

The upper catchment plantation sites of Addis Ababa discussed here are in their different stages of implementation. Over the coming months and years there is further work for the methodology to do in terms of incorporating measures for how well the plantation sites and green infrastructure is performing in terms of realizing the benefits, and in adapting to the ever changing social, political, economic and environmental drivers that exist in dynamic and demanding areas like Addis Ababa and its surrounding.

Future Plan

Based on the comparative analysis of the Addis Ababa City Orto photo 2011 with the GPS points for the reduction of forest covers in the upper catchment of sample area and field observations, the present study has identified existing forest areas and recommended major functional zones for forests development in Addis Ababa. The recommendation for the plan of the forest development is based on the slope and the contour maps fig 7. These afforestation areas could be integrated with bee-keeping activities and Dega" (temperate) fruits having the elevation of 2300m to about 3000m fig 8 below

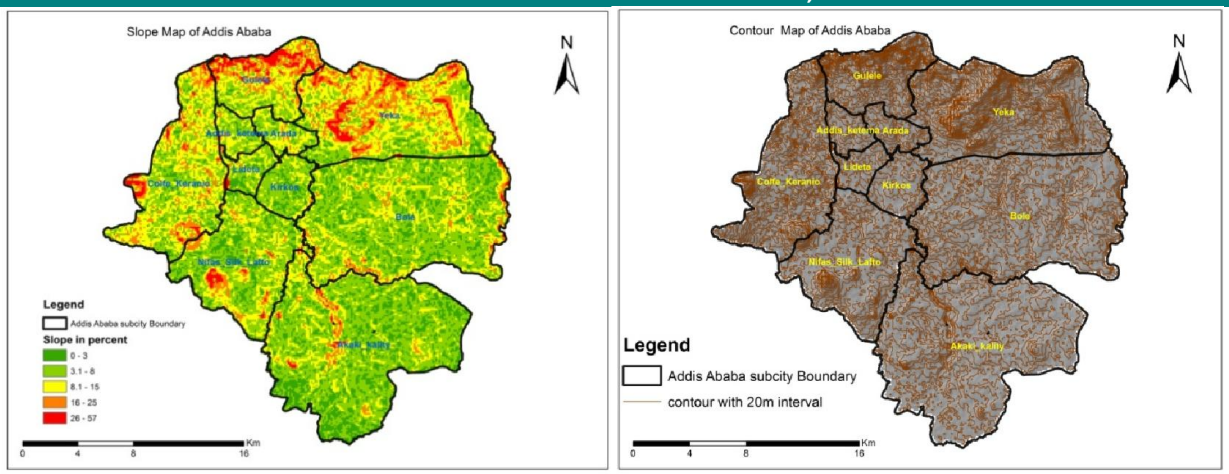

Fig 7: The Slope and Contour Map of Addis Ababa City

Afforestation Area

The whole catchment area of Addis Ababa plantation forests are reduced from time to time which requires forest development in the upper catchment of Addis Ababa. Forest development is about greening of landscapes including protecting existing natural forests or reforesting with multipurpose species denuded areas. This activities has multiple functions like, increasing access to forward forage, fruits, timber, fuel wood, construction materials and forest related activities like bee-keeping, and others.

Therefore, the area with the slope greater than 25% fig 8 is recommended as afforestation site with establishing hillside terraces on the steeper slopes where it is essential to conserve soil and water for improved growth of trees and other vegetation (WOCAT 2011). It is also important for conserving and managing biodiversity and the wildlife in general as well as the growth of vegetation in particular, along with the physical environment such as the hydrology, the soil and the landscape and make it suitable to implement bee-keeping and highland fruits that has to be managed by youngsters' of small scale entrepreneur of cooperatives creating job opportunity to bring sustainable economic development with environmental friendly activities. Actually, allocating the selected catchment area of the Addis Ababa as a forest area, it is not only important for biodiversity conservation and bee-keeping reproduction and honey production but also important to contribute in moderating local climate in particular and the globe in general. So that, the local people can derive benefits from the forest which they may consider the area as valuable land use type. Therefore, it is important to develop an integrated approach for the community and forest conservation that the community can benefit from the forest area in the form of direct and indirect use while keeping its potential through better protection of the environment.

Integrated forest conservation has not only assisting in climate control but also ecological benefits such as prevent erosion by reducing the rainfall's force on the soil's surface and by absorbing water and not allowing it to directly run off and remove topsoil. Forests also act as water filters, collecting and storing water and recharging underground aquifers, it contain a greater range of biodiversity than any other ecosystems on earth and commercial importance where humankind derives many benefits from forest ecosystems.

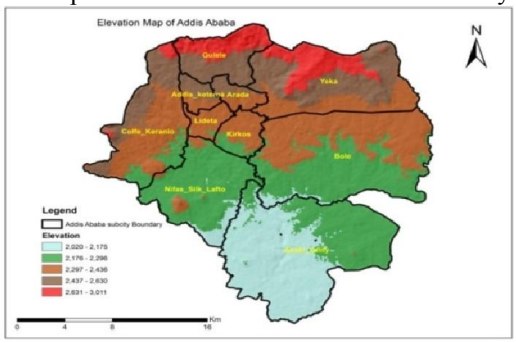

Fig 8: The Elevation Map of Addis Ababa City

Acknowledgement

I would like to thank Dr. Kumelachew Yeshitela for noble support in the process of writing this seminar paper. In other words, the materials and experiences shared by him during the lecture sessions of the course were very much helpful in finalizing the seminar paper.

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