IMPACT OF URBANIZATION ON STORM WATER RUNOFF VOLUME AND QUALITY: THE CASE OF HAWASSA CITY, SOUTHERN ETHIOPIA

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ASCHALEW SIDELIL SEBSIBE

HAWASSA, ETHIOPIA

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ASCHALEW SIDELIL SEBSIBE

ADVISOR: BROOK ABATE (Ph.D)
CO-ADVISOR: AWDENEGEST MOGES (Ph.D)

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As members of the Examining Board of the Final M.Sc. Open Defense, we certify that we have read and evaluated the thesis prepared by: Aschalew Sidelil Sebsibe entitled "**Impact of Urbanization on Storm Water Runoff Volume and Quality, The Case of Hawassa City, Southern Ethiopia**" and recommend that it be accepted as fulfilling the thesis requirement for the degree of Masters of Science in Water Resource Engineering and Management.

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Name of major advisor	Signature	Date
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I, Aschalew Sidelil Sebsibe, declare that this thesis is my original work and it has not been presented and will not be presented by me to any other university for similar or any other degree award.

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ACRONYMS

BOD	Biological Oxygen demand
CN	Curve Number
COD	Chemical Oxygen demand
Cu	Copper
E	East
EC	Electrical conductivity
EPA	Environmental protection Authority
ERA	Ethiopia Road Authority
EUEP	Ethiopia urban Expansion Plan
Ha	Hectare
LULC	Land Use and Land Cover
LID	Low Impact Development
N	North
NTU	Tepheon Turbidity Unit
OEC	Oregon Environmental Council
Pb	Lead
RCN	Runoff curve Number
RiPPLE	Research inspired Policy and Practice Learning in Ethiopia
SCS	Soil Conservation Service
SNNPR	Southern Nation Nationalities and People Region
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
UN	United Nation
USEPA	United States Environmental Protection Authority
Zn	Zink
µcm	Micro Siemens

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ABSTRACT

Land use and land cover change results from various interactions between human being and environment. This study aims to identify and compare changes in land use and land cover occurred in the last 30 years in Hawassa city and its subsequent effect on runoff volume and quality. Information on land use and land cover changes that occurred from 1986 to 2016 in the study area was compared using remote sensing and geographic information system (GIS) with field verifications; Land-sat and spot satellite image were used to analyze the change. Three sets of remotely sensed Land-sat TM 1986, 2000 and 2016 were used to produce the LULC maps at different periods through a supervised classification of the satellite imageries using ERDAS IMAGINE and Arc GIS software. The Soil Conservation System (SCS) runoff volume calculation method that best fit for Ethiopia is used. Urban runoff water samples were gathered from the major runoff outfalls. The runoff sample collected manually using PVC scoop that received the entire flow and where then transferred to sampling bottles. The preparation of composite sample for one rainfall event is done by calibrating the sampling bottle with equal volume for three grab samples and preparing one event composite sample on site for that specific runoff event and sampling station. There was a significant expansion and encroachment of land use and land cover in Hawassa city between 1986 and 2016. In the study period the buildup area increased by 181.8% between 1986 and 2000. It also increased by 184.2% between 2000 and 2016. The total increment during the study period between 1986 and 2016 was about 700%. The second most changed LULC was vegetation cover that declined by 53.5% between 1986 and 2016, by 27.8% between 1986 and 2000 and finally by 37.2% between 2000 and 2016. Cultivated land was the least changed LULC. It declined by 12.2% from 1986 to 2016 but increment between 1986 and 2000 by 5.2% but decreased by 16.5% between 2000 and 2016. Bare land area also decreased by 50.8% from 1986 to 2016. The total storm water runoff depth was 35 mm and total volume was 5,833,460 m3. The storm water runoff depth indicates that 70.8% of the total rain fall changed to runoff water. During this time the contribution of the buildup area contribution was 3.8% and that of non-buildup area was 96.2% area wise. The runoff water quality laboratory results indicate that TN, TP, TSS, TDS, COD, BOD and Bacteria in the sample water were in excess of the level of permit discharge defined by the US environmental regulation.

Key words: *Urbanization, Land use and land cover, Storm Water Runoff, Storm Water Runoff Quality*

1. INTRODUCTION

1.1. Background and Justification

Urban growth is an important global environmental issue that affects both developed and developing countries (Nigatu, 2014). Urbanization, the conversion of other types of land to uses associated with the growth of population and economy, is a significant land use and land cover change especially in recent human history. Rapid urbanization has been the main theme of urban studies in developing countries since the explosion of rates of growth in the 1960's and 1970's in very large cities (Barros, 2004). Like other anthropogenic environment interactions, urban land use and cover changes respond to socioeconomic, political, cultural, demographic and environmental conditions, largely characterized by a concentration of humans (Masek, 2000). In spite of its small area coverage relative to the earth's surface, dynamic urban growth processes, particularly the expansion of urban population in a larger extent and urbanized area, have a significant impact on natural and human environment at all geographic scales (Herold, 2005).

According to the United Nations report on World Urbanization Prospects, the world urban population is expected to increase by 72 % by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050. Thus, the urban areas of the world are expected to absorb all the population growth expected over the next four decades while at the same time people are moving to rural areas by assuming that rural life is seen as simpler and less stressful. Furthermore, in the cities and towns of less developed regions the expected population growth is more concentrated than the developed regions of Europe and America (Desa, 2012).

Associated with the rapid expansion of urbanization, a lot of land has been converted from rural to urban. From the land use and land cover change point of view, expansion of urban areas is of greater importance because of its strong effect on other land cover classes, such as agricultural lands, non built areas, forests and others. Ethiopia, having the second largest population in Africa has a total of over 80 million populations. It has a 2.3% of annual growth rate and having 4.6% average annual urban growth rate (Haregeweyn, 2006). According to Haregeweyn (2006), despite of its low urbanization rate compared to other African countries, the impact of land use and land cover changes become a big challenge to the country.

In urban and suburban areas, much of the land surface is covered by buildings and pavement, which do not allow rain water to soak into the ground. The process of urbanization has a considerable hydrological impact in terms of influencing the nature of runoff and other hydrological characteristics, delivering pollutants to rivers, and controlling rates of erosion (Goudie, 1990). The storm water runoff carries pollutants such as oil, dirt, chemicals and lawn fertilizers directly to streams and rivers, where they seriously harm water quality (Rogers, 1994).

Consequently, the need for an understanding of land use and land cover change has been increasingly recognized in global environmental research (Geist, 2006). Human's presence on the Earth and his modification of the landscape has a profound effect upon the natural environment. These anthropogenic influences on shifting patterns of land use are a primary component of many current environmental concerns as land use and land cover change is gaining recognition as a key driver of environmental change (Riebsam et al., 2002).

At different stages of urban growth, various impacts can be observed. In the early stage of urbanization, removal of trees and vegetation may decrease evapotranspiration and interception and increase stream sedimentation. Later, when construction of houses, streets, and culverts begins, the impacts may include decreased infiltration, lowered groundwater table, increased storm flows, and decrease base flows during dry periods. After the development of residential and commercial buildings has been completed, increased imperviousness and reduce the time of runoff concentration so that peak discharges are higher and occur sooner after rainfall starts in basins. The volume of runoff and flood damage potential will greatly increase. Moreover, the installation of sewers and storm drains accelerates runoff. As a result, the rainfall runoff process in an urban area tends to be quite different from that in natural conditions depicted in classical hydrological cycles (Goudie, 1990).

Meyer and Turner (2006) demonstrated that land use denotes the human employment of land which includes settlement, cultivation, pasture, rangeland, recreation and so on, whereas land cover denotes the physical state of land. It embraces, for example, the quantity and type of surface vegetation, water and earth materials. Land use change is associated with land cover change while land cover may change without the alteration of land use. As a result, simple land cover classifications are not sufficient for the analysis of change (Geist, 2006).

From the very beginning, Humans play a considerable role in the large scale modification of global environment through the interference of natural environment with the combined objective of obtaining wood for construction and shelter, tool making; providing fuel to keep warm, to cook food, to melt metals and preparing land for cultivation of food crop. According to Meyer and Turner (2006) most of the earth's surface is already modified, except those areas that are peripheral in location or are fairly inaccessible.

Ethiopia, situated in the horn of Africa, has a long history of intensive agriculture and human settlement. However, the high population pressure and associated depletion of the scarce resources have made agriculture of the country unsustainable, forcing its expansion into marginal areas such as steep slopes, swampy plains, and traditionally untapped part of the environment and putting tremendous pressure on soil, vegetation and water resources. As a consequence, considerable land use and land cover changes have occurred in Ethiopia during the second half of the 20th century (Engdawork, 1997).

Vegetation, soil, biotic life, ground water level and weather condition can be affected by land use and land cover changes. The change obviously affects more cities like Hawassa which rely on Surface water body and all storm water runoff drain to the Water body. Therefore, understanding of the complex interaction of these changes in their temporal and spatial patterns and processes is the baseline to formulate policy and strategy for the overall sustainable development and environmental management (Solomom, 1994).

1.2. Statement of the Problems

According to Ethiopian urban expansion program study (2013), Ethiopia is now one of the most rapidly urbanizing countries in the world. Among the 80 countries that had more than 10 million people in 2010, it had the 15th highest rate of projected urban population growth between 2010 and 2040. Preliminary city-level population projections suggest that some of its larger cities excluding Addis Ababa, expected to grow much more than triple their 2010 population by 2040. Hawassa will grow to more than 6-fold its 2010 population by 2040, Mek'ele to almost 5-fold its 2010 population, and Adama and Bahir Dar to almost 4-fold their 2010 populations (EUEP, 2013).

The built-up areas of these cities can be expected to expand at an even faster rate than their population. This showed that when urban population grows is accompanied by economic development and by the increasing availability of inexpensive transport the annual consumption of urban land per person growth as well. Hawassa is a growing city and many more infrastructures are under construction and expected to be constructed as the population growth rate is significant (Planet of Cities, 2012).

In Hawassa City, dramatic expansion has resulted in increase of the area that does not have the capacity to store and infiltrate water (impervious surface). The transformations of these natural land surfaces in to impervious surfaces (like streets, parking lots, foot path and other pavements etc) are radically decreasing the rate of infiltration and thereby increasing surface runoff volume from precipitation. The study of AG Consult (2007) indicated that there were high land cover changes in the past 30 years in Hawassa city. This change in land use increases impervious cover lead to flooding, erosion, habitat degradation, and water quality impairment.

Researchers have identified storm water runoff as a major contributor to water quality degradation in urbanized watershed (Field & Pitt, 1990). Every day activities such as excavation at construction site, demolishing of buildings, driving, maintaining vehicles, disposing of wastes, collecting wastes in failed septic systems and sewer structures contribute substantial amount of contaminant to runoff. Sediment that comes from active construction sites and washes of particulate materials from impervious surface is one of the most common and potentially damaging pollutants found in urban runoff (Addisu, 2009).

There have been several studies of land use and land cover changes at regional or local levels, but they often deal exclusively with quantifying land use and land cover changes using remote sensing tools or they focus on causes of land use and land cover changes through socio-economic surveys. Mapping spatial changes using remote sensing tools gives quantitative descriptions but does not explain or provide understanding of the relationship between the patterns of change and its subsequent ieffect on the hydrology of the area (Olson et al., 2004).

As Lemlem (2007) explained the land use of Lake Hawassa catchment has been changed progressively due to extreme deforestation as a result of increase in population, which results in replacement of vegetation cover by cultivation land. As the deforestation of the natural vegetation cover continues soil could be losses due to erosion. This erosion could be one of the reasons for the rise of Lake Hawassa water level and disappearance of Lake Chelekela (Lemlem, 2007).

LULC change of Hawassa watershed studied by different researchers but the LULC change of the city was studied by only Nigatu (2011). This study well described the LULC change of the city from 1987 to 2011 very well but did not relate its subsequent effect on storm water runoff volume and quality. Since few years back storm water is flooding the town overtopping the drainage systems. Runoff prevention and remediation techniques have not been effectively implemented due to lack of data. Therefore, this study is designed so as to fill the information gap decision makers and development practitioners have in the sector. Understanding such challenges is critical for formulating effective environmental policies and management strategies.

1.3. Objective of the Research

1.3.1. General objective

The main objective of this study was to detect and analyze land use and land cover change of Hawassa city and its subsequent effect on storm water runoff volume and quality.

1.3.2. Specific objectives

- ✓ To assess land use and land cover dynamics of Hawassa city in the past 30 years;
- ✓ To estimate storm water runoff volume change as a result of Hawassa City land use and land cover dynamics in the last 30 years;
- ✓ To characterize pollutants and their concentration in storm water runoff for the year 2016;

1.4. Research Questions

- ✓ How much land is changed from non build up to build up land use in the last 30 years?
- ✓ How is the storm water runoff quantity and quality changed?
- ✓ What are the major runoff pollutants and their sources?
- ✓ What are possible solutions to manage urban storm water runoff quality and quantity change?

1.5. Significance of the study

Assessing the impact of urbanization on storm water runoff change has multiple importance for sustainable urban planning and environmental protection. The study also shows how urbanization increase the impermeability of the area and its consequence effect on changing amount of storm water runoff and the pollutant load in the storm water runoff. Anyone who is concerned in conservation of the lake and the immediate waterfront ecology can find essential information from the research where to start and focus.

1.6. Limitation of the study

The limitations of this study were land use and land cover change was detected based on low resolution satellite image due to budget constraint to purchase high resolution images. For runoff water quality analysis only one session rainfall-runoff was sampled due to time and budget constraint. Number of water quality sampling sites also limited to six due to its difficulty to take water quality sample from more sites at the same time during rainfall.

2. LITERATURE REVIEW

2.1. Historical Development of Hawassa City

The growth and expansion of Hawassa city was sudden as compared to every city in the country; it happened within short period of time. Particularly since the 1970s Hawassa showed a very fast growth. But no one denies that the rise of every town and cities including Hawassa could not be out of the natural and human factors. The natural factors include accessibility, relief, climate, vegetation, water supply, soil etc. The main cause for the foundation of Hawassa city is the natural beauty of the Lake. Hawassa town has got its name and beauty from the Lake Hawassa. In earlier time this place was not inhabited by many people. It was a place were mainly pastoralist had conflict for grazing land (Kebede, 1999).

According to Kebede (1999) in 1957 the then governor of Sidama permitted and ordered the preparation of suitable master plan for the foundation of a town for tourist attraction on the land along the shore of Lake Hawassa. In 1960, Hawassa was established on a land of 1920 hectares. In 1968 Hawassa became the capital of Sidama Governorate General. The continuous promotion of Hawassa as a seat of political and administrative center (from woreda level to Governorate General, then to the capital of Southern Region Plan Office during the Dergue regime and then to the seat of SNNPR at present has become several milestones to its urbanization process and fast development. Each promotion was followed by farther construction and opening of various administrations, economic and social service giving offices and sectors (Kebede, 1999).

2.2. Land Use and Land Cover Change

The earth's surface has been changed considerably over the past decades by humans because of urbanization, deforestation and agriculture. Even though the conversion of land to agriculture and deforestation rates vary across the world, the number of people residing in cities has been increasing continuously. Urbanization has been increasing since World War II, and has not shown any sign of decline and is likely to continue into the twenty-first century (Oğuz, 2004).

The definition of land use and land cover has been used interchangeably in the land use research community because of the availability of many existing information systems. However, these two terms explain two different issues and meanings. Land cover refers to the observed biophysical cover on the earth's surface including vegetation, bare soil, hard surfaces and water bodies. Whereas land use is the utilization of land cover type by human activities for the purpose of agriculture, forestry, settlement and pasture by altering land surface processes including biogeochemistry, hydrology and biodiversity (Di Gregorio, 2000).

Land use and land cover changes became prominent as a research topic on the global environmental change several decades ago with the idea of processes in the earth's surface influence climate. In early 1980's the significance impact of land use and land cover change on the global climate via carbon cycle was understood where terrestrial ecosystems acted as a source and sinks due to the changes. Following this, the forthcoming volume of the 1991 Global Change Institute of the Office of Interdisciplinary Earth Studies (OIES) dedicated to land use and land cover changes at global level by explaining the major recent trends of changes, their consequences in environment, human causes on it as well as data and modeling of changes (Meyer, W. B and Turner, B. L., 1992).

Conversion and modification are the two forms of land cover changes described by Meyer and turner (1992) where the former is a change from one class of land cover to another example from grassland to cropland. The latter is, however, a change within a land cover category like thinning of a forest or a change in composition. Land cover changes due to human activities drive land use and hence a single class of cover could support multiple uses (forest used for combinations of timbering, slash and burn agriculture, fuel wood collection and soil protection). On the other hand, a single system of land use can maintain several covers as certain farming systems combine cultivated land, improved pasture and settlements.

Changes in land use and land cover caused through direct and indirect consequences of human activities on the environment for the purpose of having better life. One of the direct impacts of human is population growth where its increase and decrease have effects on land use especially in developing world at longer time scales. According to Lambin (2003), it can also be caused by the mutual interactions between environmental and social factors at different spatial and temporal scales as land use and land cover change is a complex process.

Verburg and Veldkamp (2002) showed that causes of land use and land cover change can be categorized as direct (proximate) or indirect (underlying). The direct causes comprise human activities that could arise from the continuous use of land and directly alter land cover which reflect that human are driving forces. They are generally operated at local levels and explain how and why local land cover and ecosystem processes are modified directly by humans. On the other hand, indirect causes are fundamental forces that strengthen the more direct causes of land cover changes. These causes are resulted due to the complex interaction of social, political, economic, technological and biophysical variables.

Land use and land cover changes have significant consequences on climate change, hydrology, air pollution and biodiversity. Meyer and Turner (1992) mentioned in their study that it caused a various microclimatic changes. The rise in global surface temperature is associated with deforestation through changes in land use. This in turn caused a strong warming in urban environment called urban heat island. Their study also showed water pollution occurred due to land cover changes from cultivation to settlement (urban areas). It has been reported also that loss of forest species has wide range of effects on biodiversity.

Identifying the causes and impacts of land use and land cover change require understanding both how people make land-use decisions and how specific environmental and social factors interact to influence these decisions (Lambin, 2003). In order to understand the impacts of dynamic land use and land cover changes, the use of land use change models become an advantage since they provide information of land use trajectories by projecting for the future. This ability of models, however, important for better environmental management and land use planning (Verburg, P. H. and Veldkamp, A., 2004) .

2.3. Urban Land Use and Land Cover Change

From a broader point of view urbanization is one of the ways in which human activities altering global land cover. Although urbanization trend is global, according to the reports of the United Nations Centre for Human Settlements (Habitat, 2001), it has showed most remarked changes in developing countries associated with the migration of rural people to cities for better opportunities. Urban growth, particularly the movement of residential and commercial land use to rural areas at the periphery of metropolitan areas, has long been considered as a sign of regional economic vitality (Yang, L. and Deal, B., 2003). However, its importance becomes unbalanced with impacts on ecosystem, greater economic differences and social fragmentation. It can be defined as the rate of increase in urban population. Dynamic processes due to urban change, especially the tremendous worldwide expansion of urban population and urbanized area, affect both human and natural systems at all geographic scales (Brockerhoff, 2000).

Since land cover changes at regional level occurred increasingly due to human activity, the changes couldn't be realized in the community. Therefore, accurate and updated information is required to design strategies for sustainable development and to improve the livelihood of cities. The ability to monitor urban land cover and land use changes is highly desirable by local communities and policy decision makers. Due to the increased availability and improved quality of multi spatio-temporal data and new analytical techniques, nowadays it is possible to monitor urban land cover and land use changes and urban sprawl in a timely and cost-effective way (Yang, L. and Deal, B., 2003).

2.4. Trends of Urban Growth

The world is undergoing the largest wave of urban growth in history. According to the United Nations Population Fund (UNFPA, 2013), rapid population growth has been concentrated in towns and cities of the world. The report also projected that by the year 2030 the vast majority of this growth will be observed in the developing world of Africa and Asia where urban growth is highly concentrated. Because cities offer a lot of opportunities such as jobs and sources of income than the corresponding rural areas, they attracted a lot of people. Following the rapid increase of population in urban areas, the growth of the world's rural population has shown a slowly decreasing pattern.

World's urban population increased four-fold between 1950 and 2003, the world's rural population less than doubled going from 1.8 billion in 1950 to 3.2 billion in 2000 (Cohen, 2006). Regarding to projection of population growth, the world's urban population is expected to increase by almost 2 billion over the next 30 years, whereas the world's rural population is actually expected to decline slightly falling from 3.3 billion in 2003 to 3.2 billion in 2030.

Ethiopia is one of the second largest populated countries in Africa with a total population of over 80 million and having an annual growth rate of 3.02%. The country is experiencing an average annual urban growth rate of 4.6%, which is a high rate by world standard (Cohen, 2004). Even though urbanization rates differ depending on the methodologies applied, Ethiopia's urbanization is low relative to other Sub-Saharan African (SSA) countries. Since the majority of the population (85%) is living in the rural areas, where agriculture is the backbone of the country's economy, it is evident that urban growth to be low. The self-sufficiency of agriculture also contributed to reinforcing of the rural peasant life from their territory. According to Central Statistical Agency of Ethiopia (CSA), it is only 16% of the population living in urban areas. Small cities and towns are among these places (Schmidt, E. and Kedir, K., 2011).

2.5. Land Use and Land Cover Change Studies in Ethiopia

From the reviewed literatures, Haregeweyn et al (2012) have investigated urban expansion in the urban fringe of Bahir Dar area, Ethiopia. Zeleke and Hurni (2001) also found a significant impact of dynamic land use and land cover changes in the northwestern Ethiopian Highlands. Bekalo (2009) identified a significantly increase of urban areas from 34% in 1986 to 51% in 2000 in Addis Ababa by the expense of agricultural land and vegetated areas driven by population growth. Dorosh and Schmidt (2010) also reported a significant urban growth for the last three decades as a result of increase in population of Ethiopian highlands. Muluneh and Arnalds (2011) stated that unsustainable growth of population contributed to environmental degradation especially in most populated areas such as in Ethiopian highlands.

From most of these studies it is evident that population pressure is one of the major drivers of land use and land cover changes through destruction of forest and vegetation cover for the purpose of agricultural and urban expansion in Ethiopia. Population growth coupled with migration from rural to cities leads to further expansion of urban areas at the expense of vegetation cover which is commonly practiced in western highlands of Ethiopia according to Zeleke and Hurni (2001) study.

2.6. Land Use and Land Cover change in Hawassa and Surrounding Area

The study of AG Consult (2007) on Hawassa watershed indicated that there were huge land cover changes in the past 30 years. Accordingly, it has presented the rate of change between 2000 and 2005 with the highest being 91% and 81% for urban and shrub land respectively, followed by 33% and 31% for wooded grass and dense shrub in that order, similarly 26% for both open forest and bare land. The Water body area (that includes Lake Hawassa and Lake Cheleleka) has remained almost constant in its total area coverage, i.e. 100.78, 102.34 and 99.59 sq km for the years 1976, 2000 and 2005 respectively. As per the study, when the two lakes area separately analyzed, Lake Hawassa showed a slight rate of increase, which is almost 9%, while Lake Cheleleka significantly decreased by about 75% in the last 30 years. Urban Built-up area has been increased by 202 % in the same period while Marsh area has progressively declined in the three periods to cumulative rate of greater than 39% (AG consult, 2007).

Based on the land use land cover map prepared by Water Works Design and Supervision Enterprise (WWDSE, 2001) 33% total area of the watershed was cultivated land in 1965 which was concentrated in Eastern and Southern part of the watershed; and the West was mainly covered with open bushy woodland. There was no direct influence of cultivation on the lake except on the Eastern side. In 2005, most of the vegetation cover that existed in 1965 had totally vanished in the Western part of the watershed, particularly, in Mulette sub watershed (Moges, 2009). The flat terrain near the lake was totally cultivated which probably was the source of erosion and sedimentation for the lake (SOS-SAHEL, 2014a).

Land use and land cover (LULC) change and erosion hazard assessment document of SOS-SAHLE (2005) mentioned that in Eastern part of the watershed particularly between Wondogenet and Wajagra, there was improvement in vegetation cover because of change in farming system and presence of Wondogenet Forestry College. This however does not indicate vegetation improvement in the whole watershed. As a result of population pressure, currently most of the vegetation in the watershed is depleted and reduced to grass land with few bush lands. According to Ministry of Water resource (MoWR, 2010), land use in the watershed is dominated by cultivation which occupies 61% of the total area (or 66% of the land area) with intensive cultivation. LULC change in the watershed has been contributing to the discharge increment of Tikurwuha and level rise of Lake Hawassa (RiPPLE, 2016).

According to Nigatu (2014) the total agricultural land is still the most dominant LULC category. Most conversions to built-up areas come from agricultural land 33% and 47% during the 1987-1999 and 1999-2011 temporal intervals respectively. On the other hand the increase in agricultural land, though it is small, indicated that there were still conversions to agricultural land within the boundary of the city administration.

2.7. Impact of LULC Change on storm Water Runoff

The natural hydrological cycle is altered by the urbanization in terms of both hydrology and water chemistry. The main problematic change is the modification of the natural water paths though the watershed (Harvey, 2003). Urbanization results in increase of the runoff volume and in a reduction of infiltration, leading to 55% of the rainfall which becomes surface runoff and 15% which becomes infiltrated water. On the other hand, for a natural forested area 50% is infiltrated water and only 10% is surface runoff.

The impact of the increase in urban storm water runoff volumes and pollutant loads is substantial. Urban storm water is responsible for about 15% of impaired river miles in the USA (US EPA, 2008) and urban storm water is the leading cause of pollution to fresh and brackish receiving waters (Makepeace, 1995). Storm water impacts can be hydrologic, chemical, biological, or physical, but the impacts of greatest concern are biological integrity and habitat alteration due to the loading of sediment, nutrients, metals, chloride, bacteria, high temperature water, oxygen-demanding substances, and hydrocarbons (US EPA, 2008). Although the impacts tend to increase as the urbanization within the watershed increases, negative impacts can be significant in watersheds that are less than 10% urbanized (Pagotto, 2000).

Urbanization significantly alters the way water flows in a watershed. In natural areas, most rainfall and snowmelt soaks into the ground to replenish groundwater or is absorbed or transpired by plants, and a significantly smaller amount runs directly into surface water bodies. In urbanized areas, water flow rapidly the hard, “impervious surfaces” of buildings, streets and sidewalks, and it is piped into streams and rivers or discharged underground. A one-square meter paved parking lot generates 16 times more runoff than a meadow of the same size (Oregon Environmental Council, 2007).

According to Raghunath (2006) storm water runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways and bridges. Essentially, any surface which does not have the capability to pond and infiltrate water will produce runoff during storm events. When a land area is altered from a natural forested ecosystem to an urbanized land use consisting of rooftops, streets and parking lots, the hydrology of the system is significantly altered. Water which was previously ponded on the forest floor, infiltrated into the soil and converted to groundwater, utilized by plants and evaporated or transpired into the atmosphere is now converted directly into surface runoff (Raghunath, 2006) .

Oberts (1994) stated that an important measure of the degree of urbanization in a watershed is the level of impervious surfaces. As the level of imperviousness increases in a watershed, more rainfall is converted to runoff. The total impervious surface area of a watershed can be estimated by associating a percentage of imperviousness with different land uses and totaling them up.

The storm water pollution problem has two main components: the increased volume and velocity of surface runoff and the concentration of pollutants in the runoff. Both components are directly related to development in urban and urbanizing areas. Together, these components cause changes in hydrology and water quality that result in a variety of problems including habitat loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion, as well as affects on our health, economy, and social well-being (Ferguson, 2002).

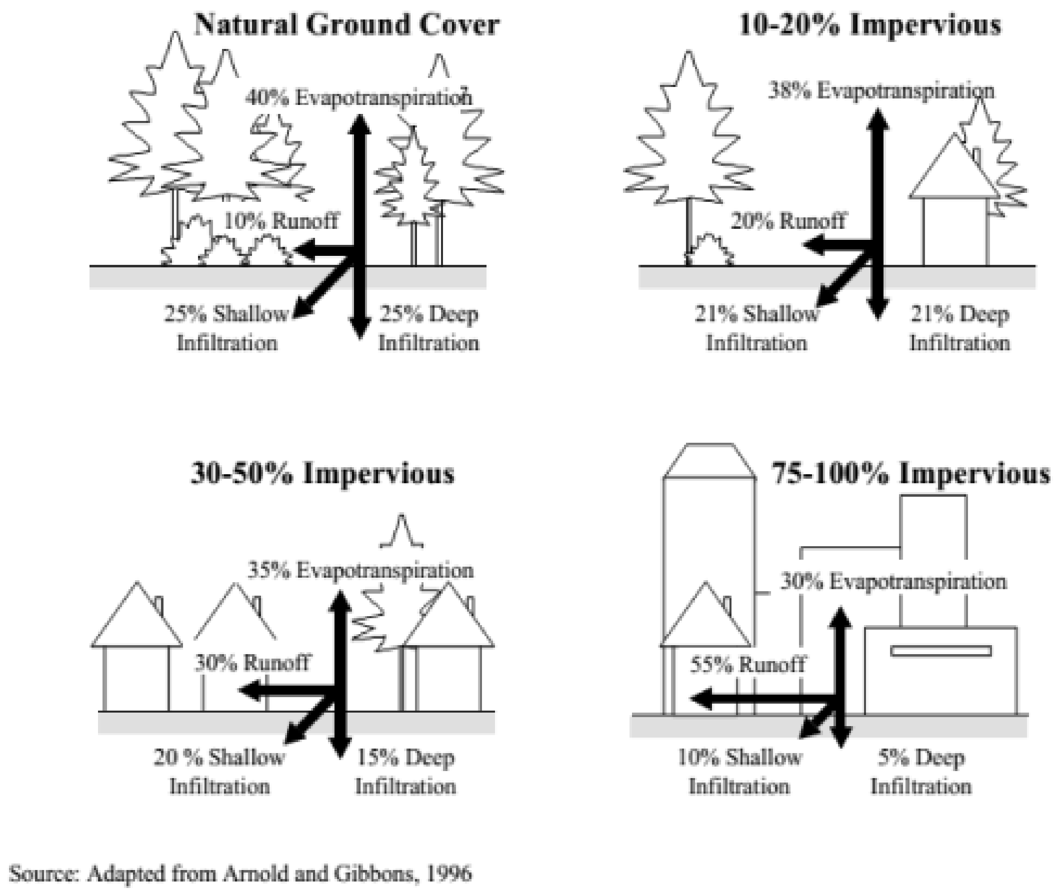


Figure 1: Effect of imperviousness on Runoff and infiltration

2.8. Storm Water Runoff Quality

Urban runoff is not simply clean rain that falls on the urban landscape and subsequently flows away. Rain falling upon a catchment collects pollutants from the air, road way surfaces, other catchment surfaces, and storm drains, and is thereafter transformed into a type of municipal wastewater (Chambers, 1997). The most recent Water Quality Inventory reports indicate that runoff from urbanized areas is the leading source of water quality impairments to surveyed estuaries and the third-largest source of impairments to surveyed lakes (EPA, 2003). Increasing urbanization has led to significant changes in the natural systems of the receiving water bodies. These changes include alterations in the hydrologic flow regime as well as shifts in the chemical and biological makeup of storm water runoff from these developing areas. As an area is developed, the natural ability of the catchments to withstand natural hydrologic variability is removed. Infiltration capacity is decreased due to the increase in impervious surface and disrupted native soils and vegetation. Anthropogenic activity also introduces chemical and biological constituents to the catchment. Trace metals, suspended solids, nutrients, pesticides, petroleum products, and E. coli and fecal coliform bacteria are generally found in higher concentrations in urbanized and urbanizing areas than in natural systems, due to increased numbers of people, vehicles, roads, and building materials introduced into the landscape. These constituents that storm water runoff carries is found to be a major source of pollution to surface water quality and groundwater resources (Adams, 2000).

Poor water quality in aquatic systems adversely affects the biota that lives in or around the water bodies. Water quality problems may also pose a threat to human health through various mechanisms - not to mention the negative economic effects on the society. There have been indications that Lake Hawassa is going through water quality changes that may lead to irreversible degradation in its water quality, and fisheries (Zinabu, 2002). Lake Hawassa, being an urban lake, is probably one of the most polluted of the Ethiopian Rift Valley Lakes (ERVL). However it is difficult to determine the magnitude of the changes as there is no system of monitoring the water quality in the lake and its watershed. Information, albeit limited, on water qualities of Lake Hawassa, and Tikurwuha River collected by different researchers at different occasion shows that the lake and its watershed are exposed to some toxic heavy metal contamination.

The causes to the pollution problems in Lake Hawassa is mostly attributed to human impacts, especially those related to industrial effluents from different factories, domestic sewage as well as chemical pollution from fertilizers, and pesticides from agricultural activities. (SOS-Sahel, Ethiopia, 2014a) untreated toxic discharges from industries in Hawassa's industrial estate have, since the 1980s, attracted increasing concern. At present, state-owned factories (textile, flour, ceramics, sisal, and tobacco), and other privately owned factories operate within the watershed. The nature and amount of waste discharged from the ceramic and sisal factories have not been investigated, but Zinabu & Zerihun (2002) have studied discharge from the Hawassa Textile Factory.

According to study by RiPPLE (2016) the estimated daily refuse collection in the city covers only about 55% of the total waste generated. During the rainy seasons, storm water flows from all corners of the city towards Lake Hawassa, carrying with it many pollutants from this improperly disposed solid waste material.

Ministry of Water Resources (2006) estimated that the 10,956 residents of the city live without any kind of sanitation services. In addition to this referral hospital and other health centers, hotels, garages, gas stations, educational institutions, government offices, sanitary structures, cemeteries etc. produce significant quantities of liquid waste that end up in the Lake with the storm water runoff. Particularly health centers, garages, gas stations, and hotels produce the major volume of waste and pose the worst threat to water quality of Lake Hawassa (MoWRD, 2006).

Untreated toxic discharges from industries at industrial estates of Hawassa, since the 1980s, have created increasing concerns. At present, about a dozen large factories (for example, textile, flour, cement products, ceramics, beer, soft drinks, tobacco, matches and chip wood), some 55 medium scale industries, 8 small scale industries operate within the watershed - not to mention other private and state owned industries that add to this list. Almost all the big factories are concentrated along the main highway, which is close to Shallow swamp that drains into Lake Hawassa. The concentration of the industries near the swamp was influenced by the minimum cost required to discharge their wastes. Topography and distance from the wetland must have been the major considerations. For instance, the approximate distances between the swamp and Hawassa flourmill, Ceramic, Sisal, Textile, and Tobacco factories are about 3.0, 2.6, 2.5, 1.0, and 1.2 km, respectively (Zerihun, 1997).

According to Moja (2014) these industries do not have functional waste treatment facilities or waste disposal systems. Instead, they dispose their waste in the nearby marshy land. It is estimated that the large-scale industrial consumption of water for processing could reach 7,000 m^3 a day - a large proportion of which ends up as wastewater discharged per day from the industrial sector ((Moja, 2014)). At the existing production capacity, Hawassa Textile Factory discharges 50 m^3 of wastewater per hour. This is at less than full capacity at the moment that could rise to 120 m^3 at full capacity in the future (Zerihun, 1997). About 1,200 m^3 of this wastewater is discharged daily. The effluent is colored as well as high in organic and suspended solids. The waste reaches the swamp, with virtually all of its chemical, biological and physical characteristics unchanged from the outlet of the factory except for its temperature. The impact of this effluent upon the Shallo wetland can reverberate throughout the Lake Hawassa hydrological system, affecting the biological, chemical and physical characteristics of the aquatic ecosystem and the communities that have long relied on it (Zerihun, 1997).

Agriculture is a major source of nitrate and phosphate in the watershed. Crop production and animal husbandry have been carried out for a long period of time in rural parts of the study area. Most of the farming practices involve the use of fertilizers, manure, insecticides, and herbicides. Animal manure is the principal means of supplementing plant nutrients in the soil. In addition to fertilizers like urea and Di Ammonium Phosphate, pesticides are the most widely used agrochemicals in the area. In areas with intensive agriculture, the use of nitrogen, and phosphorus fertilizers and discharge of wastewaters from the intensive indoor rearing of livestock can be the most significant sources of plant nutrients. When either of these agrochemicals is applied to agricultural land, a portion of it usually leaches through the soil and enters subsurface water (Moja, 2014).

The concentration of soluble nitrate-nitrogen (NO3-N) in Hawassa Lake ranges between 7.41 ppm and 15.81 ppm. The minimum value was recorded near Haile Resort and the maximum at the Southern reach of the Lake - around Bete-Mengist and Loke areas where traditional intensive agriculture is practiced. Similarly the same area where agriculture was practiced, the level of phosphate-phosphorous (PO4-P) reached the highest concentration, ranging between 0.59 ppm and 2.07 ppm. The values at the Southern reach of the Lake, around Betemengist, were the highest concentrations and the minimum value was recorded near Shallo swamp. It can be assumed that the maximum concentrations of nitrate nitrogen and phosphate phosphorous near Betemengist might be due to diffused waste products of animals which could end-up in the lake by erosion (Zerihun, 1997).

The current concentrations of nitrate and phosphate in the lake showed higher values than those from previous studies where the mean values of nitrate and phosphate were 3.73 and 0.82 ppm, respectively. Anthropogenic activity is probably the main cause for the increase in these nutrients. Most of the soil eroded from the catchment would find easy end to the lake due to the topography. The lake is situated at the natural lowest point in the watershed and the drainage of the watershed is predominantly to the west and southwest direction towards Lake Hawassa (RiPPLE, 2016).

2.9. Urban Runoff Best Management Practices (BMPs)

Storm water management practices seek to reduce, control, and prevent storm water runoff through a variety of strategies. These strategies vary in nature and effectiveness. All of these strategies, however, attempt to improve water quality and either reduce or control flooding and erosion. Due to the nature of the different management practices, they can be divided into two basic categories: remediation strategies and prevention strategies.

The management practices listed under prevention, if applied on a specific parcel of land, they have the potential to prevent storm water from running off the parcel or being drained into a natural body of water. This means that the rainwater would either infiltrate into the ground within the parcel or be gathered for some alternative use before runoff occurs. The remediation section refers to strategies that attempt to manage the storm water runoff once it crosses the parcel boundary. These techniques also attempt to reduce the pollutant levels in runoff before reaching a body of water. Prevention strategies should be given priority, except in particular sites or locations where previous development limits the implementation of a prevention strategy (Makin, 1975).

2.9.1. Prevention

One unique aspect of storm water runoff is that it rarely occurs in the natural environment. The built environment, however, offers us a different picture, and consequently a different set of problems. Traditional approaches to these problems have focused on moving water from point A to point B without much consideration for the cause of the runoff. This section’s focus on preventative strategies emerges from an understanding that the more natural an environment is, the less runoff there will be. As stated earlier, it is well understood that a major contributor to storm water runoff is the amount of impervious coverage an area has. Since many current trends in urban and suburban development have traditionally not recognized the impervious coverage/storm water runoff connection, development that continues in this manner may significantly increase runoff.

Preventative strategies comprise a decentralized approach and can be implemented at the parcel level. They encourage creating a more sensitive relationship between the built and natural environments. One way to achieve this is through low-impact development techniques. Low-impact development (LID) integrates strategies such as green space, native landscaping, and other techniques that help minimize runoff from developed land. LID focuses on managing runoff as close as it can to the source (where precipitation first makes contact with the land). The primary goal of LID design is to maximize the reduction of runoff volume from precipitation. Rather than funneling storm water runoff through a serious of pipes, LID focuses on allowing infiltration to occur, evaporating rainwater back into the air after a storm ends, and use of alternative techniques such as rain barrels. The result of LID is a landscape that mimics pre-development hydrologic conditions. One final point that merits consideration before exploring LID approaches is that LID is often more economically viable than traditional divert and drain techniques.

Since these practices are implemented at the parcel level they are easier to maintain, often requiring little or no maintenance at all. In addition, when maintenance is required it is not as disruptive to the normal flow of the City (Hollis, 1975).

2.9.1.1. Rain Gardens and Bio-Retention

Rain gardens are an excellent example of LID principles at work. They combine the knowledge of several disciplines to replicate the natural hydrologic system within a built environment. Rain gardens can significantly increase the hydrologic efficiency of areas that are highly urbanized. Runoff can be collected by rain gardens in areas near older buildings, parking lots or other areas with a high ratio of impervious coverage. Sometimes called bioretention, rain gardens employ vegetation and soil to filter out pollutants and sediments before water re-enters the hydrologic system. Creating a small swale, or retention ditch, is the first step for a rain garden. This swale contains the vegetation and catches water as it flows from impervious areas. Once here, the water is allowed to settle and slowly recharge to groundwater aquifers or evaporate into the air (Hollis, 1975).

2.9.1.2. Parking Lot and Road Design

In many urban areas, parking lots and roadways account for a large percentage of the impervious coverage. Implementing techniques to reduce the percentage impervious cover can be difficult. Instead of finding ways to reduce total coverage, some communities are turning to porous materials. Porous pavements allow the problem of runoff to be addressed at the source. Pavers, for example, leave drainage holes in 12 percent of the pavement area. With a sand setting bed underneath, and gravel to fill in the holes, this can be a good start at reducing parking lot run off. However, there is much more to parking lot design than pavers. In addition to pavers, porous concrete can be used in some areas as an alternative. This product can greatly increase infiltration rate. Special care must be taken with this product to minimize sediment infiltration into the pores. Not doing so can decrease the overall effectiveness of the product (Ferguson, 2002). An important drawback to porous paving is the cost. In addition to installation costs, which are highly variable based on the underlying soil type (USEPA, 1999). While increased infiltration through built materials is one technique, it should be accompanied by other techniques, as well. Eliminating curbs on parking lots and streets allows water to flow to pervious areas. It also eliminates the need for the traditional divert and drain techniques. As mentioned above, rain gardens can be connected to parking lots and other large impervious areas. This will increase the retention and filtration abilities of the parcel. By breaking up parking lots, through a series of rain gardens or wetlands, the total percentage of connected impervious coverage is reduced. This allows for a more natural hydrologic flow to occur.

2.9.1.3. Buffer Zones

The most common type of buffer zones is the aquatic buffer, or an area along a shoreline, wetland, or stream where development is restricted or prohibited. The buffer physically protects a body of water from development and helps filter storm water before it enters a watershed. This can help sustain the watershed’s natural ecosystem. There are three types of aquatic buffers: water pollution hazard setbacks, vegetated buffers, and engineered buffers. All the three buffers are important; however, the engineered buffers are specifically designed to treat storm water before it enters into a body of water or wetland. Local ordinances can help set up the regulations for buffers in a community and can address both new and existing development. Buffers have been effective at removing pollutants, sediment, nutrients, and bacteria from storm water runoff before it reaches a river, stream, or lake. In terms of stream protection, it is best to allow at least 100 feet as a base width for the buffer (United States Environmental Protection Agency, 2002)

2.9.1.4. Zoning

Traditional zoning also can be used to help mitigate storm water runoff through promoting better site design and establishing community goals through a comprehensive plan. While the effectiveness of zoning can be limited by local preferences, it is, nonetheless, an important tool for storm water mitigation (USEPA, 2005).

2.9.2. Storm Water Remediation

Remediation techniques are only effective at reducing the problems associated with storm water runoff. They comprise a centralized approach that is generally employed at a regional level. These techniques can be useful tools for reducing the quantity and quality of runoff into lakes, rivers, and streams. Due to the fact that remediation strategies vary in effectively treating quality and quantity of storm water runoff, a combination of strategies is usually recommended in most municipal plans and environmental studies (USEPA, 2005).

2.9.2.1. Conveyance

Conveyance is the oldest storm water management technique. Conveyance is a design that intends to moves water to a specific area using pipes and other impervious surfaces that do not allow infiltration. Conveyance has generally been a strategy for connecting storm water drainage to a wastewater sewer system. This is a practice mostly taught to engineers and has been used since Romans began designing cities. In modern times, water treatment plants have been added to the system in order to remove pollutants from both storm water and wastewater discharges. These technologies have increased the effectiveness of this technique (USEPA, 2005).

2.9.2.2. Street Cleaning

Street cleaning can be an important technique for removing contaminants, such as accumulated leaves, lawn fertilizers, and any other chemicals or oils from residential and commercial use, before they can enter into the water system. Street sweeping using equipment based on new vacuum assisted technologies can significantly reduce pollutants from urban streets. Weekly and bimonthly sweeping programs can achieve reductions of up to 80 percent in annual total suspended solids and associated pollutants (Southerland, 1996) .

2.9.2.3. Storm Water Filtration Systems

While filtration systems can vary from site to site, all filtration systems attempt to improve water quality by removing pollutants from storm water runoff. The weakness of filtration systems is that they do not control for the quantity of storm water runoff. Despite this drawback, they are useful because they can be incorporated into a site plan and are adaptable to both high-density and low density areas.

One drawback to a filtration system is that many contain an overflow chamber or valve. During heavy rains the filtration system may lack the capacity to filter all of the water entering the system, and excess water is released through the overflow valve. Due to financial concerns, filtration systems are often located near bodies of water in order to facilitate ease of discharge. The proximity of the overflow valve to bodies of water can prompt accidental contamination during heavy flow periods (USEPA, 2005).

2.9.2.4. Storm Water Wetland and Wet Ponds

Storm water wetlands or wet ponds, are wetlands that use settling and bioremediation to reduce levels of pollutants. Bioremediation is a process using biological organisms to reduce or remove pollutants from water. These wetlands, often man-made, are recognized as an important tool in storm water management: Wetlands are among the most effective storm water management practices at removing storm water pollutants. A wide range of research is available to estimate the effectiveness of wetlands. Wetlands have high pollutant removal rates, and are more effective than any other practice at removing nitrate and bacteria (Winer, 2000).

In addition, wetlands provide important management tactics, such as flood control and channel protection. They can also provide aesthetic value through tree and shrub plantings around the wetland. Natural wetlands should not be used for storm water detention ponds because the hydrology and natural plant ecosystem could be severely altered. The only drawback to a storm water wetland is that they are often difficult to construct in urban areas (Shepp, 1996).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1 Location and Area

Hawassa city is one of agglomerating urban centers in the Southern Nations Nationalities and Peoples Regional State established on the shore of Lake Hawassa. It is located in the Great Rift Valley region; 275 km south of Addis Ababa via Debre Zeit. Hawassa City was founded in 1960 during the period of Emperor Hailesilassie. Hawassa town has got both its name and beauty from Lake Hawassa. Hawassa means 'wide' in Sidama language. Now, the city and the lake share a common name i.e. Hawassa (Hawassa City Finance& Economy Departmente, 2014).

Hawassa city is serving as the capital of the Southern Nations Nationalities and Peoples Regional State and Sidama Zone. Geographically the City is found between 6^{0}49'N-7^{0}15'N latitude and 38^{0}17'E-38^{0}44'E longitude. The city is bounded by Lake Hawassa in the West, Oromia Region in the North, Wondogenet woreda in the East and Shebedino Woreda in the South. Hawassa has a total area of 157.2 sq. km divided into eight sub cities and the sub cities are divided into 32 Kebeles. These Eight sub cities are Hayek Dare, Menehariya, Tabore, Misrak, Bahile Adarash, Addis Ketema, Hawela Tula and Mehal ketema sub city Hawela Tula sub city is considered as rural area by the town administration (Hawassa City Finance& Economy Departmente, 2014) .

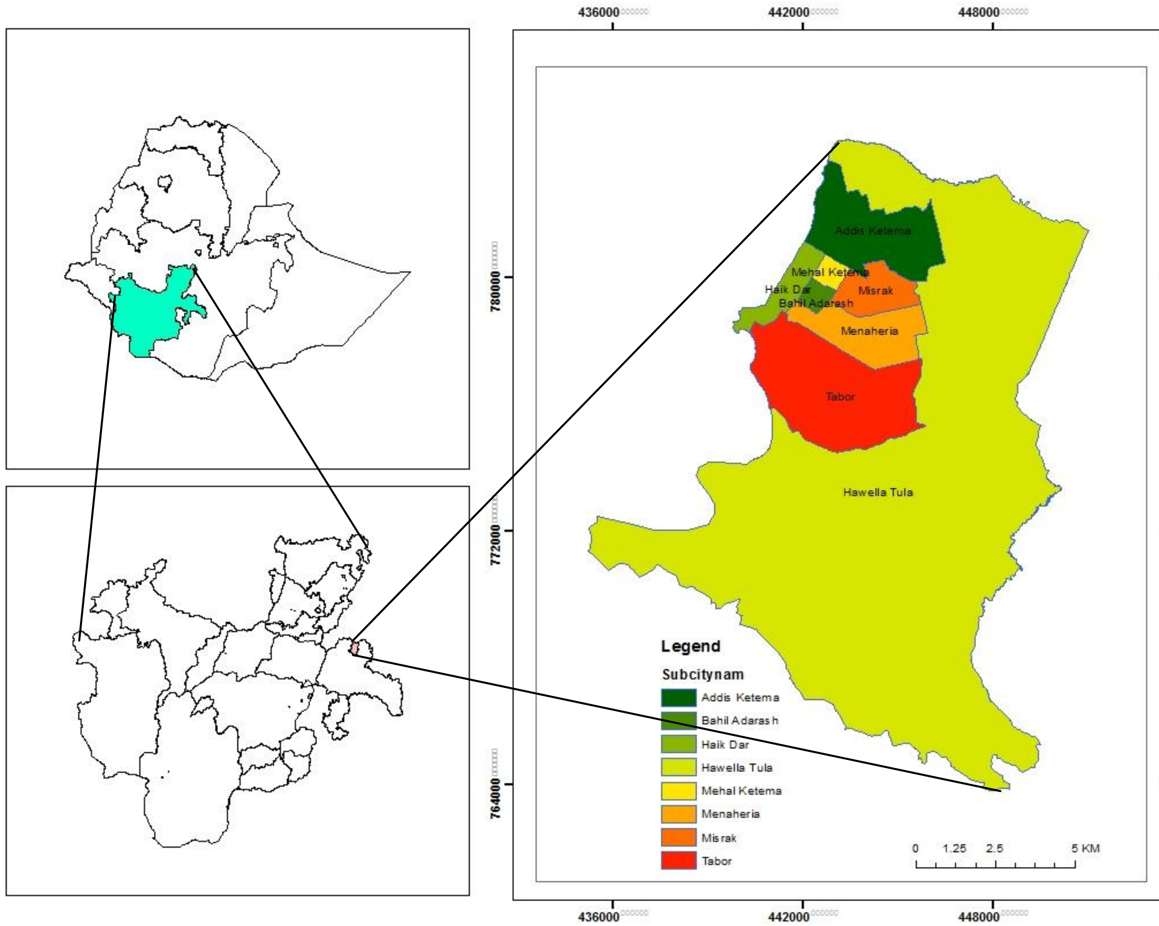


Figure 2: Map of Study Area

3.1.2. Population and Administration

Based on the 2007 National Population and Housing Census, the current projected population of Hawassa is 329,734 inhabitants, of which 169,677 were males and the rest 160,057 females. Of the 8 sub-cities, Hawela-Tula had the highest population with a total of 119,058 inhabitants and it is considered as semi urban and rural area. Accordingly, the study population becomes 210,676. According to 2007 Census, the density of Hawassa is 2,097 Persons per sq. km The annual average population growth rate of the city is 4.02% it vary from 4.8 in urban to 2.8 in rural (Hawassa City Finance& Economy Departmente, 2014).

3.1.3. Climate

Climatically Hawassa can be defined to have a warm temperate climate. Temperature ranges between 9˚C and 29˚C, while mean monthly temperature is 19 ˚C. The city has an extended period of wet season (March – October) with mean monthly rainfall varying from 17mm in the month of January during the dry season and 126 mm in the month of September during the rainy season. The mean annual precipitation is 933.4 mm. Both the amount and seasonality of the rainfall shows some variability. June to September rainfall contributes 44% to the mean annual precipitation in the catchment. The mean monthly potential evapo-transpiration ranges from 39 mm in July to the maximum of 100mm in January. The mean monthly relative humidity value is 63% with the mean minimum monthly of 53.9 in February and reaches the maximum 77.3 in September (Hawassa City Municipality, 2012).

3.1.4. Geology and Soil

Geology of the Hawassa area comprises pyroclastic deposits, trachyte, lacustrine and alluvial deposits, unsorted gravels, sandy gravel, clay and underlying basaltic rocks. Pyroclastic deposits are made up of ignimbrites, volcanic ash, tuff and rhyolites, which are considered to be part of the Nazareth series. The underlying basalt probably belongs to the Dino formation, which erupted following fissuring of the uplifted landmass. The urban area consists of soils with poor to moderate drainage characteristics. The prevailing soil distribution consist 40% black cotton soil, 30% red soil, 20% sandy soil and 10% silt soil which are derived from the weathering of basaltic lavas (Hawassa City Municipality, 2012).

3.1.5. Topography and Drainage

Hawassa City is founded on a relatively flat plain in the main Ethiopian Rift Valley having an average elevation of about 1,690 m above sea level. Regarding slope, the largest proportion of the City lies within the 0- 5 per cent slope category (IDP, 2006). As the City is relatively in higher elevation the drainage of the surface water is towards the Lake.

3.2. Study Methodology and Approach

3.2.1. Land use and land cover (LULC) change identification

The study is mainly based on primary data source. Satellite imageries were used to classify the LULC of the study area at different periods. This includes a computer based analysis of the data using GIS techniques and field observation to obtain the necessary information required for the study. To analyze the urban development process, data were collected from Ethiopia Mapping Agency, Hawassa city Municipality and Finance and Economic Development Department. The obtained imagery data were pre processed using different GIS methods to make ready and compatible for use. Then after, they were processed using GIS software to produce the LULC maps and a map showing the urban expansion of the study area at different period. In line with the data collected from the municipality of the city and Hawassa Regional urban planning Institute analysis and interpretation of the findings of the classification of LULC of the study area was conducted.

3.2.2. Sources of data

Nigatu (2014) to estimate the LULC of Hwassa city and Teshale (2015) to identify the LULC of Tabor and Alamura Ridges used Land-sat satelite images. This study was also based on remotely sensed imageries of different periods. Similar to the above studies three Land-sat sattelite images obtained from the Ethiopian Mapping Agency (/EMA) used.

3.2.3. Software

The materials used for this study were Arc GIS 10.3, ERDAS IMAGINE 2010, and GPS (Garmin 60) soft-ware version 2.40. Arc GIS 10.3 is for clipping, geo referencing to cross tabulate (to compute the LULC class matrix between images of different time), preparation of map layout, for extraction of polygon from raster, digitization of different features. ERDAS Imagine 2010 is for sub-setting, clipping, stacking bands (combining different bands) together, performing the classification of the different LULC categories, computing area, assessing the accuracy of classification.

GPS instrument is to collect the ground truths for field verification purpose it was also utilized. Ground truth helps to ensure that the classes are classified correctly and the error matrices are more accurate. Based on the information of ground truth, the initial land use land cover map were edited than the aggregated area of different classes were calculated and verified with the total area of the study area.

3.2.4. Data Pre Processing of Land-Sat Images

Pre-processing of satellite images prior to change detection is essential and has the unique goal of establishing a more direct linkage between the data and biophysical phenomena (Abd El-Kawy et al., 2010). The digital image processing is largely concerned with four basic operations: image restoration, image enhancement, image classification, and image transformation (Eastman, 1999). The image restoration is concerned with the correction and calibration of images in order to achieve a faithful representation of the earth surface as possible. Image enhancement is predominantly concerned with the modification of images to optimize their appearance to the visual system.

The challenges of urban mapping using Land sat imagery include spectral mixing of diverse land cover components within pixels and spectral confusion with other land cover features (Lu and Weng, 2006). To get a better enhanced image, different image enhancement techniques are available with different digital image processing software. One of the image enhancement works done in land sat image in this work was the spectral enhancement technique called principal component analysis. The goal of image enhancement is to improve the visual interpretability of an image by increasing the distinction between features (Shalaby and Tateishi, 2007).

To avoid the challenge of spectral mixing of the different land cover components with in a pixel and spectral confusion to occur during classification of LULC categories particularly when using Land sat-imagery for urban mapping, application of different image enhancement techniques was applied. In this project work, image enhancement was done in order to minimize this challenge for the better usage of Land-sat image. To get a better enhanced image, different image enhancement techniques were utilized such as; noise reduction, haze reduction, brightness inversion, spatial filtering (removal of noise, smoothening of image), and edge enhancement.

3.2.5. Data Processing

The urban expansion maps and other different maps of the study area were created using Arc GIS 10.1 and ERDAS 2010 analysis tools. In this study Land sat TM, Land-sat ETM+. Due to rapid change of the image was used to rectify Spot image using image to image geo referencing techniques. Land-sat TM was also geo referenced and finally clipped with the existing shape file of the study area. Different land use categories were digitized from the satellite imageries followed by building the topology to minimize errors during digitizing and to ensure that the entire polygons are closed. In the process of screen digitizing some features in the imageries were not properly identified. To solve this problem, the researcher used the image interpretation techniques of patterns, tones, textures, shapes, and site associations to derive information about land use land cover change.

3.2.6. Feature Classification

Image classification is a complex and time consuming process. In order to improve the classification accuracy, selection of appropriate classification method is required. This would also enable analyst to detect changes successfully (Elnazir et al, 2004).

There are different types of image classification techniques. Their appropriateness depends on the purpose of LULC maps produced for and the analyst’s knowledge of the algorithms (Lu and Weng, 2007). Each image was classified under four LULC categories (Table 2). A supervised classification using maximum likelihood classifier was applied with a careful selection of training sites that better match with the predefined LU/LC types for the classification with ERDAS EMAGINE 2010 using the classifier tool in the software and manual digitization. Training areas for the supervised classification were taken for the following LULC class categories: bare land, built up area, cultivated land and vegitation cover.

Table 1: LULC class's Description

cultivated land	A land use for the cultivation of small scale and large farms for subsistence crops. including Irrigated and rain fed arable lands, crop land with permanent crops, farming and fallow fields
Bare land	All vacant spaces, sands, rocky areas including bare soil
Built up land	Continuous and discontinuous urban fabric, Residential, industrial and commercial units, road and railway networks and other associated lands. Including urban, rural settlements and Asphalted roads.
Vegetation Cover	An area of the land covered by natural and manmade trees including coffee trees, chat and a vast avocado trees with the mixture of shelter trees being planted by man forests such as fuel woodland and shrubs, sparsely planted trees other natural forests also grass lands included here

Source; Field Survey, 2016

3.2.7. Post Classification

After classification, majority analysis was used in order to avoid minor fragmented classification arrangements on the output map. The majority analysis was repeated four times until fine classification had removed. The simple approach consists of comparing the properly coded results of two separate classifications. Finally, ground verification after classification was made in order to check the precision of the classified LULC map. Based on the ground verification necessary correction and adjustments were made. One means of classification smoothing involves the application of a majority filter. In such operations a moving windows is pass through the classified pixel in the window is not the majority class, its identity is changed to the majority class. If there is no majority class in the window, the identity of the center pixel is not changed. As the windows progresses through the data set, the original class code are continually used, not the labels as modified from the previous window position (Baldyga et al, 2004). Majority filters can also incorporate some form of class and/or spatial weighting function.

Data may also be smoothed more than once. Certain algorithms can preserve the boundaries between land cover regions and also involve a user-specified minimum area for any given land cover type that will be maintained in the smooth output (Lillesand and Kiefer, 2004). The

Spatial Analyst extension in ArcGIS software was used for the post-classification processing task. Three tasks have been employed to smooth the classified output from Land sat images.

- Filtering the classified output. By using Majority filter tool, the isolated pixels were removed from the classified map.
- Smoothing class boundaries and clumping classified output. These steps smooth the ragged class boundaries and clump the classes. The Boundary Clean tool is used.
- Generalizing classified output by removing small isolated regions. This step reclassifies small isolated regions of pixels to the nearest classes. The Region group, Set Null and Nibble tools are used.

3.2.8. Accuracy Assessment

Knowing that there is not any possibility to gather data from past years, accuracy of produced maps for the years 1986, 2000 and 2016 was determined using visual interpretation. In this project work, the assessment was carried out using Google earth map, spot image and ground truth points from field observations as the major sources of reference data. A discussion with elders and experts working in Hawassa City about the past and present status of LULC of the study area was also conducted. A set of reference points has to be generated to assess accuracy and random points were generated for each derived maps. These points were verified and labeled against reference data i.e. ground truth and Google earth image The overall, user's, producer's accuracies, and the Kappa statistic were then calculated from the accuracy matrices and followed by a brief explanation of each type of accuracies and Kappa statistic.

3.3. Storm Water runoff Volume Calculation

3.3.1. Runoff Volume Calculation Method Selection

The fast growing of Hawassa changed the land use/land cover from agriculture and forest to urban area. The urbanization rapidly changed permeable areas to impermeable land cover. The land use land cover change of the city is calculated using satellite image and data found from the city municipality. The Soil conservation system (SCS) runoff volume calculation method is used that best fit for Ethiopia (ERA, 2002). The curve number for the different land use/cover is also taken from Ethiopian Road Authority manual. Some land use types that does not fit to curve number given on the manual merged to closure land use type.

Equation for SCS is:

$$Q = (P - Ia)2/((P - Ia) + S) \text{ ------------------------------ } (1)$$

Where: Q = accumulated direct runoff, cm

P = accumulated rainfall (potential maximum runoff), cm

Ia = initial abstraction including surface storage, interception, and infiltration prior to runoff, cm

S = potential maximum retention, cm

The relationship between Ia and S was developed from experimental catchment area data. It removes the necessity for estimating Ia for common usage. The empirical relationship used in the SCS runoff equation is:

$$Ia = 0.2 * S \text{ -- } (2)$$

Substituting $0.2*S$ for Ia in the above equation, the SCS rainfall-runoff equation becomes:

$$Q = (P - 0.2 * S)2/(P + 0.8 * S) \text{ --------------------------------- } (3)$$

S is related to the soil and cover conditions of the catchment area through the CN.

CN has a range of 0 to 100, and S is related to CN by:

$$S = 2540/CN - 25.4 \text{ -------------------------------------- } (4)$$

3.3.2. Catchment Area Calculation

A catchment area is determined from topographic maps and field surveys. For large catchment areas it might be necessary to divide the area into sub-catchment areas to account for major land use changes, obtain analysis results at different points within the catchment area, or locate storm water drainage structures and assess their effects on the flood flows (ERA, 2002).

3.3.3. Rainfall Amount

The SCS method is based on a 24-hour storm event which has a Type II time distribution. The Type II storm distribution is a ’typical" time distribution which the SCS has prepared from rainfall records. It is applicable for interior rather than the coastal regions and should be appropriate for Ethiopia. The country is divided in to several hydrological regions which display similar rainfall patterns, as indicated on the annexed map (appendix 1). Using statically analysis ERA (2000) has developed rainfall intensity-duration curves for commonly used design frequencies (appendix 2).

3.3.5. Hydrologic Soil Groups

Soil properties influence the relationship between rainfall and runoff by affecting the rate of infiltration. The SCS has divided soils into four hydrologic soil groups based on infiltration rates (Groups A, B, C, and D). Consideration shall be given to the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes shall be made in the soil group selected. Also runoff curve numbers vary with the antecedent soil moisture conditions, defined as the amount of rainfall occurring in a selected period preceding a given storm. In general, the greater the antecedent rainfall, the more direct runoff is from a given storm. A five-day period is used as the minimum for estimating antecedent moisture conditions. Antecedent soil moisture conditions also vary during a storm; heavy rain falling on a dry soil can change the soil moisture condition from dry to average to wet during the storm period (ERA, 2002).

Soil type of Hawassa city is Calcaric fluvisols developed from recent alluvial and lake deposits (Geological Survey of Ethiopia, 2014). This soil type is categorized under hydrologic group soil type B (ERA, 2002).

3.3.6. Runoff Curve Numbers

The SCS uses a combination of soil conditions and LULC to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area.

Once the LULC of the city is found it is reclassified in to build up and non-build up area. Curve number of 98 for build up land cover and 61 considered for non-build up land covers (Paul, 2001).

3.4. Runoff Water Quality Sampling and Analysis

The city of Hawassa has different topographical urban catchments that each conveys the urban storm runoff to separate outfalls. The storm collection network of the city is open storm drains. Currently the urban runoff is joining the lake at three identified outfalls and nine wet lands near to the lake. Sampling stations are established at the major outlet sites to monitor the urban storm water runoff quality. The three outfalls where the storm water runoff directly joins the lake automatically selected and 30% of the outfalls where the storm water runoff join the wet lands are also selected randomly for storm water sampling.

Urban runoff water samples were gathered from the six sampling stations for one rainfall runoff event simultaneously. Water quality characteristics have been determined in both low and high flow conditions. The runoff sample collected manually using PVC scoop that received the entire flow and where then transferred to sampling bottles. For bacteriological analysis 500 ml sterilized plastic sampling bottles, for BOD/COD 500 ml standard bottle (black glass bottles), for total nitrogen, total phosphorus, EC, Turbidity, TSS, TDS, metals 500ml plastic sampling bottles that are free from any chemicals are used.

The preparation of composite sample for one rainfall event was done by calibrating the sampling bottle with equal volume for three grab samples and preparing one event composite sample on site for that specific runoff event and sampling station. In each month, one-runoff event were sampled during the 2016 rainy season (July, August and September) for a total of 3 rainfall events. Grab samples in each runoff event were collected at the start of the runoff, middle of the run off event and finally when the storm water flows decreased significantly.

The composite samples are taken to the Hawassa University Laboratory for BOD/COD, bacteriological, TSS and TDS analysis. For metals, total nitrate and total phosphate the sample is taken to Addis Ababa EPA. The water quality analyses were generally conducted according to standard methods appropriate for turbid samples. All samples are preserved in the laboratory under 4^0C until analyzed. For the whole water quality parameter analyses, cost considerations dictated that only a composite sample would be used for analysis purposes.

Table 2: Storm Water Runoff Sampling Sites

S.No.	Runoff outlet sites	ID of station	Location (UTM)	Elevation (m)
1	Referal Hospital	S_1	0440417N & 0778410E	1696
2	Amora Gedel	S_2	0441068N & 0779117E	1682
3	Fikir Haik	S_3	0441287N & 0779806E	1685
4	Chembelela Hotel	S_4	0442053N & 0780794E	1689
5	01kebele near to Electric and light office	S_5	0442379N & 0781300E	1693
6	Tikur wuha river at the bridge	S_6	0442825N & 0783894E	1688

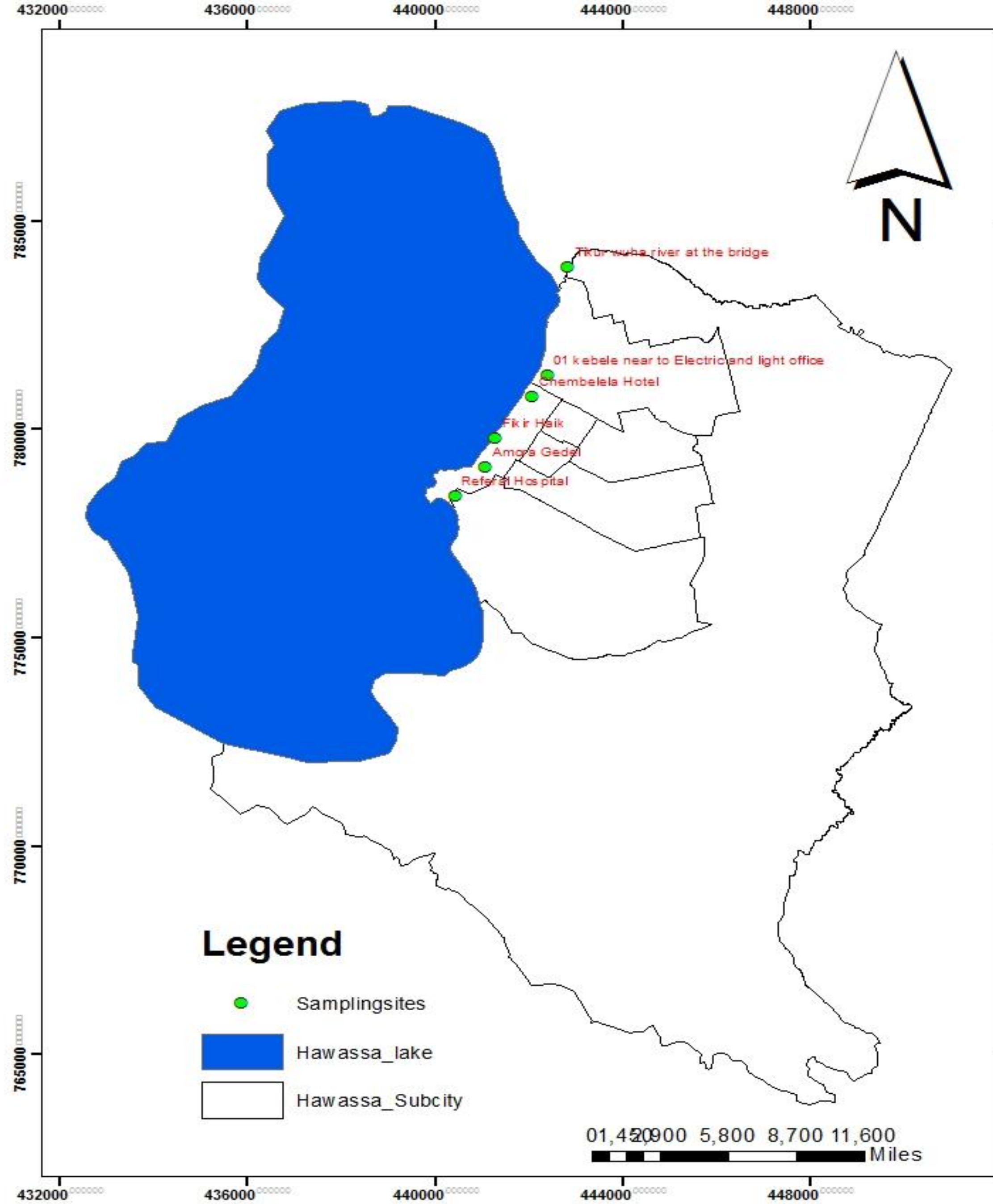


Figure 3: Location Map of Sampling Sites

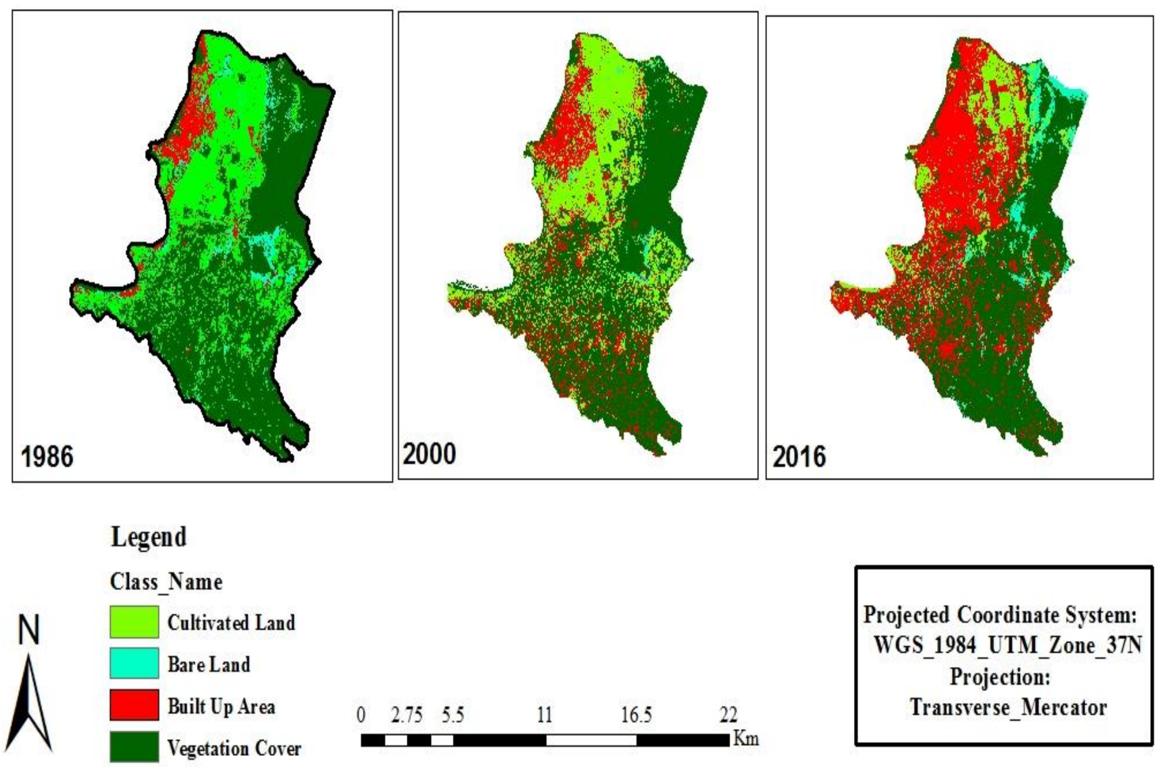
4. RESULTS AND DISCUSSION

4.1. LULC of Hawassa City

4.1.1. LULC of 30 years of Hawassa city

The land cover maps generated after running a maximum likelihood supervised classification as well as a post classification algorithm are presented in figure 4 below.

Figure 4: Hawassa City Land Use Land Cover Map (1986, 2000 and 2016)



As shown on figure 4 above and table 3 below, there has been an increase of built up areas with respective values 3.8% of the study area in 1986 to 10.7% in 2000 and 30.5% in 2016. Cultivated land cover also increased from 59.9% in1986 to 63% in 2000 but decreased to 52.6% in 2016. Whereas vegetation cover showed consistent decrease in the study periods with values 35.4%, 25.5% and 16.4% in 1986, 2000 and 2016 respectively. Bare land cover also consistently decreased from 0.9% to 0.7% and finally to 0.5% in 1986, 2000 and 2016 respectively. Agricultural land was the most dominant land cover class in the study area but started declining after 2000. Because of the successive decrease of vegetation cover, built up areas have dynamically increased in the study periods. This could be due to an increase of population growth associated with high demand for land and urban supplies.

Table 3: Hawassa city LULC of 1986, 2000 and 2016

LULC Class	1986		2000		2016	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Cultivated Land	9869.2	59.9	10382.3	63.0	8670.0	52.6
Build-up Land	627.2	3.8	1767.3	10.7	5022.8	30.5
Vegetation Land	5828.6	35.4	4207.9	25.5	2708.0	16.4
Bare Land	154.5	0.9	121.0	0.7	76.0	0.5
Total Area	16479.6	100	16478.4	100.0	16476.8	100

4.1.2. Built up area Expansion

The increment in infrastructure development of Hawassa from time to time has played a major influence for the expansion of built up areas. The main focus of this study was assessing and examining the spatial extents of built up areas within the three study periods. To achieve this, a reclassification was made to generate LULC of built up and non-built up areas as shown in table 4 below. The proportion of built up areas in 1986 was 3.8% of the entire study area. In 2000 the percentage of built up areas increased to 10.7 % and in 2016 it reached to 30.5% of area coverage.

Table 4: Built and non built-up areas between 1986 and 2016

LULC Class	1986		2000		2016	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Build-up Area	627.2	3.8	1767.3	10.7	5022.8	30.5
Non build-up Area	15852.4	96.2	14711.1	89.3	11454.0	69.5
Total Area	16479.6	100.0	16478.4	100.0	16476.8	100.0

Similar study conducted by Nigatu (2011) in Hawassa city showed that the buildup area cover was 12.5% in 2011 but the current study showed that the buildup area cover in 2016 was

30.5% of the total city administration area. This indicates that the majority build up area almost 18% was constructed in the last 6 years. Probably this happened due to the construction of the new huge industrial zone and related residential houses construction. Another study conducted in Bahirdar city by Atalel (2014) showed that buildup area cover was 9.4% of the total area in 2010. When we compare the result of Atalel and Nigatu the development of Hawassa is more than that of Bahir Dar city.

4.1.3. Change detection of LULC

In the study period the buildup area increased by 181.8% between 1986 and 2000. It also increased by 184.2% between 2000 and 2016. The total increment during the study period between 1986 and 2016 was about 700%. The second most changed LULC was vegetation cover that declined by 53.5% between 1986 and 2016, by 27.8% between 1986 and 2000 and finally by 37.2% between 2000 and 2016. Cultivated land was the least changed LULC. It declined by 12.2% from 1986 to 2016 but increment between 1986 and 2000 by 5.2% but decreased by 16.5% between 2000 and 2016. Bare land area also decreased by 50.8% from 1986 to 2016.

Table 5: LULC changed between the study periods

LULC Class	change between 1986 and 2000		change between 2000 and 2016		change between 1986 and 2016	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Cultivated Land	513.0	5.2	-1712.3	-16.5	-1199.2	-12.2
Build-up Land	1140.1	181.8	3255.5	184.2	4395.5	700.8
Vegetation Land	-1620.7	-27.8	-1499.9	-35.6	-3120.6	-53.5
Bare Land	-33.5	-21.7	-45.0	-37.2	-78.5	-50.8

4.2. Storm Water Runoff Volume Estimation

The runoff volume of Hawassa city for three study periods (1986, 2000 and 2016) estimated based on the LULC change of the city discussed above and curve number calculated below.

The curve number of the buildup area and the non-build up area is calculated and presented in the table 6 below.

Table 6: Cumulative CN value for build up and no-build up area

LULC Class	1986			2000			2016		
	(ha)	(%)	CN	(ha)	(%)	CN	(ha)	(%)	CN
Build-up Area	627.2	3.8	98.0	1767.3	10.7	98.0	5022.8	30.5	98.0
Non build-up Area	16479.6	96.2	61.0	14711.1	89.3	61.0	11454.0	69.5	61.0
Cumulative CN			62			65			72

Ethiopian road authority (ERA, 2000) has taken long time rainfall amount and developed 50 mm 24-hour rainfall amount for the study area. This value is used for the three study periods.

Table 7: Storm water runoff amount in the study periods

Year	Runoff depth (mm)	Runoff volume (m^3)	% age changed to runoff
1986	35	5,833,460	70.8
2000	37	6,041,100	73.3
2016	40	6,564,274	80.0

4.2.1. Storm Water Runoff volume of 1986

The total storm water runoff depth was 35 mm and total volume was 5,833,460 m^3. The storm water runoff depth indicates that 70.8% of the total rain fall changed to runoff water. During this time the contribution of the buildup area contribution was 3.8% and that of non-buildup area was 96.2% area wise.

4.2.2. Storm Water Runoff volume of 2000

The total storm water runoff depth was 37 mm and total volume was 6,041,100 m^3. The storm water runoff depth indicates that 73.3% of the total rain fall changed to runoff water. During this time the contribution of the buildup area contribution was raised to 10.7% and that of non-buildup area was decreased to 89.3% area wise.

4.2.3. Storm Water Runoff volume of 2016

The total storm water runoff depth was 40 mm and total volume was 6,564,274 m^3. The storm water runoff depth indicates that 80.0% of the total rain fall changed to runoff water. During this time the contribution of the buildup area contribution increased to 30.5% and that of non-buildup area was declined 69.5% area wise.

4.2.4. Storm Water Runoff volume in the last 30 years

The storm water runoff depth produced by the 24-hour rainfall is 35 mm in 1986, 37 mm in 2000 and 33.26 mm in 2016. In another word 70.8% of the rainfall changed to runoff in 1986, 73.3% in 2000 and 79.7% in 2016. This indicates that the impermeable layer is increasing from time to time following the LULC change of the study area. The storm water runoff increment was only 4% in the first 15 years but it was more than 8.7% in the second 15 years of this study period.

Looking in to the above figures the volume of storm water produced by the city is huge. Yet this water is not changed to development in the contrary deteriorating the fresh Lake water. The city water supply authority needs around 9 million meter cube of water annually for domestic use only taking in to consideration 80 liter per person per day (GTP-II, 2015). When compared the two values, the 24-hour rainfall-runoff cover 75% of the annual domestic water demand of the city.

4.3. Pollutants and their Concentration

The result of storm water quality parameters for the study area is presented and discussed in this section. The estimated urban runoff quality is compared with allowable storm water quality standards set by USEPA (2003) and with other similar study done in Bahir Dar city (Addisu, 2009). These comparisons serve as indicators of the level of the study area urban storm water runoff pollutants load.

Table 8: Statistical summary of water quality characteristics for the study catchment

No.	Sampling site	WQ Parameters in mg/l otherwise specified											
		TSS	TDS	Turbidity (NTU)	EC (µcm)	TN	TP	Cu	Pb	Zn	BOD	COD	E.coli (1000col/l)
1	S1	144.1	117.8	400.3	310.7	1.3	11.6	26.6	0.2	1.0	388.0	714.0	3.0
2	S2	323.6	378.7	490.8	405.0	4.4	2.6	14.1	13.1	0.2	475.0	852.0	2.0
3	S3	93.5	100.0	325.9	407.3	6.8	5.6	71.7	8.1	53.0	116.0	370.0	44.0
4	S4	154.4	220.7	329.0	432.3	5.2	2.0	46.4	4.9	0.2	253.0	463.0	8.0
5	S5	188.3	266.7	372.4	422.0	3.2	3.3	49.5	5.8	0.8	210.0	609.0	19.0
6	S6	197.6	250.0	394.6	344.3	3.6	0.8	49.3	5.8	0.4	162.0	1286.0	13.0
	mean	183.6	244.5	385.5	386.9	4.1	4.3	42.9	6.3	9.3	267.3	715.7	14.5
	Min	93.5	100.0	325.9	310.7	1.3	0.8	14.1	0.2	0.2	116.0	370.0	2.0
	Max	323.6	378.7	490.8	432.3	6.8	11.6	71.7	13.1	53.0	475.0	1286.0	44.0
Bahir Dar		365	178		339	22.9	0.46					3.28	169
Pooled		78.4				2.34	0.32	13.5	67.5	162	14.1	52.8	1500col/l Schuler (1999)
NURP (USEPA, 1983)		147				2.5	0.34	66.6	175	176	10.4	66.1	

4.3.1. Total Solids

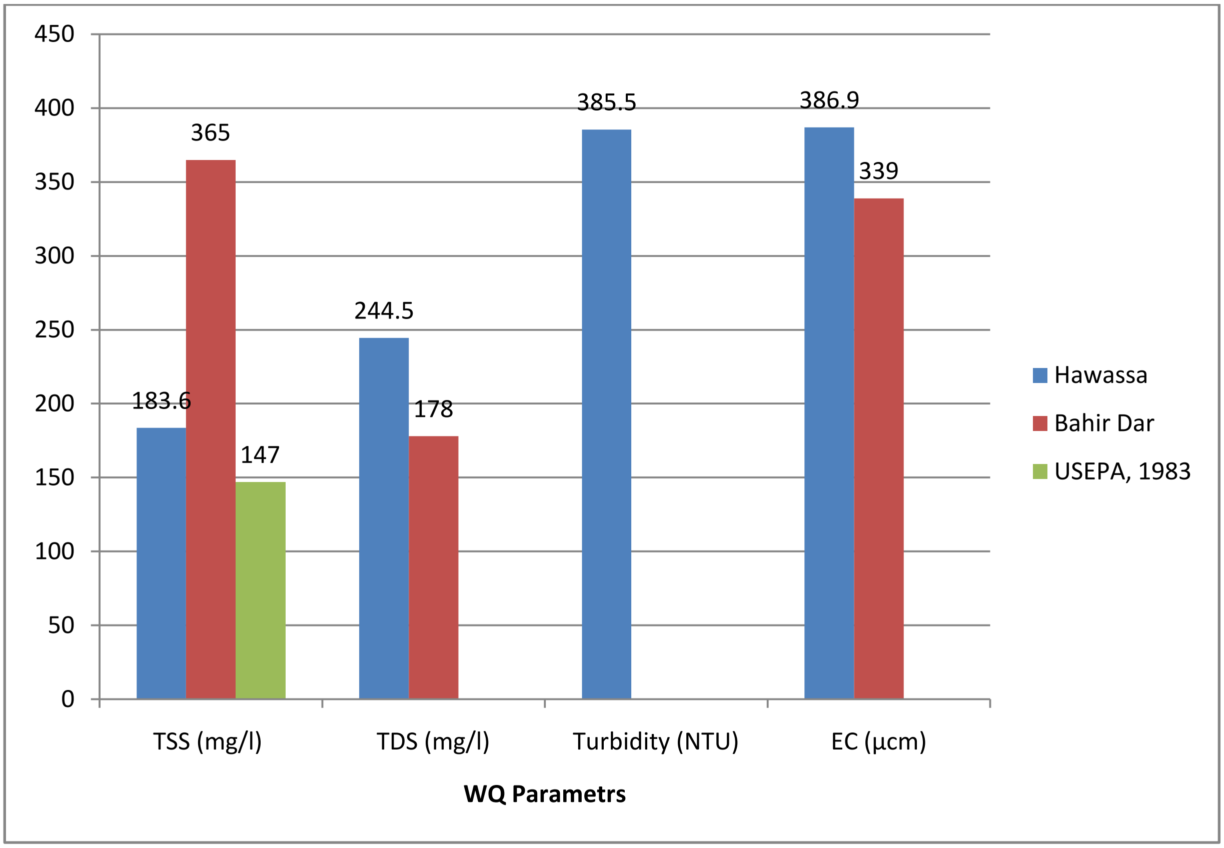
The total suspended solid (TSS) concentration ranges from 93.5 mg/l to 323.6 mg/l with average concentration of 183.6 gm/l. This figure indicates that the mean concentration of the study area exceeds the allowable limit set by both Pooled and NURF. The study area result is less than the TSS concentration of Bahir-Dar city by similar study. Dissolved solid result ranges from 100 mg/l at Fikir haik to 378.7 mg/l at Amora gedel sampling site. The average result of the dissolved solid is 245.5 mg/l. The TDS of the study area is by far greater than the result found in Bahir Dar city. The maximum total solid comes from station 2 (Amora gedel site). The elevated value of total solids at this site is due to the road construction along this drainage system during sampling. The least total solid found at station 3 (Fikir haik site) that drain from the center of the town. There is continuous cleaning of the road and the drainage system and major construction is completed in this catchment area. That is why low concentration of total solids found in this sampling site.

4.3.2. Turbidity and Electrical Conductivity

Turbidity is a measure of the cloudiness of water. Cloudiness is caused by suspended material in the water. The laboratory analysis indicates that the mean value of turbidity for the study area is 385.5 NTU. The maximum value is observed at Amoragedel sampling site. As discussed earlier this is a site with maximum suspended material found. The six sites result ranges from 325.9 to 490.8 NTU.

Electric conductivity is the ability of a gaseous solution to carry electric current, this ability depends on the electric conductivity presence of ion and water with high inorganic compounds are relatively good electric conductors. From the six sampling station Chembelela site have the highest value that is 432.3 μm. The average conductivity result of the study area is 386.9 μm. Chembelela sampling site is out falloff a catchment that encompasses the biggest market place. The different waste of the market place might increase the inorganic level of the runoff water that subsequently result relatively high electrical conductivity.

Figure 5: Concentrations of TSS, TDS, Turbidity and EC



4.3.3. Total Nitrogen and Total Phosphorous

The average concentration of total nitrogen and phosphorus is 4.1 mg/l and 4.3mg/l respectively. 2.5 mg/l and 0.34 mg/l are the allowable limits for total nitrogen and phosphorus respectively (USEPA, 1999). The result found in the study area indicates that the concentration of both nutrients exceeds the allowable limit set by USEPA (1999). Fikir haik and referral hospital sampling sites have the maximum total nitrogen and total phosphorus concentration 6.8 mg/l and 11.6 mg/l respectively.

Excess nitrogen in urbanized catchment generally results from waste water (failing septic system) and fine sediment from erosion or street. Since, there is no major erosion in this catchment area the potential source of the high nitrogen concentration could be connecting domestic waste with the storm water drainage system. During the field visit it is observed that street boys around the city center and drinking houses near Fikir haik use the drainage systems for urinals. Most of the hotels also concentrated in this catchment with high probability of domestic waste connection with the storm water ditch. Research conducted by RiPPLE (2016) also found that high level of Nitrate in the Lake near to old Palace which is close to Fikir Haik. The two researches result show that the runoff water is source of nitrate for the Lake.

The presence of high concentration of both TN and TP increased the nutrient level of the Lake and stimulated the growth of plants and algae which can subsequently reduce dissolved oxygen level and harm the entire ecosystem.

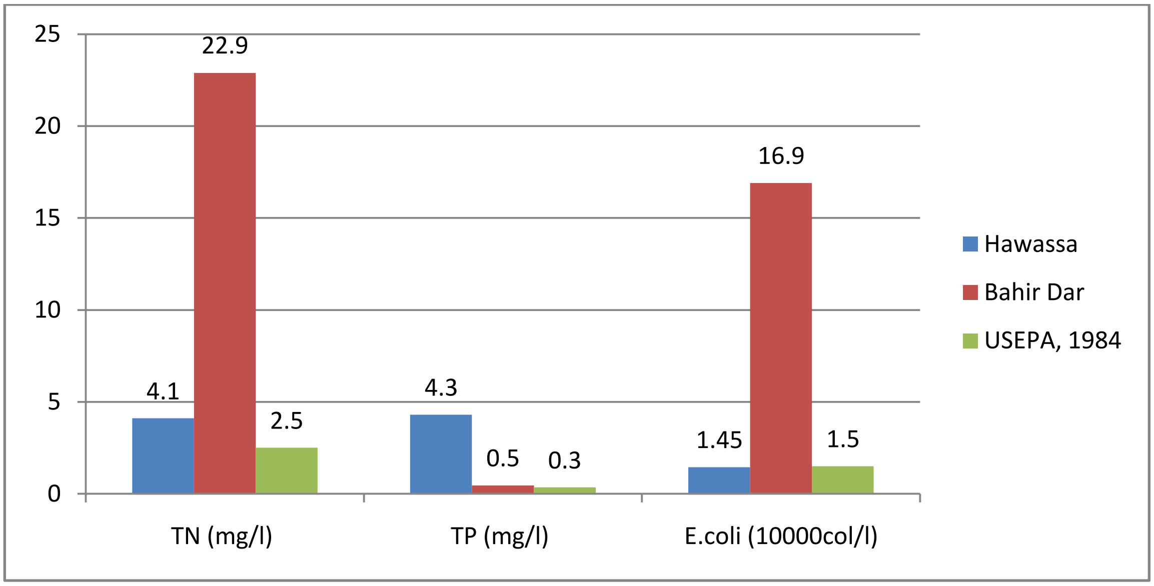
The elevated P level at referral sampling site could possibly result from home based soap manufacturing industries and referral hospital that discharge its domestic effluents to the sewer system which drains the storm water runoff to this outlet.

The study area result of TN by far less than Bahir Dar city result and the TP result of the study area is higher than Bahir Dar city. This indicates that Domestic waste water connection with the sewer system is less in Hawassa and discharge of soap waste to the sewer system higher in Hawassa than Bahir Dar city.

4.3.4. Bacteria

Total coliform counts in water bodies are an important parameter for checking possible sewage contamination. It is found that fecal coliform concentration from the sampling sites is above the standard, 1500 colon/l (Schuler, 1999). The six site result ranges from 2000 colon/l to 44000 colon/l. with mean concentration of 14,500 colon/l and max concentration 44,000 colon/l at Fikir haik sampling site. The laboratory result is clear evidence of domestic waste water contamination in all monitoring sites. The high total coliform for station 3 most probably arise from untreated and illegal domestic waste water that most hotel discharge in to the storm draining ditch.

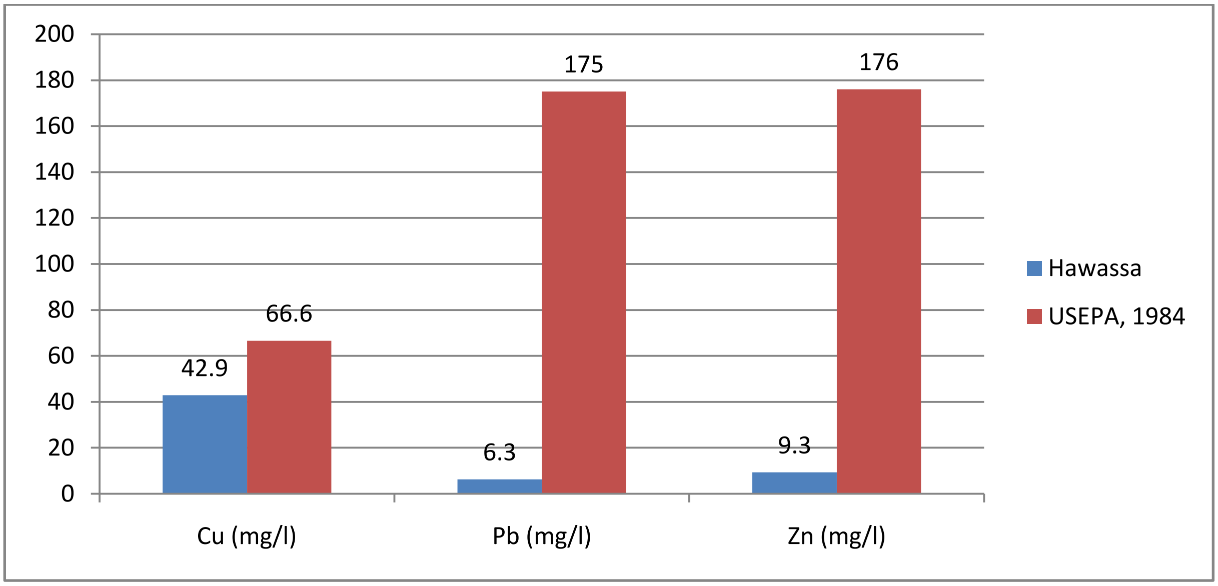
Figure 6: Concentration of TN, TP and E.Coli



4.3.5. Metals

The laboratory result of Lead and Zinc in all the six sampling site showed that the concentration is below the allowable limit. The mean concentration of Pb and Zn is 6.3 mg/l and 9.3 mg/l respectively while the allowable limit is 175 mg for Pb and 176 mg/l for Zn. Both metals are no threat for the time being. Whereas, the result of copper from all the six sampling sites, maximum concentration is 71.73 mg/l and the minimum is 14.14 mg/l, indicate that it is above the standard set by pooled (13.5 mg/l) and lower than NURP (66.1 mg/l) except Fikir haik sampling site with concentration of 71.7 mg/l. The high concentration of copper at Fikir haik need further study to investigate the exact source for the elevated concentration.

Figure 7: Concentration of TN, TP and E.Coli



4.3.6. BOD/COD

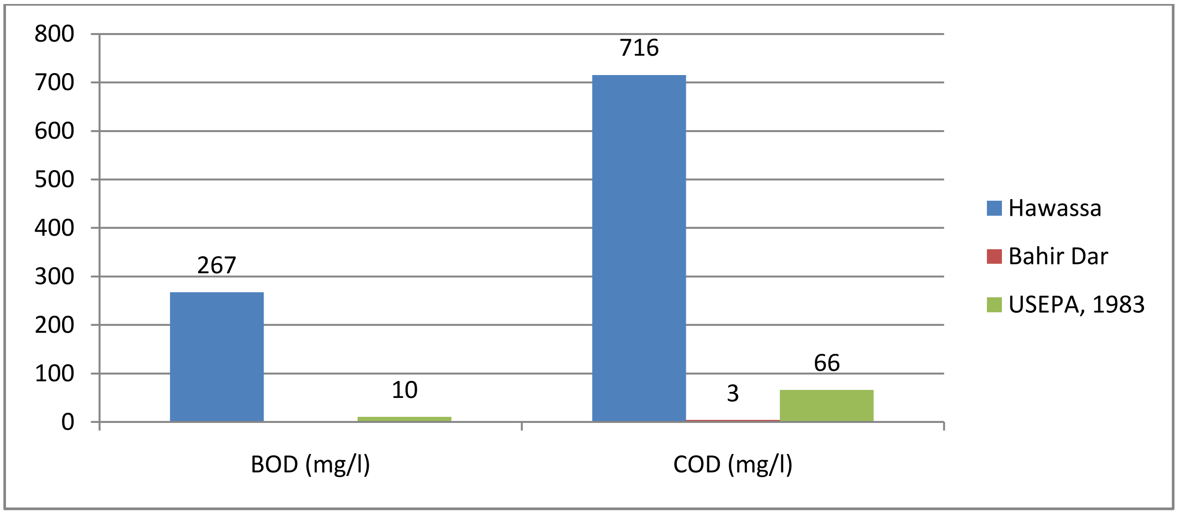
Natural organic detritus and organic waste from urban and agricultural runoff, waste water treatment plants, and failing septic systems acts as a food source for water-borne bacteria. Bacteria decompose these organic materials using dissolved oxygen, thus reducing the DO present for fish. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions.

The oxygen-demanding substances found in urban storm water can be measured by Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Maintaining appropriate levels of dissolved oxygen in receiving waters is one of the most important considerations for the protection of fish and aquatic life. The amount of dissolved oxygen in urban runoff is typically 5.0 mg/l or greater, and it rarely poses a direct threat to in-stream conditions.

In the study area the mean BOD concentration was 267.33 mg/l and COD concentration was 715.67 mg/l. The maximum concentration for BOD, 475 mg/l, and COD, 1286 mg/l, found at Tikur wuha sampling site. The maximum allowable limit by NURP is 10.4 mg/l for BOD and 66.1 mg/l for COD. BOD concentration is 25 fold and COD concentration 11 fold beyond the permit limit. The high value of COD at Tikur wuha is due to most industries and manufactories concentrated in the catchment area. A transect walk made to see the influent final disposal sites. The major factories such as Textile, Moha Soft drink and BGI discharged their waste to Chefe wet land that drain to Tikur Wuha River and finally join the Lake.

The unpleasant color and pungent odor of effluents discharged from the above listed factories seams there is no complete waste treatment system that bring the discharged waste to the permit limit.

Figure 8: Concentrations of BOD and COD



4.4. Effect of LULC Change on Storm Water Run Of volume and Quality change

The fast growth of Hawassa city in the last 30 years resulted in significant change of none build up land use to build up land use. In 1986 the buildup area was only 4.75 % of the total area where as in 2016 out of the total city area 24 % was occupied by build up land use. Following the increase in build up area runoff water depth also increased from 26.63 cm in 1986 to 33.26 cm in 2016. The incensement in the depth of runoff water is not proportional to the increment in build up area. This is due to the most changed land use type is cultivated land which has also significant runoff contribution. Increase build up land cover means growth in population number and related activities like industries and factories. According to Moja (2014) most industries in Hawassa do not have functional waste treatment facilities or waste disposal systems. Instead, they dispose their waste in the nearby marshy land. The sanitation system in Hawassa City is composed of different kinds of dry-pit latrines. Significant proportion of the residents, estimated at 10,956 live without any kind of sanitation services.

The City has neither a central sewage system nor liquid waste disposal services, and the solid waste site is also used as disposal site for liquid waste. As a result, every corner of the city seems a legally-accepted place to discharge human excreta (feces and urine) and sludge (RiPPLE, 2016). When runoff comes wash all these wastes and join the fresh Lake water. The water quality test also indicates that most of the parameters except the metals are higher than what is recommended by (USEPA, 1999).

5. SUMMARY AND RECOMMENDATIONS

5.1. Summary

LULC change of Hawassa city was estimated based on satellite image for 1986, 2000 and 2016. The result showed that the percentage of change from non build up area to build up area increased by almost 700% in the last 30 years. In the first fifteen years it increased from 3.8% to 10.7% and from 10.7% to 30.5% in the second fifteen years. Cultivated land constitutes the dominant land cover in all the study periods. The cultivated LULC change was decline only by 12.2% and that of vegetation cover was decline by 53.5%. This implies the increment of build up area was as the scarification of cultivated land.

The change in build up area of the study area changed the storm water runoff amount. The depth of the direct runoff created from the 24-hour rainfall increased from 35 mm to 37 mm and finally to 40 mm in 1986, 2000 and 2016 respectively. The percentage of precipitation converted to runoff changed from 70.8% to 80% during the study period.

The change in volume and concentration of pollutants in the runoff water were directly related to LULC. Runoff water quality analysis of this study show that except the metals (Cu, Zn and Pb) all the other water quality parameters of the study area are higher than what is recommended by (USEPA, 1999). The high concentration of TN and Fecal coliform in storm water runoff coming from the city center is indication of sewage system connected with storm water runoff ditches or improper disposal of human faceas in the area of study and the high concentration of BOD and COD coming from industrial zone also indicate the incomplete treatment of industrial wastes and the application of fertilizer and pesticides along Tikur wuha river by farmers using the river for irrigation purpose.

5.2. Recommendation

The following recommendation are forwarded to minimize the effect of Hawassa city urbanization impact on storm water runoff water quantity change as well as quality to prevent the dwellers from flooding threat and the vulnerable nearby Lake from pollution.

- ✓ The city administration need to take into consideration how fast the build-up area is increasing and impacting the hydrology of the area. The dwellers and institution need to be encouraged to have soak away pit to drain runoff water coming from roofs rather than piping to storm water ditches.

- ✓ Result of the water quality result showed the possibility of illegal connections of domestic waste with the storm water draining system. The city administration need to work a lot to create awareness and to have system to control illegally connected septic tanks and discharging domestic wastes to the storm water drainage ditches.
- ✓ Most Industries and factories discharge their wastes to Cheleleka wetland which finally drain to the Lake. The COD of sample taken from this catchment show high inorganic compound in the runoff water. The main source of this result could be the waste generated from these industries. Therefore, the factories waste water treatment system efficiency need to be checked.
- ✓ As Hawassa is a special town growing rapidly and near to afresh Lake, need to have sites to continuously monitor the quality of the storm water runoff. Specially near to industry zone, city center (where service giving institution are concentrated), universities, and health centers. This will help to know the status of pollution and major pollutants and quantify the pollutant load precisely.

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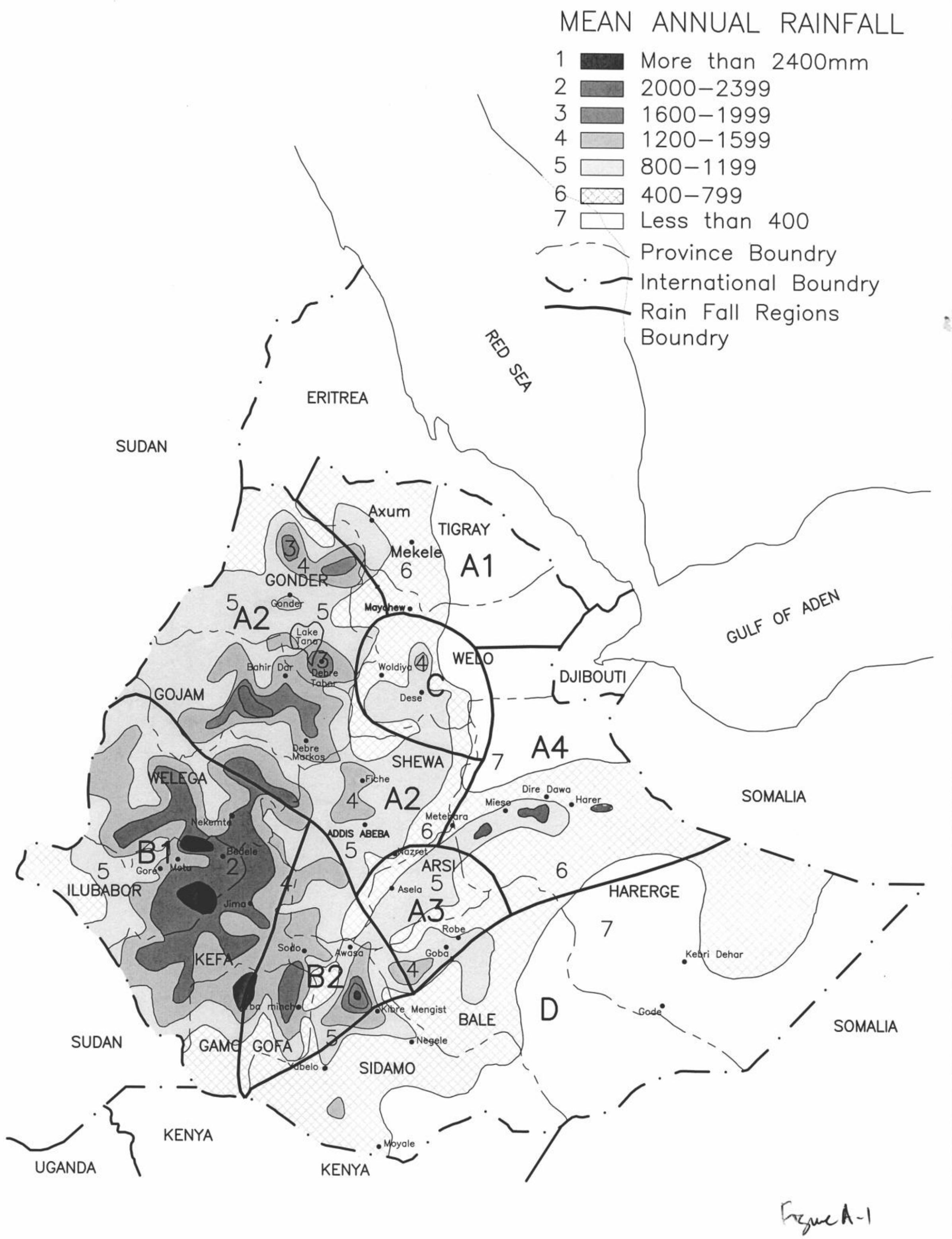
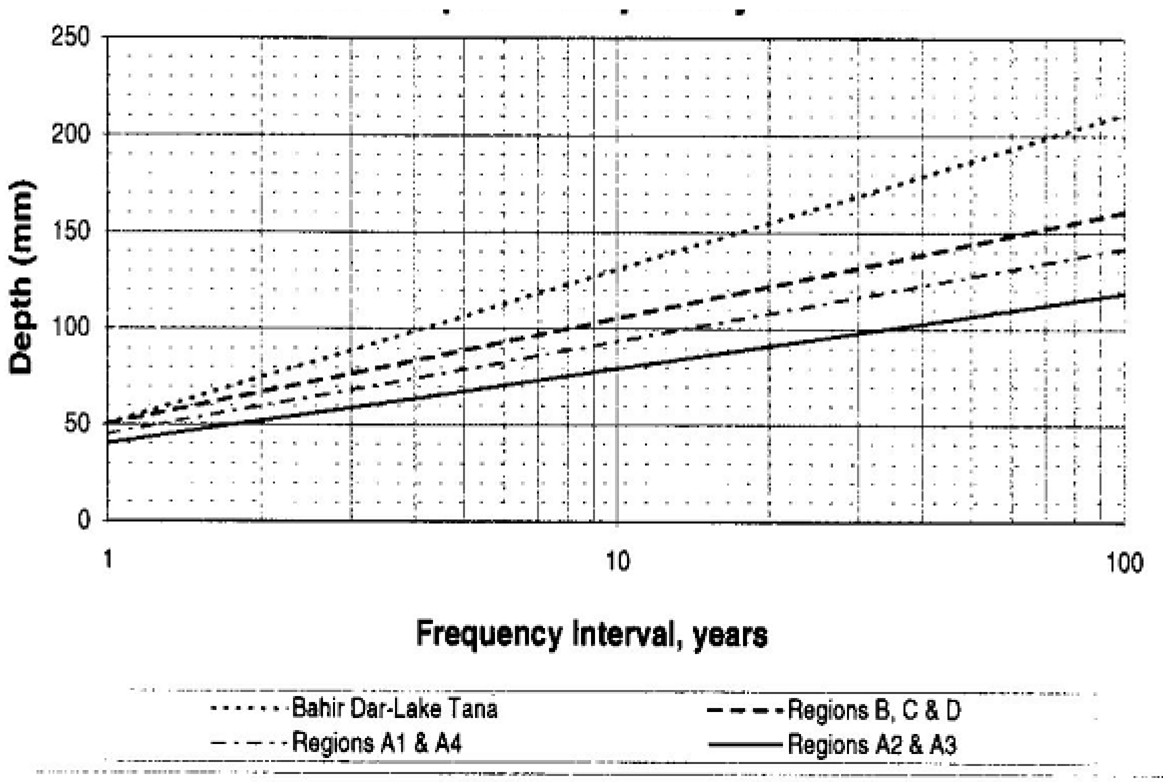
APPENDIX 1: Rainfall regions



APPENDIX 2: 24-Hour Rainfall Depth- and Frequency Curve



Region	24 HOUR DEPTH (mm) vs. FREQUENCY (yrs) TABLE					
	2	5	10	25	50	100
A1, A4	60	79	93	113	127	142
A2, A3	52	67	79	95	107	118
B and C	65	84	98	118	132	147
D	67	89	105	127	144	161
Bahir Dar	74	106	131	163	187	211

APPENDICES 3: Runoff depth and volume of Hawassa city (1986, 2000 and 2016)

Parameter	1986	2000	2016
24-hours rainfall, p(mm)	50	50	50
Curve number (CN)	62	65	72
S=2540/CN-25.4	15.31	13.68	9.88
0.2*S	3.06	2.74	1.98
0.8*S	12.24	10.94	7.90
P-0.2*S	46.94	47.26	48.02
(P-0.2*S)(P-0.2*S)	2203.27	2233.94	2306.35
(P+0.8*S)	62.24	60.94	57.90
(P-0.2*S)(P-0.2*S)/(P+0.8*S)	35.40	36.66	39.83
runoff depth, Q(mm)	35	37	40
Area (km2)	164.8	164.8	164.8
runoff Volume,V(m3)	**5,833,460**	**6,041,100**	**6,564,274**
rainfall changed to runoff (%)	70.8	73.3	79.7