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WATER RESOURCE MANAGEMENT PROGRAM

**THE IMPLICATION OF LAND USE LAND COVER CHANGES ON GROUND
WATER RECHARGE USING GIS-BASED WETSPASS MODEL: IN THE CASE
OF ADDIS ABABA CITY, ETHIOPIA.**

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STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this Thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the thesis has been given recognition through citation.

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Abstract

Understanding the groundwater availability is very important to plan, develop and manage the water resources sustainably. In Addis Ababa city the impact of land use land cover change on groundwater recharge was not well studied previously. Therefore, this study was aimed to investigate the land use land cover changes that occurred for the last two decades and its impact on ground water recharge in Addis Ababa city. Land use land cover classification has been carried out in the year 2000 and 2020 using Arc GIS.

Besides, WetSpss-M model has been simulated two times for the year 2000 and 2020 using similar input data but in the case of land use land cover data was given the respective years. Addis Ababa city has received a long-term average of 1115.7 mm rainfall. Based on the model output recharge was decline. In the case of 2000 model simulation 160.9 mm or 14.3 % from annual precipitation was turn in to recharge which is equivalent to 82,219,000 cubic meters (Mm³) for Addis Ababa city (with in the area of the city about 511 km²). But this percent was decline to 9.26 % from the annual mean precipitation was turn into ground water recharge for the year 2020 simulation which is equivalent to 103.3 mm or 52,786,000 cubic meters (Mm³) with the same city area (511 km²). In both simulation 88 % recharge was occurred during kiremt /rainy seasons while 12 % of recharge was occurred in bega /dry season. WetSpss was successfully simulated spatial and temporal differences of ground water recharge and the assessment of land use land cover changes was also don very effectively using Arc GIS and ERDAS software's.

Keywords: Recharge, Runoff, WetSpss model, Water balance, land use land cover, Arc GIS software.

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Acronyms

ASCII	American Standard Code for Information Exchange
AWSSA	Addis Ababa water supply and sanitation authority
CDMA	Code Division Multiple Access
DEM	Digital elevation model
ERDAS	Earth Resource Data Analysis System
EWWDSE	Ethiopian water works Design and supervision enterprise
ET	Evapotranspiration
GCP	Ground control point
GIS	Geographical Information system
GPS	Global positioning system
LULC	land use land cover
MIKE SHE	System Hydrological European
MoWIE	Ministry of water irrigation and energy
NDVI	Normalized difference vegetation index
NGO	Non-governmental organization
NMA	National meteorology agency
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
TOPMODEL	Topographic Hydrologic Model
TM	Thematic mapper
USGS	United states geological survey
WBC	Water balance components
WetSpass	Water and energy transfer between soil, plant and atmosphere at quasi-steady state

CHAPTER ONE

1. Introduction

1.1 Background

Land use land cover change usually brings large changes in flood peak and infiltration properties, thus affecting the entire hydrological environment of the area. In order to evaluate such negative effects caused by land use and land cover change, it is necessary to estimate the changes in surface runoff and groundwater recharge rate. The urban land use expansion is the most important change in the increase of impervious surface, which will affect the groundwater level, interception, evaporation and consequently influence runoff (Scales, 2018). Increase in imperviousness has a major impact on groundwater by reducing recharge and it was the major concern over the past years to those who are involved in groundwater studies.(Mishra et al., 2014).

In the past two decades, Addis Ababa city has been rapidly grown and expanded along the nearby area due to urbanization and population growth. This creates a rapid land use land cover change occur in the last 20 years in Addis Abba city. In the study area crop lands, forest area, bare lands and pocket green areas are now changed to huge buildings or infrastructures as a result of expansions of urbanization (Arsiso et al., 2018a). This situation makes increasing imperious layer and reduce vegetation covers and it also has a negative effect on ground water recharge by altering storm water in to runoff and reducing the infiltration ratio in to the ground water.

According to Leta (2007), natural recharge refers to precipitation that contributes to soil moisture content and crosses the water table and becomes part of the groundwater flow system. The net recharge is the difference between total precipitation and the cumulative loss by direct runoff and effective evapotranspiration. The methods to estimating ground water recharge can be classified into physical techniques and empirical modeling.

WetSpass model is a physical model it is spatially distributed computation model for water and energy transfer between soil, plants, and atmosphere under quasi-steady state. It simulates spatial and temporal patterns of actual evapotranspiration lost from a given watershed, surface runoff, and groundwater recharge (Batelaan & Smedt, 2007).

WetSpass model had used by different researcher, according to those researchers, the model was estimating groundwater recharge and it was giving a good and accepted output. Therefore, this study was aimed to implement WetSpass model to estimate the local ground water recharge and use geographic information system (GIS) to know how the land use land cover changes affecting local recharge in Addis Ababa city.

1.2 Statement of the Problem

Addis Ababa city administration has currently focus on ground water than surface water to address potable water supply and they are drilling many boreholes with in Addis Ababa city. They have also plan to commence new projects for future water related development activities by the city administration without a proper assessment of groundwater potential and its fluctuation (Muleta & Abate, 2021). The abstraction and consumption of the groundwater in Addis Ababa area is not based on understanding of the amount of recharge that the area receive. The development of a ground-water system is considered to be safe if the rate of ground-water withdrawal does not exceed the rate of natural recharge (de Vries & Simmers, 2002).

Land-use and land-cover changes are one of the main human induced activities altering the groundwater system(Mishra et al., 2014). Due to rapid development in the Addis Ababa city, land-use and land cover is subjected to changes causing the area to form impervious surfaces by convert crop land and forest land in to settelment due to urbanization and population growth in Addis Ababa area specially for the last two decades. The expansion of urbanization also decreasing the area of bare land, forest and crop lands where as increasing the ratio impervious land in the study area. Therefore, land use land cover change can significantly alter of the areas of hydrology by decrease infiltration rate and increase runoff rate, hence causing low base flow and their effects on the ground water recharge process.

Substantial amount of research on ground water recharge has been done by estimating using GIS based WetSpass model in Ethiopia. (Yigrem, 2020) also estimating ground water potential using GIS based WetSpass model in Jewha watershed, and he was recommended sufficient amount of water potential available in the area. In northern Ethiopia Briki Watershed eastern zone of Tigray were used WetSpass model for their

recharge estimation (Meresa & Taye, 2019). There is a research also on land use land cover changes on Addis Ababa and it described how different land use types are converted in to build up area (Abebe & Megento, 2016) .

The previous studies of the area were addressing the decline of ground water resources volume in Addis Ababa city due to over exploitation/over pumping (Moges, 2011). But there are no sufficient and satisfactory researches that have been quantify and present the redaction of recharge with the land use land cover change of the area.

Generally, this research work will fill the above-mentioned gaps and solve the problem related to future proper utilization of groundwater system in Addis Ababa city by investigate the implication of land use land cover change and its impacts on the declining of ground water recharge in the study area.

1.3 Objective

1.3.1 General objective

The overall objective was to assess the implication of land use and land cover changes on ground water recharge in the case of Addis Ababa city.

1.3.2 Specific objectives

The specific objectives of this thesis were

- 1) To analyzed the temporal and spatial change in land use and land cover for Addis Ababa city.
- 2) To estimate the ground water recharge using GIS-based WetSpass model under 2 scenarios by 2000 and 2020
- 3) To assess the implication of changes in land use land cover on ground water recharge.

1.4 Research question

The main research questions of this study were:

- 1) What are the major land use land cover changes occurred in Addis Ababa city for the last 20 years?
- 2) How can estimate ground water recharge of Addis Ababa city using GIS based WetSpass model?

- 3) Does land use land cover change have impact on the groundwater recharge in Addis Ababa city?

1.5 Significance of the study

This study will create some awareness on the impact of land use land cover change on ground water recharge and how different land use class alter water balance parameters. Generally, this research has the following specific importance.

- To have a sustainable groundwater development and management strategies.
- To aware discharge and recharge relationship when abstraction ground water.
- To know the effects of different land type on ground water recharge system.

In addition, this study will be baseline for another study for water resources, modeling or estimating the recharge of ground water potential of the area and for planning and development activities.

1.6 Scope

Geographically the study was limited within Addis Ababa city administration boundary the area significantly lands use land cover changes had been occurring from agricultural to urban settlements and a huge impervious land has been extended for the last twenty years. Contents wise the study mainly focus on firstly, assessment on time interval land use land cover change between 2000 and 2020 and classify different land use types in the study area by using multispectral satellite imagery. Secondly, estimating ground water recharges by using GIS based WetSpss model and associated this water balance parameter with land use land cover change to know whether it has negatively or positively linked to ground water yield. Thirdly, to describe the relationship of ground water recharge with land use and land cover change. To identify which land use type can affect ground water recharge more and quantify the extant of land use land cover change that happening for the past consecutive decades.

CHAPTER TWO

2. Literature review

2.1 Ground water

Ground water can be occurring in saturated zone or unsaturated zone. Unsaturated zone groundwater is occurring when just surface water to being subsurface it is found immediately beneath to earth surface. Saturated zone ground water occurring when water percolated in to saturated zone from unsaturated zone. The ground water from this zone is the major sources of springs and boreholes. Aquifer can be defined a ground water reservoir and it can be classified as confined and unconfined. An aquifer is a geological unit that store and transmit water at rates fast enough to supply reasonable amounts to wells. Unconsolidated sands and gravels, sandstones, limestones, and dolomites, basalt flows, and fractured plutonic and metamorphic rocks are example of rock units known to be aquifers. A confining layer is a geological unit having little or no intrinsic permeability-less than about 10^{-2} darcy. Groundwater moves through most confining layers, although the rate of movement is very slow (Muleta & Abate, 2021) .Rainfall and recharge estimation is important to balance recharge and discharge. Groundwater is useful to keep the ecosystem in addition to use for drinking water. (Thomas et al., 2009).

2.2. Rainfall and Recharge Relationship

Recharge from rainfall is the most important among the various component of the water balance equation. Recharge is the fraction of rainwater that after infiltrating and satisfying the soil moisture deficit, percolates down and reaches the water table. The recharge is a function of several factors such as soil characteristics, soil moisture conditions, depth of water table, topography, land use characteristics, intensity, duration and seasonal distribution of rainfall. (Thomas et al., 2009). Land use land cover also affect the rainfall recharge relationship. after subtracting what is lost to overland flow (runoff) and evapotranspiration (ET) from rainfall the amount of ground water recharge will be known.

The maximum quantity of water that can be extracted from an aquifer usually depends upon the recharge levels of the aquifer. One of the usual forms of recharge is by rainfall. In the case of unconfined aquifers, a fraction of the rainfall reaches the water table and the rest is either lost as evapotranspiration or as runoff. This fraction determines the safe yield

of the aquifer and hence its estimation to a reasonable degree of accuracy is essential for the proper management of aquifers (Viswanathan, 1984).

2.3 Groundwater Recharge

Recharge is defined in a general sense as the downward flow of water reaching the ground water table, developing an accumulation to the groundwater reservoir. According to Leta (2007), direct recharge refers to precipitation that contributes to soil moisture content and crosses the water table and becomes part of the groundwater flow system. The net recharge is the difference between total precipitation and the cumulative loss by direct runoff and effective evapotranspiration.

The actual recharge rate is controlled by several factors: precipitation intensity, soil moisture content, elevation of the area, the horizontal hydraulic conductivity of the aquifer and its hydraulic gradient and the vertical hydraulic conductivity of the soil (Viswanathan, 1984).

Recharge rates changed from time to time, depending on land cover types of the area, the intensity of precipitation and its seasonal distribution, air temperature, and other factors. Among the other factors are land use. For example, recharge rates are much higher in highly vegetated area than in impermeable cities and asphalt roads (Adhikari et al., 2020)

Recharge is the actual inflowing of water into a given aquifer. Natural recharge to the saturated zone in a groundwater reservoir come from vertical percolation of precipitation and from the losses of the streams flowing after important rains in the upper part of the catchment(Thomas et al., 2009). A positive value is used to represent recharge into the aquifer system.

Water percolated in to the ground-water systems in recharge areas and moves through them, as dictated by hydraulic gradients transmissivity and hydraulic conductivities, to discharge areas. Recharge rates differ from time to time, depending on land cover types of the area, the intensity of precipitation and its seasonal distribution, air temperature, and other factors. Among the other factors are land use, for example, recharge rates are much higher in highly vegetated area than in impermeable cities and asphalt roads (Aish, 2010)

Recharge to an aquifer can be estimated by first calculating the effective rainfall using a soil moisture budgeting technique, and then by applying a recharge coefficient to indicate

the proportion of this effective rainfall that contributes to groundwater recharge (Misstear et al., 2009).

Groundwater models used for analyzing groundwater systems (infiltration– discharge relations) are often steady state and, therefore, need long-term average recharge input. On the other hand, the spatial variation in the recharge due to distributed land-use, soil type, slope, etc., can be significant and should be accounted for in these regional groundwater models. Stream flow recession analysis clearly shows this spatial variability of recharge (Aish, 2010).

2.4 Groundwater in Addis Ababa area

The groundwater depth map of Addis Ababa area shows shallow ground water depth at the central and the northern part of the town. According to Muleta & Abate, (2021), the central part of the town shows confined groundwater conditions. Especially at some places of Filwoha, Lideta and Kality areas exhibits artesian groundwater conditions. The confinement at the central part of the town varies from 23 to more than 100 meters. The confinement is maximum along elongated strip north-south direction (Filwoha, Lideta, Mekanisa, Lafto, Kality) and the confinement decreases both in the eastern and western direction from this elongated strip. Most of the shallow groundwater area at the north of the town is unconfined. Large proportion of the central part of the town is under confined groundwater condition with groundwater depth varying from 0 to 40 meters. The depth of the groundwater in general, increases in the south direction. There are also deep groundwater areas more than 120 meters depending the topography of the area (Muleta & Abate, 2021).

2.5 Groundwater recharge and land use land cover change

It was observed that the groundwater recharge is mainly dependent on land use land cover changes. The forested areas have shown relatively higher recharge as compared to degraded and agriculture lands. The increase in paved area which lead to increase in runoff volume and decrease in time of concentration, which effect the decrease in percolation rate and once the percolation rate gets affected, it is obvious the groundwater storage will decline

The land-use change could happen mainly due to population growth, increasing urban areas, change in agricultural practices and reduction in the net cropped area. These activities in the present and future will likely influence the surface runoff, evapotranspiration and groundwater recharge variations over the spatial and temporal scales significantly (Adhikari et al., 2020).

The influence of land use and land cover changes on ground water recharge processes is not yet well quantified. Therefore, simulating the effects of land use change on hydrology leads at present to the results that carry quite a bit of uncertainty. Obvious effects are that a forest cover will increase the evapotranspiration, and that urbanization will reduce evapotranspiration and infiltration and increase surface runoff (Hasan et al., 2020).

2.6 Land use land cover change in Addis Ababa city.

Addis Ababa city in 1986, land use and land cover were dominated by forest cover in the northern and northwestern parts of the city while agricultural and grasslands dominated the southern and southeastern sectors. The built-up area was concentrated in the central part of the city. The land use and land cover maps of the 1999 and 2011 shown an expansion of built-up areas leading to the shrinkage of the forest and agricultural lands in all parts of the city (Arsiso et al., 2018a).

Rapid and unplanned expansion and commercial development, along with population pressure, has exerted tremendous negative impacts on green space in the City of Addis Ababa. At present the green spaces. crop lands and grass lands of Addis Ababa area are almost transformed to urban habitats (Abebe & Megento, 2016).

2.7 Ground water recharge estimation techniques

An accurate estimation of groundwater recharge is essential for efficient and sustainable groundwater management because water resources are critical to economic development. Various direct and indirect methods and sophisticated models have been used for the estimation of groundwater recharge since its direct measurement is nearly impossible. Usually, the key methods for groundwater recharge estimation are numerical models, hydrological budgets, water table fluctuations, and tracer techniques. (Singh et al., 2019)

The hydrological budget method is widely used by hydrologists for estimating groundwater recharge. Tracer techniques are extensively used in water-scarce areas for estimating groundwater recharge from irrigation and rainfall. Numerical models predict that spatial heterogeneities in the basal thermal boundary layer are preserved through laminar flow in the rising plume, indicating that geochemically-zoned hotspot tracks are the surface expression of lower mantle heterogeneities. The hydrological budget method is widely used by hydrologists for estimating groundwater recharge (Demisse, 2014).

2.8 Application of GIS and remote sensing Technology for ground water recharge estimation

Now a day geo-spatial technology has advance and minimizing the efforts of human being to acquiring spatial information through ground-based measuring by spatial technology. GIS software's used for many purposes it is efficient to collect data, integrated, stored, processing, manipulating and displaying the output of spatial data. In the present study GIS and Remote sensing approach is used to analyze the phenomena of agricultural land transformation into urban land use. The change detection method has been applied to realize the problem.

GIS and remote sensing are one of the latest, time and cost-effective technology for groundwater exploration by acquiring full information and access all parameters of factors which controls groundwater potentials and recharge zone areas by using different software's (Yeh et al., 2009).

A GIS was used to construct a recharge map to serve as input to a groundwater flow model. The GIS was used to identify all possible combinations of soil and vegetation

types. Each combination was assigned a recharge rate based on field measurements, supplemented with simulation estimates only when necessary (Fayer et al., 1996).

2.9 The WetSpass Model

WetSpass was constructed as a physically distributed estimation of the long-term average, spatiotemporally varying, water balance components: groundwater recharge, surface runoff, and actual evapotranspiration (K. Abdollahi et al., 2012).

WetSpass can estimate a long-term seasonal and annual ground water recharge by subtracting seasonal and annual runoff and evapotranspiration from annual precipitation (Armanuos et al., 2016)

WetSpass was successfully applied in Belgium (Batelaan & Smedt, 2007), Jewaha watershed, Ethiopia (yigrem, 2020) and Raya basin, Northern Ethiopia (Hailu et al., 2018). Accordingly, those researchers who are mentioned above simulated successfully the ground water recharge in different parts of the country using WetSpass model this is also the main interest of this paper.

The total water balance of a specific area can be calculating by summarizing the whole water balances of each raster cells. For instance, the vegetation area water balance can be calculating per grid as Equation's blow (1)– (3) describe it briefly.

$$P = I + Sv + ETv + Rv$$

$$ETv = Tv + Es$$

$$ETtot = I + Tv + Es$$

where P is the average annual precipitation (mm/year). I is the interception (mm/year) and depends on the vegetation types. Sv is the surface runoff (mm/year) related to precipitation amount, precipitation intensity, interception, and soil infiltration capacity. ETv is the actual evapotranspiration (mm/year). Rv is the groundwater recharge (mm/year) calculated as a residual term of the water balance. The actual evapotranspiration, ETv (mm/year), is the sum of Tv and Es. The total actual evapotranspiration, ETtot (mm/year), is the sum of interception (I), transpiration (Tv) and the evaporation, Es (mm/year) from the bare soil. A similar procedure as that for the vegetated surfaces is followed for the calculation of bare-soil,

open-water, and impervious surfaces. The only difference is that there is no vegetation in these cases and thus there is no interception and transpiration (Batelaan & Smedt, 2007). The long-term spatial average recharge Computation was the main objective for development of the WetSpa model (Batelaan & Smedt, 2007).

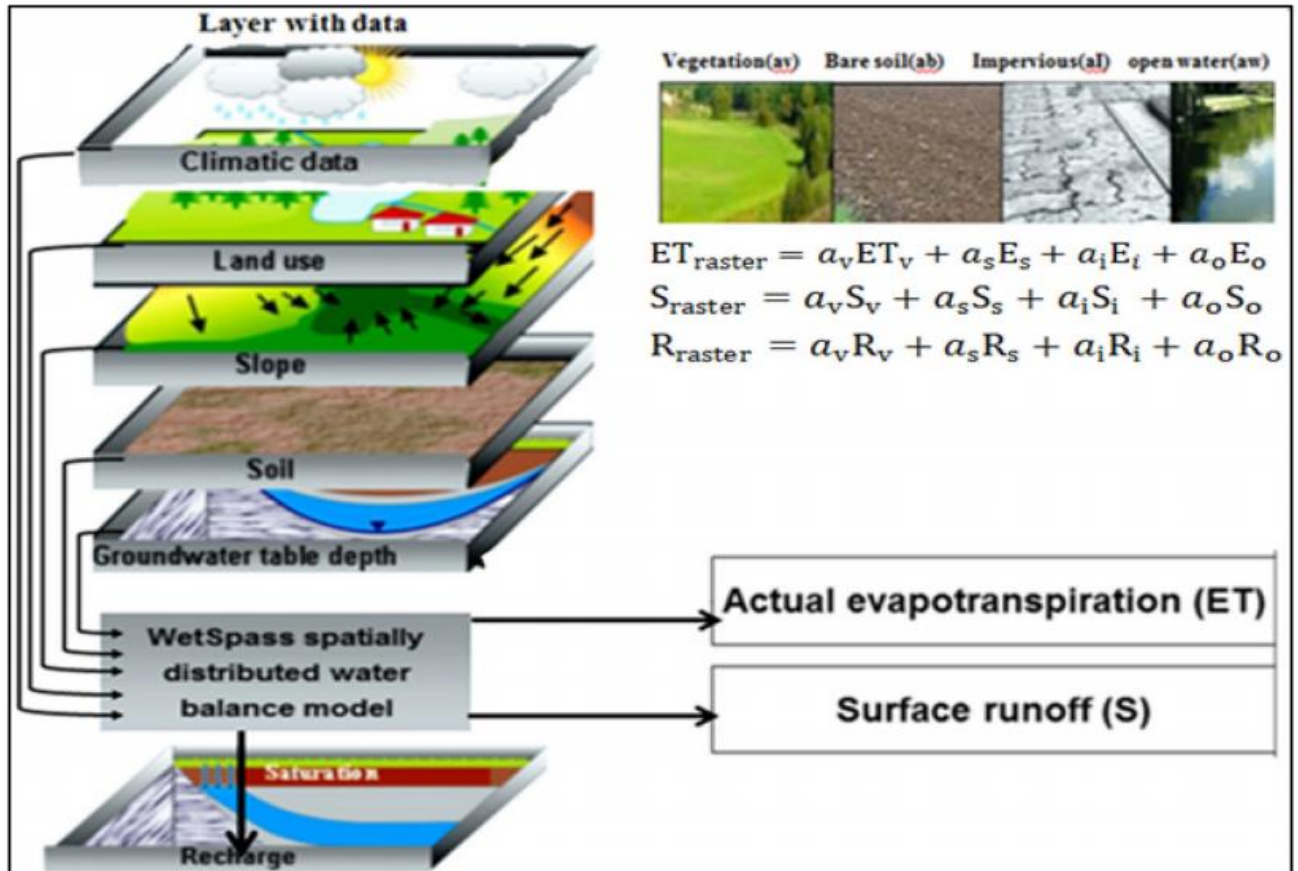


Figure1 : Schematic water balance of hypothetical raster cell (Zeabraham et al., 2020)

CHAPTER THREE

3. Material and Methods

3.1 Description of the study area

Addis Ababa is located in the upper Awash catchment in the central parts of Ethiopia (Fig 2) its geographical bounded between 8°45' to 9°15' N and 38°30' to 39°00'E with elevation difference 1750 to 3250 m above sea level. The city lies at the foot of mount Entoto in the north and the highest point is in the mount Entoto in the north and lowest elevation is lies in south eastern part of the city around Akaki.

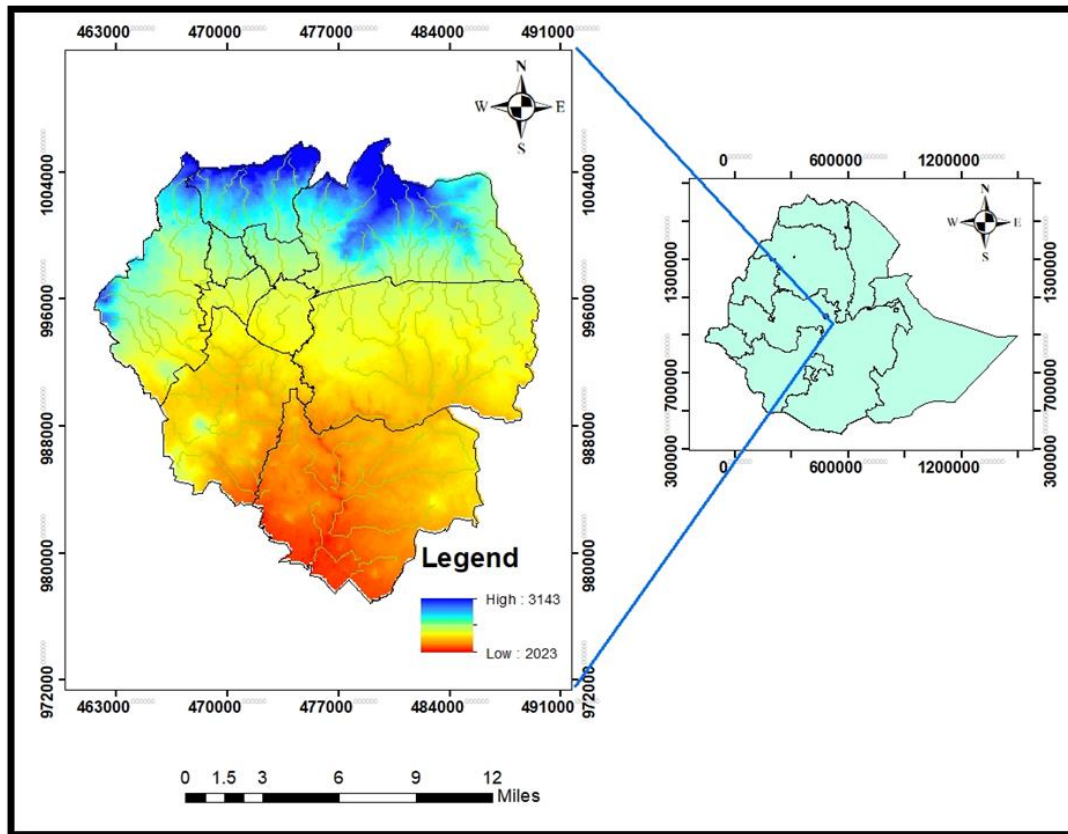


Figure 2: Study area map of Addis Ababa

3.1.1 Climate

Precipitation

Precipitation is the most important meteorological element for water balance model. Its spatial and temporal distribution has determined the amount of recharge and runoff in

specific area. Temporal and spatial distribution of precipitation in Addis Ababa collected from meteorological stations found within the study area. In Addis Ababa there are two distinct rainy seasons. During kiremt/summer season (Jun, July, August and September) Addis Ababa has received a huge amount of precipitation than dry season (October to May). Mean annual rainfall of the study area is 1120 mm/year. Kiremt/summer and bega/winter long term mean rainfall is 841 and 279 mm/year respectively and monthly rainfall is ranged from 47.83 mm on December to 1719.06 mm recorded in August. Therefore, from annual precipitation that Addis Ababa has received 75.1 % in kiremt/summer and 24.9 % is in the dry season.

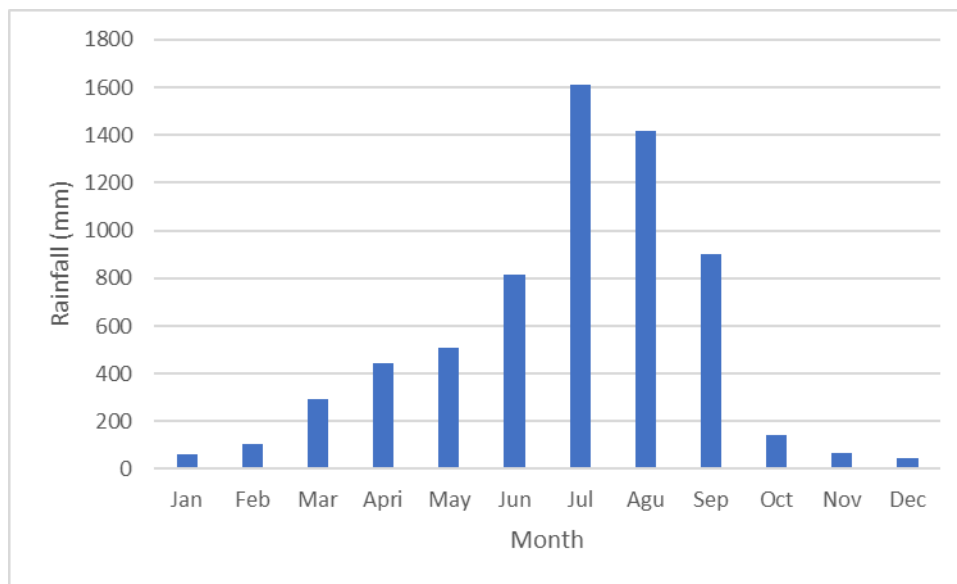


Figure 3: Monthly rainfall value of Addis Ababa

The spatial distribution of precipitation in Addis Ababa city is expected to have a huge difference among the stations but according to the data collected from different meteorological stations it shows a small difference. For instance, high values recorded in Entoto station and low values recorded from Akaki station. Topography/ elevation of the area can determine the amount of rainfall that receives high elevation areas receive high amounts of rainfall and lowland areas have received relatively low amounts of rainfall.

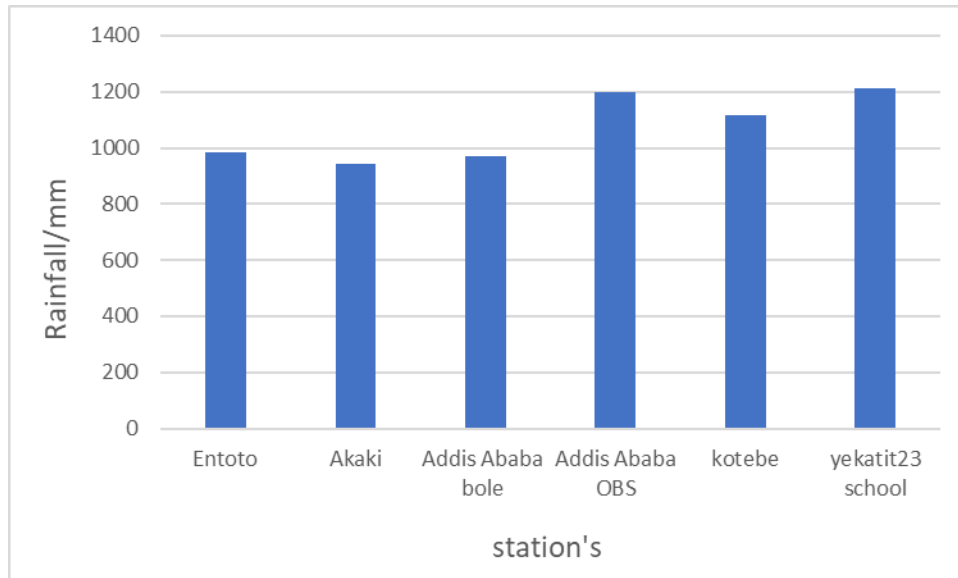


Figure 4: Rainfall distribution in Addis Ababa city

Temperature

Temperature is one of the elements or controls of climate in a given area for instance it can affect wind and evapotranspiration. This may have impact on the hydrological cycle and local water balance.

The long term annual average temperature of Addis Ababa is 16.9°C and kiremt (summer) temperature is 16.28 and during bega (dry) season is 17.21 and maximum temperature has been recorded in May 21.4 and minimum also in August 11.31 °C. Seasonal variation of temperature is important to know the overall hydrological process in the study area.

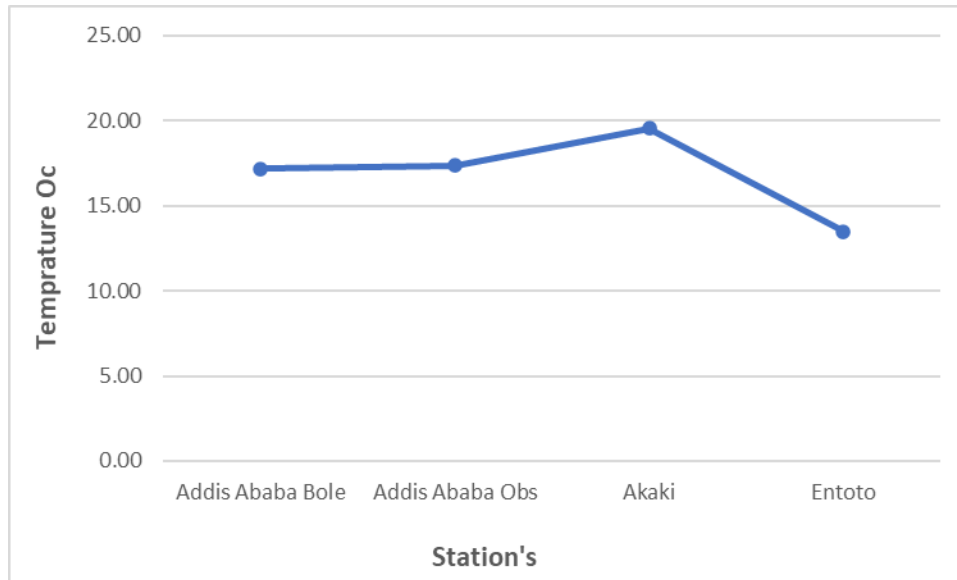


Figure 5: Areal variation of temperature in Addis Ababa

Areal distribution of temperature is determined by topographic high altitude has low temperature and low altitude has high temperature. Akaki station had recorded relatively higher value than Entoto station.

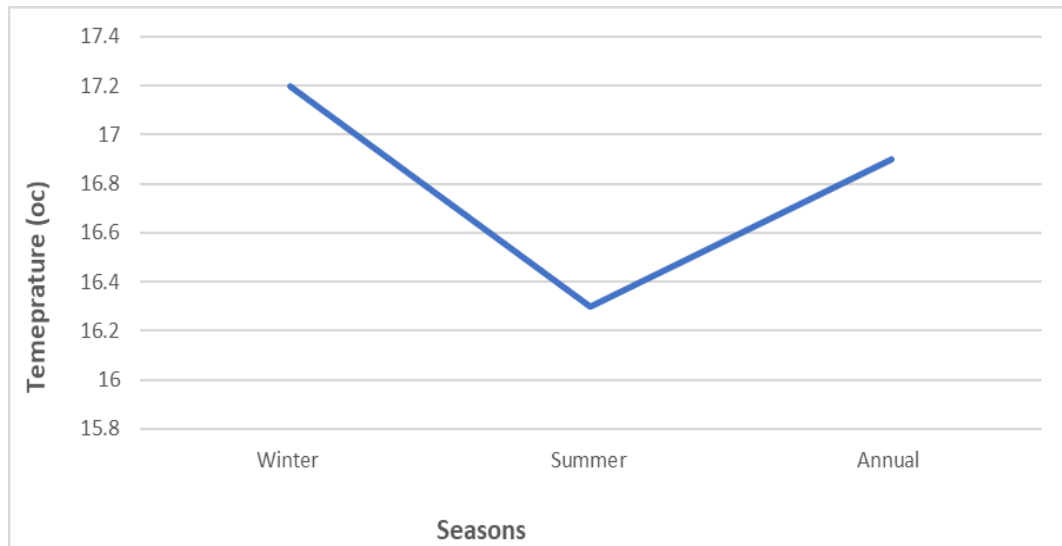


Figure 6: Seasonal temperature Difference of Addis Ababa

Potential Evapotranspiration

Potential evapotranspiration is the process of losing water from specific area and it is very important to understand water balances of that area. Therefore, annual average potential evapotranspiration of Addis Ababa area is estimated 778.48 and during kiremt (summer)

season 244.44 mm recorded. In addition, during bega (winter) season 534.04 MM has estimated.

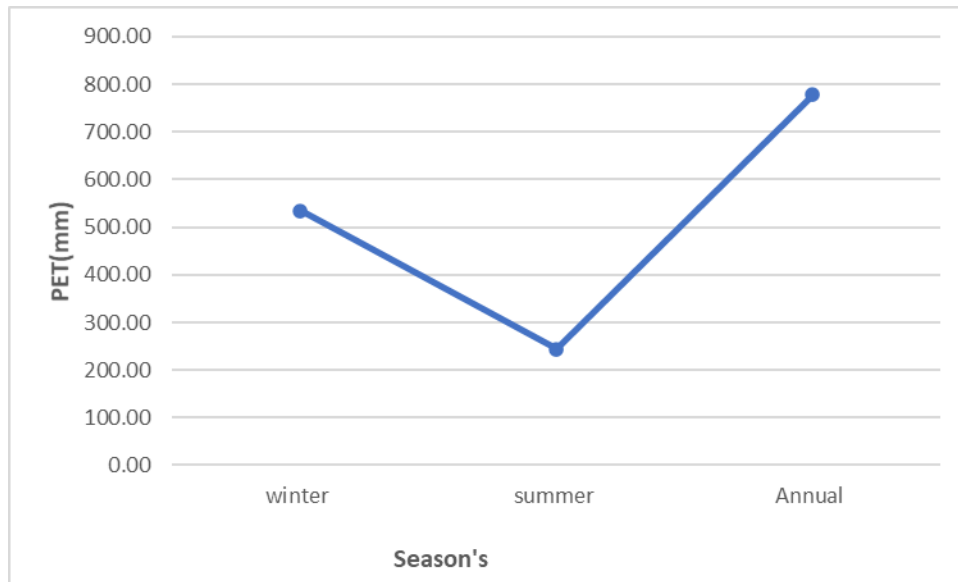


Figure 7: Seasonal difference PET of Addis Ababa

3.1.2 Soil

Based on American agricultural department soil can be categories in to three such as loam, clay and silt but depends of its portion it can be further categories like clay loam silt, clay and loam etc. According to ministry of agriculture report Addis Ababa city has dominated by three types of soil texture namely clay, loam and loam clay. Loam and loam clay soil texture is found in northern of Addis Ababa city whereas clay is more dominated in southern part of the city.

3.1.3 Hydrological flow data

Addis Ababa city has drain by two main rivers namely main Akaki river and little Akaki river. Flow data for these two rivers was obtain from ministry of water, energy and irrigation and adding discharge of the two rivers to get the total surface runoff volume of Addis Ababa city. In the river outlet there is recording gauge and continuously recording daily river flow.

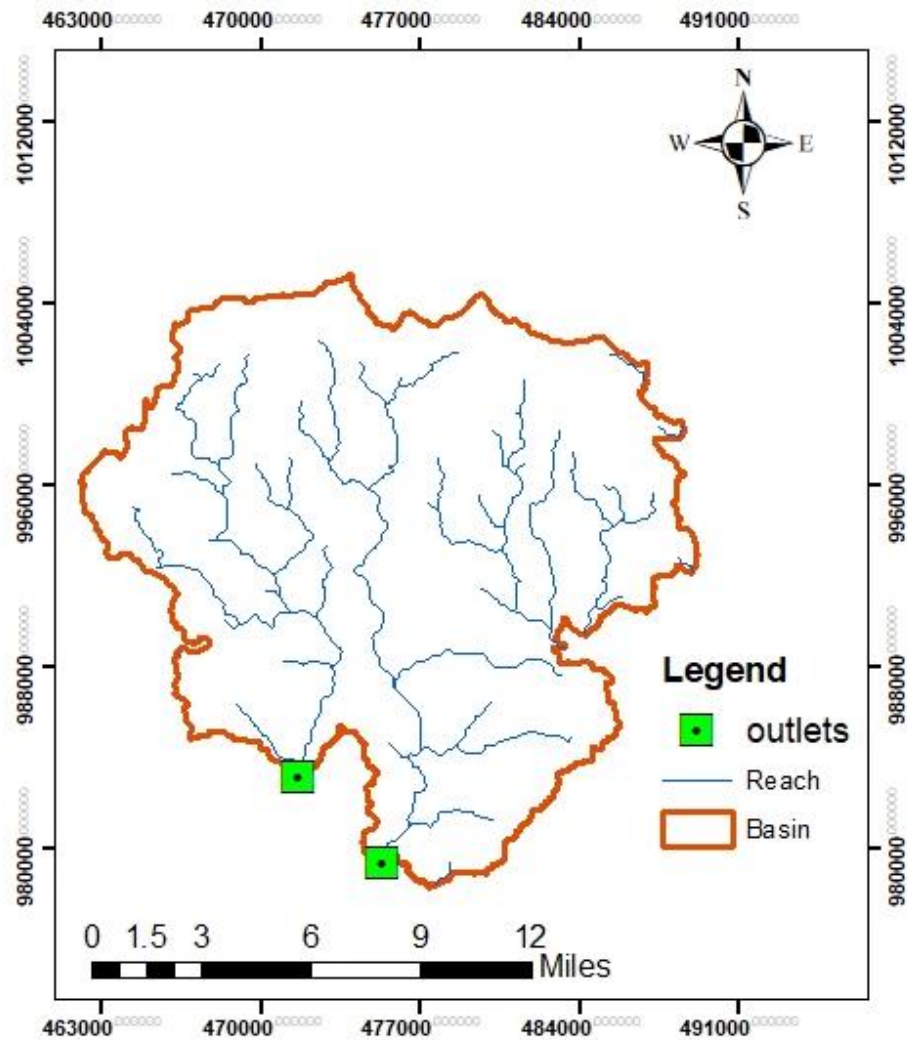


Figure 8 River flow map of Addis Ababa city

3.1.5 Geology

The area that covers the city of Addis Ababa and/or the Akaki River catchment consists of various volcanic rock units of different composition and age. Following a traverse from North (Entoto Mountain) to South (Kaliti-Akaki area), the geological formations change from the oldest volcanic sequences to the youngest. proposed the stratigraphy of the area starting from Sululta to Nazareth. Accordingly, the suggested Miocene Pleistocene volcanic succession in the Addis Ababa area from bottom to top are Alaji rhyolites and basalts, Entoto silicics, Addis Ababa basalts, Nazareth group, and Bofa basalts. Alaji series covers the Entoto Mountain and extends to the North beyond the study area. It

comprises of basalts associated with rhyolites, trachytes, ignimbrites, tuffs and agglomerates(Abebe & Megento, 2016)

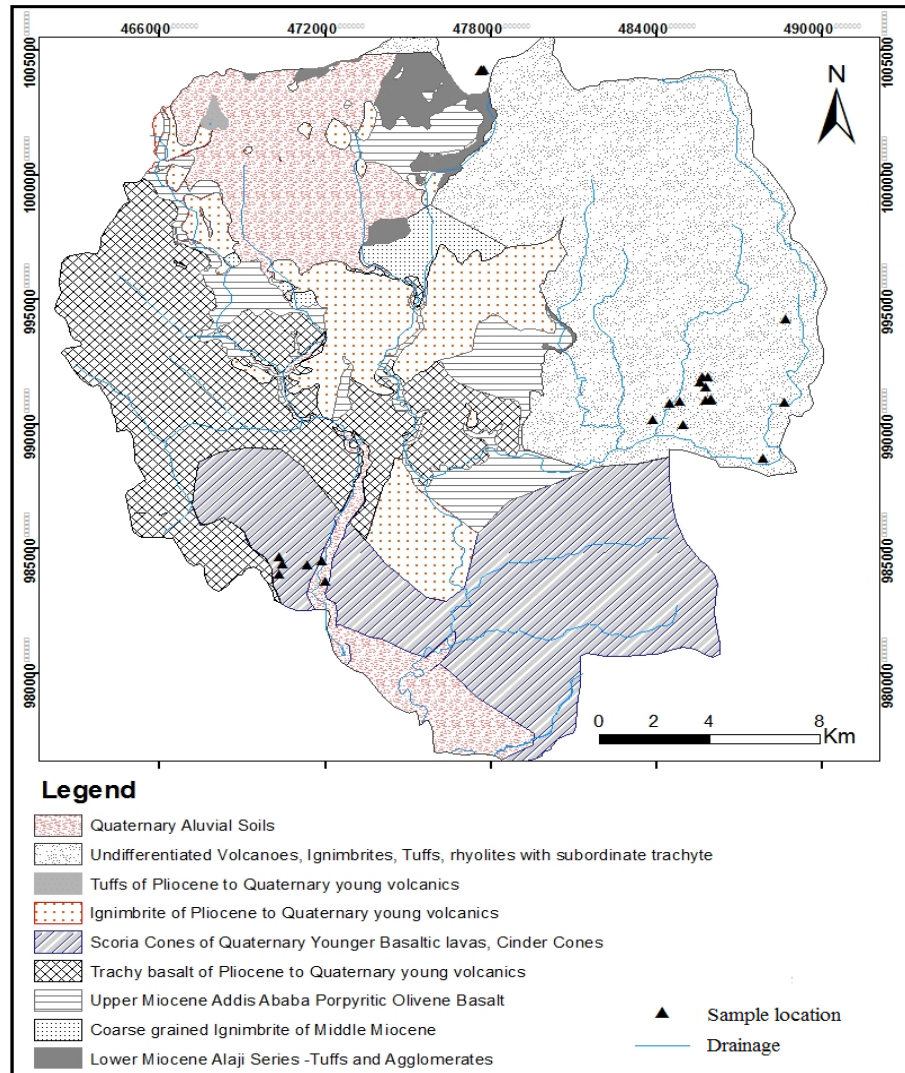


Figure 9: Geology map of the study area (source: <https://www.researchgate.net>)

Entoto silicics composed of rhyolite and trachyte with minor amount of welded tuff and obsidian). The rhyolitic lava flow outcrop on the top and the foothills of the Entoto ridge, predominantly in the Western side Addis Ababa basalts overlie Entoto silicics and outcrops mainly occur in the Entoto Mountain, central Addis Ababa, along Akaki River course (South) in the vicinity of Lega – Dadi dam to the north of Lake Gefersa and Southern part of the city. Younger volcanic can broadly be classified into Nazareth Group

and Bofa Basalts. According Alemayehu, T. (2001). the Nazareth Group rocks out crop dominantly to the South of Filwuha Fault and extend towards Nazareth, Aphanitic basalt, welded tuffs, ignimbrites, trachytes and rhyolites make up this group. Bofa basalts are found South ward from Akaki River, South-Eastern part of Addis Ababa and it comprises of olivine porphyritic basalt, scoria, vesicular & coriaceous basalt, and trachy - basalt lava flows.

3.1.6 Topography/Elevation

Addis Ababa has topographical diversified from 2,049m. to 3,386m. as minimum and maximum elevation. The highest elevation is in the northern part of the city in Entoto and the lowest point is found around bole airport. The gradient degree is varying from 0 to 76. The value 0 represent gentle slope and the value 74 is also stands for steep slope. Generally, the majority land is gentle slope it is preferable for settelment.

3.1.7 Land use and land cover changes

The effect of land use land cover change on ground water recharge are the main focus of this study. Land use land cover change has impact on the hydrological process particularly in recharge, evapotranspiration, interception and runoff. For this study classification was done by the year 2000 and 2020 in order to know land use land cover change occurred in the study period and to analysis its effect on ground water recharge. After classification accuracy assessment was conducted to verify the result by collecting ground references.

In the study area there are different land use types in terms of areal coverage buildup, crop land, forest, grass land and bare land is found orderly. Based on 2020 land use classification the study area has different land use proportions for instance, buildup area consists 68 % of the land it is the largest land use type in the study area. Crop land is also consisting 24.4 %, grass land 3.2 % forest 4.3% and bare land 0.034 %.

3.2. Data source and methods of data collection

3.2.1 data source

Table 1: Model Input and sources of data

No	Input data	Sources
1	Topography	DEM (30*30m) by downloading from USGS.
2	Slope	DEM (30*30m) by downloading from USGS.
3	Land use land cover	From downloading Satellite image
4	Temperature	National meteorology agency (NMA)
5	Precipitation	National meteorology agency (NMA)
6	PET kiremt(summer) & bega (winter)	National meteorology agency (NMA)
7	Wind speed kiremt (summer) & bega (winter)	National meteorology agency (NMA)
8	Groundwater depth	Addis Ababa water supply and sewerage authority (AWSSA)/ OWWC
9	Soil	Ministry of agriculture (MoA)
10	Number of rainy days lookup table	National meteorology agency (NMA)
11	Land use parameters	WetSpas users guide
12	Soil parameter lookup table	WetSpas users guide

3.2 Method of data collection

3.2.1. Spatial data collection

Remote sensing data is the process of gathering data from the earth's surface without being in actual contact with target feature using EME and it helps to analyze the spatial and temporal land use land cover changes in the study area. The nature of data that are going to be collected for this specific study forced to use satellite images as the major data collection technique. Satellite images data were obtained by downloading land sat TM sensor images from Google Earth.com. USGS web page for the year 2000, 2020 G.C. with

the same spatial and temporal resolution. It helps to extract information on land use land cover change detection and conversion rate of the parcel of land from one types of land use to the other in the study area.

3.2.2 Meteorological Data collection

For this study more than two meteorological station data was used to represent the study area for all meteorological input data. There are more than 10 stations within or near to Addis Ababa city which are currently recording precipitation and temperature they are (Addis Ababa bole airport, Addis Ababa obs, Akaki, Entoto, Koteba, kolfa and yekatit 23 school, sululeta, sendafa, sebeta). but, sunshine hours, wind speed, humidity and other weather elements acquired only from three stations Addis Ababa bole, Addis Ababa OBS, and Suluta.

After collected monthly meteorological data from NMA different data organizing and preparation activities were done using MS-excl. Meteorological stations are representing a particular area that are around station point. Therefore, to convert point data (stations) to areal data spatial interpolation technique kriging interpolation algorism had been Applied to prepare all meteorological input Maps.

3.2.3 Potential Evapotranspiration

Many hydrologists use different method to estimating potential evapotranspiration of a given area. The Hargreaves method (Hargreaves et al., 1985), the Priestley-Taylor method (Priestley and Taylor, 1972), Temesegn method and Penman-Monteith method (Monteith, 1965). for this study evapotranspiration was calculated using Thornthwaite's method. this method is easy and very accurate method to estimated monthly evapotranspiration.

It can be calculate using the following formula.

$$PET (unadjusted) = 16(10T/I) A$$

PET potential evapotranspiration in MM/month

I= Heat index for the months in a year = $\sum i$

$I = (T/5)^{1.514}$ for each month in the year

$$A = 6.75 * 10^{-7} I^3 - 7.71 * 10^{-5} I^2 + 1.792 * 10^{-2} + 0.49239$$

Multiply with the adjustment factor to obtain the final value of PET.

Adjustment factor for use in Throntwaite formula

Table 2: Adjustment factor

Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(North)	1.04	0.94	1.04	1.01	1.04	1.01	1.04	1.04	1.01	1.04	1.04	1.04

3.2.4 Hydrological data collection

Ground water elevation has been obtaining from AWSSA, and OWWC (Oromia water works construction). The data had been well organized in MS- excel format and it has all necessary information. Therefore, raster map was prepared by using spatial interpolation tool(kriging) in Arc GIS 10.7 interface

3.2.5 Biophysical data collection

Soil data was obtaining from ministry of agriculture and verify the data with world digital soil map which is obtain from FAO web page. Whereas slope and elevation maps had producing from DEM 30 by 30 which is downloaded from USGS-SRTM. Land use land cover map were also prepared by collecting sample signatures of a pixel from different land use class and categorized it with similar land use class using supervised classification with maximum likelihood algorithm on Arc GIS 10.7 interfaces.

3.3 Spatial data analysis

ArcGIS 10.7 software was helpful to store, integrated, analyze and preparing output of spatial data. Therefore, for this study ArcGIS has used to analyze land use land cover change and preparation of all input data for WetSpass model. ERDAS imagine 2014 also efficient to classify the land use land cover change with high accuracy. Landsat TM images were processed and interpreted to analyzed land use land cover changes that are occurred for the last 20 years with in the study area. Satellite images for the year 2000 and 2020 G.C.'s was visually and digital interpretation was carried out and image processing or image classification process was done. Off course, there is no single method is suitable for all cases each image detection methods depends on an expert's knowledge or skill, type

of image data we used, and characteristics of the study area Change detection can be applied (Abebe & Megento, 2016).

Before used the image data directly, it was conducted image pre- processing and image enhancement. Then, land use land cover map was also prepared by collecting sample signatures of a pixel from different land use class and categorized it with a corresponding land use type using supervised classification with maximum likelihood algorithm on Arc GIS 10.7 interfaces. Land use land cover change has been classified into five major classes viz. crop land, vegetation, bare land, builtup and grass land. Classification samples were collected using GPS from each land use type minimum 25 samples using stratified random sampling methods. Finally, overall accuracy, producer accuracy and user accuracy were don by creating confusion matrix table and the assessment of classification was check or validate by testing the kappa coefficient. Finally, post classification change detection method was applied to know changes observed within a 20 years' interval.

3.4 WetSpass model

WetSpass model was run to estimating the value of water balance components: actual evapotranspiration, runoff, interception and recharge. For this specific study grid map was prepare in 90m × 90 m and parameter table to give the model as an input and water balance calculation will perform on each cell. Water balance for each raster cell can be obtain by summing the independent water balances for the forest, bare soil, impervious and water body.

Model calibration was performed by adjusting the different parameters placed on the model within the range values. The parameters are namely: alfa coefficient, “a” interception, Lp coefficient and runoff delay factor “x”. the parameters were kept optimizing up to reaching t\he goodness of fit between the simulated and observed stream discharge recorded at main Akaki river and little Akaki rivers.

The model calibration was done using simulated (the sum of surface runoff and base flow) and observed data (actual recorded stream flow). The model result shows that the annual value of runoff in Addis Ababa area is vary in range from 95.99 mm to 3028.59 mm as a minimum and maximum value respectively, with a mean of 577.36 mm in depth ratio. The seasonal variation of runoff value is 726 mm and 69mm in kiremt/summer (Jun to September) and bega/winter (October to May) seasons respectively. Also, the volumetric

ratio of the surface runoff and base flow to streams has been simulated by WetSpass model.

The total flow in a stream or river from a Addis Ababa city is a function of Q base flow and Q surface runoff which is equivalent to the long-term monthly average river discharge from the watershed (Khodayar Abdollahi et al., 2017). The summation of base flow and surface runoff simulated by WetSpass model is used to calibrate the model with ground observed stream flow data obtained from summation of Akaki river and little Akaki river gauge station. Calibration was don successfully with A correlation of coefficient of determination R^2 of 0.85 were obtained with the parameters of the optimal soil moisture alfa coefficient value of “ x ” = 9.5, $LP = 0.1$, interception parameter “ a ” = 9.5, and a runoff delay factor “ x ” = 0.57.

2.4 Conceptual Framework

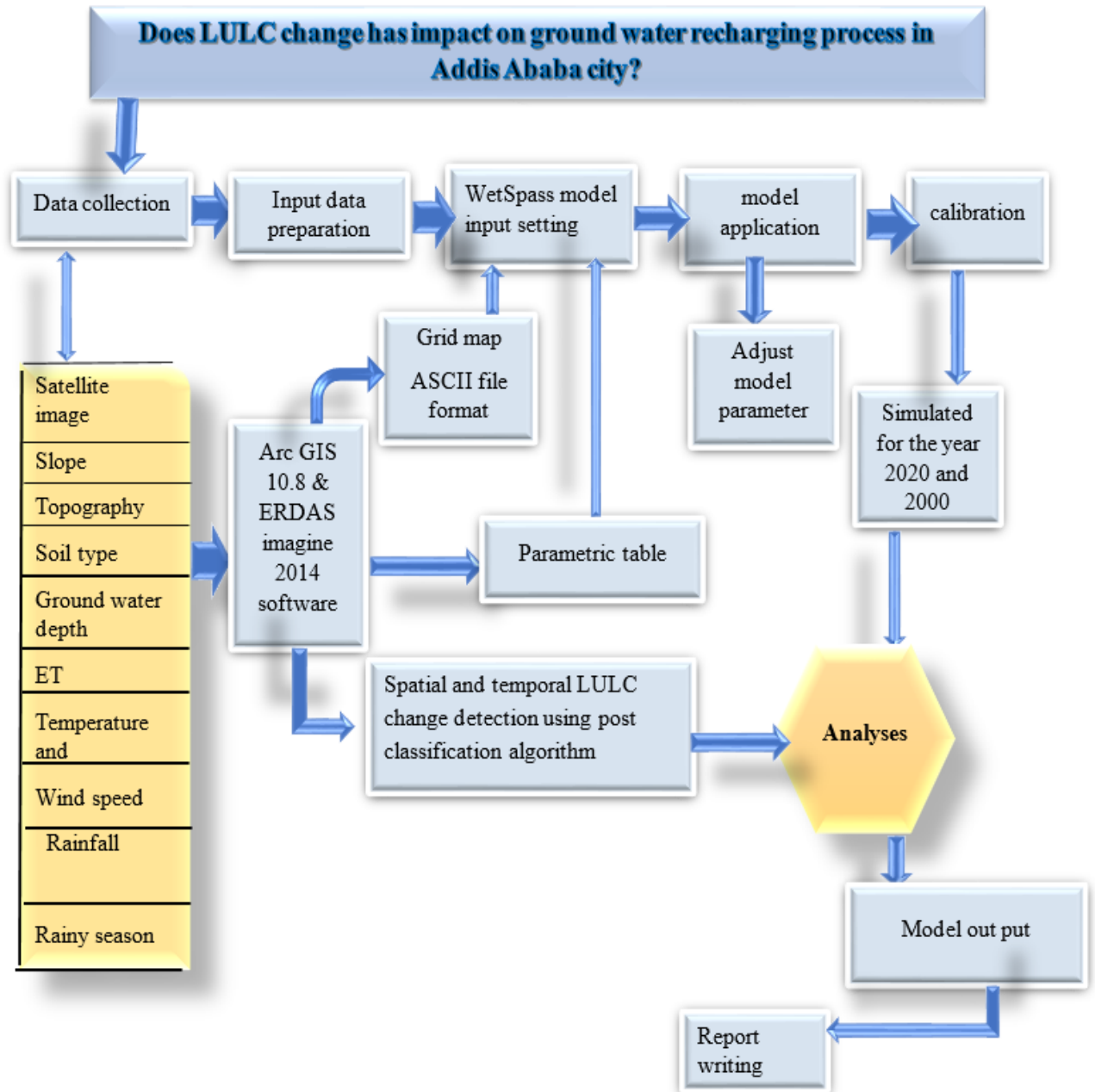


Figure 10: Conceptual frame work

3.3 Materials and Software used

Materials

All the data and its sources used to produce land use land cover change to assess the ground water recharge of Addis Ababa city are presented table (1).

Software's

The software's that was used for this research is based on its capability to achieve the objectives of the study. Arc GIS software was used to prepare different data, to classify land use classes and to know the change and finally to produce the output in map format. ERDAS was also used as an alternative tool to classify land use land cover change of the study area. WetSpas-M model also used to estimate spatial water balance components. Finally, Mendeley reference also used to put in text citation as well as to put reference at the end properly

3.5 preparation of model input dataset

The WetSpas model demanding different long-term mean input data includes meteorological data (rainfall, wind speed, temperature, potential evapotranspiration), hydrological data like ground water elevation and also biophysical layer data such as slope, land use land cover, elevation and soil spatial data are needed as an input to run WetSpas model.

WetSpas data can be monthly or annually, monthly data can be categorized as kiremt/summer (rainy season) or bega/winter (dry season) as a result, in Addis Ababa Jun, July, August and September known as a kiremt (summer) season and eight months from September to may are also known as a bega (winter). These input data were preparing in grid maps and parameter tables format since WetSpas are required it as inputs to simulate water balance components in a given area.

3.5.1 Grid maps

All grid maps have been prepared with the same raw and column and similar cell size to be compatible with the WetSpas modal. Therefore, the input bio-physical and meteorological grid maps for this specific study should have the same cell size, columns and rows which is 311 and 324 respectively and the cell size of all input map is 90*90. All meteorological grid maps were prepared for each month from January to December 12

months and take in to account a long-term monthly average meteorological data ground water depth. The rest of the necessary maps were no change throughout the year so that soil, slope, topographic elevation and land use/land cover maps was the same in all months with in the year. Of course, in most areas land use/ land cover is different in separate season but in Addis Ababa area land use land cover has not vary most of the city area is covered by settlement/built-up area and around Entoto area has covered by forest which is the same throughout the year and some pocket farm land area also covered by crops in both season since the farmers produced crops using irrigation.

Precipitation

Precipitation is one of the most important parameters of hydrologic cycle. Hydrological cycle starts from evapotranspiration from open water bodies, soil, plants etc. with Ground water recharge and precipitation has direct relationship. Precipitation is one of the major sources for ground water recharge.

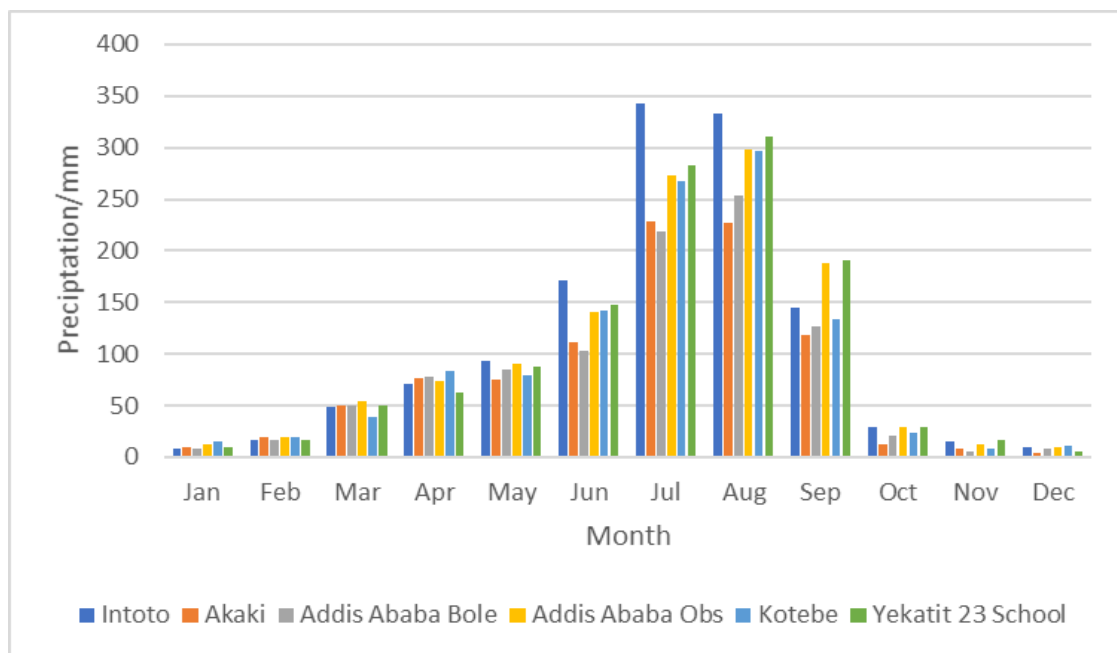


Fig11. Spatial rainfall distribution of Addis Ababa city

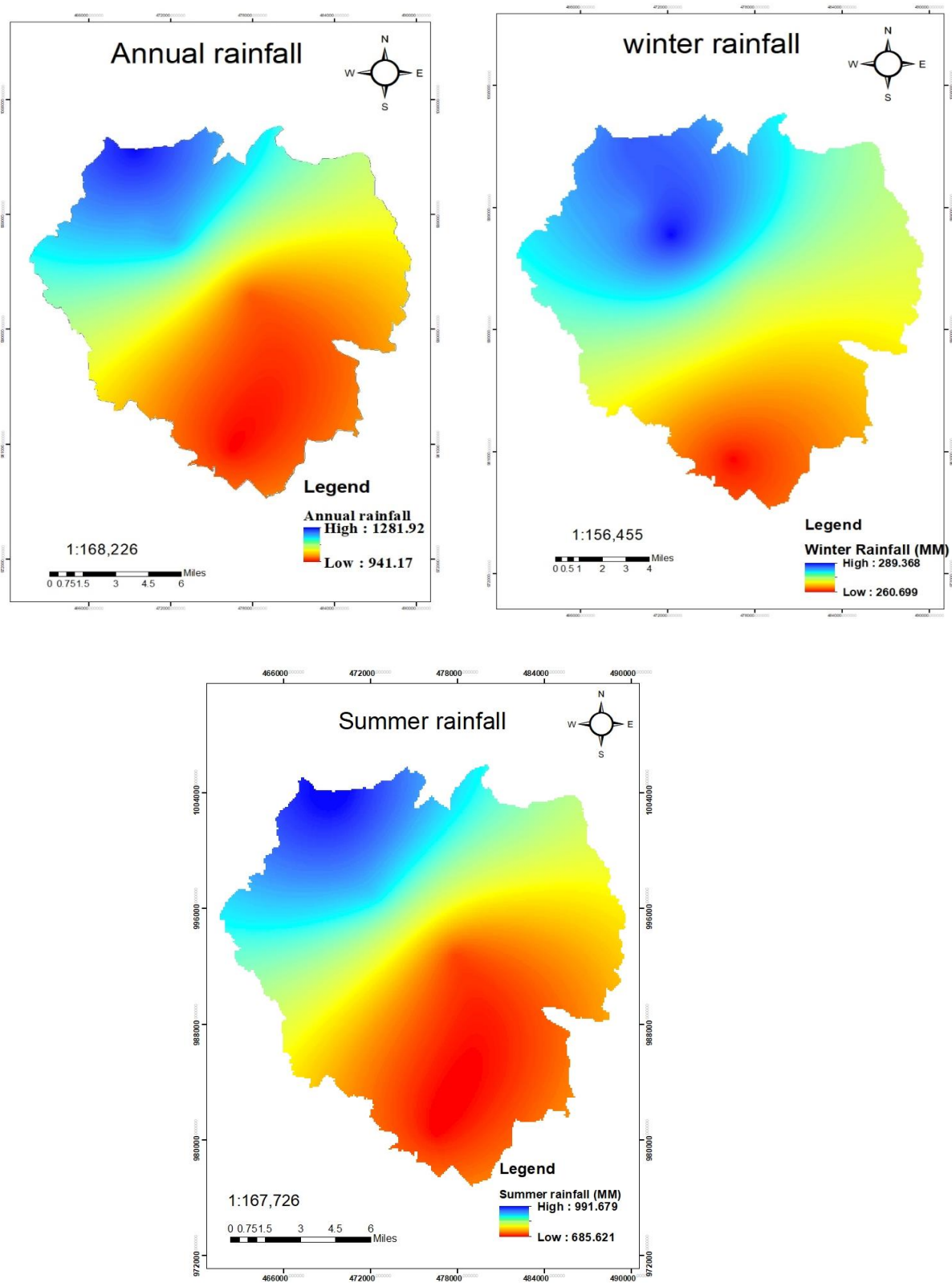


Figure 12: Seasonal and annual average of rainfall map of Addis Ababa

Temperature

Temperature is one of the elements of weather condition that are controlling factors of hydrological cycle. There are four stations with in the study area (Addis Ababa Bole, Addis Ababa Obs, Akaki and Entoto) were used to provides a temperature data. There is spatial variation of temperature across the study area. Akaki station has higher temperature values 19.87°C and Entoto station also the lowest temperature 14.1 °C recorded.

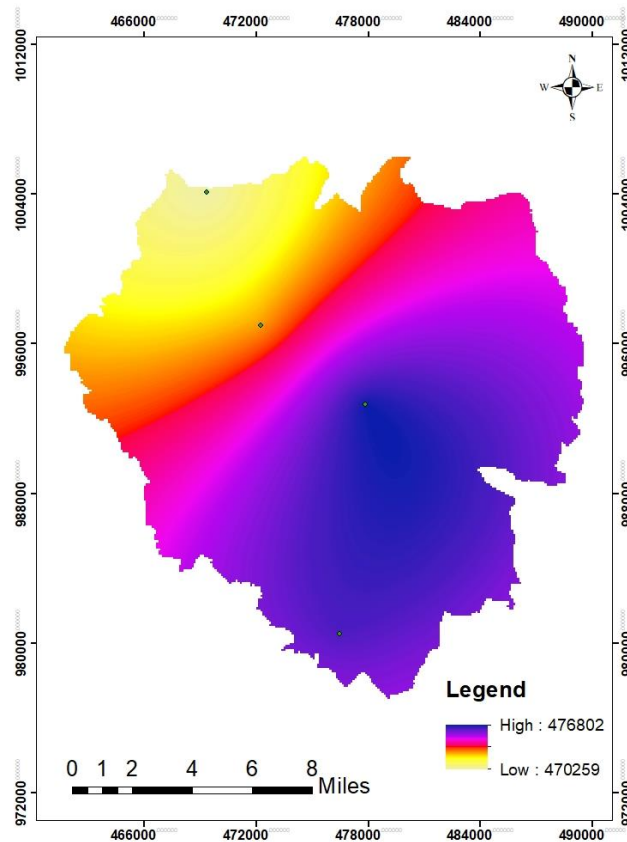


Figure 13: Spatial differences of temperature in Addis Ababa city

After collecting point data from each station and convert in to areal data using Arc GIS kriging interpolation method. Annual average temperature value ranges between 11.31 °C to 21.4 °C, and annual mean temperature is 16.9 °C. In bega the average temperature is 17.2 °C and the range is between 14.09 °C to 19.83 °C. During kiremt (rainy) season a mean temperature is 16.286 °C and its ranges is between 12.278 °C to 19°C.

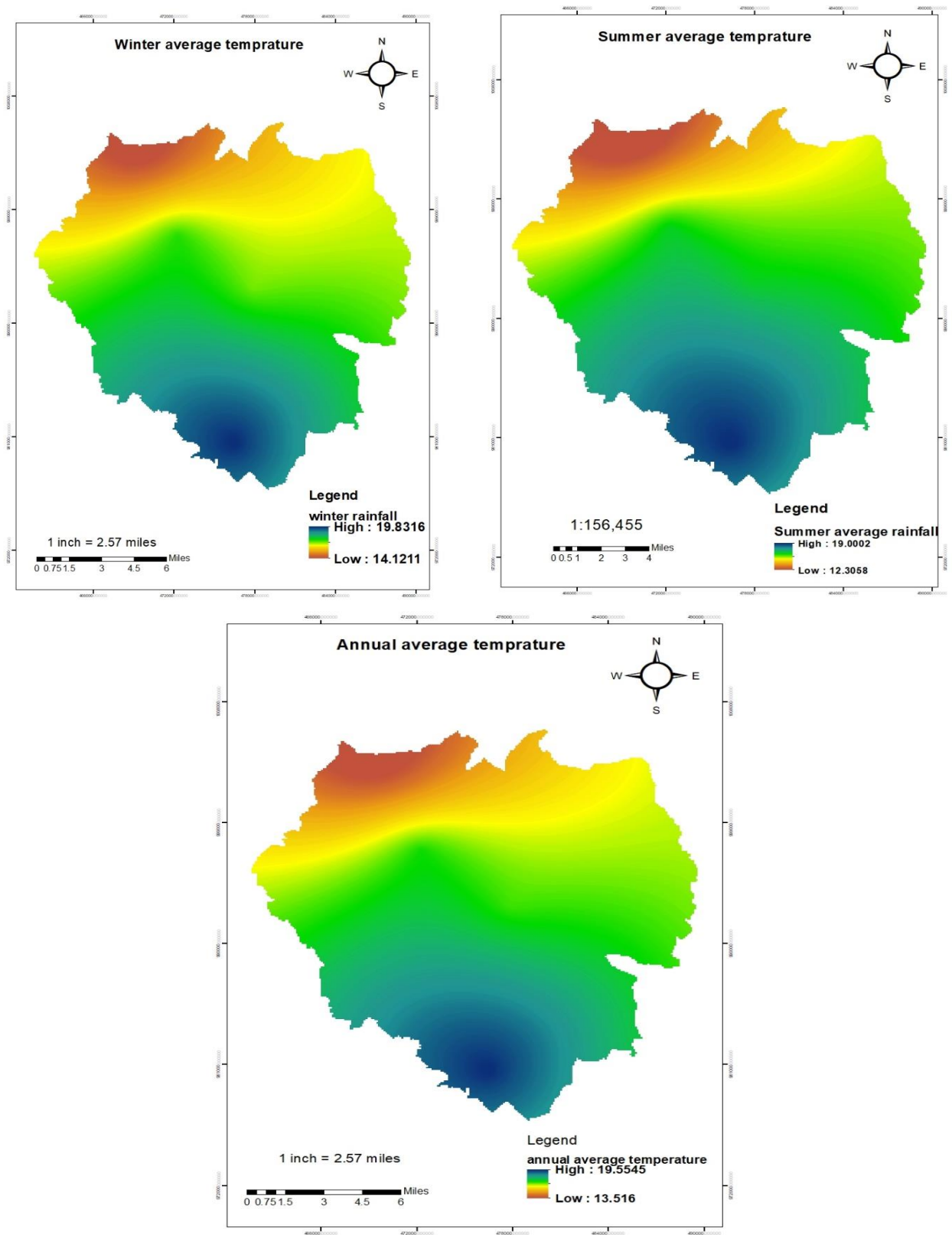


Figure 14: Winter summer and annual mean temperature map of Addis Ababa

Potential evapotranspiration

Potential evapotranspiration (PET) is the process of losing water from earth surface by evaporation and transpiration. There are different methods to calculate potential evapotranspiration. For this case evapotranspiration estimating using Thornthwaite's method. Four station data was used to get estimating spatial evapotranspiration value for Addis Ababa city. Akaki station has high evapotranspiration data throughout the year whereas Entoto station recording the lowest value of annual PET.

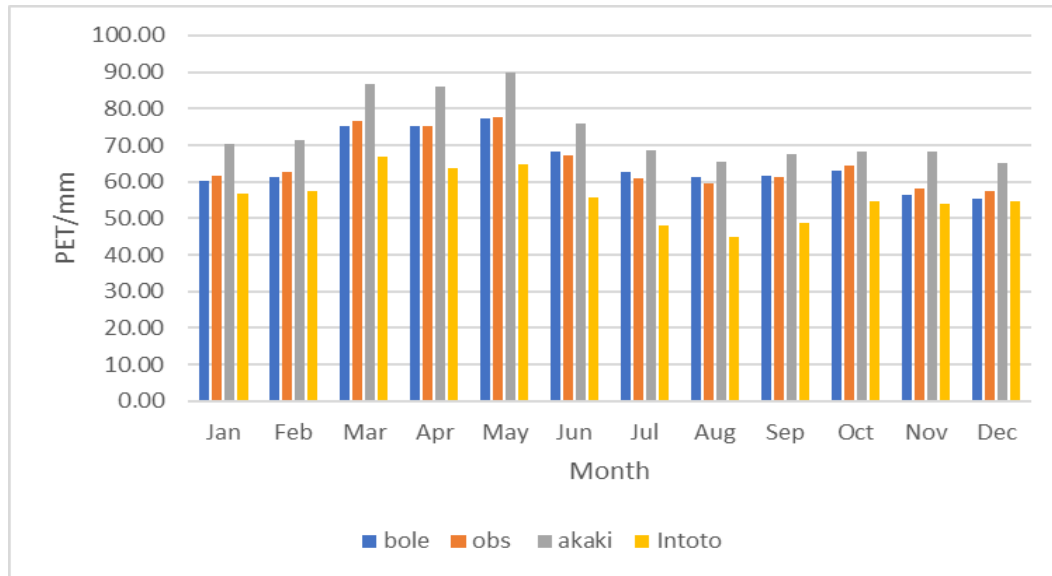


Figure 15: Spatial variation PET in Addis Ababa city

Potential evapotranspiration of Addis Ababa city was varying from 244.44mm kiremt(summer) to 534.04 mm in bega (winter) and the average annual potential evapotranspiration of Addis Ababa was 778.48 mm. Monthly value has a range from 90.03 mm and 44.8 mm as the minimum and maximum annual PET respectively. Akaki station records the highest values throughout the year whereas Entoto station has lowest values than other station.

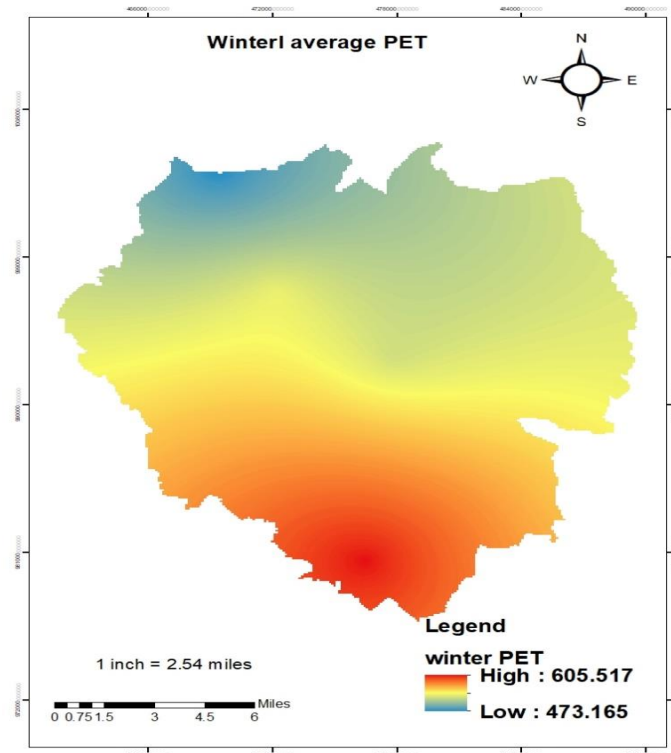
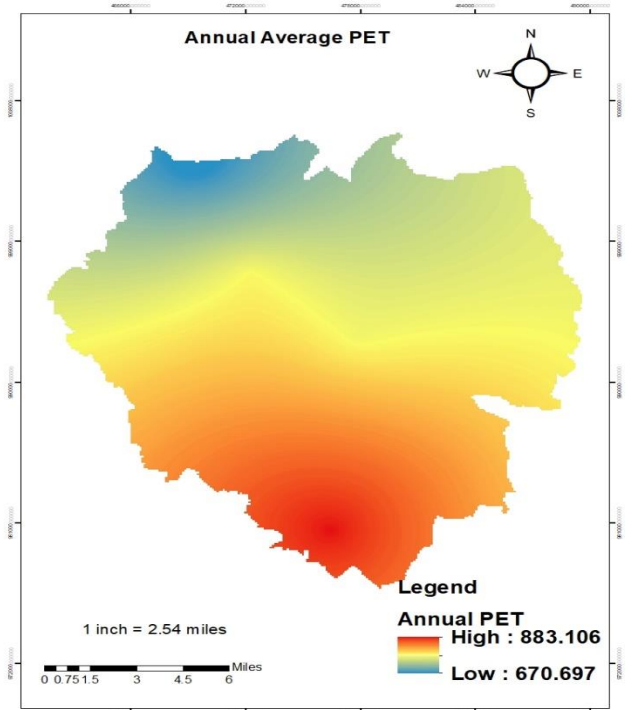
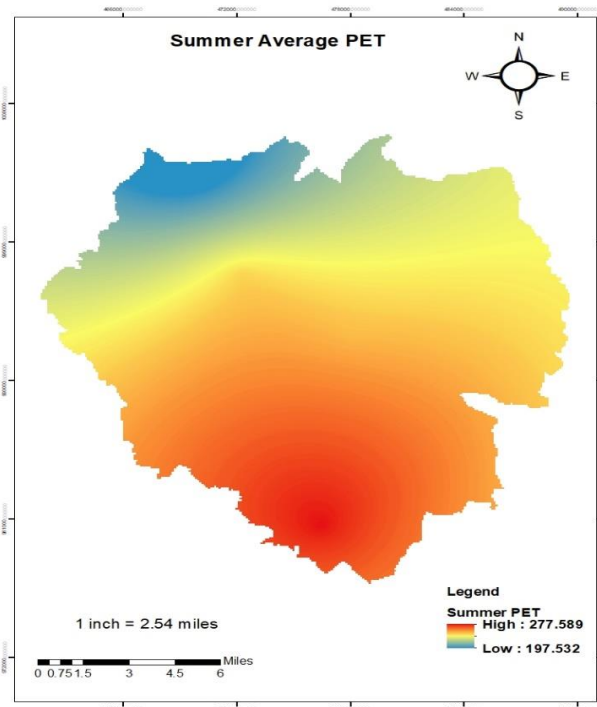


Figure 16: Seasonal and annual PET map of Addis Ababa

Wind speed

Wind speed control the rate and amount of evapotranspiration of a particular area. Spatial distribution of wind speed was prepare using Kriging spatial interpolation method on Arc GIS software. In Addis Ababa city average speed of wind speed has vary from 2.9 m/s, on Jun and 2 m/s on April Month and the annual range of wind speed are 2.4.

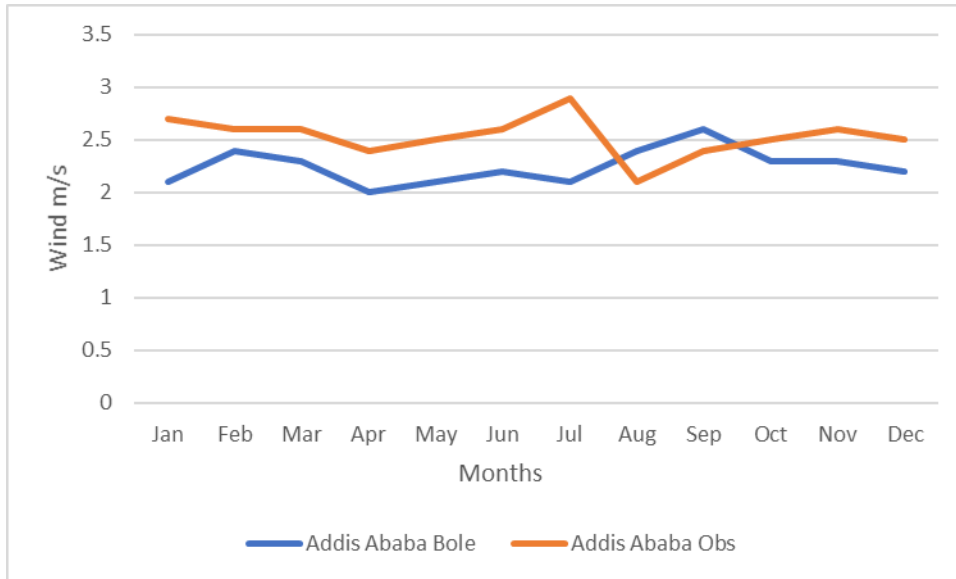


Figure 17: Monthly average wind speed value of stations in Addis Ababa area

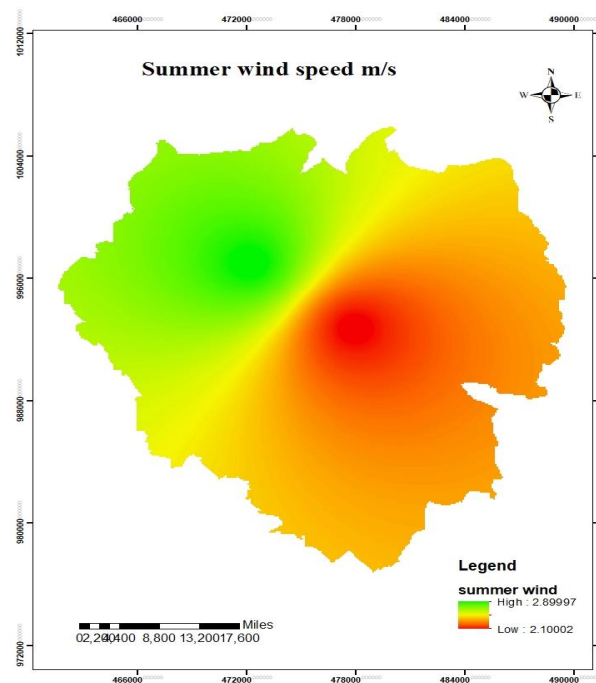
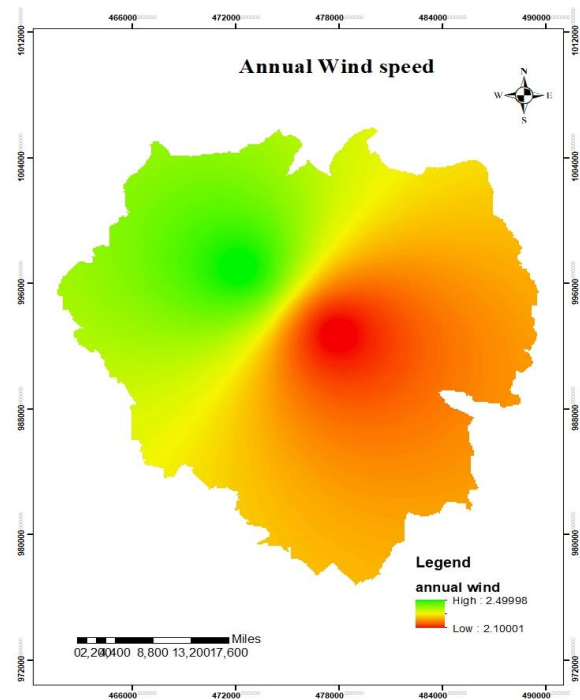
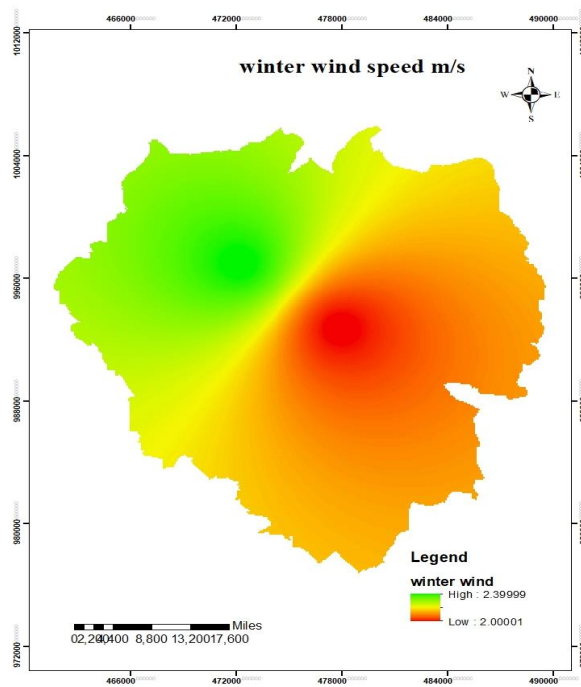


Figure 18: Seasonal and annual average wind speed map of Addis Ababa area

Topography

Topographic map was collected by downloading DEM from USGS web page. The Digital Elevation Model (DEM) 30*30m resolution was obtain from ASTER. The lowest point in the study area is located on the south and south eastern part of the study area with the elevation and higher elevation also located in northern parts of Addis Ababa with the elevation of 3230.

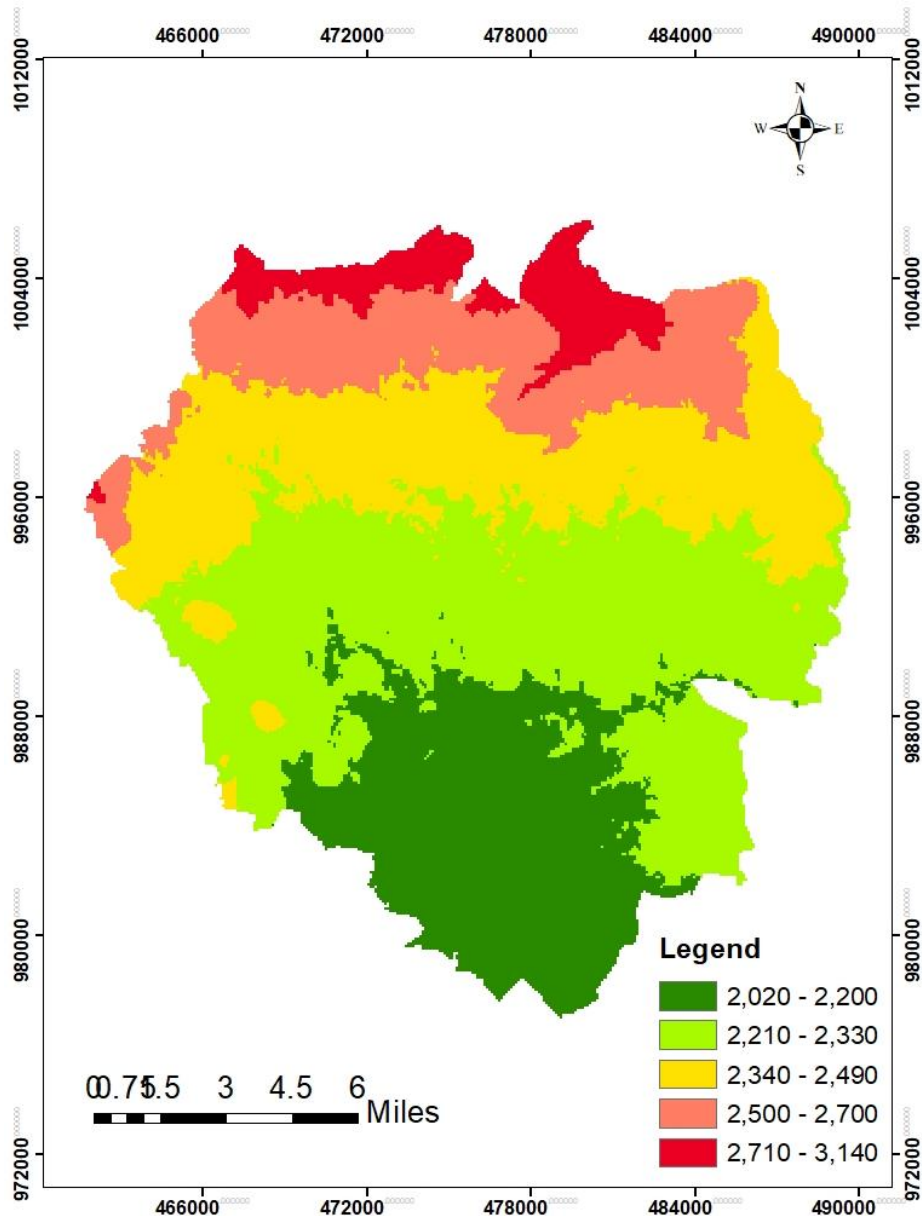


Figure 19: Topographic/elevation map of Addis Ababa

Slope

Slope is essential parameter to understand the hydrological system of the given area. Steep slope part of the area is considering as recharge areas where as gentle slope is also known as discharge areas. Slope has a direct relationship with topography setup of an area. Slope map of the study area was prepared from DEM (30m*30m) by using ArcGIS 10.7. As we can see Figure 20 its gradient is ranging from 0 to 76. The vale 0 stands for gentle slope and 74 is represent steep slope. Addis Ababa area has gentle slope in a wide area and it is suitable/ preferable for settelment. High slope/steep slope is sited in northern part of Addis Ababa around Entoto area it is suitable for forest and also highly suitable for ground water recharge.

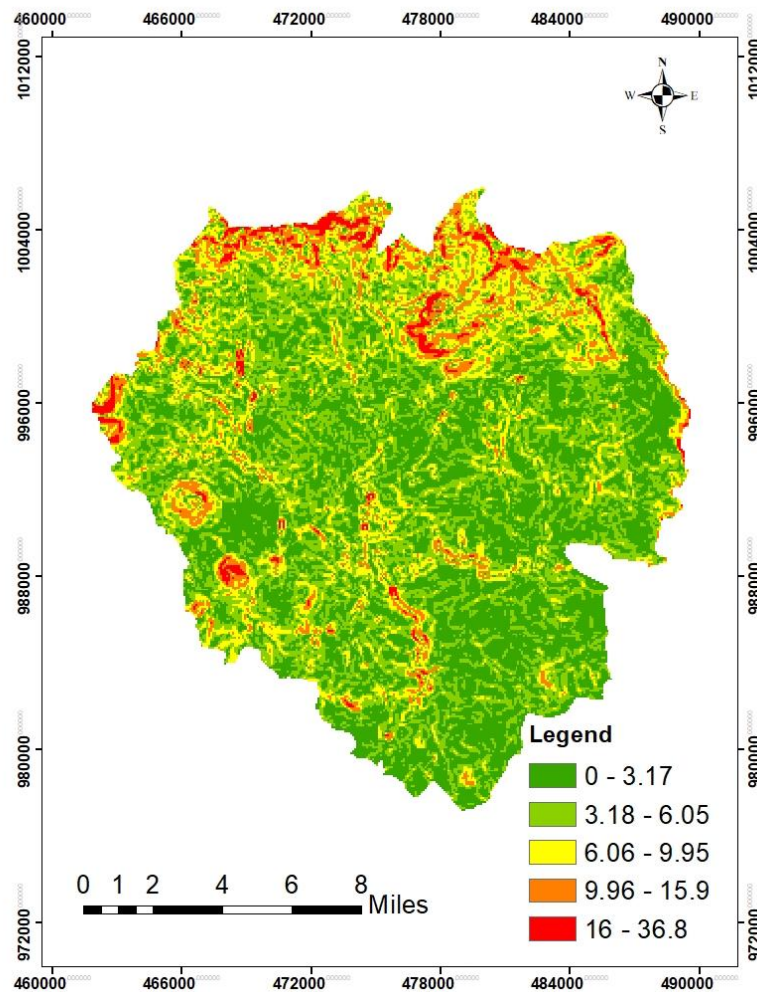


Figure 20 Slope map

Land use Land cover

Land use is one of the most important parameters that affects water balance components such as runoff, evapotranspiration and recharge. Land use and land cover maps of Addis Ababa were preparing by the year 2000 and 2020 in order to show the conversion rate of different land use class in the study period in Addis Ababa city.

Before land use land cover classification, remotely sensed land sat 8 data was downloading from USGS web page and then pre-processing techniques were employed like sub-setting the study area, raster band combinations in Red Green-Blue order, image enhancement techniques were employed to improve the images or optimize the image for analyze in the visual system. Land use land cover map for 2000 and 2020 were produced by supervised classification using the maximum likelihood classifier. The images were interpreted or classified into five land use classes, namely built-up, forest, bare land, grass land and crop land, (Table 4).

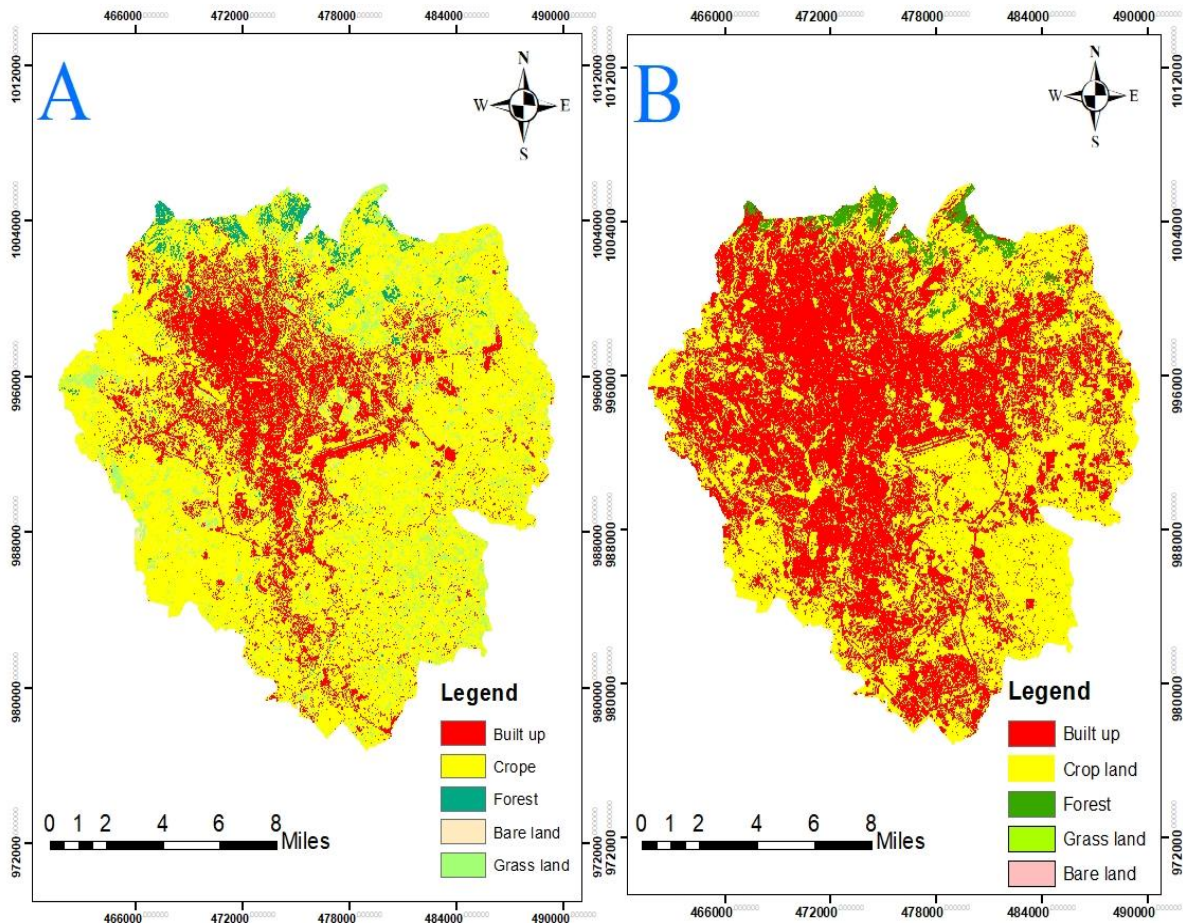


Figure 21: Land use Land cover map of Addis Ababa for the year 2000(A) and 2020(B)

In Addis Ababa city there are different land use types by 2020. In terms of areal coverage form the total area Addis Ababa city which is 511km² (51,100 hector) builtup area cover the larges area it is 347.643km² or 68 %. and crop land use type also has 103.815 km² or 20.31 % of the total area of Addis Ababa. Forest, grass and bareland covers 4.32, 7.34 and 0.03 km² respectively.

Soil data

The other most important thing that control the ground water recharge process is soil structure of the study area. Soil data for Addis Ababa city was obtaining form ministry of agriculture and verify the data with FAO world digital soil maps. Based on the collected data Addis Ababa area soil's texture has classified in to three this soil classification was categorized accordingly the United States Department of Agriculture (USDA) textural classification. Therefore, Addis Ababa city soil can be categorized as loam, clay and loam clay (Figure 23). The WetSpass model needs soil data both in map format and parametric table format for recognition of soil and other biophysical character. Soil map was prepared similar to the other model input maps. Therefore, it had had cell size 90 *90 and 311 and 324 column and row respectively and finally the map was converted in to digital numbers by using Arc GIS conversion tool raster to ASCII.

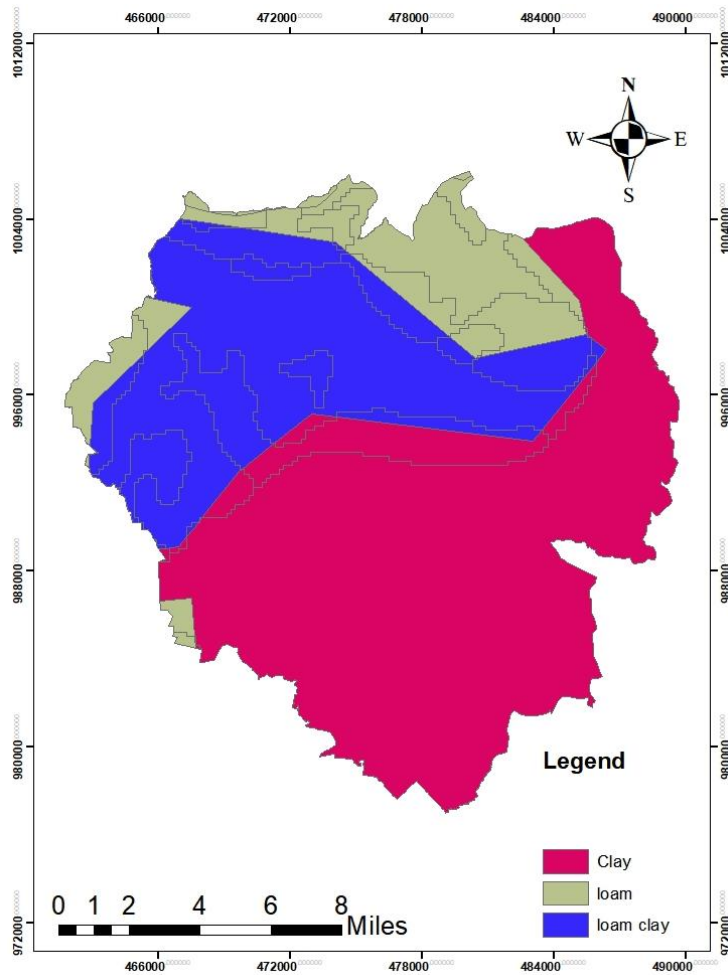


Figure 22 Soil map of the study are groundwater depth (source: <http://www.fao.org/home/en/>)

Ground water level data

Groundwater level map is a vital to estimate groundwater recharge. Addis Ababa city has more than 3000 boreholes for potable water use purpose. For this study 182 sample borehole data was taking and the data were collected from ministry of water and irrigation, Oromia water works supervision and design and Addis Ababa water supply and sanitation authority. These data were presented in point data format and it need to convert in the map on using ArcGIS Kriging algorithm. Borehole depth in Addis Ababa is varying from 96.6 to 448.9 in southern parts of Addis Ababa has relatively shallow wells whereas increasing the depth in central and northern parts of the city.

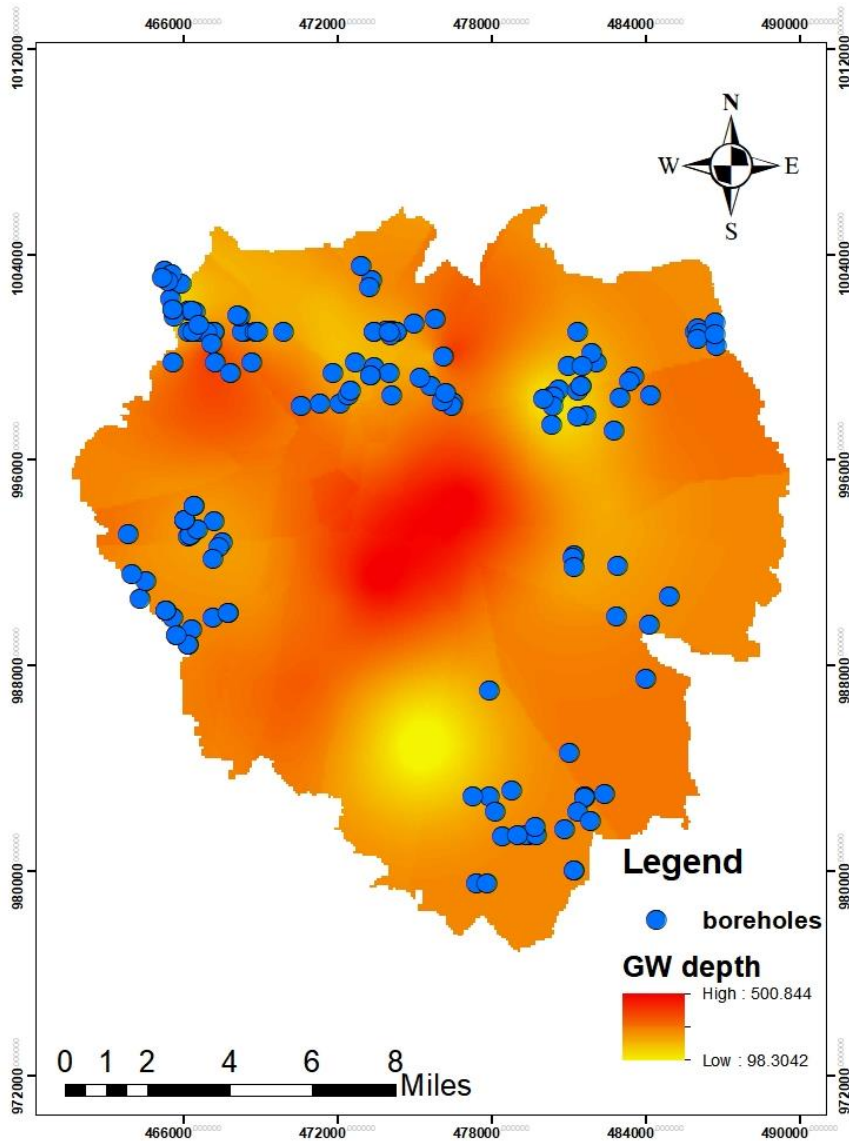


Figure 23 Ground water depth variation in the study area

3.6 Parametric table/Look up tables

WetSpas model require two kinds input data in order to run the module successfully. In addition to grid map, it requires parametric table include number of rainy days, land use and land cover and soil parameter that are modified from the WetSpas user guide and they are attaching as appendix. All parameter table were prepared in ASCII table format and in table file format (TBL).

CHAPTER FOUR

4. Result and discussion

Accuracy assessment result

Accuracy assessment was conducted by create confessional matrix between ground truth and map classified data. Ground truth points were collected using Google map and map data was used the classified map of 2020 to assessing land class on ground will or will not assigned properly on classified map. The classified map data versus the reference data were used to assess the classification accuracy by creating matrix. Afterwards, overall accuracy, user's and producer's accuracies and the kappa statistic were then derived from the error matrices (Biro et al., 2013)

Table 3: Accuracy assessment result

Class value	Built up	Crop	Forest	Grass	Bareland	Total	Accuracy
Built up	109	0	1	0	1	111	0.98
Crop	0	9	0	1	0	10	0.9
Forest	0	0	10	0	0	10	1
Grass	0	0	0	10	0	10	1
Bareland	1	1	0	0	34	36	0.94
Total	110	10	11	11	35	177	0
Accuracy	0.99	0.9	0.9	0.9	0.97	0	0.97

The overall accuracy user accuracy and producer accuracy has calculated below. Diagonals the shaded result is classified correctly according to table 3 data Off-diagonals were misclassified.

$$\text{Overall accuracy} = \frac{\text{Total number of correctly classified pixels (diagonal)}}{\text{Total number of reference pixel}} * 100$$

$$172/177 * 100 = 97.2 \%$$

$$\text{Ratio} = 0.972$$

The User's Accuracy is the accuracy from the point of view of a map user, not the map maker. the User's accuracy essentially tells us how often the class on the map will actually be present on the ground. This is referred to as reliability. The User's Accuracy is complemented of the Commission Error, User's Accuracy = 100%-Commission Error. The User's Accuracy is calculating by taking the total number of correct classifications for a particular class and dividing it by the row total. As per the result of user accuracy for this case under forest and grass land class 100% and built up, crop land and bareland has acceptable result.

$$\text{User accuracy} = \frac{\text{Total number of correctly classified pixels in each category} / * 100}{\text{Total number of classified pixels in that category (the row total)}}$$

Table 4: User accuracy

<i>land use classes</i>	<i>correctly classified pixel for each land use categories</i>	<i>User Accuracy</i>
<i>builtup</i>	109/111 * 100	98
<i>crop</i>	9/10 * 100	90
<i>forest</i>	10/10 * 100	100
<i>grass land</i>	10/10 * 100	100
<i>bareland</i>	34/36 * 100	94

Producer's Accuracy is the map accuracy from the point of view of the map maker (the producer). This is how often are real features on the ground correctly shown on the classified map or the probability that a certain land cover of an area on the ground is classified as such. The Producer's Accuracy is complemented of the Omission Error, Producer's Accuracy = 100%-Omission Error. It is also the number of reference sites classified accurately divided by the total number of reference sites for that class. Based on table 5 producer accuracy result for all land use types had acceptable result.

$$\text{Producer accuracy} = \frac{\text{Total number of correctly classified pixels in each category} / * 100}{\text{Total number of reference pixels in that category (the column total)}}$$

Table 5: Producer accuracy

<i>land use classes</i>	<i>correctly classified pixel for each land use categories</i>	<i>producer Accuracy %</i>
<i>builtup</i>	$109/110 * 100$	99
<i>crop</i>	$9/10 * 100$	90
<i>forest</i>	$10/11 * 100$	90
<i>grass land</i>	$10/11 * 100$	90
<i>bareland</i>	$34/35 * 100$	97

Kappa coefficient reflects the difference between actual agreement and the agreement expected by chance kappa of 0.85 means there is 85% better agreement than by chance alone.

$$\text{Kappa coefficient} = \frac{(TS * TCS) - \sum (\text{column total} * \text{row total}) * 100}{TS^2 - \sum (\text{column total} * \text{row total})}$$

$$\frac{(125 * 113) - \sum ((110 * 112) + (10 * 10) + (11 * 10) + (11 * 10) + (35 * 36))100}{22500 - \sum ((110 * 112) + (10 * 10) + (11 * 10) + (11 * 10) + (35 * 36))}$$

$$\text{Kappa coefficient} = 87$$

Where

TS is total sample =125

TCs total corrected sample 113

4.1 Land use land cover change analyses

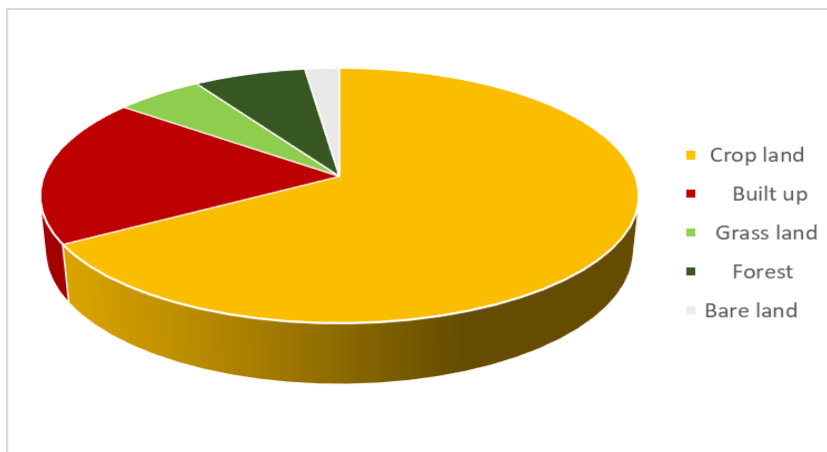
In the study area, land use land cover classes have changed significantly. Changes are normally quantified per area or percentages of each land use class. Therefore, the change detection statistics between 2000 and 2020 of the study area are presented in Table 5. Table 5 shows that the built-up area has changed significantly, from 96 km² or 18.79% in the year 2000 to 347.6 km² or 68 % in the year 2020. This is possibly due to the expansion of urbanization and development of infrastructure. This can be also seen in Figure 25 in which the red color (built up) areas have increased drastically within the 20 years' interval. A large fraction of cultivated land, forest and bare land have changed into settlement areas. High urban expansion during the last couples of decades has led to a significantly increasing in the settlement areas while decreasing the crop area with a high

portion and bare land grass land and forest also changed in to settelment with a minimum amount relatively to others.

Table 6: Areal variation of different land use type by 2000 and 2020

Year	2000		2020	
Land use type	Area (km ²)	percent (%)	area (km2)	percent %
Crop land	340	66.54	124.8	24.4
Grass land	28	5.48	16.5	3.2
Built up	96	18.79	347.6	68
Forest	36	7	22.07	4.3
Bare land	11	2.15	0.17	0.034
Total area	511		511	

The major changes within 20 years' interval shown by the two different land use land cover maps of the study area see (Fig 24) are forest, bare land, grass land and crop land are together decreased from 415 km² in 2000 to 163.54 km² in 2020. Due to urbanization, population growth the percentage of built-up land has increased in the region from 96 km² in 2000 to 347.6 km² in 2020.



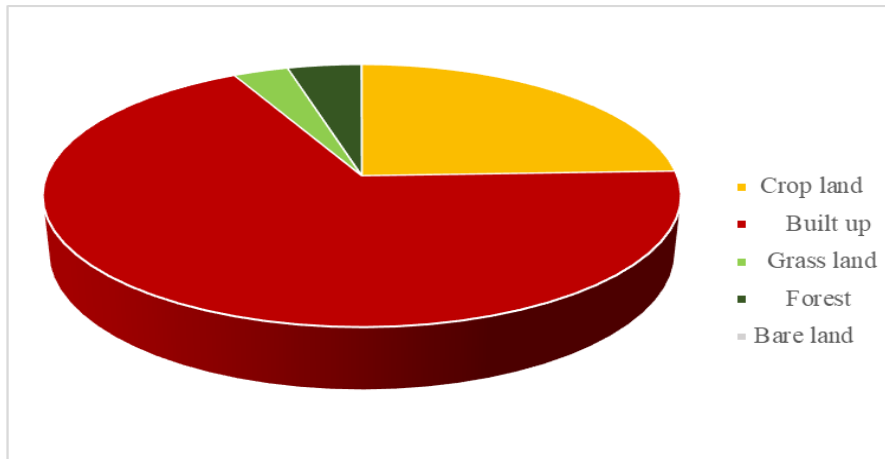


Figure 24: The comparison of areas occupied by different land use class by the years 2000 and 2020 respectively

The land use land cover change map indicated that the settlement land use class has extremely increasing see figure 25 how much the red color (built up) area is changed in Addis Ababa city within 20-year interval.

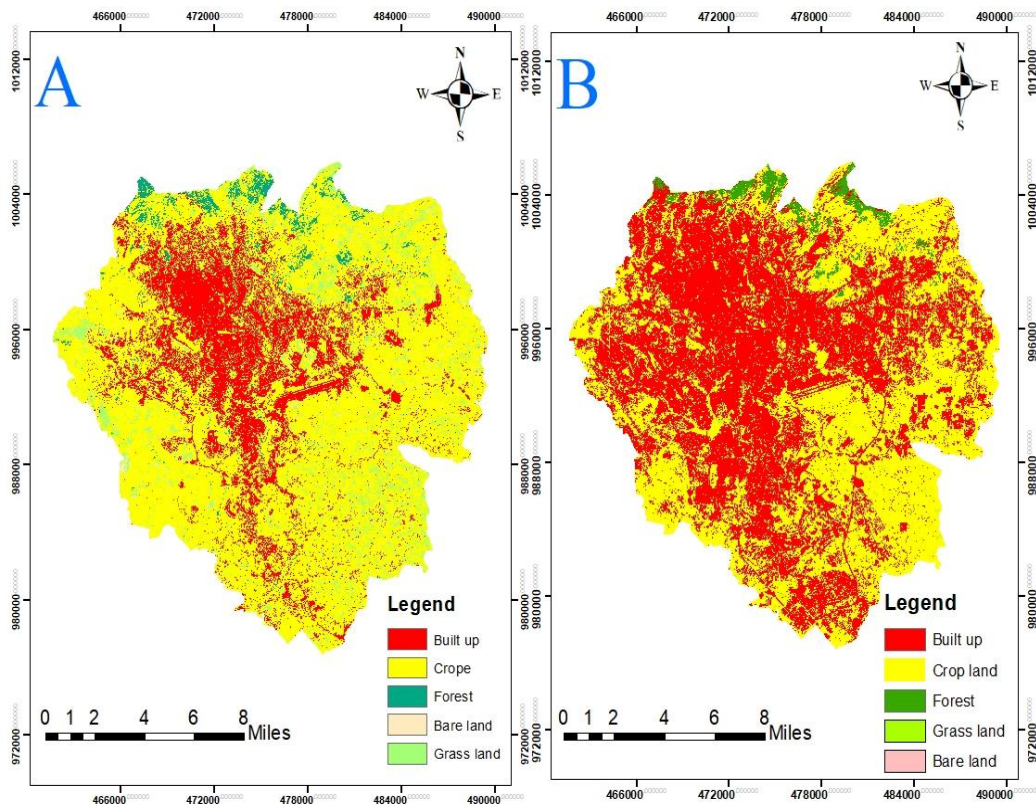
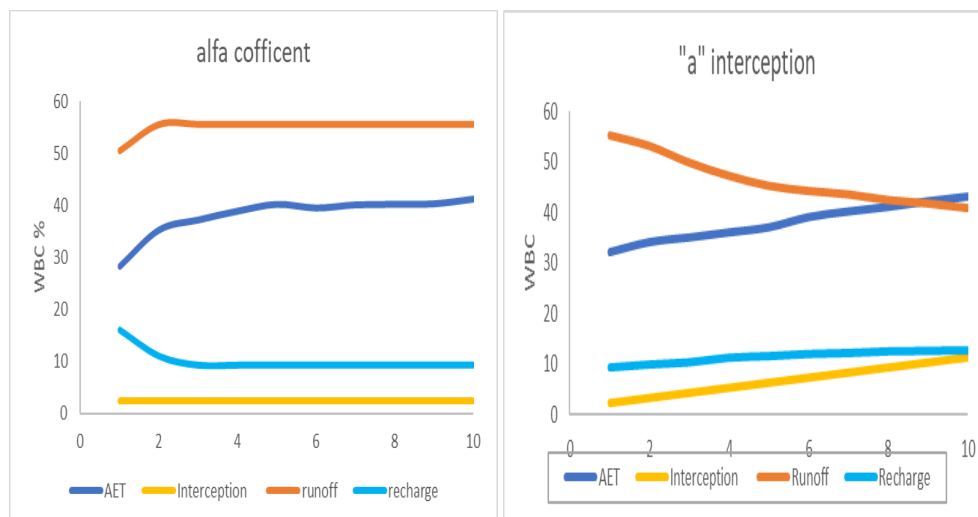


Figure 25: Land use Land cover change of Addis Ababa for the year 2000(A) and 2020 (B)

4.2. WetSpass model analysis

4.2.1. Sensitivity Analysis

In order to use the parameters of WetSpass monthly model, the sensitivity of all parameters and input variables should be assessed. This is used to understand the model response in terms of the variation of parameters. A sensitivity analysis was carried out for the monthly model. To conduct the sensitivity analysis of the parameters, the average value of all meteorological data in WetSpass -M model input data set should be prepared. The other biophysical data puts as it is. In order to assess the parameter sensitivity (“a” interception, alfa coefficient, Lp coefficient etc.) the reasonable range has been assigned. In every run, the values of parameter were increased by 1% of the range compared to the previous run. All input variables and other parameters were kept the same except for the target parameters. To perform the sensitivity of different water balance component due to the variation of input variable, the target variable was increased by 25% to 100% and the other variable kept constant. The result of sensitivity of the different water balance components to variation in parameters and input variables are shown and presented in (Figure 26 and Figure 27). The interception coefficient, alfa coefficient, and Lp coefficient parameter is relatively sensitive to the water balance components. The interception value with respect to changing the value of the parameters shows that generally low sensitivity in comparison with the other water balance components. Whereas, recharge and runoff responds to variations in a large number of factors probably because it is estimated as the residual of the water balance. (K. Abdollahi et al., 2012)



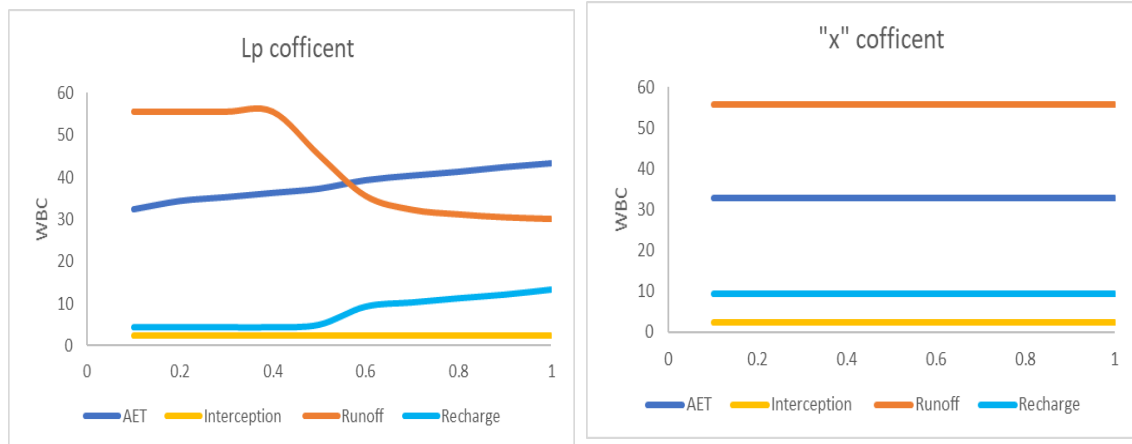
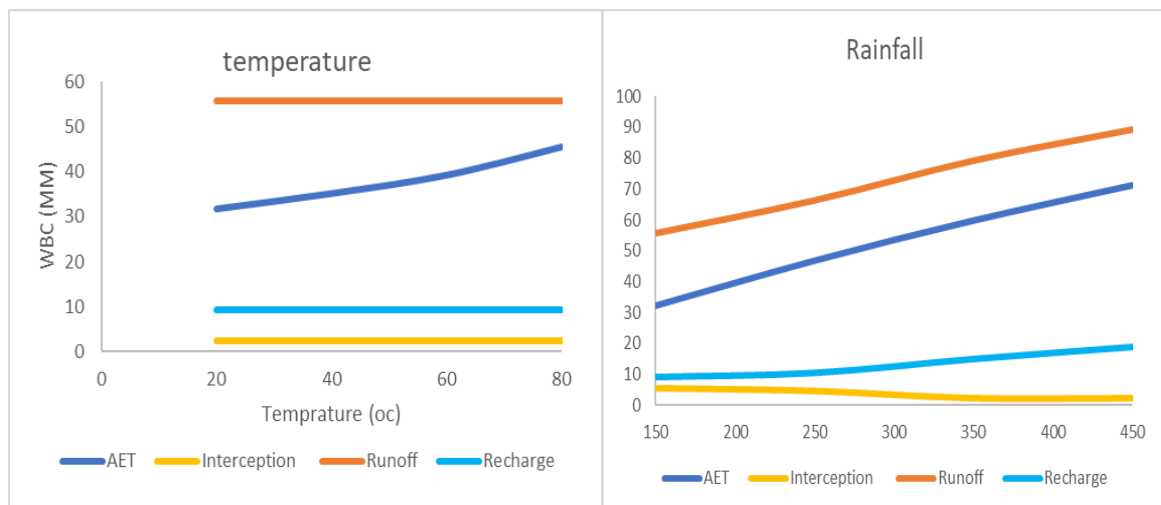


Figure 26: Sensitivity of water balance component with changing different model parameters; a) Alpha coefficient b) Interception coefficient c) Lp coefficient d) "X" coefficient

Input variables sensitivity analysis shows that the potential evapotranspiration (pet) and rainfall variables are the most critical input parameter. Whereas, the temperature input variables are less sensitive to the model result (water balance components).



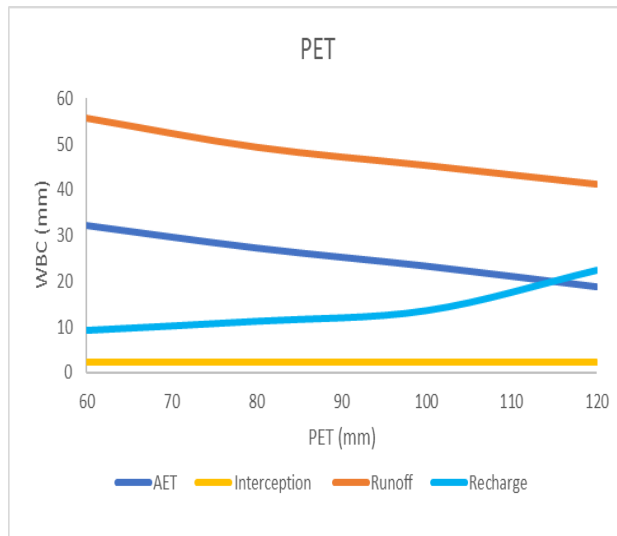


Figure 27: Sensitivity of water balance component with changing different input variables

Model simulation result for 2000

Mean annual recharge was 160.99 mm and was estimated to represent about 14.39% of the mean annual precipitation. About 88% of the recharge took place during the kiremt/summer (Jun to September) season, while the remaining 12% occurred during the dry season (October to May).

Table 7: Simulated of WBC result 2000

Description	AET	Runoff	Interception	Recharge
Simulated value	376.7607895	546.4605998	34.01317181	160.9931266
Simulated WBC in percent %	33.69	48.868	3.042	14.397

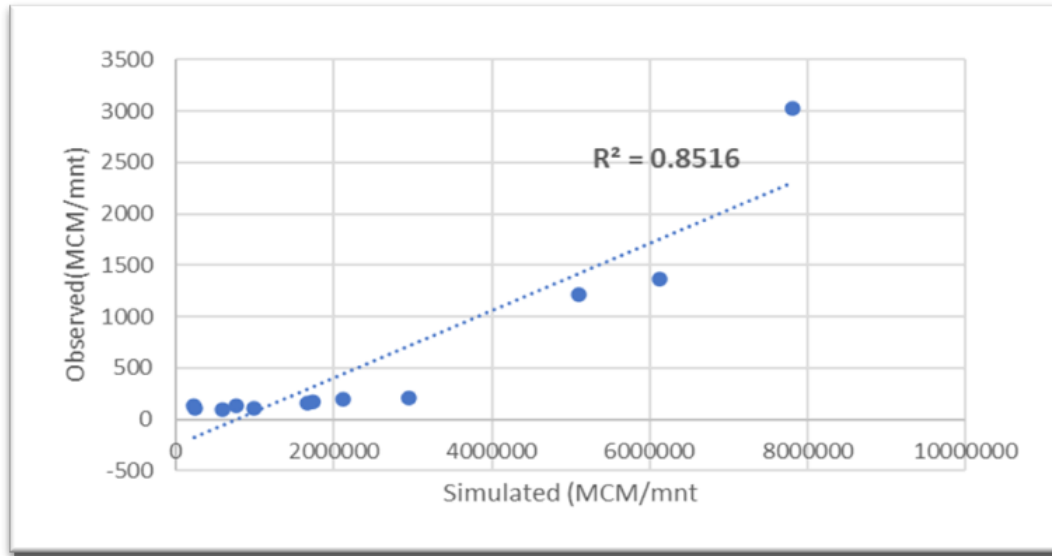


Figure 28: Model calibration on 2000

Model simulation result for 2020

According to WetSpss model simulation in 2020 was indicated a significant difference on water balance components due to Land use land cover changes. The mean annual recharge was decline to 103.3 mm it holds 9.267 % of the total mean annual rainfall (1115.7mm) of Addis Ababa. The rest 90.7 % of the precipitation lost from the area by Evapotranspiration and runoff. About 88 % of the recharge took place during the kiremt/summer season (Jun to September), while the remaining 12 % occurred during the dry season (October to May). Runoff value was also increasing by 2020 simulation from 546 mm (48.8%) 2000 to 620.26 mm (55.64%) in 2020 this indicated that the expansion of built up in the study area. Evapotranspiration also reduces from 376.76 (33.9 %) 2000 to 327 (32.76%) by 2020.

Table 8: Simulated WBC in Addis Ababa 2020

Description	AET	Runoff	Interception	Recharge	total
Simulated WBC	365.227	620.26	25.89	103.3	1115.73
Percent of each WBC	32.76%	55.64%	2.32%	9.267%	100%

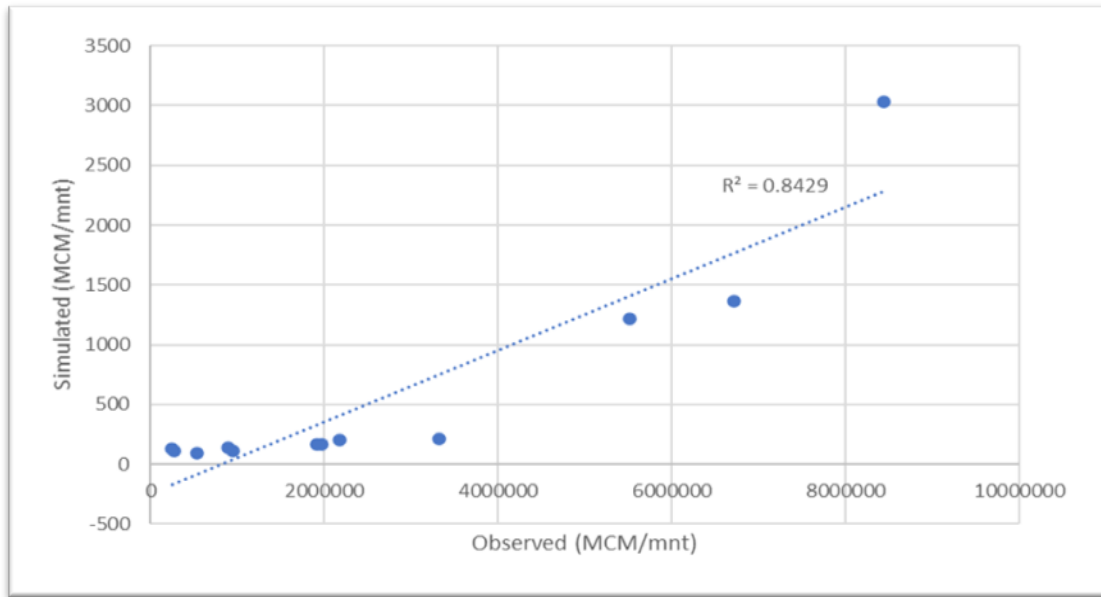


Figure 29: Model calibration for the year 2020

The differences of simulated water balance components in the year 2000 and 2020 are presented below Fig.30. According to the model result runoff has increased while evapotranspiration and recharge has decreasing between 2000 and 2020.

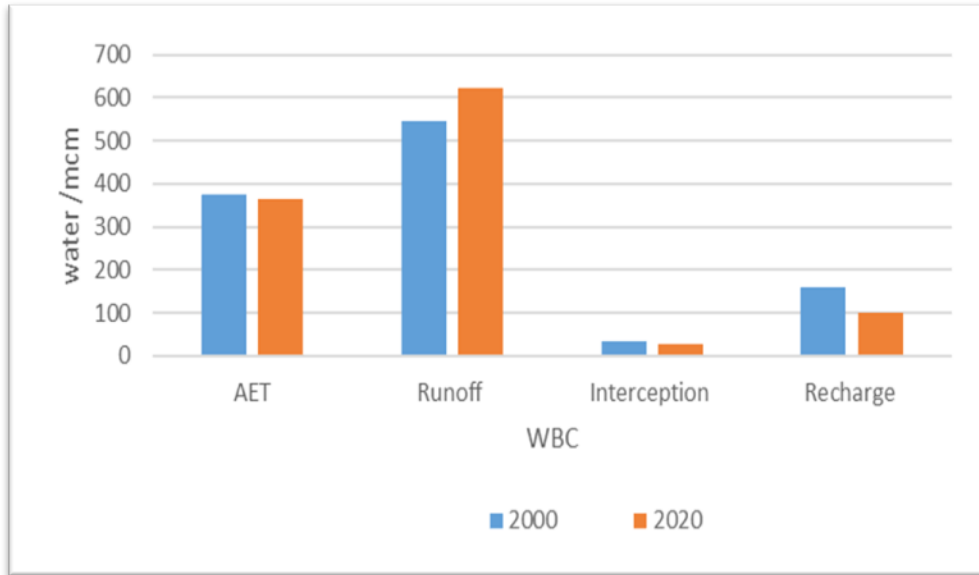


Figure 30 The difference of simulated water balance components between the year 2000 and 2020 Addis Ababa

4.2.3 Output of the model

The major output of this model is monthly water balance components of a given area. The model was simulated monthly water balance components which are; actual evapotranspiration (AET), surface runoff and recharge. The output of the model is in grid map format and water balance has computed in each pixel.

Actual evapotranspiration (AET)

The model can calculate the actual evapotranspiration by taking in to account the evaporation from open water body, transpirations through vegetated cover, interception loss by vegetation and evaporation from bare soil. Actual evapotranspiration is one of the elements that can determine recharge in the study area. As the model output shows maximum and minimum evapotranspiration is 64.66 and 1.07mm and it accounted 32.76% of annual rainfalls that Addis Ababa had received.

Land use Land cover is one of the most controlling factors for Evapotranspiration. The model simulated map shows that the evapotranspiration value in vegetation area particularly around Entoto area is very high. Crop land also relatively high evapotranspiration. In Addis Ababa area major land use class is settlement/imperious land

this type of land class also promoting runoff before infiltration or evapotranspiration activities has occurring.

Runoff

One of the outputs of WetSpass-M model is monthly surface runoff (SV). The amount of runoff can be determined by different elements like vegetation type, soil texture, slope, land use land cover and other meteorological characteristics of the study area.

The model result shows that the annual value of runoff in Addis Ababa is vary in range from 3.40 mm to 174.217 mm as a minimum and maximum value respectively, with a mean of 88.809.

The land use and land cover class which are Bare land and settlement are hosted high runoff rate annually in Addis Ababa area in contrary to this natural forest, crop land and grassland has low runoff. This is due to low runoff coefficient value of the listed land cover types. The slope value of the topography also significantly affects the runoff; it has a direct relationship with rate of surface runoff.

Groundwater recharge

Groundwater recharge is depending on various elements like slope, land use class soil texture and groundwater level (Kuisi et al., 2013). Today different kinds of model are available to estimate recharge in a given area. For this study, the WetSpass model has chosen to estimates monthly long-term spatiotemporal distribution of groundwater recharge in Addis Ababa area. This model can simulate recharge by computing water balance by subtraction evapotranspiration and runoff from the total rainfall. The model has computed monthly groundwater recharge based on the different input variables. Recharge is estimated as the remaining of the water balance components from precipitation.

Based on the WetSpass result, the estimated annual recharge of Addis Ababa by 2020 is 103.3. But it is varying from month to month from 0.094 to 35.529 mm as a minimum and maximum value respectively. Annual mean recharge represents 9.267 % of the total annual rainfall. About 88% of the total annual groundwater recharge of the study area is occurred in the kiremt/summer season (Jun to September) season, and the remaining 13% groundwater recharge is percolate in dry (October to May) season. This temporal variation is made due to the variation of different climatological and biophysical input parameters,

average rainfall, permeability of local geology and soil type. There is high duration, and amount of precipitation distribution and high soil moisture in the kiremt/summer season which accelerated groundwater recharge.

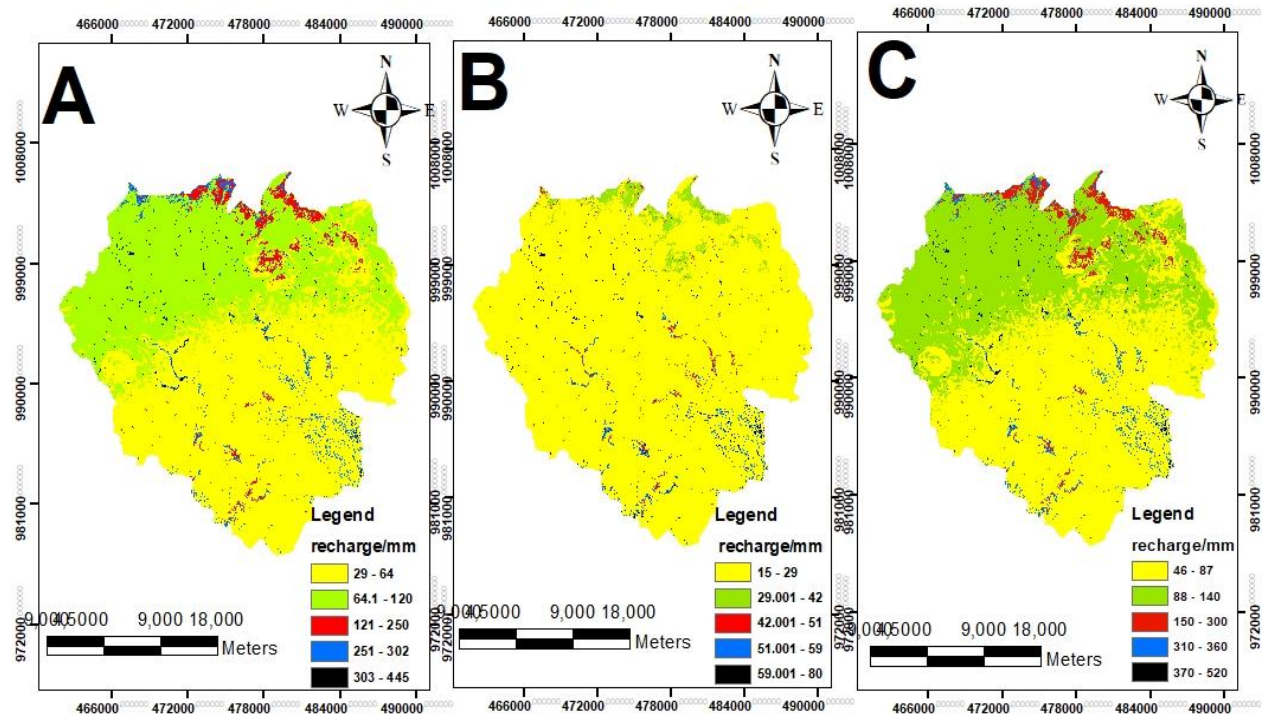


Figure 31: Recharge maps of Addis Ababa; (A) kiremt(summer) recharge (B) bega(winter) recharge (C) annual recharge

4.3. The implication of land use land cover change on ground water recharge

Different land use type has different recharge capacity as shown figure 32 forest area has high recharge capacity than the others due to forest makes reduces recession period of the runoff water and also it can infiltrate in to the root zoon by percolate in to groundwater and keeping soil evaporation by regulating local temperature. Whereas, builtup land use type has low recharge capacity due to high ration of impermeable surface. Impermeable surface also promoted runoff before the water percolated or infiltrated to the ground water.

According to spatial analysis in Addis Ababa area built up land use class increasing from 96 km² (18.79%) to 347.6 km² (68 %) of the total area of Addis Ababa city. This land use land cover change has a negative implication on ground water recharge. The WetSpass model output also indicated ground water recharge estimation has decline from 160.9 mm to 103.3 mm. Therefore, there is the implication of land use land cover change on ground water recharge redaction.

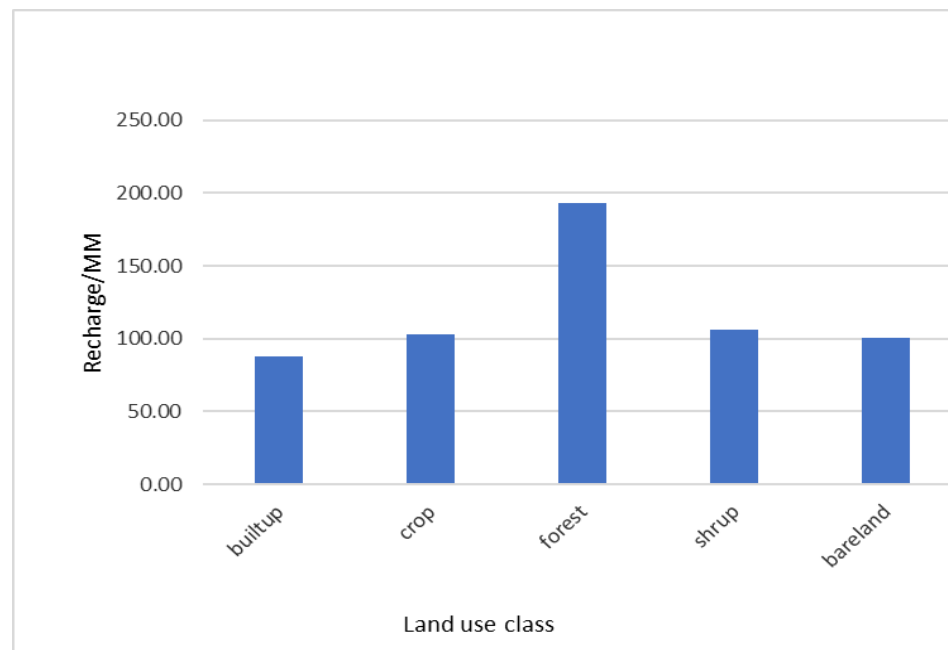


Figure 32: Spatial variation of recharge per each land use class in Addis Ababa area

Discussion

This study was aimed to assessing the effects of land use land cover change occurred with the last 20 years interval on ground water recharge by estimating long-term seasonal and annual average groundwater recharge value by using WetSpass model for Addis Ababa city. The demographic, social and policy issues are among the major causes for Land use land cover changes of a given area. According to Arsiso et al., (2018b) Addis Ababa population had exhibited significant increase over the past two decades. The city has been undergoing rapid rate of urbanization triggered by rural-urban migration and socio-economic development. The city's population had tripled between 1961 and 1984 and almost doubled between 1984 and 2008 (CSA, 2012). Such an increment in population requires additional space for settlement and construction of auxiliary services and infrastructure. In addition to the literatures, eye witnesses of Addis Ababa city residents

confirm that Addis Ababa city has been expanded dramatically. Now in all directions crop land, grass land and forest areas have been converted into the built-up area. This trend was increasing particularly for the past 20 years due to population growth and urbanization.

According to Scales, (2018) there is a negative correlation between impervious percentages and groundwater recharge whereas, the impervious percentage has positively correlated with surface runoff. Vegetation, and grass land has a positive correlation with ground water recharge. On the contrary, vegetation, and grass lands have a negative correlation with runoff whereas positive relationship in Evapotranspiration. Therefore, based on the analysis of land use land cover change detection indicated that rapidly increasing the built-up area. This situation has a negative correlation with ground water recharge and it has a positive relation with run off and this is an implication of ground water recharge may decline in Addis Ababa city due to land use land cover change occurred within the study period.

Model results indicated that groundwater recharge distribution in Addis Ababa city varies from place to place. The northern part receives the highest recharge because of the area has been covered by forest and there is relatively high annual rainfall and low temperature. The north western part also has better recharge volume due to soil type and meteorological advancement facilitate to have better recharge. Central and southern parts of Addis Ababa receive lower recharge due to impermeable land cover and low annual rainfall high temperature are the responsible factors. The amount of runoff is higher than recharge in the study area due to impermeable land use ratio being higher as a result of built-up area expanded time to time. Therefore, the volume of runoff increasing means the volume of recharge is decreasing.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1 Conclusion

Water resource is a critical element to sustain life and it should be investigating and understand the hydrological environment for planning, managing and proper utilization of water resource. Now a days. Surface water use is decreasing due to different reasons like contamination and pollution and the water resource concentration it makes give attention for groundwater utilization. So as the available resource should be investigated and managing properly is one of the current concerns. There are different physical and empirical models to estimating ground water volume and to understand water balance components of a given area.

This study was aimed to investigate the land use land cover changes that occurred for the last two decades and its impact on ground water recharge on Addis Ababa city. Land use land cover classification has been carried out for the year 2000 and 2020 using Arc GIS to understand the conversion rate among different land use class. One of the spatially distributed physical models is WetSpass model. The WetSpass-M model has been simulated two times by 2000 and 2020 using similar input data but in the case of land use land cover data was taken the respective years in order to identify the impact of it. Therefore, WetSpass model has been run successfully in Addis Ababa area to know the variation of recharge at different study time. According to WetSpass simulation in the year 2020 was shown a significant difference from 2000-year simulation. Regarding to the year 2020 model output mean annual recharge was 103.3 mm it comprises 9.26 % of the total mean annual rainfall (1115.7 mm) of Addis Ababa. The rest 91 % the precipitation lost from the area by Evapotranspiration and runoff. About 88% of the recharge taking place in kiremt/summer season, while the remaining 12% percolated during bega/winter season. For the year 2000 simulation recharge was 161mm. there is 57.7 mm difference between the two-time simulation. The major finding in this study was the declining of recharge in Addis Ababa area due to land use land cover change. In general, the module result supported the impact of land use land cover change on water balance components. Runoff value was increasing form 546 mm (48.8%) in the case of 2000 simulation to 620.26 mm

(55.64%) for the year 2020 simulation. This indicated that the expansion of built-up land use in the study area makes increasing the volume of runoff. Evapotranspiration also decreasing from 376.76 (33.69 %) for the 2000 simulation to 365.227 (32.76%) in the 2020. According to spatial analysis in Addis Ababa area built up land use class increasing from 18.79 % to 68 % of the total area of Addis Ababa city. The WetSpass model output also indicated ground water recharge estimation has decline from 160.9 mm to 103.3 mm. Among the different land use class built up land use class has lower recharging capacity whereas forest has higher recharging capacity than any other land use class. Therefore, it can be summarized land use land cover change has a negative impact on ground water recharge in Addis Ababa city and ground water recharge has been decline rapidly.

5.2 Recommendation

The main finding of this study considering as the initial investigation on the effect of land use land cover change on groundwater recharge of Addis Ababa. Based on WetSpass model output indicated ground water recharge has declining. Land use land cover is the responsible factor for the redaction of recharge.

- ✚ This study will be an input for further investigation who are engage in the water resources studies.
- ✚ The land use land cover change assessment indicated that built up land use class increasing from 18.79 % to 68 % of the total area of Addis Ababa city in the year 2000 and 2020 respectively. Crop land, forest, grass land and bare land area has decreasing. The Assessment of land use land cover of the study area has effect on ground water recharge. Future land use activities in Addis Ababa city need to consider the local hydrology.
- ✚ Based on the WetSpass model result, in the Addis Ababa city ground water recharge has decline rapidly. Therefore, the government need to focus other sources for future water supply project rather than depending on ground water.
- ✚ The government need to be considered to increasing local ground water recharge by using different methods like artificial recharging or improve land use approach in order to increasing ground water volume.

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AppendixI. Monthly average temperature value of Different stations with in Addis Ababa

Month	Addis Ababa Bole	Addis Ababa Obs.	Akaki	Entoto
Jan	16.29	16.68	18.99	13.47
Feb	17.46	17.86	20.1	14.66
Mar	18.54	18.87	21	15.23
Apr	18.86	19	21.22	15
May	18.85	19	21.4	14.88
Jun	17.81	17.83	20	13.59
Jul	16.7	16.59	18.76	11.93
Aug	16.47	16.35	18.36	11.31
Sep	16.8	16.89	18.9	12.28
Oct	16.72	17.1	18.74	13.13
Nov	15.98	16.4	18.97	13.27
Dec	15.52	16	18.29	13.14

AppendixII. : Monthly average wind speed value of Different stations in Addis Ababa

month	Addis Ababa Bole	Addis Ababa Obs	average
Jan	2.1	2.7	2.4
Feb	2.4	2.6	2.5
Mar	2.3	2.6	2.45
Apr	2	2.4	2.2
May	2.1	2.5	2.3
Jun	2.2	2.6	2.4
Jul	2.1	2.9	2.5
Aug	2.4	2.1	2.25
Sep	2.6	2.4	2.5
Oct	2.3	2.5	2.4
Nov	2.3	2.6	2.45
Dec	2.2	2.5	2.35

AppendixIII. Observed total mean flow of Addis Ababa

Month	Akaki	Little Akaki	Total flow (MCM)
Jan	125.92	3.127	129.047
Feb	107.666	2.267	109.933
Mar	132.951	5	137.951
Apr	156.946	8.506	165.452
May	157.938	6.044	163.982
Jun	178.099	31.071	209.17
Jul	1183.687	179.501	1363.188
Aug	2409.299	619.3	3028.599
Sep	925.054	288.038	1213.092
Oct	170.559	31.547	202.106
Nov	99.803	10.101	109.904
Dec	88.054	7.94	95.994
max			3028.599
min			95.994

AppendixIV. Soil parameter

	SOIL	FIELD CAP AC	WILTIN GPNT	PAW	RESID UALW C	A1	EVAPOD EPH	TENSI ONHH T	P_F RAC _SU M	P_F RAC _WI N	Teta
1	Sand	0.12	0.05	0.07	0.02	0.51	0.05	0.07	0.09	0.01	0.136
2	loamy sand	0.15	0.07	0.08	0.035	0.47	0.05	0.09	0.09	0.01	0.176
3	sandy loam	0.21	0.09	0.12	0.041	0.44	0.05	0.15	0.09	0.01	0.266
4	silty loam	0.29	0.1	0.19	0.015	0.4	0.05	0.21	0.26	0.07	0.408
5	loam	0.25	0.12	0.13	0.027	0.37	0.05	0.11	0.15	0.02	0.33 3
6	silt	0.3	0.1	0.2	0.04	0.35	0.05	0.61	0.09	0.01	0.429
7	sandy clay	0.26	0.16	0.1	0.068	0.32	0.05	0.28	0.54	0.3	0.351
8	silty clay	0.36	0.19	0.17	0.04	0.29	0.05	0.33	0.62	0.41	0.563
9	clay loam	0.33	0.19	0.14	0.075	0.27	0.05	0.26	0.62	0.41	0.493
10	sandy clay	0.32	0.23	0.09	0.109	0.25	0.05	0.29	0.8	0.68	0.471
11	silty clay	0.43	0.27	0.16	0.056	0.23	0.05	0.34	0.84	0.75	0.754
12	clay	0.46	0.33	0.13	0.09	0.21	0.05	0.37	0.95	0.85	0.85 2

AppendexV. Rainy days

Code	Rainy Days
1	1
2	6
3	14
4	6
5	19
6	11
7	21
8	21
21	20
22	11
23	13
24	12
25	3
26	4
27	10
28	18
29	19
30	17
31	22
32	21
33	19
34	14
35	12
36	12
37	1
38	6
39	11
40	9
41	16
42	17
43	21
44	22
45	21
46	13
47	11
48	12

AppendexVI. Monthly average precipitation value of Different stations in Addis Ababa

Moth	Entoto	Akaki	Addis Ababa bole	Addis Ababa OBS	kotebe	yekatit23 school
Jan	8.61	9.6	7.75	12.59	14.9	9.36
Feb	16.5	19.96	16.07	18.87	18.67	16.14
Mar	48.09	49.78	50.28	54.56	38.34	49.48
Apri	70.29	76.84	77.24	74.24	83.35	63.2
May	93.09	74.69	84.28	90.08	79.83	88.24
Jun	171.53	111.71	102.56	141.13	141.6	147.54
Jul	343	228	218.21	273.47	267.89	282.51
Agu	33.53	227.48	253.11	297.7	296.12	311.07
Sep	145.39	118	127.23	187.79	134	191.22
Oct	28.94	12.14	21.28	28.68	24	29.35
Nov	14.915	8.32	5.47	11.84	7.79	17
Dec	8.855	4.55	8.6	9.705	10.29	5.83

AppendexVII. Model simulation for the year of 2000

Running at 6/9/2021 5:57:25 PM with the following parameters:

a:6 , alfa:6 , wSlope:0.4 , wLanduse:0.3 , wSoil:0.3 , x:0.3 , LP:0.1 , Mean intensity:4 , Beta:0.75 , Contribution:0.5

Time Step	AET	Runoff	Interception	Recharge	Qsurf[m ³ /mnt]	Qb[m ³ /mnt]
1	1.51717925	5.882325191	0.181457369	3.103932285	205881.3817	19399.57678
2	1.98698812	3.901176182	0.504544422	4.615215434	198305.5809	43394.77905
3	21.9302569	17.7674901	2.317596242	8.191953084	681353.8278	83745.79106
4	38.6323753	41.59278923	2.11636572	0.787385587	1660153.771	67730.50321
5	52.8902265	31.07681152	3.899779806	3.194929396	1585734.535	70766.18614
6	60.2553716	67.91448498	3.954005556	7.416008381	2852727.335	99424.69198
7	64.9108738	140.0480987	6.810202688	48.19513921	5757501.656	375788.1391
8	63.0458677	155.9426041	6.826050215	53.65236643	7185241.642	617168.3945
9	61.3761661	67.894808	5.377782291	17.01854423	4531890.772	569242.1973
10	6.92032476	8.078663361	1.117162864	6.98094949	1642320.449	470562.5823
11	1.91485055	3.544897437	0.498651284	4.226126119	616767.5451	379335.225
12	1.38030879	2.816450909	0.409573353	3.610576927	283606.0453	307067.5245

AppendixVIII. Model simulation for the year of 2020

Running at 6/9/2021 4:54:20 PM with the following parameters:

a:6 , alfa:6 , wSlope:0.4 , wLanduse:0.3 , wSoil:0.3 , x:0.3 , LP:0.1 , Mean intensity:4 , Beta:0.75 , Contribution:0.5

Time Step	AET	Runoff	Interception	Recharge	Qsurf[m ³ /mnt]	Qb[m ³ /mnt]
1	1.16166703	6.664814435	0.129229851	2.676785509	233268.5052	16729.90943
2	1.58261177	4.689093387	0.359392501	4.231497253	234098.8201	38994.2899
3	20.1289895	21.34286933	1.653824849	6.41706688	817230.0726	69352.38543
4	34.8947205	47.64078326	1.504381659	0.094780234	1912596.436	52606.66554
5	50.5041263	37.20058179	2.78696496	0.588934214	1875799.293	43135.83799
6	59.3427071	77.73597073	2.827922899	1.224135137	3283498.764	40002.7231
7	64.6600878	157.4333867	5.577159172	31.0562379	6495218.164	224103.5292
8	62.889869	174.2173946	5.714190851	35.52905995	8046174.261	390134.2716
9	61.3429287	79.05942907	3.880818269	6.050934608	5180932.296	330419.045
10	6.0992094	9.635171312	0.80971548	6.245110687	1891510.685	286846.2255
11	1.55037808	4.239996884	0.360652888	3.895352401	715853.0964	239480.6217
12	1.0704551	3.402527998	0.292628034	3.334223015	333844.4089	200449.3601

AppendixIX. Land use parameter table

Cod e	LUSE_TYPE	RUNO FF_VE G	VEG _AR EA	BA RE _A RE A	IMP _AR EA	OPE NW _AR EA	ROO T_D EPT H	LAI	MIN _ST OM	VEG_ HEIG HT	nMa ning	Land Facto r	Aerodyn Resistanc e
1	city center builds up	grass	0.2	0	0.8	0	0.3	2	100	0.12	0.03	0.66 7	212.0135
2	build up	grass	0.5	0	0.5	0	0.3	2	100	0.12	0.04	0.5	212.0135
3	industry	grass	0.4	0	0.6	0	0.3	2	100	0.12	0.035	0.571	212.0135
4	infrastructur e	grass	0.6	0.1	0.3	0	0.3	2	100	0.12	0.04	0.5	212.0135
5	sea harbor	grass	0.6	0.1	0.3	0	0.3	2	100	0.12	0.045	0.444	212.0135
6	airport	grass	0.2	0	0.8	0	0.3	2	100	0.12	0.03	0.667	212.0135
7	excavation	bare soil	0	1	0	0	0.05	0	110	0.00 1	0.09	0.22 2	426.6676
10	open build up	grass	0.6	0.1	0.3	0	0.3	2	100	0.12	0.045	0.444	212.0135
21	agriculture	crop	0.8	0.2	0	0	0.4	4	180	0.6	0.03 7	0.54 1	115.0131
23	meadow	grass	1	0	0	0	0.3	2	100	0.2	0.07	0.286	177.4676
27	maize and tuberous p	crop	0.8	0.2	0	0	0.3	4	180	1.5	0.05	0.4	76.02446
28	wet meadow	grass	1	0	0	0	0.3	2	100	0.3	0.055	0.364	152.4954
29	orchard	forest	0.8	0.2	0	0	0.8	6	150	3	0.05	0.4	54.69945
31	deciduous forest	forest	1	0	0	0	2	5	250	18	0.1	0.2	27.19617
32	coniferous forest	forest	1	0	0	0	2	6	500	15	0.1	0.2	28.6306
33	mixed forest	forest	1	0	0	0	2	5	375	16	0.1	0.2	28.09757
35	heather	grass	1	0	0	0	0.2	6	110	0.75	0.05	0.4	104.3904
36	shrub	grass	1	0	0	0	0.6	6	110	2	0.05	0.4	66.32867
37	beach/dune	bare soil	0.3	0.7	0	0	0.5	2	110	1	0.04	0.5	91.76073
44	mud flat/salt marsh	open water	0.4	0.2	0	0.4	0.3	2	110	0.5	0.035	0.571	124.2209
51	navigable river	open water	0	0	0	1	0.05	0	110	0.001	0.02	1	426.6676
52	lake	open water	0	0	0	1	0.05	0	110	0.001	0.02	1	426.6676
53	estuary	open water	0	0	0	1	0.05	0	110	0.001	0.02	1	426.6676

54	sea	open water	0	0	0	1	0.05	0	110	0.001	0.02	1	426.6676
55	unnavigable river	open water	0	0	0	1	0.05	0	110	0.001	0.02	1	426.6676
201	highway	grass	0.6	0.1	0.3	0	0.3	2	100	0.12	0.025	0.8	212.0135
202	district road	grass	0.6	0.1	0.3	0	0.3	2	100	0.12	0.04	0.5	212.0135
301	spruce	forest	1	0	0	0	2	12	320	13	0.4	0.05	29.91872
302	pine	forest	1	0	0	0	2	6	550	15	0.4	0.05	28.6306
303	beech	forest	1	0	0	0	2	6	320	20	0.4	0.05	26.46295
304	birch	forest	1	0	0	0	2	5	320	16	0.4	0.05	28.09757
305	oak	forest	1	0	0	0	2	4	150	17	0.4	0.05	27.62242
306	poplar	forest	1	0	0	0	2	5	250	18	0.4	0.05	27.19617
307	reference grass	grass	1	0	0	0	0.3	2	140	0.12	0.035	0.571	212.0135

	Name of Boreholes	X UTM	Y UTM	Z M	Depth,bgl (m)	DWL	SWL	Q(l/s)	Current Working Hour/day	Daily Production	Monthly Production	Annual Production	K/K
1	Ankorcha-1	480029	998401	2450	144	44.96	20	18.9	22	1497	44906.4	538876.8	Yeka
2	Ankorcha-2	481462	998906	2451	200	90	72	3.2	16	184	5529.6	66355.2	Yeka
3	Ararat	480321	997370	2399	180	29	10.52						Yeka
4	Asko 1/95	465500	1002150	2580	176.4	73.79	2						KK
5	Asko 1/97	465717	1001230	2524	174	55.98	43	5.5	10	198	5940	71280	KK
6	Bole Highschool	476933	994457	2334	500	145.20	62.80						Bole
7	CMCVI	482682	994124	2293	240	96	38	26	18	1685	50544	606528	Bole
8	Dereke Bridge	475638	999991	2448	232	58	23	16.6	18	1076	32270.4	387244.8	Gulele
9	EBV22	481101	991646	2250	250	79	25.52	0	0	0	0	0	Bole
10	EBV24	480760	992453	2261	270	61	22	27	17	1652	49572	594864	Bole
11	Egzeabheirab	471026	1002023	2633	222	128	23	12	16	691	20736	248832	Gulele
12	Gofa mebrat hayil	471925	990400	2212	352	51.14	21.8						
13	Hamile-19	474518	1001467	2497	260	97.58	39.84	16	20	1152	34560	414720	Gulele
14	Italy Embassy(new)	476287	1000116		409	124.53	95.3						Gulele
15	Kaliti Gebrael-1	475300	984900	2120	93	25.93	(0.89m)	9	16	518	15552	186624	Kality
16	Mekanissa Kotari	470682	987316	2221	357	141.22							
17	Mikililand-4	466841	1000105		392	126.39	73.9						Ak
18	Nifas Silk	473446	991371	2264	507	137.98	93.2						NS
19	Shegole new	469150	1001150	2547	240	105	0	30.7	16	1768	53049.6	636595.2	KK
20	Shiro meda	473314	1002774	2620	287.3	188.88	85.15						Gulele
21	Success	466842	993128	2307	250	95	38						KK

AppendexX. Some of the ground water depth