ASSESSING IMPACT OF LAND USE AND LAND COVER CHANGE ON GROUNDWATERRECHARGE: THE CASE OF DIRE DAWA WATERSHED, ETHIOPIA

Selamawit Mesfin Negede

A Thesis Submitted To
The Department of Geomatics Engineering School of civil Engineering and Architecture

Presented in Partial Fulfillment of the requirement for the Degree of Master's inGeoinformatics Engineering

Office of Graduate Studies
Adama Science and Technology University

February, 2024
Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled **“Assessing Impact of Land Use and Land Cover Change on Groundwater Recharge: The Case of Dire Dawa Watershed, Ethiopia”** is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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Name of the student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled **“Assessing Impact of Land Use and Land Cover Change on Groundwater Recharge: The Case of Dire Dawa Watershed, Ethiopia”** prepared under my/ourguidance by Selamawit Mesfin submitted in partial fulfillment of the requirements for the degree of Mater’s of Science in Geoinformatics. Therefore, I recommend the submission ofrevised version of the thesis to the department following the applicable procedures.

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APPROVAL PAGE

I, the advisor of the thesis entitled **"Assessing Impact of Land Use and Land Cover Change on Groundwater Recharge: The Case of Dire Dawa Watershed, Ethiopia"** and developed by Selamawit Mesfin, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

______________________	______________________	______________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Selamawit Mesfin Negede, have read and evaluated the thesis entitled **"Assessing Impact of Land Use and Land Cover Change on Groundwater Recharge: The Case of Dire Dawa Watershed, Ethiopia"** and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geoinformatics.

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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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CN	Curve number
DEM	Digital Elevation model
EEPC	Ethiopian Electric Corporation
EFAP	Ethiopian Forestry Action Program
ERA	Ethiopia Road Authority
ET	Evapotranspiration
FMWRE	Federal ministry of water resources of Ethiopia
GWD	Global Weather Data
HRU	Hydrological response units
HSPF	Hydrologic simulation program factor
ITCZ	Inter-Tropical convergence Zone
KINEROS	Kinematic runoff and erosion model
LULC	Land use land cover
MoWE-	Ministry of water and energy
MUSLE	Modified Universal soil loss equation
NMSA	National metrology service Agency
NSE	Nash-Sutcliffe efficiency coefficient
OAT	One-at-a-time
PBIAS	Percent Bias
PET	Potential Evapotranspiration
PRMS	Evapotranspiration Precipitation run of modelling system Revised
RUSLE	universal soil loss equation
SCS	Soil conservation service
SUFI2	Sequential uncertainty analysis fitting version 2
SYLD	Sediment Yield

ABSTRACT

Evaluating the impacts of land use land cover changes on groundwater recharge at the watershed scale can facilitate the development of sustainable water resource strategies. This study investigates the historic land use/landcover change and its potential impacts on the groundwater recharge of Dire Dawa Watershed, Ethiopian. ERDAS Imagine coupled with GIS software to detect a change in land use/land cover in the watershed. Physically-based, semi distributed hydrological model, SWAT model, was utilized to simulate the groundwater recharge associated to land use/land cover changes from 2000 to 2022. Image classification revealed Land use/landcover maps with six Land use/land cover types of three historical periods 2000, 2010, and 2022.Relative change assessment results depict that area under agricultural land and built-up area is expanded by 49.18%, and 22.6 % respectively at the expenses of other revealed Landuse/land cover class. The shrub land and forest decreased by 105.39, and 28.8 respectively as compared from 2000 to 2022 historic land use/ land cover maps. The SWAT model performed well in simulating monthly river discharge. The result shows that,the observed and simulated value is in good fit by R2 of 0.84 and NSE of 0.75. The recharge estimation using the land uses of the years 2000, 2010, 2022 indicates that recharge decreasedby 20 %, 5.17% and 25% between the years 2000 to 2022, 2010 to 2022, and 2000 to 2022 respectively. On the other hand, surface runoff is amplified by 15 % from 2000 to 2010, 5% from 2010 to 2022, and 10% from 2000 to 2022. The results of this research could help watershed managers, Policy makers,and all stalk holders to create sustainable plans for managing water resources and land use land cover.

Key words: Dire Dawa watershed, LULC change, Groundwater recharge, SWAT

CHAPTER 1. INTRODUCTION

1.1 Background

Water resource, which is the backbone and crucial element of life, is needed in sufficient quantity and quality to meet the increasing demand for domestic, agricultural, and industrial processing operations (Al-Ruzouq et al., 2015); Meresa and Taye (2019). Groundwater is an essential part of the natural water cycle and is present nearly everywhere beneath our feet. As part of the water cycle, groundwater is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals. It forms the largest available store of fresh water on the Earth (Gleick, 2000).

Groundwater resource management plays a crucial role in ensuring sustainable water supply forvarious purposes. According to the United States Geological Survey (USGS, 2016), effective management strategies are necessary to address the increasing demands and potential threats togroundwater resources (USGS, 2022). Through monitoring, allocation, and conservation measures, stakeholders can maintain the quality and quantity of groundwater. Implementing policies that encourage responsible water use, promoting education and awareness programs, and investing in infrastructure for efficient extraction and recharge are essential components ofsuccessful groundwater resource management. Maintaining groundwater levels at the national,regional, and local scales for sustainable livelihoods requires a thorough understanding of the techniques and methods to surface water conservation and groundwater recharge estimation

Identifying of groundwater recharge has shifted from a basic problem to an urgent and fundamental issue in hydrogeologic research for the sustainable development of groundwater (Batelaan & De Smedt, 2007; Rwanga & Ndambuki, 2017). It is noted that quantification of groundwater recharge rate is a prerequisite for efficient and sustainable management of groundwater.

Recharge can be greatly affected by climate change and anthropogenic activities. One of the most important anthropogenic interventions is changes in land use and land cover (LULC) (Siddik et al., 2022). Population increases, agricultural development, and the expansion of urbanareas all are contributing to LULC change, which affects surface runoff and groundwater

recharge patterns (Lamichhane and Shakya, 2019). Land use land cover changes are known to have an impact on groundwater–surface water interaction. However, the effects of such changesare poorly understood (Scanlon et al., 2005; Stonestrom et al., 2009). Since the beginning of industrialization, intensive anthropogenic activities that include agriculture, urbanization mining, etc. have consequently resulted to alteration of the physical landscape with effect on theregional water balance of surface and groundwater systems (Ashaolu et al., 2019).

To meet the increasing demand for water due to the rapid growth of population, urbanization, and industrialization, especially in developing countries, it is very important to evaluate groundwater resources quantitatively for future development plans in the region. Dire Dawa watershed also experience this type of problem declining of groundwater recharge from time totime (Ayele et al., 2023), and (Kassa et al, 2023). In order to address these issues, the current study applied advanced geospatial techniques, such as GIS and remote sensing along with the SWAT model, to come up with groundwater recharge distribution, and a map of groundwater recharge with 2000, 2010 & 2022 of land use land cover map in the study area.

1.2 Statements of Problem

Globally, freshwater availability is declining as a result of increasing population pressure, landuse change, industrial growth, urbanization, and climate change (Garg et al., 2020). To supportthe freshwater from surface sources in the country, the demand for groundwater resources is increasing in Ethiopia as a result of the country's fast population growth and economicdevelopment (Abraham et al., 2022a).

At present, there are still large gaps in knowledge, skills, and experiences for a proper assessment and sustainable development and management of groundwater. The use of groundwater needs to be based on the amount of groundwater recharge. In Ethiopia, limited recharge estimation and groundwater flow modeling studies were conducted (Mengistu et al., 2021).

Groundwater resources are the primary source of water for the Dire Dawa administrative council even though availability of sufficient replenishment of the abstracted water is not clearly known. The groundwater demand in the study area increased recently due to the expansion of irrigation practice, the industrial sector expansion, and increasing urbanization in and around the city

(Gebremikael & Dawod, 2020). Surface water sources are often limited, and the majority of them are dry during the dry seasons. The population of Dire Dawa thus primarily relies on the groundwater supply, and only a few of the springs that emerge from the nearby mountains, (Abate, 2010).

The study area watershed has been experiencing significant land use land cover changes (Erena& Worku, 2019), fast urbanization, and industrialization which significantly causes degradation of groundwater quantity as well as minimize the groundwater recharge. Consequently, diminishing groundwater yields and declining groundwater levels are the major problems encountered in the watershed.

In the area, most of the previously conducted researchers were mainly focused on assessing theimpact of land-use/land-cover change on groundwater quality and surface hydrology neglecting its effects on the groundwater recharge. The focus of this study was on estimating the potential impact of LU/LC change on groundwater recharge, which significantly determines the sustainability of groundwater use and its management.

1.3 Objective of the study

1.3.1 General objective

The main objective of this research is to analyze the impact of LULC changes on groundwaterrecharge using GIS based SWAT model in Dire Dawa watershed.

1.3.2 Specific objectives

- To analyse the trend of Land use Land cover change of the watershed from 2000 to 2022.
- To estimate groundwater recharge at different period 2000, 2010 and 2022.
- To determine the impact of land use/land cover change on groundwaterrecharge in the study area.

1.4 Research question

1. What does the trend of LU/LC change look like over the past 22 years?
2. What would be the groundwater recharge for the three different periods 2000, 2010, and 2022?
3. How the land use land cover change affects the groundwater recharge?

1.5 Significance of the Study

Analyzing resource foundations, devising suitable responses, and formulating effective strategies for sustainably managing natural resources within both the broader national context and the specific study area.

Understanding groundwater recharge helps assess the availability and sustainability of water resources. By knowing the recharge rates, authorities can develop comprehensive water management strategies to ensure a secure and reliable water supply for domestic,agricultural, and industrial purposes.

Knowledge of groundwater recharge is essential in land use planning. It helps prevent over-extraction of groundwater in areas where recharge rates are low, reducing the riskof land subsidence and depletion of aquifers. Effective land use planning, informed by recharge studies, can contribute to sustainable development practices.

Studying recharge enables policymakers to identify areas vulnerable to water scarcity, facilitating the implementation of targeted interventions such as artificial recharge projects, rainwater harvesting, and water conservation measures.

1.6 Scope of the Study

Geographically, the study is limited to the Dire Dawa watershed, where considerable changes in land use and land cover have been taking place for the past 22 years. First, the content will examine how land use and cover have changed throughout the time period between 2000 and 2022 and identify various land use types in the research area using multispectral satellite images.Second, to estimate ground water recharges using the GIS-based SWAT model and associate this water balance parameter with land use land cover change. Thirdly, to explain effects of changes in land use and land cover on ground water recharge.

1.7 Structure of the Thesis

The thesis is divided into six chapters. Chapter one begins with the background of the study area, objectives of the research, and significance of the study are all presented in the introductionsection. Chapter two, the literature review part, reviews previous studies in the scope of this thesis. Following chapter two is chapter three; the key topics of chapter three include the research area's location, climate, drainage, physiography, soil types, and land use land cover, geology and hydrogeology. In Chapter four explained the Research methodology and Materialsused, the data’s collected to run ArcSWAT model and their primary and secondary source are explained. Chapter five is the result and discussion section, under this chapter the results of analyzed data, ArcSWAT model outputs spatial distribution and temporal trend results of (Actual evapotranspiration, Runoff, and Groundwater Recharge) discussed. Finally, Chapter sixwill conclude with a recommendation. The study's results and recommendations are presented in this chapter.

CHAPTER 2: LITERATURE REVIEW

2.1. Groundwater Recharge

Groundwater recharge is the process by which water from precipitation, canals, rivers, lakes, and streams percolates through the soil to the subterranean water system. Moreover, a number of factors, including vegetation, terrain, soils, and geology, influence the percentage of precipitation that percolates to the water table. (Teklebirhan et al., 2012) Additionally it is the downward flow of water that adds to the groundwater reservoir by reaching the water table. According to (Ayenew & Alemayhu, 2001) recharge can happen naturally via precipitation, rivers, canals, and lakes. It can also be caused by human activity.

The amount of groundwater is depending on the porosity of rocks, which is the volume of spacesthat are open within them, and the geographic distribution of these rock formations. Differences in groundwater potential between regions, nations, and continents are intrinsically linked to thekinds of rocks that are present, their extent, and the rates and conditions that control the rechargeprocess. Recharge, in this sense, refers to the amount of water that is added to the groundwater reservoir from outside sources like rivers, precipitation, lakes, or even nearby aquifers. This flow of water is vital to maintaining and replenishing the groundwater levels within a specific geological formation or aquifer (Kebede & Kebede, 2013).

Underground freshwater reserves are replenished by a process called recharge, which is mainlyobtained from precipitation (rainfall or snowmelt) but can also come from seepage from water bodies like rivers, lakes, and canals. This recharge seeps through the unsaturated zone and buildsup inside the aquifer. When the aquifer fills, water may come up at the surface as springs or seepage, which helps to maintain base flow the steady flow of low-land rivers during dry weather until the aquifer reaches a saturation point where the outflow is equal to the rate of recharge, creating a balance between the aquifer's input and output of water (Walraevens et al.,2009).

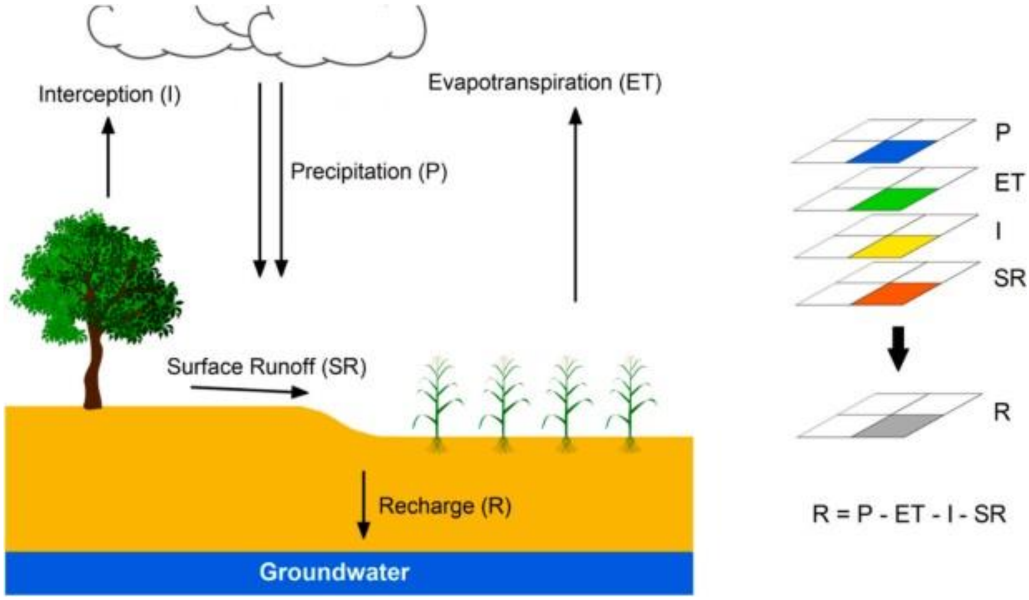


Figure 2. 1Water balance components and recharge computation (Siddik et al., 2022)

where, R is groundwater recharge, P is precipitation, ET is evapotranspiration, I, is interceptionand SR is surface runoff.

From a resource perspective, the long-term viability of urban groundwater development relies upon regular input of water to the subsurface as groundwater recharge (Berrett, 1999).

It is the most important parameter for groundwater sustainability in arid and semiarid regions because the abstraction from a groundwater reservoir should, in the long term, not be larger thanthe long-term average recharge. Quantifying groundwater recharge is thus a prerequisite for efficient and sustainable groundwater resource management (Tilahun & Merkel, 2009).

Spatial variation in recharge due to distributed land-use, soil texture, topography, groundwaterlevel, and hydro meteorological conditions are very important parameters that should beaccounted for in recharge estimation. (Rwanga & Ndambuki, 2017).

There are three principal mechanisms of recharge defined by (Lerner, 1990) as:

Direct recharge (Diffuse): surplus precipitation or irrigation water supplied to the groundwater reservoir to make up for soil moisture deficits and evaporation.
Indirect recharge: the water table is replenished by surface watercourse beds, such as those found beneath rivers and lakes

Localized recharge: an intermediate type of ground water recharge that happens when water is concentrated horizontally at the surface without clearly defined channels like small depressions, joints, or rivulets.

The previously mentioned mechanisms usually work in concert rather than in isolation, which makes the assessment challenging. However, a number of factors, such as climate, terrain, drainage, the geologic framework, soil quality, land use/land cover, vegetation, etc., influence an area's conditions for recharge and discharge. For example, in semi-arid regions, where potential evapotranspiration exceeds average precipitation, significant rainfall events are required for ground water recharge. Additionally, this process is impacted by the soil's capacityfor infiltration, the hydraulic character of the subsurface material, the existence of cracks, joints,and depressions on the surface that permit evapotranspiration to escape, etc. For numerous reasons, it is necessary to have accurate estimations of groundwater recharge (Misstear, 2000),including:

Assessing groundwater reservoirs within districts associated with river basins.
Issuing abstraction licenses, particularly for substantial groundwater withdrawals in accordance with the Water Framework Directive (WFD).
Assessing the contribution of groundwater's baseflow to rivers and fragile wetland ecosystems to ensure their preservation.
Evaluating groundwater vulnerability, where higher recharge rates indicate increased susceptibility.
Designating Source Protection Areas (SPAs) around significant wells and springs, withthe size contingent upon recharge levels.
Identifying zones susceptible to nitrate contamination, necessitating the identification of Zone of Contribution (ZOC).
Analyzing the impact of alterations in climate patterns and land use practices on water resources and their supplies. Please, avoid using bulletin throughout the entire document. Make the statement in paragraph.

2.2 Groundwater Recharges in Ethiopia

The approximate amount of annual groundwater recharge of Ethiopia is estimated about 28,000 Mm^3 (Obuobie, 2008).

including aquifer replenishment, groundwater flow modeling, and the understanding of the impacts of urban, industrial, and agricultural development on groundwater resources (Demlie, 2015). In many parts of the country, particularly in rural and urban areas, groundwater is an essential source of water for domestic and industrial uses. Nevertheless, the availability of groundwater is not constant because of environmental and geological factors. The geophysical and climatic conditions of the area determine whether groundwater is present. Ethiopia is uniquein that it has a diverse range of geological, geographical, and environmental conditions, makingit difficult to identify an abundance of aquifers. As such, understanding the hydrological cycle and the complex relationship between discharge and recharge is essential for managing water resources within the hydrogeological context and gaining insight into this cycle. (Berhanu et al.,2014).

2.3 Application of GIS and RS Technology for ground water recharge estimation

Remote sensing and Geographic Information System (GIS) technologies have indeed revolutionized the way we assess and manage groundwater resources. These technologies offera range of advantages that make them indispensable tools in understanding, monitoring, and conserving groundwater. (Sener et al., 2004)

1. **Spatial Coverage:** Remote sensing enables the collection of data over vast geographicalareas that might be difficult to access on the ground. This extensive coverage helps in mapping the distribution of land features, vegetation, and potential hydrological indicators related to groundwater.

2. **Spectral Resolution:** Different sensors on remote sensing platforms capture data in various spectral bands. This allows the differentiation and analysis of various surface features related to groundwater, such as soil moisture content, land use, vegetation health, and geological formations affecting groundwater movement.

3. **Temporal Availability:** Remote sensing platforms can collect data repeatedly over time, allowing for the analysis of changes and trends in groundwater-related parameters.Temporal datasets facilitate the monitoring of seasonal variations, long-term trends, andresponses to environmental changes.
4. **Data Manipulation and Integration:** GIS technology provides tools for organizing, analyzing, and visualizing spatial data. By integrating remote sensing data with other geospatial information like topography, geology, and hydrology, GIS enables a comprehensive understanding of groundwater dynamics.

5. **Identification of Potential Zones:** Remote sensing data, combined with GIS analysis, helps in identifying potential areas for groundwater exploration by assessing surface features that

indicate the presence of groundwater resources, such as vegetation patterns, land surface characteristics, and hydrological indicators.

6. **Estimation of Groundwater Resources:** Through sophisticated modeling and analysis, remote sensing data contributes to estimating the total volume and potential recharge areas of groundwater resources within a specific region. This information aids in better management and planning of water resources.

7. **Cost and Time Efficiency:** Remote sensing allows for rapid data collection over large areas at relatively lower costs compared to traditional ground-based surveys. This efficiency is especially valuable in areas with limited accessibility or where ground surveys are logistically challenging.

In essence, the integration of remote sensing and GIS technologies significantly enhances our ability to understand, monitor, and conserve groundwater resources. Their combined capabilitiesoffer valuable insights that support sustainable management practices and aid in addressing water resource challenges around the world. (Tweed et al., 2006). Besides water resource mapping, remote sensing can also quantitatively measure hydrological fluxes, such a precipitation, evapotranspiration, river stages and discharges (Wang & Xie, 2018) (. & Chen, 2016).

2.4 Land use land cover change

Changes in land-use and land-cover (LULC) have a significant impact on the environmental andsocioeconomic sustainability of communities. Changing one land-use type for another frequently has compounding and cumulative effects. When rural and forested areas are converted into urban land-use patterns, the hydrological cycle is significantly impacted, and

rates of soil erosion are altered concurrently. Urbanization is one of the major contributors to these changes. (Yuan, 2008). In order to meet the demands of human production, land covers must frequently be changed or converted. In the past 200 years, population growth, technological development, and ensuing demand have significantly increased the impact of human activities on land, resulting in significant changes to entire landscapes that have a profound impact on climate, hydrological patterns, biodiversity, and nutrient cycles, especiallyin developing countries. (de Sherbinin, 2002).

Most land in Ethiopia is used by smallholder farmers who mostly practice subsistence farming. Because of the country's fast population growth and lack of agricultural intensification, smallholders are requiring more land for crop cultivation and the support of their livelihoods. This demand frequently results in deforestation and the conversion of different land covers, which move away from their natural state to create more space for croplands. (Adamu, 2013).

Most research indicates that croplands have expanded, encroaching upon larger areas of naturalvegetation like forests and shrublands. Empirical evidence consistently demonstrates a strong connection between socioeconomic factors and shifts in land use and cover: as populations increase, there's a heightened necessity for arable land, grazing areas, and fuel wood. Settlements expand to meet the growing demands for food, energy, and livestock. In Ethiopia, the causes of deforestation and resource degradation are primarily attributed to population pressure, lack of awareness, and inadequate management practices. These adverse environmental impacts lead to additional problems. For instance, the destruction of vegetation amplifies surface runoff, affecting groundwater recharge processes.

2.5 Interaction of land use and land cover change and hydrology

Understanding the dynamics of changes in land use and land cover (LULC), including their locations, timings, rates, and the underlying social and physical forces that propel these changes, is crucial in comprehending their impact on global Earth systems. (Maidment, 1993). Factors like demography, institutions, technology, biophysical, national and local policies and macroeconomic activities result in an extensive alteration of LULCC which affect the hydrological systems both, at the basin and regional scales (Dibaba et al., 2020).

Changes in vegetation cover play a significant role in influencing various components of the hydrological cycle, including infiltration, runoff, evaporation, and precipitation patterns. The equilibrium between precipitation, evaporation, transpiration, and resultant runoff can be affected by alterations in land use and land cover, leading to both short-term and long-term effects on the hydrological system. (Asmare et al., 2020). Cutting-edge research in the field of international hydrology is actively investigating the intricate relationship between changes in land use and land cover and their impact on regional water balance. This body of research underscores that alterations in regional vegetation ecosystems resulting from changes in land use and land cover significantly affect the regional hydrological cycle. The modifications in LULC not only have identifiable social and economic benefits but also result in unforeseen andmulti-directional effects on various components of the water balance. (Worku et al., 2019).

2.6 Groundwater recharge and land use land cover change

According to most of researchers, recharge, referring to the replenishment of groundwater resources, can be significantly influenced by both climate change and human activities. Amongthese human-induced factors, changes in land use and land cover (LULC) play a pivotal role inaltering recharge dynamics. (Siddik et al., 2022). The relationship between hydrology and landuse/cover change is deeply intertwined within an ecosystem and plays a pivotal role in shaping the health and functionality of watersheds and their associated ecosystems. There are direct andimpactful connections between various spatially distributed properties within a watershed and the processes that occur within it. (Chakilu & Moges, 2017).

Certainly, changes in land use and land cover (LULC) significantly impact critical componentsof the water balance, including groundwater recharge, evaporation, and overland runoff. Thesechanges can lead to alterations in the flow patterns of rivers, affecting both the timing and distribution of runoff. (Abraham et al., 2022b).

2.7 Groundwater recharge estimation technique

quantifying recharge is a critical aspect of managing water resources sustainably. Here are somefactors and considerations that play a crucial role in determining the reliability of recharge estimation techniques:

Methodology Suitability: Different techniques (such as soil water balance, groundwater modeling, isotopic methods, etc.) have varying applicability depending on geological, hydrogeological, and climatic conditions. Understanding the specific characteristics and limitations of each method in relation to the local environment is crucial.

Data Availability and Quality: Reliable recharge estimation often depends on the availability and quality of data. This includes meteorological data, soil properties, land use patterns, topography, and groundwater level measurements. Assessing the adequacy and reliability of these data sets is vital for accurate estimations.

Temporal and Spatial Scales: As you rightly pointed out, the scales at which recharge estimatesare needed vary based on the objectives of the study. Some techniques may be better suited forproviding estimates at a local scale over short periods, while others may offer more generalizedestimations covering larger areas and longer timeframes. Understanding the temporal and spatial scales required by the study is crucial in selecting the appropriate method.

Complexity vs. Resources: Some techniques might be more complex or resource-intensive thanothers. Balancing the trade-offs between accuracy and the resources (financial, technical expertise, time) available is essential in choosing an appropriate method.

Validation and Calibration: The reliability of recharge estimation techniques often depends on how well they have been validated and calibrated using observed data from the study area. Techniques with a proven track record of accurately estimating recharge in similar hydrogeological settings are generally more reliable.

Uncertainty and Sensitivity Analysis: Assessing the uncertainties associated with different methods and conducting sensitivity analyses to understand how variations in input parameters affect recharge estimates is crucial. Understanding these uncertainties helps in interpreting andcommunicating the reliability of the estimated recharge values.

Integration of Multiple Techniques: Sometimes, combining multiple methods or using a multi- method approach can provide a more comprehensive understanding of recharge. Integrating various techniques can help cross-validate results and improve the overall reliability of estimates. Ultimately, the choice of a recharge estimation method should be guided by a

thorough understanding of the local hydrogeological conditions, available data, research objectives, and the limitations of each technique to ensure the most reliable estimates possible for a given situation. (Scanlon et al., 2002).

Developing hydrological models to assess and quantify the impacts of land use on hydrological processes is a crucial aspect of watershed management and environmental planning (Poelmanset al., 2010). TOPMODEL (Topographic Hydrologic Model) is suitable for determining the areas of runoff in mountainous regions (Gumindoga et al., 2014). The Soil and Water Assessment Tool (SWAT) has been extensively used to forecast the impacts of diverse soil textures, vegetation covers, and land use changes on water yield, sediment erosion, and non- point source pollution. This process involves managing a multitude of intricate and extensive parameters. (Singh & Saraswat, 2016). Other recent study uses GIS and WetSpass model simulate accurately the spatial and temporally distribution of long-term average recharge (Siddiket al., 2022).

Recharge is also estimated by chloride ion mass balance method, empirical method, water-balance method, water budget model method or by multiplying the magnitude of water-level fluctuations in wells with the specific yield of the aquifer material. But commonly groundwater recharge is determined to a large extent as an imbalance at the land surface between precipitationand evaporative demand (Teklebirhan et al., 2012).

2.8 SWAT model

The Soil and Water Assessment Tool (SWAT) is a semi-distributed watershed model particularly useful for watershed-scale water resource applications and watershed management(Arnold et al., 1998; Bhatta et al., 2019). The method is suited for humid, semi-arid, and arid conditions (SCS, 1985). The Soil and Water Assessment Tool (SWAT) model provides estimates of the various partitions (e.g., runoff, recharge, transmission losses, evaporation) of the hydrologic cycle (Arnold & Fohrer, 2005). The Soil and Water Assessment Tool (SWAT) stands out among various hydrological models due to its capability to be effectively deployed in large-scale watersheds exceeding 100 square kilometers. Its compatibility with Geographic Information System (GIS) interfaces enables seamless integration of spatial data, facilitating continuous-time simulations. SWAT's proficiency in generating numerous sub-basins and its

capacity for comprehensive spatial analysis of watersheds further enhance its appeal and utilityin hydrological modeling. These features collectively contribute to making SWAT one of the most preferred and versatile models available for watershed analysis and management. (Desta &Lemma, 2017). is one of the major models which have a strong capacity to integrate natural and manmade impacts on watershed hydrology and used in many hydrological studies.

Studies were conducted using the SWAT model to describe the availability and scarcity of freshwater for sustainable development (Mosase et al., 2019). According to Akoko et al. (2021), Combining SWAT with other models can give a multifaceted strategy a solid foundation. Research studies should prioritize aligning scientific discoveries with regional, national, and municipal policies. This involves incorporating established environmental benchmarks at local and regional levels, such as acceptable environmental flow rates in rivers, recommended forestcover in countries, and permissible limits for pollutants in the environment. Research outputs should emphasize alterations, patterns, and associated impacts in accordance with these thresholds. By providing robust scientific insights, these analyses will significantly aid in shaping national and local environmental policies, enhancing their development and implementation. The SWAT model uses the water balance equation to simulate the hydrologicalcycle presented in Equation 1 below

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \_\_\_\_\_\_\_\_\_\_ (Eq1)$$

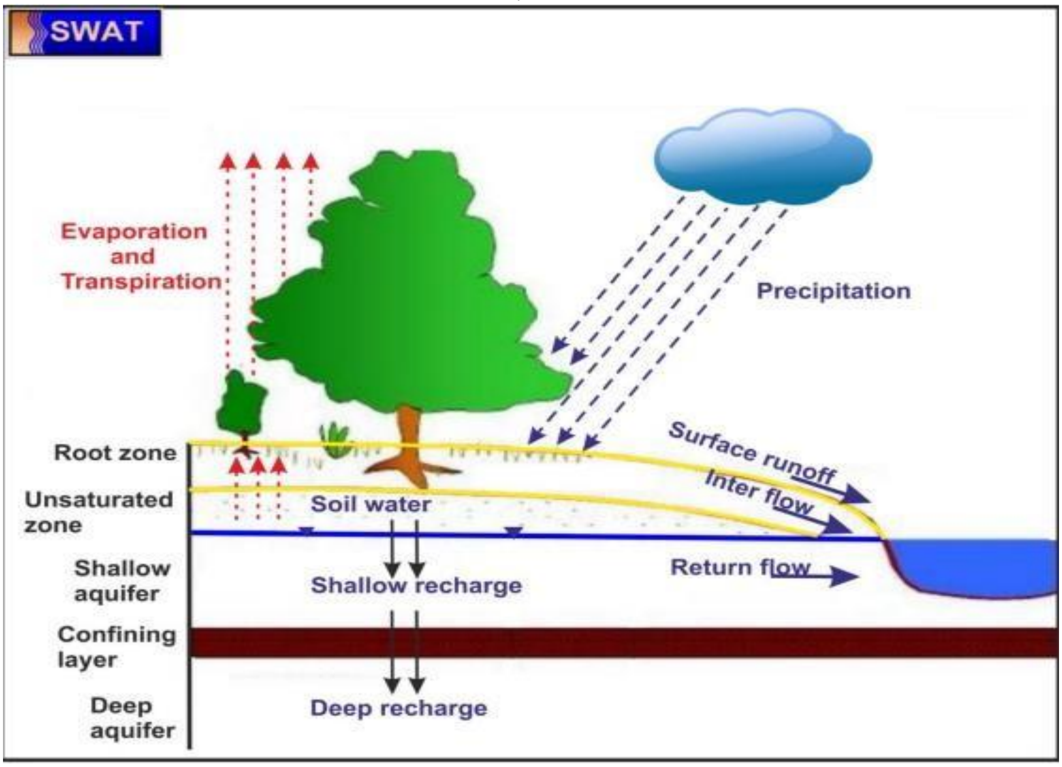


Figure 2.2 Schematic representation of the hydrologic cycle in SWAT model (Neitsch, 2005)

The SWAT model was chosen for the following reasons:

The model is an open-source code giving the user the flexibility for making modifications as needed,
It simulates hydrologic processes continuously and not just event by event which gives recharge estimates over large time frames
The model allows futuristic simulations which can aid in water management decisions(Al-Dousari et al., 2010).

This model was applied by many researchers they concluded the model has a satisfactory performance (A.W.Coffin, 2018; Al Khoury et al., 2023; Magnoni et al., 2020; Mensah et al., 2022a; Okrah et al., 2023; Taia et al., 2023; Tolera & Chung, 2021).

2.8.1. SWAT Calibration and Uncertainty Procedures (SWAT-CUP)

As hydrological modeling is subject to large uncertainties, the definition and quantification of the model uncertainty became the subject of much research in recent years. To meet this demand, researchers have developed a variety of uncertainty analysis techniques for watershedmodels. These include Bayesian methods, such as the Mark chain Monte Carlo ―MCMC‖, Generalized Likelihood Uncertainty Estimation ―GLUE‖, Particle Swarm Optimization
―PSO‖, and Sequential Uncertainty Fitting ―SUFI-2‖ (Abbaspour et al., 2007). Glue, Parasol,PSO, SUFI-2, and MCMC have been interfaced with SWAT in a single package called SWAT-CUP (SWAT Calibration Uncertainty Programs) (Abbaspour et al., 2007).

2.9 Empirical review

In line with growing concern of sustainable development, assessing groundwater quantity and quality management methods have become the subjects of recent research. This section presentsa review of empirical studies conducted in different regions of the world. The review mainly focused on those studies inspected the impacts of land use land cover change on groundwater recharge.

2.9.1 Global perspective

Most of previous study globally and locally done on impacts of land use land cover changes ongroundwater recharges. Beselly et al. (2021) investigated Seasonal Spatio-temporal Land CoverDynamics in the Upper Brantas Watershed. As a result of their findings, the river discharge wasconsiderably influenced by changes in LULC, especially in the cultivated and controlled vegetation and urban/built-up region. Specifically in the Upper Brantas Basin, it was shown thatthe rise in urban/built-up area and the decrease in farmed and managed vegetation areaaccounted for about half of the increased river discharge. Lei et al. (2022) Investigated the Influences of land use changes on the dynamics of water quantity and quality in the German lowland catchment of the Stör. According to their findings, between 1987 and 2019 there was adrop in arable land and a corresponding rise in grassland and urban land, which had a substantialimpact on water quantity and quality characteristics. Liu et al. (2023) works on the Impacts of land use/cover change on water balance by using the SWAT model in a typical loess hilly watershed of China, the results demonstrate that runoff change was primarily caused by urbanization, while evapotranspiration change was primarily caused by forest expansion. These findings are important for comprehending how LUCC and water balance relate to one another and can offer useful information for managing water resources and the long-term sustainabilityof such watersheds.

Nath et al. (2021) Investigated on the Impact of urbanization on land use and land cover changein Guwahati city, India and its implication on declining groundwater level. Their research of historical groundwater level data indicates a consistent reduction in the depth to groundwater level. The study conducted by Scanlon et al. (2005) the Impact of land use and land cover changeon groundwater recharge and quality in the southwestern US, shows Thick unsaturated zones have a salt reservoir that is easily mobilized under higher recharge brought on by LU/LC variations, potentially lowering the quality of groundwater. Quantitative understanding of the relationships between ecosystem change, recharge, and groundwater quality is necessary for sustainable land use.

According to Wang et al. (2023), Spatiotemporal Oasis Land Use/Cover Changes and Impacts on Groundwater Resources in the Central Plain of the Shi yang River Basin. resulted in a declinein groundwater level of 5 to 18 meters in the eastern and northern areas of the Weiwei Plain from 2008 to 2018; the biggest dip was at Shui yuan. the study conducted by Mensah et al. (2022b) on the Integrated modeling of hydrological processes and groundwater recharge basedon land use land cover, and climate changes, Result analysis indicates To boost the long-term viability of water resources in every basin, ongoing research and the creation of context-specificgroundwater recharge models are vital. The long-term effects of natural and anthropogenic forces on interactions between river basins call for the integration of modeling capabilities andknowledge across biophysical responses, environmental issues, policy, economics, and social factors.

The study conducted by Barua et al. (2021) on integrated modeling of hydrological processes and groundwater recharge based on land use land cover, and climate changes. demonstrates howit's important to understand the applicability and uncertainty of methodologies for calculating recharge rates in semi-arid regions in order to evaluate the long-term implications of changing land use and comprehend the groundwater system.

2.9.2 Local perspective

In the context of Ethiopia, the impact of LULC changes on groundwater recharge have been assessed by several studies in different parts of the country, Mitiku et al. (2023) investigated that Examining the impacts of climate variabilities and land use change on hydrological responses of Awash River basin, Ethiopia. The outcomes indicated how the quality and quantityof water resources have come under intense strain from climate and land use change. These twovariables may have an impact on the flow regime, flow extremes, and water availability. According to Yifru et al. (2021) studies on Assessing the Effect of Land/Use Land Cover and Climate Change on Water Yield and Groundwater Recharge in East African Rift Valley, differently from some of the other researches, they reached the conclusion that future water resources planning and management are likely to be far more impacted by climate change thanLULC change.

A study conducted by Abuhay et al. (2023) on assessing the impacts of land use/land cover changes on the hydrology of the Upper Gilgel Abbay watershed using the SWAT model, The outcome demonstrates that, on the other hand, groundwater flow, lateral flow, soil water, and ET were all decreased over time. Dibaba et al. (2020) conducted their study on Watershed Hydrological Response to Combined Land Use/Land Cover and Climate Change in Highland Ethiopia: Finchaa Catchment, shows that changes in the amount of surface runoff, aquifer recharge, and river flows caused by land use and land cover (LULC) and climate change have an impact on the availability of water resources. According to Haregeweyn et al. (2015), The changes in land use and land cover in the Gilgel Tekeze watershed in the highlands of NorthernEthiopia resulted in a 39 mm/year decrease in the average groundwater recharge in the studied region.

According to research reviewed by Negese and Miano (2021). Summary of findings: Since thereis little information available from previous research on these issues, future research should focus more on the investigation of the impacts of land use and land cover change on groundwaterhydrology and the prediction of future soil loss and hydrological imbalance under these changesin the country. Guder et al. (2022)/1stated their findings as LULCC impacts are only one aspectof hydrological effects. The interaction of different elements, such as terrain characteristics andclimate variability and change, usually produces the observed facet. Study conducted by Kuma

et al. (2021) demonstrates that the influence of climate change on hydrologic responses is greaterthan the impact of LULC change. Abraham et al. (2022a) shows that the impact of LULC changeis less significant than the impact of climate change on hydrologic responses. According to thestudy conducted by Abraha et al. (2011) Analysis of the temporal trend patterns of some hydrometeorological factors that have a significant impact on groundwater recharge conditionsand LULC of the catchment, particularly vegetation cover in the Awassa catchment, has been done to address the drop in the rate of recharge. Tumsa et al. (2022) shows. In the Guder catchment, Oromia, Ethiopia, the conversion of LULC has been endangering elements of the water balance and negatively impacting the ecosystem.

The study conducted by/1Getachew and Manjunatha (2022) Furthermore demonstrates how theLake Tana basin's shifting land use is a significant problem that affects the water's natural flow.

2.10 Previous Works

Various geological and hydrogeological studies were carried out in the Dire Dawa and the surrounding areas. The following is a summary of the various studies that have been conductedin and near the Dire Dawa river catchment,

Table 2. 1 previous research on study area

NO	Author	Topic	Organization	Status
1	Tilahun & Merkel (2009)	Estimation of groundwater recharge using a GIS-baseddistributed water balance model in Dire Dawa, Ethiopia	University of Oslo	Hydrogeolo gy Journal, 17(6), 1443-1457
2	Eyilachew Yitayew (2010)	Anthropogenic Impacts on groundwater resources in the urban environment of Dire Dawa	University of Oslo	Abate, 2010) M.Sc. thesis
3	Solomon Gebretsadik (2011)	Groundwater flow modeling ofdire dawa sub-basin, Ethiopia	University of Twente, Netherland	MSc thesis
4	Meresa Kiros (2006)	GIS-based vulnerability andhazard mapping for the protection of the Dire Dawa Groundwaterbasin	UNESCO IHE Institute forwater educationin the Netherlands	MSc thesis

Quantifying the changes in groundwater storage over space and time is necessary (Abraham etal., 2022a). In the case of Dire Dawa many studies are focused on research related to groundwater qualities(Abate, 2010; Alemayehu, 1999; Dawit et al., 2017; Gebremikael & Dawod, 2020, 2021; Gudissa et al., 2022; Kasso & Bekele, 2018; Sahele et al., 2018; Seada, 2021; Tilahun & Merkel, 2010) there is only one research done 14 years ago in 2008 by

KetemaTilahun & Broder J. Merkel, Estimation of groundwater recharge using a GIS-based distributedwater balance model in Dire Dawa, Ethiopia, According to (Tilahun & Merkel, 2009),The current knowledge based on the available information tells us that the recharge to the Dire Dawa aquifer is less than what was already thought. The future groundwater development andmanagement in the area should take this into account. The previous studies of the area were addressing the decline of groundwater resources due to over-exploitation/over-pumping. But there are no sufficient and satisfactory researches that have been quantifying and presenting thereduction of recharge with the land use land cover change of the area.

Generally, this research work fill the above-mentioned gaps and solve the problem related to the future proper utilization of groundwater systems in Dire Dawa by investigating the implicationof land use land cover change and its impacts on the decline of groundwater recharge and also a seasonal variation of LULC change in study area.

CHAPTER 3: MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location and accessibility

The Dire Dawa Rivers catchment is situated in the eastern part of Ethiopia positioned southeast of the Awash River basin. It spans between latitudes 9°26'00" - 9°45'30" N and longitudes 41°41'0" - 42°6'30" E within Universal Transverse Mercator (UTM) coordinates, falling in zone 37 north. Dire Dawa town is approximately 515 kilometers away from Addis Ababa, the capital city of Ethiopia, and approximately 333 kilometers from the international port of Djibouti.

Geographically, Dire Dawa is bordered to the North, East, and West by the Somali Regional State, while its southern and southwestern boundaries are shared with the Oromia Regional State. The city is nestled along the foothills of surrounding mountains and is drained by tributaries of five major rivers: Dechatu, Goro, Laga Hare, Butuji, and Melka Jabdu. Of these, Dechatu stands as the largest river, coursing through the heart of the city.

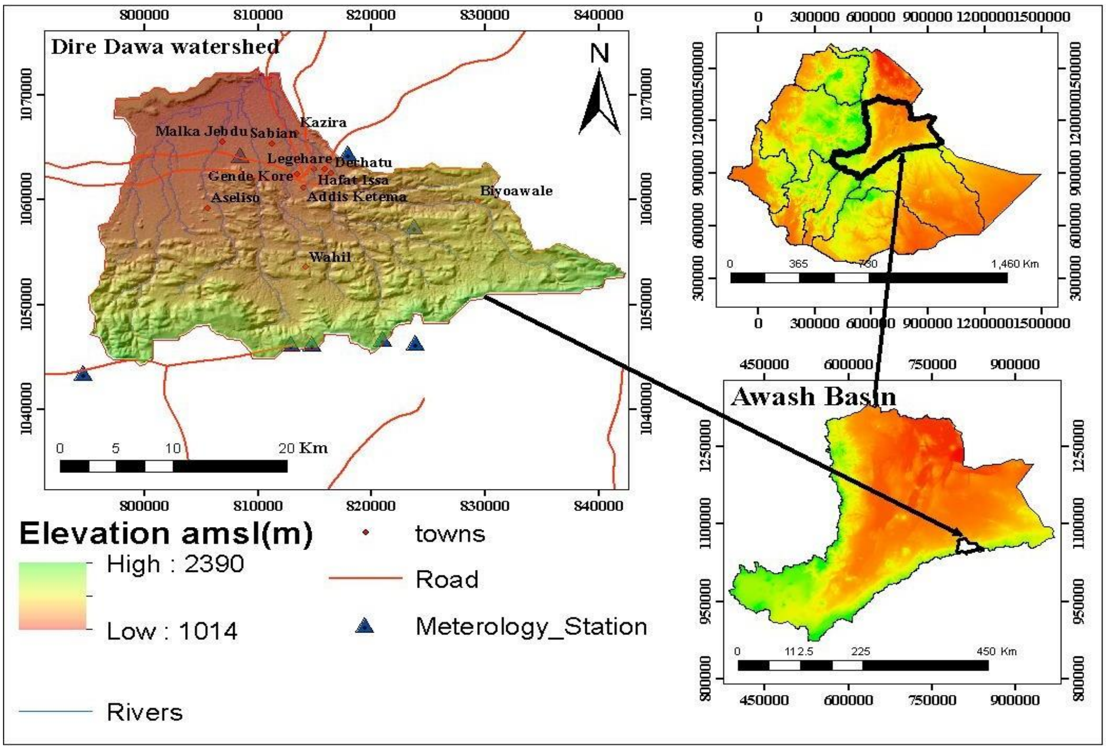


Figure 3. 1 Location map Dire Dewa catchment

3.1.2 Topography, Drainage, and Slope

he Dire Dawa region is positioned at the eastern edge of the primary Rift Valley system, exhibiting three distinguishable geomorphic features: the plateau region, the escarpment, and the valley depression. This topographical diversity becomes evident when observing the area from a three-dimensional perspective.

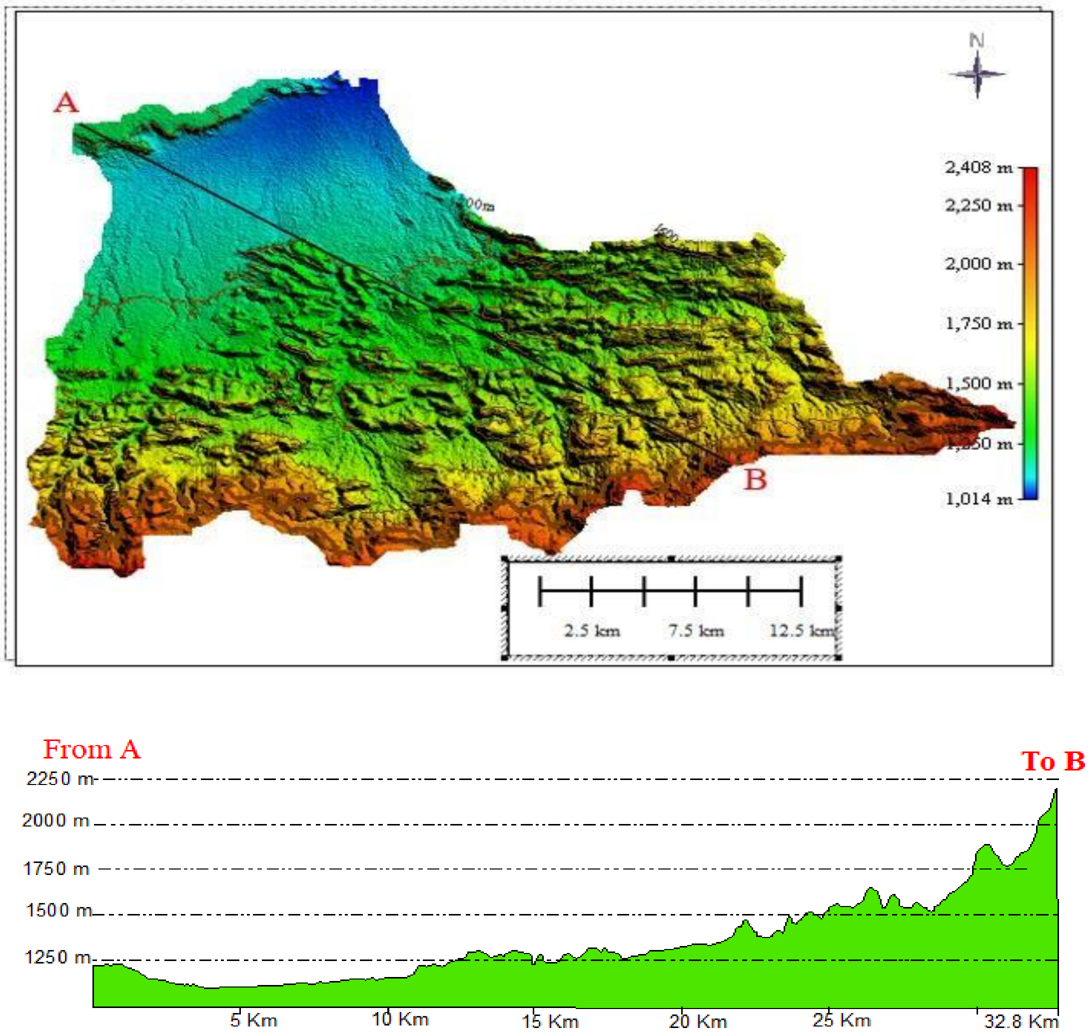


Figure 3. 2 Elevation (a), and Path profile(b), of Dire Dawa Watershed

3.1.3 Physiography

The Dire Dawa rivers catchment is situated within the Awash River basin, positioned at the southern edge of the Afar Depression. The area's physiography is predominantly influenced byvolcanic tectonics rather than erosional activities. It exhibits a wide array of topographic features with significant spatial variations. The terrain encompasses steep, towering mountains alongsideexpansive flat plains, generally oriented from south to north in terms of its overall topographicaldirection. According to Minalah Bushra (2007) it is characterized by successive short running

E-W oriented step faults forming half graben and horsts. The aggregates come from the highergraben by the runoff is dropped at the toe of the horst towards the north. The elevation of the area is varying from more than 2300m at Dangago to below 1000m at the north part of Shinile.

The area is geologically categorized into three primary features: the escarpment, transitional zones, and alluvial plains. The escarpment region is marked by steep slopes, gullies, and dry valleys predominantly composed of sedimentary and basement rocks. These areas experience high runoff due to their steep gradients and rock surfaces that allow for minimal water retention.

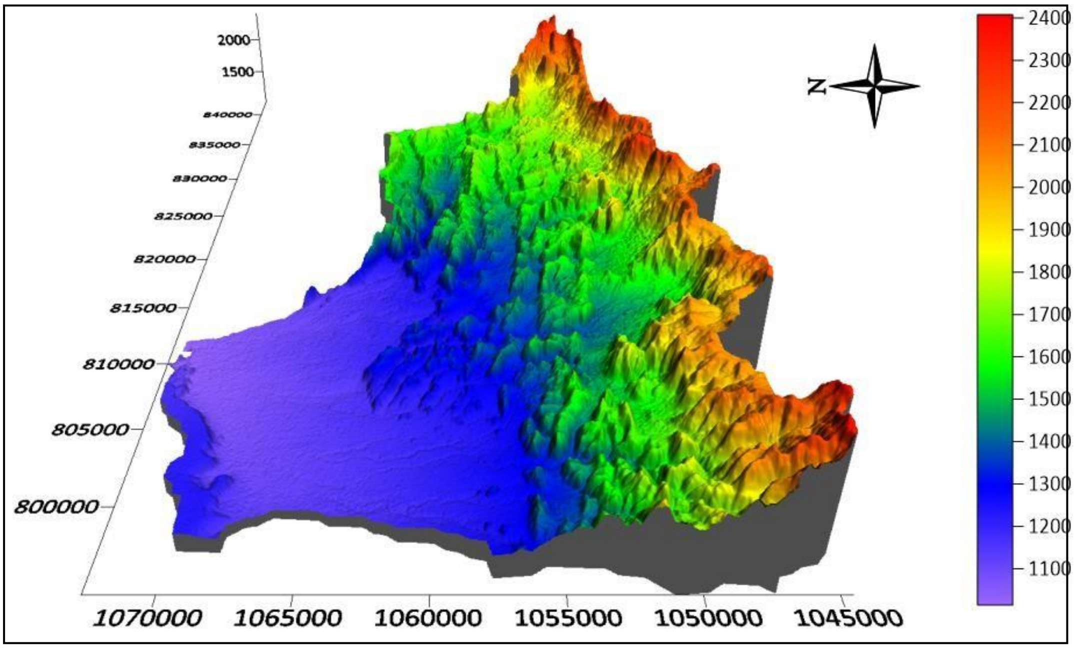


Figure 3. 3 Three-D Physiography of Dire Dawa Watershed

3.1.4 Climate

The Dire Dawa area is characterized as Hot Semi-Arid Zone; whereas the Eastern and southernpart of the region is classified as Warm Temperate Climate Zone. In the Hot Semi-Arid ClimateZone (the western, north-western and south-western part.(Tilahun, 2006) The mean annual maximum temperature of the area is 32.1 0 c while its mean annual minimum temperature of

19.10 c.The rainfall type of Dire Dawa is a bimodal type characterized by two rainy seasons andone dry season, namely belg a small rainy period ranges from the months of half of February toMay, and Kiremt, second rainy season occurring from June to September.

as kiremt, and Mid-February to May is the first rainy season, which is locally known as belg

(Tolosa & Tolossa, 2021).

The main peak rainfall season of the area are July, August, and September it reaches up to 450mm, and lower rainfall (dry season) recorded during the (November, December, January, and February). The temporal variation of the mean monthly rainfall of selected station of the study area shown in the figure4.5 below.

The Mean annual minimum temperature of the study is 9.8^{0}C and mean annual maximum temperature of the study area is 20.9^{0}C. The mean monthly temperature high February & Marchand low in July & August (figure 5.5) with mean value of 19.05^{0}C

Table3.1 Meteorological Stations within and Around Dire Dawa Watershed.

Name	X	Y	Elevation	Annual Precipitation	Temperature
CFR1	9.55	41.95	1567	817.79	-
CFR2	9.45	41.95	2143	827.10	-
Melka `	9.65	41.85	1095	1004.92	27.30
Dire Dawa	9.55	41.85	1375	1058.73	24.50
CFR3	9.45	41.85	2069	1062.22	-
Kulibi	9.65	41.75	1090	1463.95	21.46
Kersa	9.55	41.75	1285	1451.63	20.53
Dengego	9.45	41.75	2193	1416.89	21.47

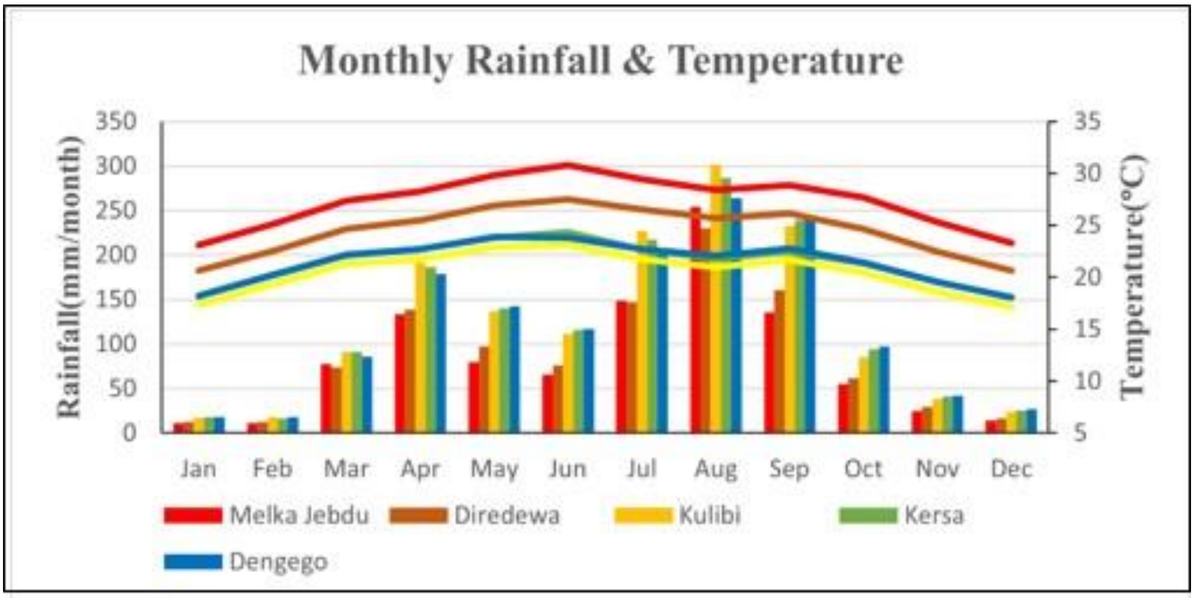


Figure 3. 4 The long term means monthly rainfall and temperature of selected meteorology station of Dire Dawa Watershed

3.1.5 Drainage

The Dire Dawa Administrative Council (DDAC) lacks the fortune of abundant, perennial riversthat are prevalent in other regions of the country. Instead, its topography, characterized by highrelief, has resulted in the area being crisscrossed by numerous small intermittent rivers shaped by tectonic activity. These rivers, acting as tributaries, contribute to the flow of the main perennial river, Awash. The rivers originating from the southern highlands of Kulubi and Dengego flow towards the lowlands of northern Shinile town within the Dire Dawa region. Dueto fault lines and faulted blocks, the mountainous areas display a primarily rectangular drainagepattern, while the overall drainage pattern across the study area exhibits a dendritic structure. Key intermittent and perennial streams responsible for draining the Dire Dawa region include Dechatu, Chacho, Lege Hare, Dube, Goro, and Lege Oda. Among these, Dechatu, Cherecha, and Lege Oda stand out as major intermittent streams, serving as primary recipients ofprecipitation runoff from the southern escarpment zone. Despite being dry for much of the year,these streams experience a significant surge in flow during the rainy season. (WWDSE, 2004).

3.1.6 Local Geology

The geology of Dire Dawa Administrative Council comprises various metamorphic, volcanic and sedimentary rocks. The metamorphic rock, which mainly includes gneisses and migmatites,

represent the oldest rock types in the area. They are largely of pre-Cambrian origin or crystallinebasement complexes. They mainly exposed 38 in the escarpment zone and limited out crop occur in the vicinity of Dire Dawa. Very limited out crops of volcanic rocks are exposed in theimmediate vicinity of the town. However, significant out crops of extrusive lava flow (mainly basalt) and few small out crops of intrusive can be observed in the bordering areas with in DireDawa watershed. Sedimentary rocks of the area include various sandstone, limestone, alluvial sediments and travertine. The alluvial sediments are composed of sands, silt and clay with minorwadi gravel. They occupy nearly the entire low-lying flat alluvial plain. The travertine is exposed in limited areas with in the town and its vicinity WWDSE (2004).

3.1.6.1 Precambrian and the Upper Paleozoic formations

The Basement Complex consists of high-grade gneisses, gneissose granites and migmatites of the Lower Complex, pelitic and psamitic biotite schists, amphibolite schists, quartzites and marbles of the Boye Group (Middle Complex) and phyllites, greenstones, cherts, serpentinites, tale schists and basic intrusive of the Soka Group (Upper Complex). The Basement complex outcrops in deep gorges of the Wabe Shebelle drainage system in the southwestern part of the sheet along the Maya, Ramis, Geba, Gelan and Galeti rivers, as well as the escarpment area near Dire Dawa. From the hydrogeological point of view the carboniferous sandstone of the Wayu and Soka valleys are mentioned in the framework of the Basement Complex.

3.1.6.2 Mesozoic sediments

The Mesozoic sediments consist of the "lower" littoral Adigrat sandstone overlain by the Jurassic Hamanlei-Gebredare formation with predominant limestone, which is overlain with theregressive "Upper" sandstone of the Amba Aradam formation. The Adigrat sandstone unconformably overlies the basement complex. The sandstone is over 150 m thick in the southwest (Goha – Galeti section) and about 200 m thick in the Soka section, while it is less than 20 m in the Kersa area and in the Geba and Ramis valleys it thins out in places (Seife/M. Berhe 1982). The major part of the sequence consists of massive, thick bedded quartzite sandstone. An iron oxide rich conglomerate usually occurs at the base. The Hamanlei-Gebredareformation (in northern Ethiopia known as Antalo limestone) varies in thickness from 200 m in the Dire Dawa area up to 600 m in the Galeti section (Seife M. Borhe 1982).

The upper part of the limestone is well bedded grey fossiliferous limestone interbedded with buff-coloured dolomites.

The sandstone of the Amba-Aradam formation consists of a thick sequence of quartzite sandstone with conglomerates and gravels up to 5 cm in diameter. The thickness of the sandstonevaries from 150 m up to 200 m in the Galeti and Soka valleys (Seife M. Berhe 1982). In the Kulubi area the sandstone is interbedded with basaltic flows (lava flows with the sediments or sills). A limestone intercalation, ranging from 15 to 25 m, is found in the Gara Muleta area.

3.1.6.3 Tertiary volcano-sedimentary complex

The Oligocene-Miocene volcanic group consists of basaltic and acidic volcanic rocks. The Alaje formation (previously Lower Trap basalts) predominately consists of basalts. The basalt rests unconformably on the eroded surface of the sandstone and is overlain with the Arba Guracha silica (dominantly rhyolitic ignimbrites and unwelded ash flows to the south west of Asebe Teferi) on the rift floor, and by the Jebel Sadlle basalts and the Gara Muleta Stratoid basalts in the plateau area. The Anchar Basalts (previous Upper Trap basalt), overlying the Arba GurachaSilicics, extend south of the railroad connecting Kora and Bike villages. The Pliocene sediments,forming a sequence up to 50 m in thickness, are found between Awash Station and Afdem overan area of approximately 1,000 km2. The formation consists of diatomite, volcanic materials, red lateritic soils, sandstones and conglomerates. The Pliocene Nazret Group covers an area in the southwestern corner of the map sheet. The group consists of ignimbrites and unwelded tuffs.The silicics are overlain by the Lower Stratoid Basalts in the Assebot area. The Lower StratoidBasalts consist of a series of basaltic rocks with rare intercalations of ignimbrites, which can betraced discontinuously along the southern Afar Rift margin towards the Aysha and Tadjoura areas. They are unconformably overlain by the Afar Stratoid Basalts. This unit is made up of a series of stratified layers of basalts, which have intercalations of rhyolite, ignimbrite and detritalsediments. The Afar Stratoid Basalts are widespread and cover over 2/3 of the Afar floor. The stratoid formation is a product of fissural volcanism and it is affected by innumerable vertical faults and open fissures with an NNE to NE trending strike.

3.1.6.4 Quaternary formations

The surroundings of Mieso and Assebot villages are covered with Pleistocene ignimbrites and unwelded pyroclastics with limited intercalations of lacustrine sediments. The Pleistocene to subrecent basalts covers the northwestern corner of the sheet. The Ayelu Amoisa volcanic complex emitted rhyolitic material over the same area. Post-caldera activity around Amoisa volcano is made up of recent basaltic lava flows, well preserved basaltic and scattered cones. The recent sedimentary formations of the Southern Afar are mainly lacustrine deposits with varied facies and thicknesses. They are well developed in the northwestern part of the map. Thequaternary alluvial sediments cover a major portion of the Afar bottom. These deposits consist of cobbles and coarse-grained sediments near the escarpment, while they are fine detrital sediments on the Afar plain. The wadi gravels are well developed along the water sources in theeastern part of the Afar Depression. The alluvial and colluvial sediments are also found overlying different rocks on the synthetically tilted blocks at the escarpment south of Dire Dawa.The alluvial sediments are also found in lake sub-basins on the eastern plateau near the Awash-Wabe Shebelle watershed.

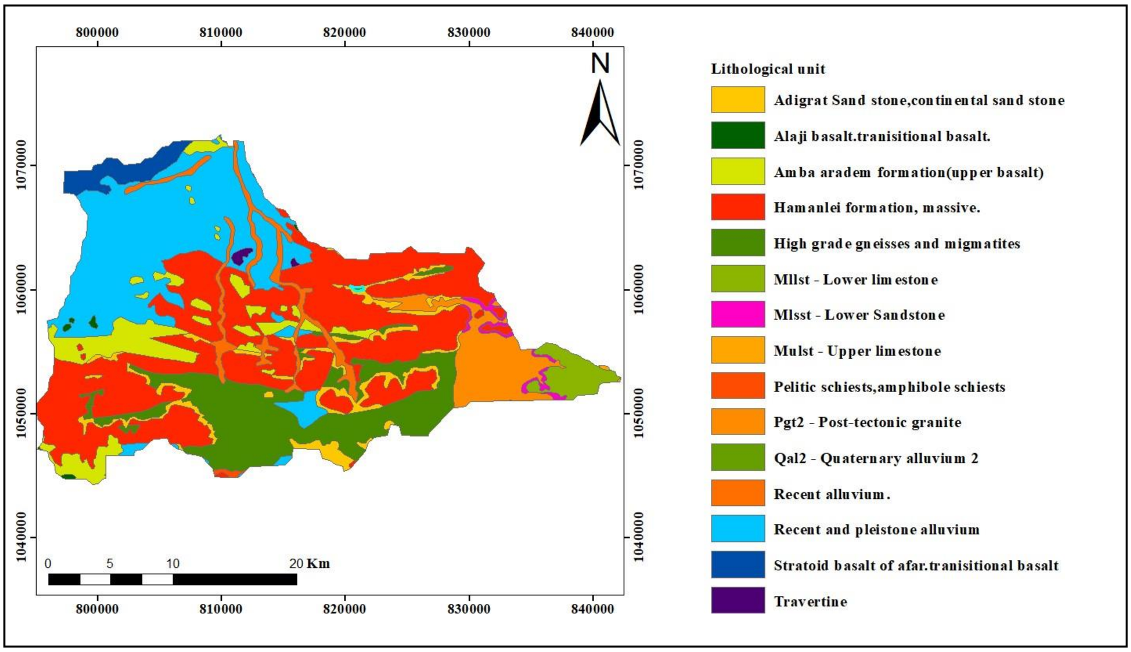


Figure 3. 5 Geological map of Dire Dawa Watershed (After Geological Survey of Ethiopia2010 hydrogeological map of Dire Dawa & Harar sheet

3.1.7 Hydrogeological Characteristics

The water resources in Dire Dawa are mainly derived from the ground water. The contributionof surface water is limited to the rainy seasons. The surface water in most of the wadis disappearsinto the ground up on reaching the plains. During the dry season the only surface water is the base flow from springs WWDSE (2004). The geological formation and hydro geological conditions of the area is a function of geomorphology, on the escarpment outcrops pre-Cambrianrocks, Adigrat sandstone, Hamanalei limestone, upper sandstones and basalts, the down thrownplain (foot of the escarpment) is dominantly covered by alluvial deposits. Both the plains (downthrown block) and the escarpment are highly dissected by east-west trending faults. The groundwater occurrence, distribution and flow regime are highly governed by topography, tectonics, and geological formation, aerial and topological relationship of the geological formation. Based on these major factors, the Dire Dawa Administrative Council can becategorized into two groundwater systems i.e., the escarpment and the foot of the escarpment that is groundwater basin of Dire Dawa Town WWDSE (2003).

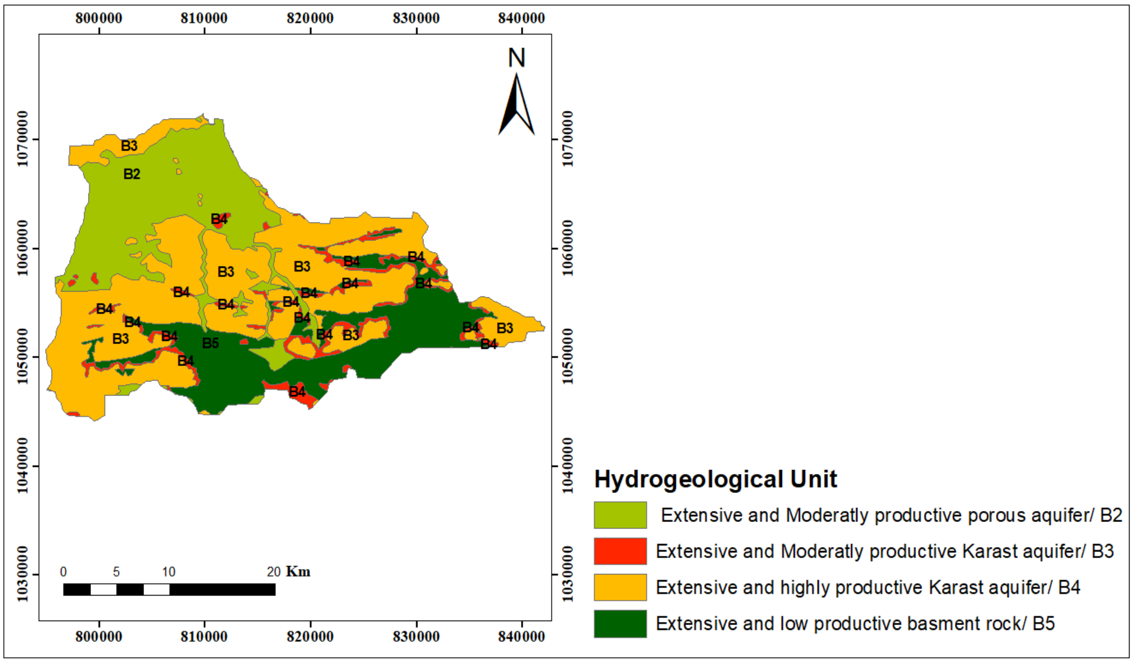


Figure 3. 6 Hydrogeological map of Dire Dawa Watershed (After Geological Survey ofEthiopia 2010 hydrogeological map of Dire Dawa & Harar sheet

3.2 Data collection and data analysis

3.2.1 Climatic Data

Various available data were gathered from concerned deferent organizations, persons and different websites. Among them the different organizations and institutes as well as agencies are Meteorological data like climatic data were collected from National Meteorological Agency (NMA), river flow data were collected from Ministry of Water and Energy.

The following spatial and hydro meteorological data was collected and used in this study for theassessment of the impact of land use land cover change on ground water recharge, using geospatial technologies like remote sensing, Geographical Information System (GIS) and GPSintegrated with field survey:

Table 3.2 Input data for Land use and Landcover map preparation and SWAT model with its source

Data type	Data source
1. Topography& Slope: DEM (30*30m)	Downloaded from USGS-SRTM
2. Satellite image	(https://earthexplorer.usgs.gov/)
3.Temperature	National meteorology agency (NMA)
4. Precipitation	National meteorology agency (NMA)
5. Rainfall	National meteorology agency (NMA)
6. Stream flow	Ministry of water and energy
7. Soil	FAO

3.2.2 Hydrometeorology Data

There are eight meteorological stations within and around the study area and monthly data of the meteorological parameters are obtained from NMA of Ethiopia. The stations are selected based on data availability and their position concerning the study area. Therefore, the nearest station which has long-term continuous data is very crucial to estimate the hydrometeorology of a catchment or a basin at large. For the processing of meteorological data (precipitation, evapotranspiration, temperature, Relative humidity, sunshine hour and wind speed), the period (1999-2022) is chosen with an average value for each seasonal time step, i.e., the winter and summer seasons corresponding to the periods October-May and June-September, respectively. Annual and seasonal meteorological parameters were prepared from the available meteorological data. Monthly precipitation recording data are available in all stations, but temperature records have only been recorded in five stations. Mean monthly values of precipitation were used to derive mean annual precipitation, summer season precipitation (June–September), and winter season precipitation (October–May).

The missed records of the station were adjusted by the commonly used method which is calledthe Averaged method. In the estimation of missing data from a rain-gauge station, the performance of a group of neighbor stations including the one with missing data was considered.A comparison of the recordings of these stations is made by using their normal rainfall as the standard of comparison. Normal rainfall is the average value of rainfall at a particular date, month, or year over a specified 22-year period. Thus, the term normal monthly precipitation ata station means the average precipitation for a particular month at the station based on 22-year of record. Insertion of missing data to a station must be done carefully. If too much data is estimated, the quality of the total data set may be weak due to interpolation. Sometimes, if too many gaps exist in a record, it may be worthwhile to neglect that station than to have a station record with too much interpolated data. According to a WMO (World Meteorological Organization) guideline, not more than 10% of a record should have interpolated data. where there is a lack of meteorological stations, daily precipitation, and temperature data werecollected from SWAT Global Weather data (https://www.uoguelph.ca/watershed/w3s/) to fill the data gap represented by CFSR1. CFSR2, and CFSR3.

3.2.3 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. USGSweb page for the year 2000, 2010 & 2022 G.C with the same spatial and temporal resolution. Ithelps to extract information on land use land cover change detection and conversion rate of theparcel of land from one types of land use to the other in the study area.The selection of the images is based on the following criteria:

The images had no cloud cover over the study area.

The images were of good quality according to the USGS rating criteria.

The resolutions of the images were similar.

Table3.3 Landsat image data source for the three period

Sensors	Satellite	Path	Row	Date of acquisition	Spatial Resolution (m)
Landsat ETM+	Landsat_7	166	053	23/Dec/2000	30m
Landsat TM	Landsat_7	166	053	25/Jan/2010	30m
Landsat OLI	Landsat_8	166	053	20/Dec/2022	30m

3.2.4 Soil data

Soil data was obtained 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 was produced from DEM 30 by 30 which is downloaded from USGS-SRTM. Land use land cover map was 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.

Table 3.4 Software used

No	Software	Use
1	QGIS	For Analysis and mapping
2	ERDAS IMAGIN	Preprocessing and image enhancement
3	ArcSWAT	To analysis hydrological process
4	SWAT-CUP	For validation and calibration
3	ENVI	To classify satellite image
5	Google earth pro	To assess the area before going to the field
6	Endnote	Reference and citation

3.3 Identifying trend of Land use Land cover change

3.3.1 Image processing

Image processing constitutes a crucial component of numerous remote sensing operations. Almost all digital imagery necessitates some form of processing to be applicable in the majorityof applications. It encompasses the manipulation and interpretation of digital images utilizing computer assistance (Chipman et al., 2000). In this study only three types of digital image processing operations were used: layer stacking, image rectification and restoration (preprocessing), image enhancement and image classification. The first part of image processing is usually known as preprocessing, since it must precede most other image processing operations. Pre-processingis aimed at correcting distorted or degraded data to create a more faithful representation of the original scene. This typically involves the initial processing of raw image data to correct for geometric distortions, to calibrate the data radiometrically and to eliminate noise present in the data (Fundamentals of Remote Sensing). During layer stacking, the Universal Traverse

Mercator (UTM) system with WGS 84 as a datum was assigned as a preference as far as projection is concerned. All seven bands of ETM+ were considered for Layers stacking. After layer stacking, all the scenes have the same co-ordinate system UTM Zone 37 North using WGS84 as a datum.

3.3.2 Image Enhancement

Image enhancement stands as a fundamental technique within image processing, aimed at preparing an image for enhanced interpretation within specific applications. Its primary objective is to render crucial features within raw, remotely sensed data more discernible and interpretable to the human eye. The following image enhancement techniques were used beforeimage classification was performed.

3.3.2.1 Contrast Enhancement

It is used to increasing the contrast between targets and their backgrounds by changing the original values using more available range. From contrast enhancement techniques linear contrast stretch where used to identify the lower and upper bounds from the histogram and applying a transformation to stretch this range to fill the full range.

3.3.2.2 Spatial Filters

are used to highlight specific features in an image based on their spatial frequency. The types ofspatial filters applied in this study are low-pass and high-pass filter. Low-pass filter reduce the smaller detail in the image and give stress to larger, homogeneous areas of similar tone and results to smooth the appearance of the image.

3.3.2.3 Directional or Edge Detection Filter

is used to highlight linear features, such as roads or field boundaries and also be to enhance features which are oriented in specific directions. These filters are mostly useful in applicationsas extraction of geological structures (fundamental of remote sensing).

3.3.3 Image Interpretation and Classification.

Different image interpretation elements were used to distinguish variations among features. Forinstance, pattern, tone, shape, size association and texture ware used for effective of land

use/cover classification. Classification is one of the digital image processing that is very usefulfor different land use land cover mapping. The analyst that is classifying an image must distinguish between spectral classes and information classes. Spectral classes are groups of pixels that have nearly uniform spectral characteristics. Information classes are the various groups that the analyst is trying to identify in an image.

Information classes may include classes such as deciduous and coniferous forests, various agricultural crop types, etc. Each object has unique and different characteristics of reflection oremission in different environment as a result an object can be identified using reflected /emittedelectromagnetic radiation from that object (Billah et al., 2004). Remotely sensed datasets provide useful thematic information and extracting thematic information from the data is obtained through image classification. There are variety of techniques for extracting thematic information from an image. From these Unsupervised and supervised image classifications arethe most frequently applied classification techniques in remote sensing.

For accurate image classification, band selection also crucial since one feature which is not discriminated apparently may be clearly differentiated on another band. For this purposes Interpretation and classification was carried out by utilizing FCC and TCC. The Landsat ETM+2011 image has seven bands with a spatial resolution of 28.5 m and additional one panchromaticband which is merged to improve a spatial resolution of the features to 15m and similar color composite (4:3:2 FCC and 3:2:1 TCC band combination) has been used for the LULC classes mapping (Fig.4.3). The false color composite and object based supervised classifications were done using ERDAS Imagine 15 software. Ground truth data which were collected during field survey were used for supervised image classification using the algorithm of Maximum likelihood classifier.

3.4 Accuracy Assessment, Kepa coefficient

One of the most important final steps at classification process is accuracy assessment. The aim of accuracy assessment is to quantitatively assess how effectively the pixels were sampled into the correct land cover classes. Moreover, the key emphasis for accuracy assessment pixel selection was on areas that could be clearly identified on both Landsat high resolution image, Google earth and Google Map. The high-resolution image of Google Earth linked with ERDAS

Imagine and knowledge about the study area aided the classification. Repeated classifications were done to increase the accuracy using the signature editor tool.

Individual pixels on the images were used as validation units for the image accuracy assessment.User’s, producer’s, overall, and Kappa Coefficient assessments were done as part of the accuracy assessment.

$$The\ Overall\ Classification = \frac{Number\ of\ correct\ points}{Total\ number\ of\ points} ------ (Eq\ 2$$

$$Kappa\ Coefficient\ (T) = \frac{(TS * TCS) - \sum(CT * RT)}{TS^2 - \sum(CT - RT)} -------- (Eq\ 3)$$

Where TS=Total Sample, TCS= Total column sample, CT= Column Total, RT= Raw Total.

3.4.1 Land-use land-cover change detection

Change detection is the practice of detecting differences in the condition of an object or phenomenon by studying them at various intervals of time using remote sensing techniques. Because of repetitive spatial coverage within a short period time and consistent image quality, change detection is considered one of the major applications of remotely-sensed data obtained from Earth-orbiting satellites. Because change detection is enforced by factors such as spatial, spectral, thematic, and temporal features, choosing appropriate method for change detection is critical in obtaining a more accurate change detection result. (Sahalu, 2014). It's very necessaryfor detecting changes in various forms of land-use, such as an increase in urban built-up area ora decrease in agricultural land, and so on. By studying the same area at multiple time periods using satellite photos or aerial photography, the user can determine the change in land-use and land-cover in that location. According to(Gashaw et al., 2018), the percent and rate of change of each land use and land-cover were calculated by using equation 3.5 and equation 3.6 respectively shown below

$$Percent\ Change = \frac{Ay - Ax}{A} * 100 ------------ Eq4.$$

Where For writing an equation use standard equation writer software.

Ax= Initial area of land use land cover
Ay=Final area of land use land coverA=Total area

3.5 Groundwater Recharge Estimation

The complexity of groundwater modeling into groundwater resource development and sustainable management can be managed by using Soil and Water Assessment Tool (SWAT) hydrological model and remote sensing for groundwater recharge estimation. To simulate the hydrologic processes (including recharge) in the watershed the SWAT model has been used. Steps for SWAT model setup and detail analysis is listed below.

3.5.1 Watershed delineation

Arc SWAT utilizes Digital Elevation Models (DEMs) to delineate catchment slopes, create stream networks, and establish sub-catchment boundaries. In this study, the SRTM DEM, boasting a 30- meter resolution, has been employed for these purposes. Furthermore, the elevation data derived from the DEM is utilized to classify the research region. The watershed delineation process facilitates data organization in readiness for the subdivision of the watershed into smaller subunits.

3.5.2 HRU Analysis

The watershed is divided into distinct hydrologic response units (HRUs), representing homogeneoussub-basins characterized by specific attributes such as soil type, slope, and land use. To conduct simulations, overlapped layers of prepared soil and land-use datawere integrated within the defined watershed using Arc SWAT. The resulting layer from this integration is vital for the SWAT model'sanalysis as it assigns unique land, soil, and slope categories to each HRU. These categories dictate the response of the land to precipitation, runoff, infiltration, and various hydrological processes throughout the simulation (Yesuf et al., 2015).

3.5.3 Weather data definition

Once the database setup within Arc SWAT for watershed delineation is completed, the monitoring point layer that was established during this process is expanded to incorporate the locations of the designated weather stations. This expansion involves the inclusion of various weather data such as precipitation, wind speed, relative humidity, sun radiation, maximum andminimum temperatures, among other relevant meteorological information. These weatherstations play a crucial role in providing the necessary data inputs for executing a basic SWAT simulation.

3.5.4 Sensitivity Analysis

Conducting sensitivity analysis is the initial phase in the calibration and validation procedure for a specific watershed or sub-watershed in SWAT. During this phase, the user leverages theirexpertise to determine which variables warrant modification. Sensitivity analysis serves as a hydrological simulation method to evaluate the responsiveness of various elements within the system. Identifying the most sensitive parameters, which hold significant influence over the behavior of the simulated process, is instrumental. This selection allows for a reduction in the parameter set used during the calibration stage. This streamlined approach notably cuts down the time required for calibration and validation, simplifying the overall process. Moreover, it minimizes uncertainties, consequently enhancing the accuracy of calibration. (Woldesenbet et al., 2017).

3.5.5 Model Calibration and Validation

The calibration and validation process in SWAT initiates with establishing realistic uncertaintyranges for process-based input parameters. This determination of parameters to adjust relies on expert judgment or sensitivity analysis. Sensitivity analysis involves assessing the model output's rate of change concerning variations in model inputs or parameters. It plays a crucial role in pinpointing essential parameters and defining the necessaryprecision levels required for calibration (Ma et al., 2000).

Calibration is an effort to better parameterize a model to a given set of local conditions, thereby reducing the prediction uncertainty. Model calibration is performed by carefully selecting valuesfor model input parameters by comparing model predictions (output) for a given set of assumedconditions with observed data for the same conditions. Model validation is the process of demonstrating that a given site-specific model is capable of making sufficiently accurate simulations, although “sufficiently accurate” can vary based on project goals Validation

involves running a model using parameters that were determined during the calibration process, and comparing the predictions to observed data not used in the calibration (Refsgaard, 1997). parameters that were obtained during the calibration phase(Getachew, 2019; Ibrahim, 2018). Model validation compares the field observations (data that was not utilized in calibration) to model predictions without changing any input parameter values to evaluate the calibrated model.

3.5.6 Model Performance Evaluation

Upon establishing the model's credible predictive ability in both calibration and validation stages against an independent dataset of observed values, it becomes viable for making future predictions under diverse management scenarios. Multiple methodologies are available for evaluating the performance of the SWAT model throughout calibration and validation phases. In this specific study, two distinct approaches were employed to quantitatively assess the SWAT model: the Nash-Sutcliffe simulation efficiency (NSE) and the coefficient of determination (R2). These metrics served as tools to assess and gauge the model's precision and consistency in reproducing observed data across various testing phases.

3.5.6.1 Coefficient of Determination (R2)

The coefficients of determination describe the proportion of the total variances in measured data bythe model. It is the magnitude linear relationship between the observed and the simulated values thatrange from **0** to 1. The R2 is calculated using the equation:

$$R^2 = \frac{[\sum_i^n (Q0 - Qm0)(Qs - Qms)]^2}{\sum_i^n (Qo - Qmo)^2 \sum_i^n (Qs - Qms)^2} - - - - - - - - - - Eq7$$

Where;

Q0; is Observed flow data in m^3/s,

Qmo; is mean values of the observed data.Qs; simulated flow data in m^3/s.

Qms; is mean values of simulated data.

A value of 1 indicates a perfect fit and therefore a very reliable model or less error variancewhere as a value of zero indicates that the model fails to accurately model the dataset

3.5.6.2 Nash-Sutcliffe Efficiency

(NSE) The NSE determines the proportionate level of residual error compared to the measuredvariance in the data.

3.5.6.3 SWAT Model simulation

The hydrologic component is a fundamental aspect of the SWAT model, utilizing key variables to address the water balance equation. Precipitation, surface runoff, evapotranspiration, percolation, and flow variables are integrated within the model to achieve a comprehensive solution to the water balance equation. The hydrologic component is a fundamental aspect of the SWAT model, utilizing key variables to address the water balance equation. Precipitation, surface runoff, evapotranspiration, percolation, and flow variables are integrated within the model to achieve a comprehensive solution to the water balance equation (Kurbah & Jain, 2017)

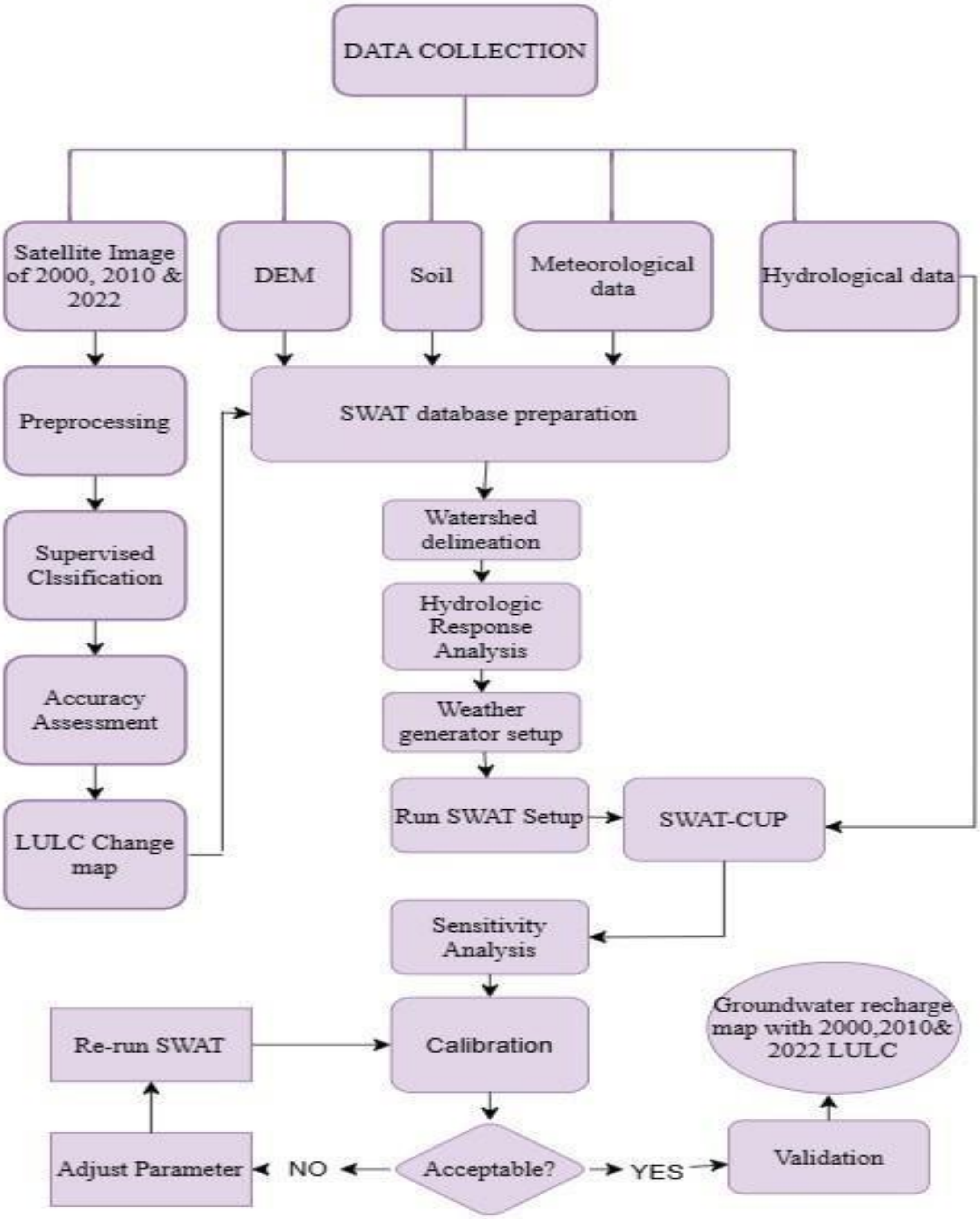


Figure 3. 7 The conceptual framework of the study

CHAPTER 4: RESULTS AND DISCUSSIONS

In this chapter, different results which were obtained related to the Land use land cover maps from Satellite image and the hydrological component, the SWAT outputs of the Spatial and temporal water balance component of the Dire Dawa catchment are identified and discussed. Furthermore, the land use land cover change detection and its impact on the seasonal and annual areal distribution SWAT results of the groundwater recharge were assessed and discussed.

4.1. Trends of Land use/cover change of Dire Dawa watershed

4.1.1 Land use land cover Maps

For this study area six majorland use and land cover Classes (Shrub land, Forest, Agricultural land, Settlement, Barren land,and Riverside sand) grouped. The identification of the trend of Land use and Land cover changeof the catchment from 2000 to 2010, and 2022 done. The Land degradation issues have been largely attributed to poor land use practices, inadequate management systems, and a lack of effective soil conservation measures throughout the study area. Land use has a significant impact on infiltration, erosion, and evapotranspiration as a component of the runoff process.

Compared to shrub land, the areal coverage of agricultural land, built-up areas, and Riverside sand has increased. The forest coverage was 12.25% in 2000, but by 2010, it had dropped to 4.45%, indicating significant deforestation during this time. However, after restoration, in 2022,the forest coverage increased to 7.95%. shown in table 4.2, and figure 4.3 below.

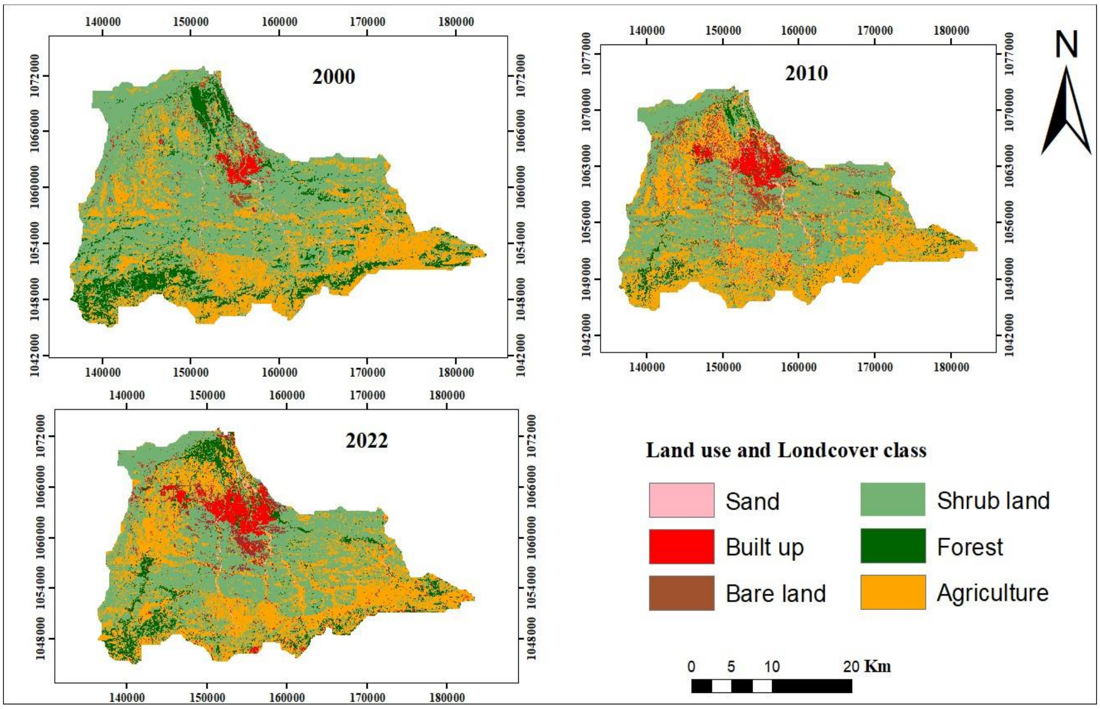


Figure 4. 1 Land use and landcover map of the study area (2000, 2010, and 2022)

Table 4.1 the Land use and landcover classes and their areal coverage in 2000, 2010, and 2022

	2000		2010		2022	
	Area (Km^2)	**Area (%)**	**Area (Km^2)**	**Area (%)**	**Area (Km^2)**	**Area(%)**
Shrub Land	372.38	53.36	323.20	45.17	266.99	38.56
Agriculture	217.81	30.82	266.99	38.13	284.56	40.48
Forest	84.31	12.25	31.62	4.54	55.51	7.95
Built Up	12.44	1.77	35.13	5.00	41.45	5.91
Bare land	9.97	1.42	41.45	5.94	40.75	5.85
Riverside sand	2.74	0.39	8.57	1.22	8.78	1.25

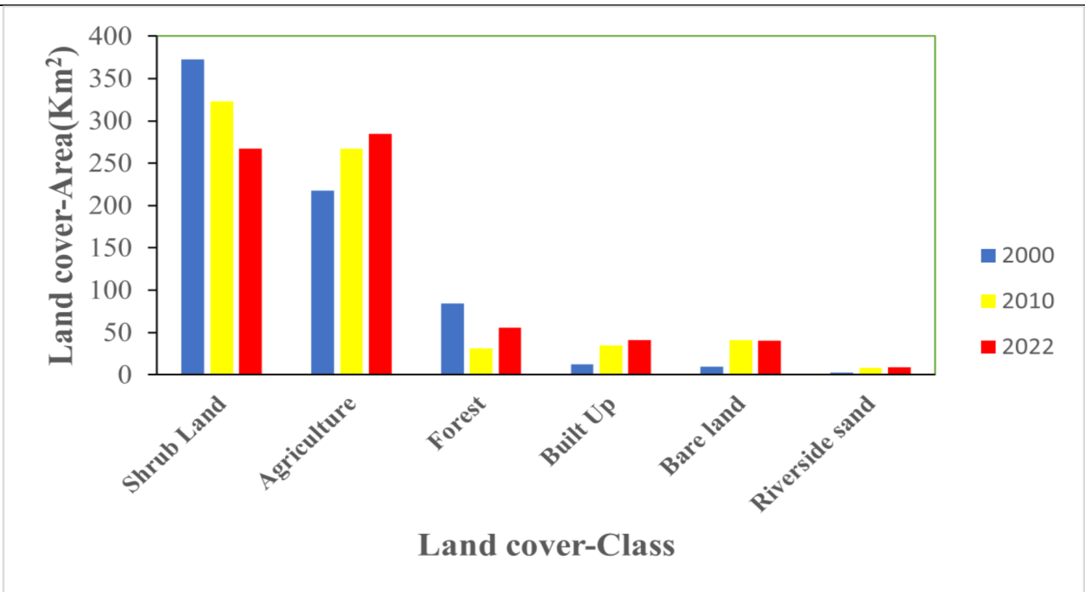


Figure 4. 2 Land use land cover classes and their relative area

4.2 Accuracy Assessment

For a supervised classification of different year images, the acceptable standard of accuracy results is above 85% overall accuracy level and over 85% Kappa coefficient (Fugara et al. 2009). We took 50 ground truth Global Positioning System (GPS) points for each of the six land-use types in the Dire Dawa catchment to validate the LULC classification on the 2000,2010, and 2022 image. The accuracy assessment results indicated a valid supervised image classification for the 2022, 2010, and 2000 images with 88%, 89%, and 86% of the overall accuracy respectively. The table 4.2 below shows the accuracy assesment of image year 2022.

Table 4. 2 Overall accuracy assessment for LULC image classification (2022)

	Shrubland	Agriculturalland	Forest	Bulit up	Bare land	Riverside sand	User
Shrub land	10	0	0	0	0	0	10
Agriculturalland	1	7	0	0	0	0	8
Forest	1	0	7	0	0	0	8
Built up	0	1	0	7	0	0	8
Bare land	0	0	0	0	6	0	6
Riverside sand	1	1	0	0	1	7	10
Producer(total)							

$$Overall\ Accuracy = 88\ a\%$$

4.3 Land use land cover Change

Remotely sensed imagery is critical for showing land use land cover change detection because it has the high ability to provide spatial and temporal information on a given area. To realize thedifference in state of LULC the post-classification comparison change detection techniques were used since it is widely used and simple to understand. This approach also gives detailed 'from-to' information that can be efficiently extracted. The statistics of this variation will be computed by comparing values of the area of one data set with the corresponding value of the second data set in the common area in each period.

4.3.1 Land-use land-cover changes for the three periods (2000, 2010, and 2022)

The land-use land-cover change detection from the period 2000 to 2010, 2000 to 2022, and 2010to 2022 shown in the table below.

Table 4. 3 Land-use land-cover change from the period 2000 to 2010, 2000 to 2022, and 2010

to 2022

	2010-2000		2022-2010		2022-2000	
	Area (Km^2)	**Area (%**	**Area (Km^2)**	**Area (%)**	**Area (Km^2)**	**Area (%)**
Shrub Land	-49.18	-56.21	-6.61	-8.19	-105.39	-14.8
Agriculture	49.18	17.57	2.35	7.31	66.75	9.66
Forest	-52.69	23.89	3.41	-7.71	-28.8	-4.3
Built Up	22.69	6.32	0.91	3.23	29.01	4.14
Bare land	31.48	-0.7	-0.09	4.52	30.78	4.43
Riversidesand	5.83	0.21	0.03	0.83	6.04	0.86

4.4 SWAT model setup

Topography and slope of the area (Dire Dawa watershed) 30m resolution SRTM data downloaded from USGS earth explorer. The topography of the watershed ranges from 1014m to 2408 m.

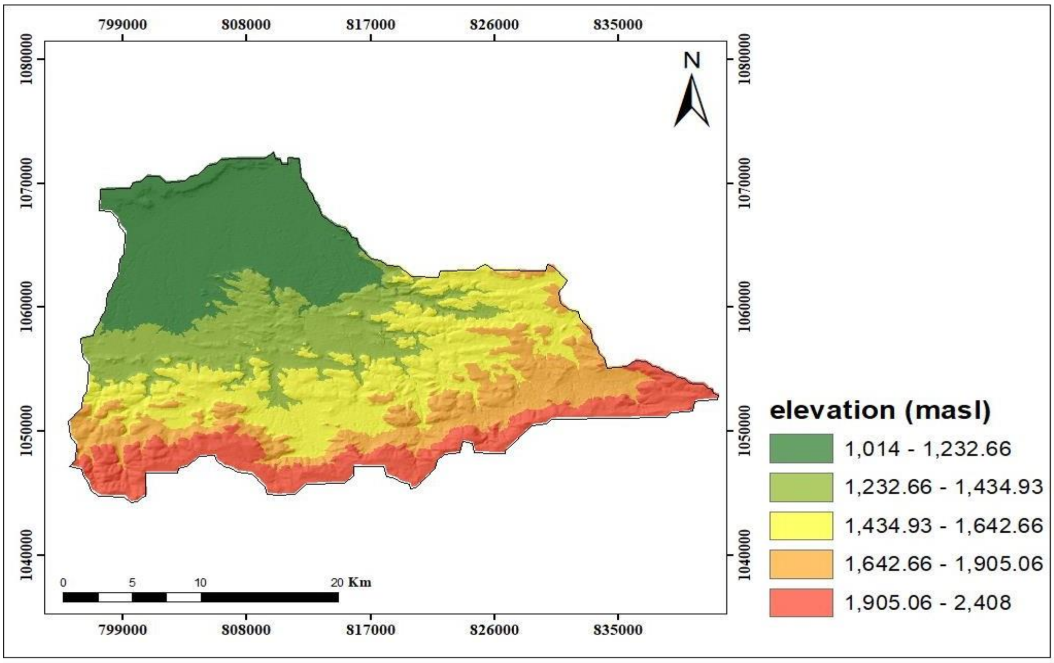


Figure 4.3 DEM map of Dire Dawa Watershed

4.4.1 Soil Type

Before rainwater seeps deeper into the soil and recharges the aquifer system, it is first stored inthe pores of the soil. Every type of soil has a variable capacity to store and transport water because the quantity of evapotranspiration from the soil is influenced by factors such soil texture, soil structure, and soil moisture content.

Soil properties influence the relationship between runoff and infiltration rates which in turn control the degree of permeability; it shows the influence of soil parent material and the spatialvariability in the degree of weathering. Soils are formed on account of the climate, physiographic, geology, living organisms, and other factors responsible for soil formation and development. Those soils associated with lacustrine sediments, river alluvium and pumice are weakly developed and unconsolidated which are high permeable and likely to generate little surface runoff (Ayenew 1998). Unconsolidated sediments are common below the rift shoulder slopes and at the foot of volcanic mountains. Many areas bordering the rift bear well-developedsoils overlying weathered ignimbrite and pumice

Table 4. 4 The soil Texture class and areal coverage in percent

Soil Class	Aerial Coverage (%)
Sandy Clay loam	64.99
Clay Loam	28.33
Clay	6.27
Sandy Clay	0.17
Sandy loam	0.13
Loam	0.11

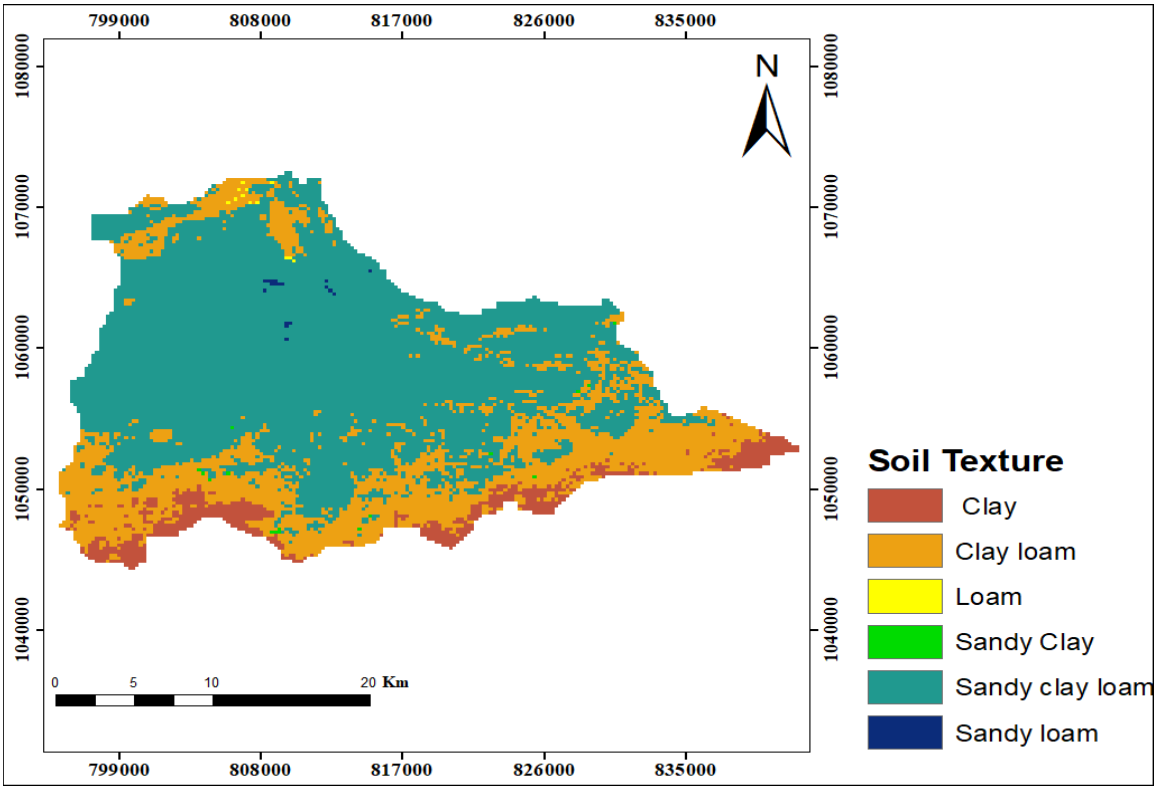


Figure 4. 4 soil maps of the study area

4.4.2 Slope

As shown by the slope map(figure 5.4). The presence of faults is what causes this change in slope. To estimate the slope indegree, a digital elevation model (DEM) is created using topographical map contour data.

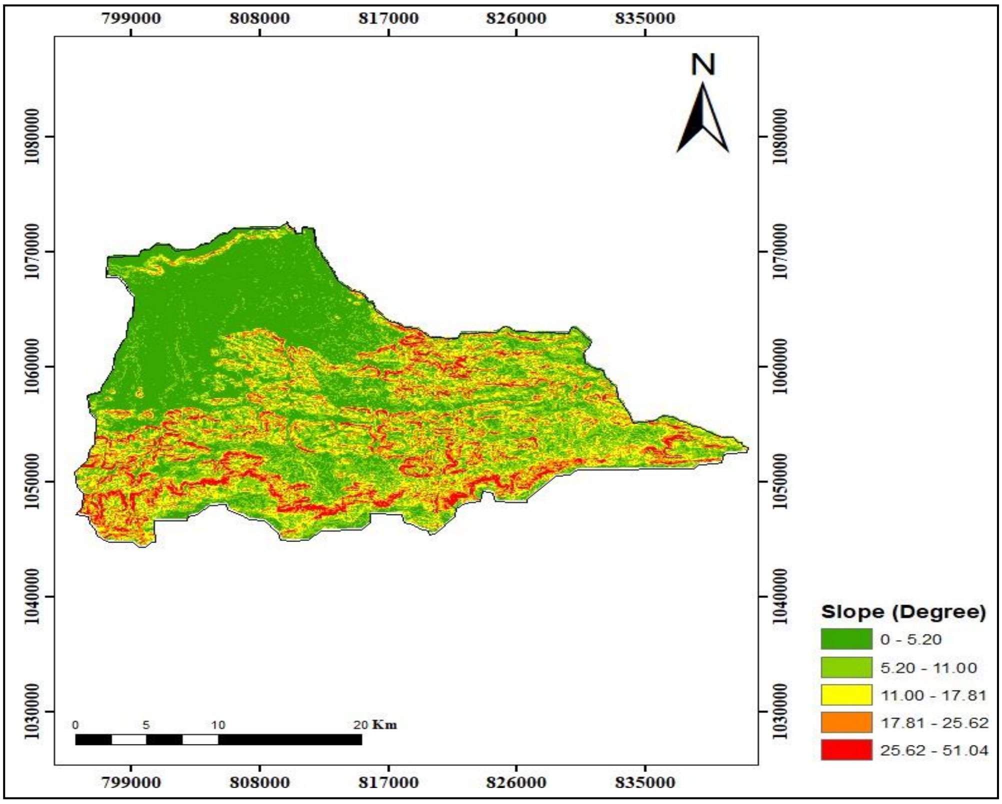


Figure 4. 5The slope map Dire Dawa catchment

4.4.3 Watershed Delineation

As was discussed in earlier sections, a DEM with a 30 m resolution was used to carry out anautomatic delineation operation for the watershed. The model's estimated threshold area of 13,
88.42 hectares was utilized to establish the required minimum drainage area for the formationof the river network and 30 sub-basins make up the Dire Dawa catchment.

The HRU analysis, which calls for the LULC, the soil, and the slope of the basin, was used toperform the HRU definition. According to Neitsch et al. (2005), ARCSWAT offers three

choices for the definition of HRUs. The method that takes into account the spatial variability ofthe processes is used in this work, and the datasets were created in spatial format and connected.The multiple HRU definition criteria were then selected then performed for most applications the default settings for land use threshold (20%), soil threshold (10%), and slope threshold (20%) for the slope of individual sub-basin areas. Overall, there were 250 HRUs defined in theentire watershed within 30 sub-basins.

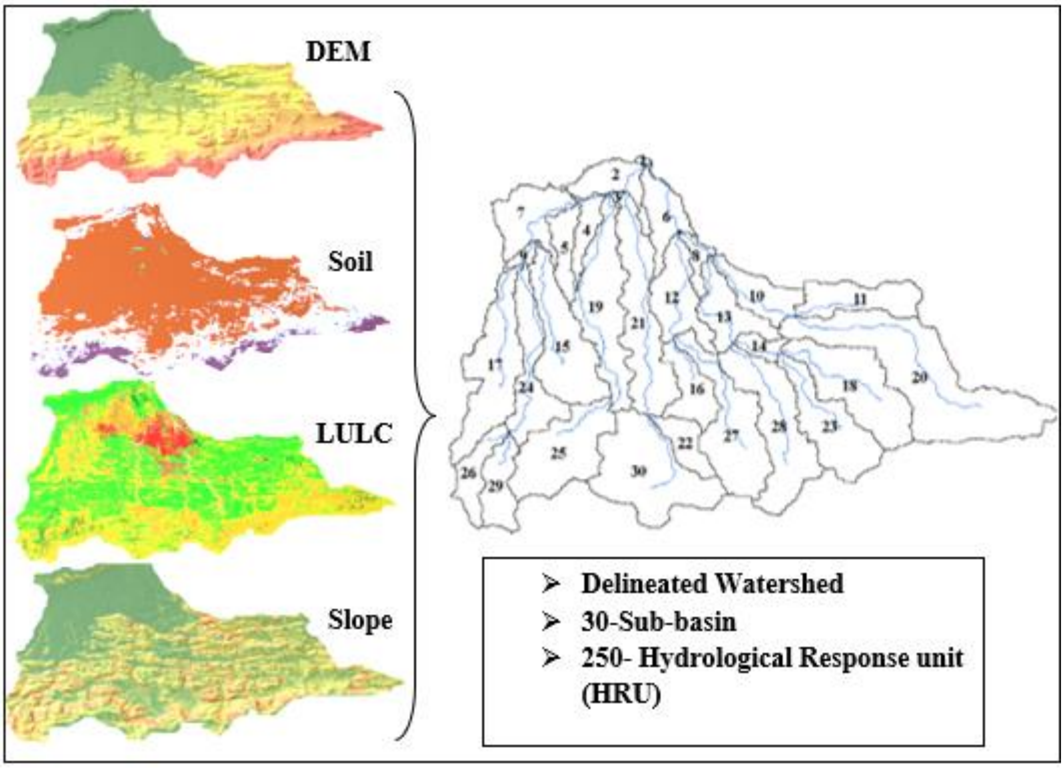


Figure 4. 6 Delineated Watershed with (HRU) of Dire Dawa catchment

4.4.4 Model Sensitivity Analysis

As suggested by Neitsch et al. (2011), the sensitivity of the simulated streamflow to fifteen hydrological parameters were tested using the default lower and upper bound parameter values.Based on the sensitivity test, 13 parameters have a considerable effect on streamflow simulation,which means that they have a relative. Sensitivity of more than or equal to 0.01 (Table 4.5. These parameters were selected for the calibration process.

Table 4. 5 The most sensitive parameters and their range

Sensitivity Rank	Parameters	Description	t-Stat	P Value
1	CN2	SCS runoff curve Number	7.709	0.0
2	GW-DELAY	Groundwater delay (days)	-7.319	0.0
3	CH-K2	Effective hydraulic conductivity in mainchannels	-6.225	0.0
4	SOL-AWC	Available water capacity of the soillayer	-2.839	0.006
5	CANMAX	Maximum canopy Storage	-2.109	0.038
6	ALPHA-BF	Base flow alpha factor (days)	-1.443	0.153
7	ESCO	Soil evaporation compensation factor	-1.281	0.203
8	EPCO	Plant uptake compensation factor	-0.804	0.423
9	GW-QMN	Threshold depth of water in the shallowaquifer	0.483	0.631
10	SOL-K	Saturated hydraulic Conductivity	-0.415	0.679
11	CH-N2	Manning 's ―n‖ value for the main channels	-0.333	0.739
12	SOL-Z	Depth from the soil surface to bottom of thelayer	0.306	0.759
13	RCHRG-DP	Deep aquifer percolation fraction	-0.077	0.938

4.4.5 Model Calibration and Validation

Santhi et al. (2001) proposed a procedure for calibrating SWAT for river discharge and sedimentyield. They recommended that the results of SWAT calibration are acceptable if:

(i) the simulated mean flow (monthly or daily) differs from the mean measured flow by a value that iswithin ± 15 %; (ii) the coefficient of determination is (R^2) greater than 0.60; and (iii) the Nash-Sutcliffe model efficiency (NSE) is greater than 0.50. After playing with the selected fifteen parameters for a long time, it was coming up with good results showing good agreement betweenthe simulated and observed river discharge data. For validation purposes, the fitted parameter value in the calibration approach has been adjusted directly and showed a good agreement.

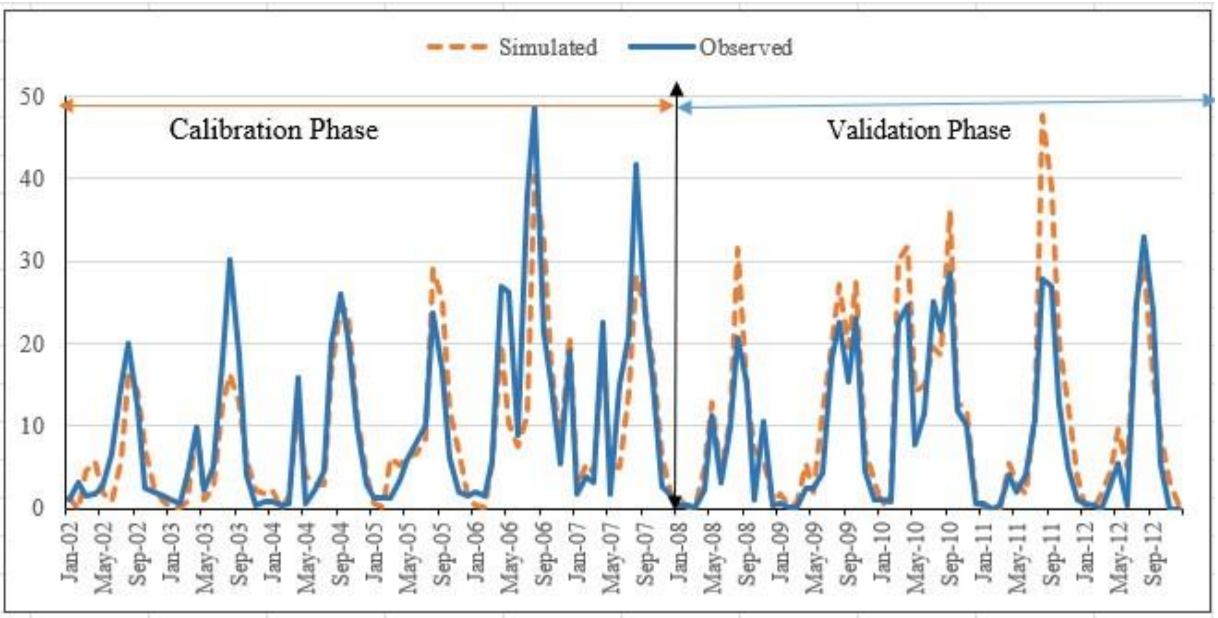


Figure 4. 7 Hydrograph of Measured and simulated average monthly flow rate

4.5 Evaluation of SWAT Model Performance

The calibration and validation result showed that the SWAT model performed well in simulatingmonthly river discharge. It can therefore be concluded that the SWAT model built for the DireDawa watershed realistically represents the hydrological flows in the basin and can, therefore, be used for future impact studies.

Table 4. 6 The SWAT model performance evaluation

GaugingStation	Statistical tested	Monthly Model Efficiency Measure		
		R^2	NSE	PBIAS
Erer2nd erergota	Calibration	0.84	0.75	-0.1
	Validation	0.79	0.72	-11

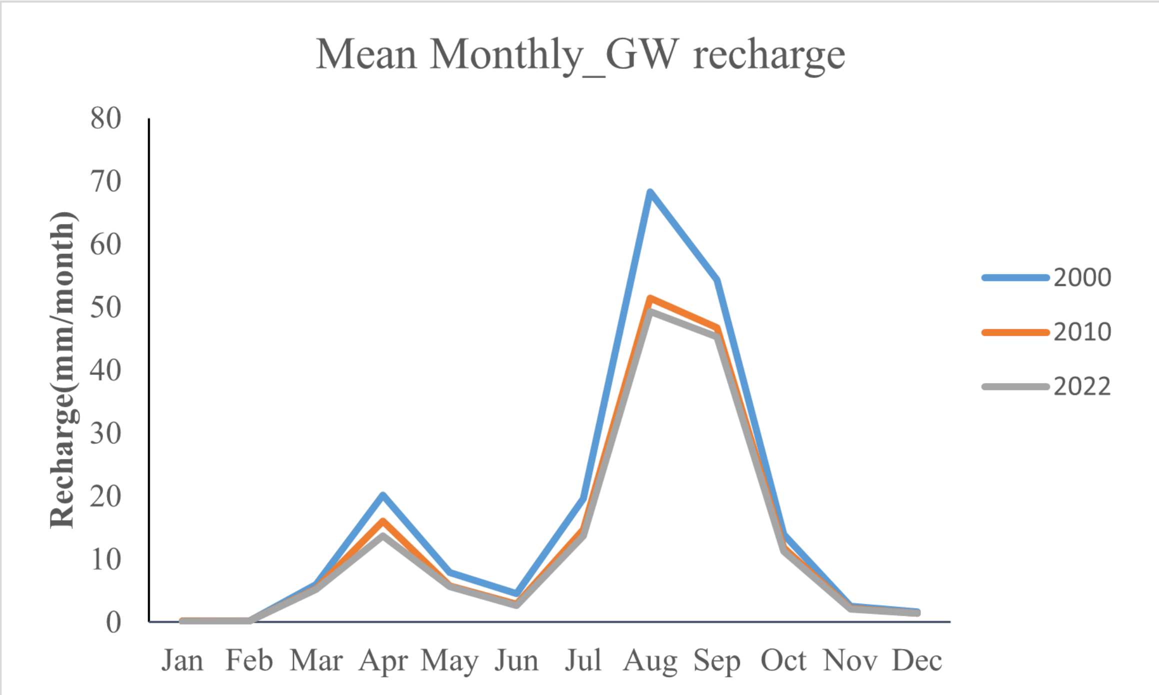
4.5.1 Ground water recharge response to Land-use land-cover changes

LULC change is an important characteristic in the runoff process that affects infiltration, erosion, and evapotranspiration. Understanding the effects historic land-use changes have on hydrology is required to understand the future impacts of land use and land cover on hydrological regimes at the catchment level. The response of the LULC change on watershed hydrology of the Dire Dawa watershed was examined by running the SWAT model after successful calibration and validation phases. To simulate the impact, SWAT input parameters were kept constant except for the LULC map as per many scholar's assertions (e.g., Getachew and Melesse, 2012; Gebremicael et al., 2013; Gwate et al., 2015). Based on this, the simulated results of 2000, 2010, and 2022 LULC scenarios were used to assess the hydrological responseof the major water balance components: Surface runoff (SURQ), and Recharge (RCHG), Table(4.7) and Figure (4.6) depict the average annual basin-scale values for the Surface runoff and recharge showed changes under each historic LULC map.

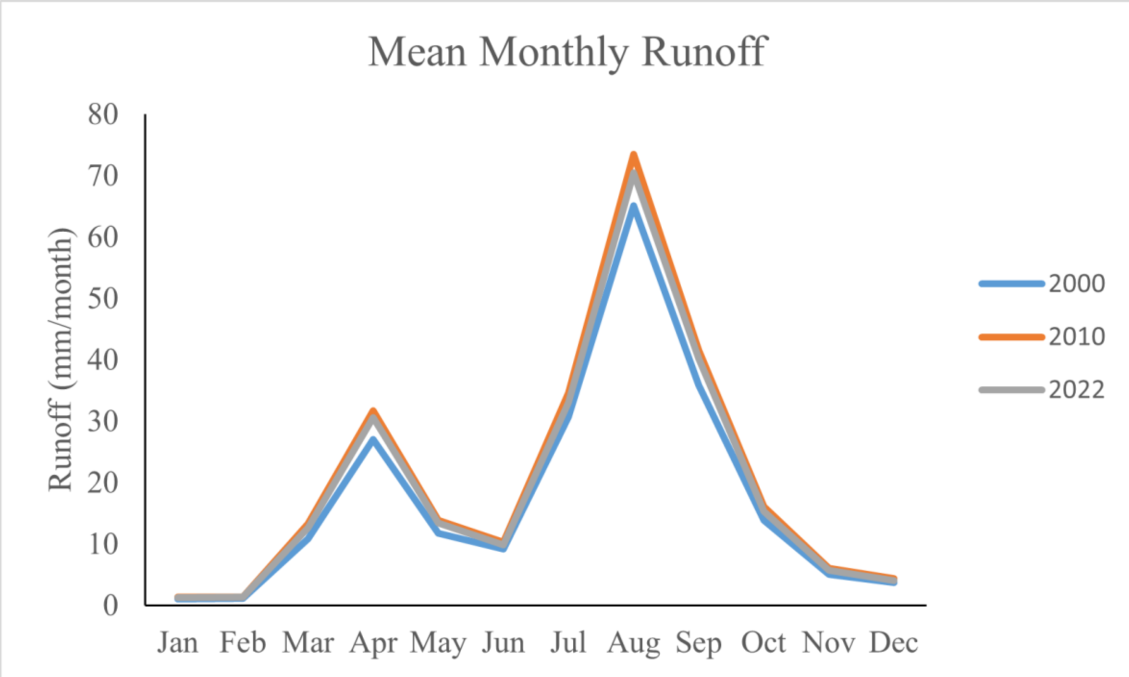
Concerning the respective LULC scenarios, it was observed that SURQ showed a consistent increment from 215.18 mm in 2000 to 248.12 mm in 2010, and 257.96 mm in 2022 (Table 4.7).These changes indicated that the mean annual surface runoff surface runoff is amplified by 15
% from 2000 to 2010, 5% from 2010 to 2022, and 10% from 2000 to 2022. The impact of these changes resulted from the unstoppable transformation of shrubland and forest to agricultural land and an increase in built-up areas in the watershed since 2000. The continuous increased annual surface runoff can be attributed to the fact that between 2000 and 2022 the soil was poorly covered or even bare, so interception was lower and the curve number higher than in thereference year 2000. On the other hand, Recharge was observed to have a continuous decline under all scenarios. It reduced from 199.42 mm in 2000 to 158.87 mm in 2010 and 150.66 mmin 2022; representing a total decrease of 20 %, 5.17%, and 25% between the years 2000 to 2022,2010 to 2022, and 2000 to 2022 respectively. The decrease in annual Recharge can be attributedto less soil infiltration, more surface runoff, and higher Evapotranspiration in the years studied. In general, this finding is similar to the results obtained in previous studies in different parts ofEthiopia (Mechal et al. 2022; Solomon et al. 2010; Solomon et al. 2014; Abate 2011; Rientjes et al., 2011; Temesgen et al., 2014; Temesgen et al., 2018; Ariti et al., 2015). the results of the groundwater recharge and surface runoff were presented in Table 4.7.

Table 4. 7 Mean monthly Groundwater recharge and surface runoff using LULC map of 2000,2010, and 2022

		Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2000	RCHG	0.21	0.22	6.03	20.15	7.94	4.51	19.67	68.25	54.36	13.91	2.51	1.66	199.42
LULC	SURQ	1.02	1.11	10.87	27.03	11.76	9.13	30.69	65.06	35.90	13.84	5.01	3.76	215.18
2010	RCHG	0.17	0.20	5.37	16.03	5.79	2.86	14.74	51.43	46.75	11.83	2.25	1.45	158.87
LULC	SURQ	1.41	1.40	13.26	31.71	13.85	10.35	34.68	73.43	41.52	16.08	6.09	4.34	248.12
2022	RCHG	0.13	0.20	5.22	13.69	5.62	2.69	13.77	49.27	45.28	11.27	2.13	1.39	150.66
LULC	SURQ	1.28	1.35	12.60	30.64	13.45	9.86	43.05	70.43	40.20	25.28	5.73	4.09	257.96



(a)



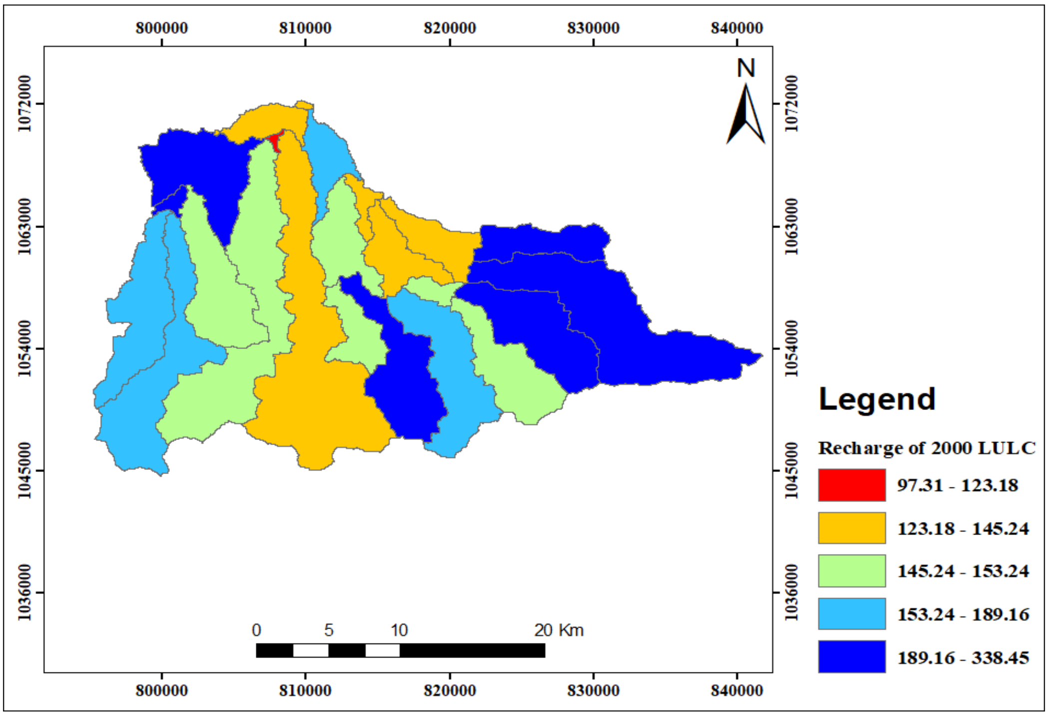
(b)

Figure 4. 8 The long term mean monthly (a) Groundwater recharge and (b) surface runoff forthe three historic period (2000, 2010, and 2022) LULC maps.

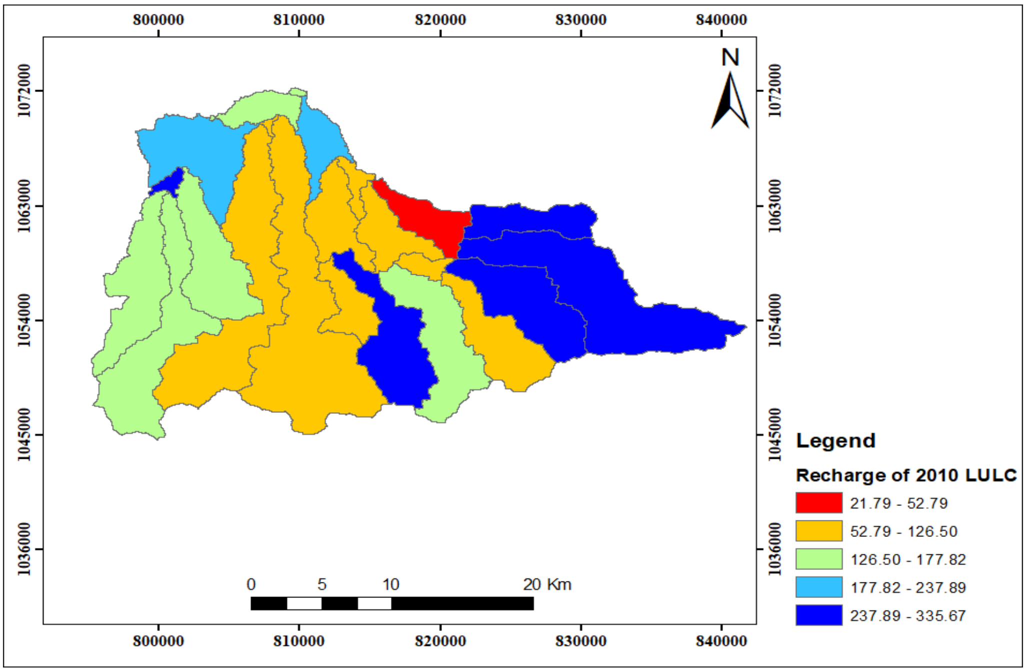
The above figure 4.6 and table 4.7 shows the decrease in amount of groundwater recharge and increase in surface runoff amount as compered from historic period LULC maps of 2000, 2010,and 2022. The long-term average monthly groundwater recharge and surface runoff analyzed for different LULC maps by keeping other input parameters constant, to quantify the impact of land management practice on water resource. The impact of expansion in agricultural activityand urbanization result in decreasing in amount of groundwater recharge and decreasing in amount of surface runoff. the groundwater recharge of 2000 LULC map compared to 2010, and2022 shows decrement in 41mm and 49 mm respectively, the main reasons are deforestation, urbanization (increase in population growth), and intensive agricultural activities.

4.5.2 Spatial Hydrological Response to Land-use land-cover changes

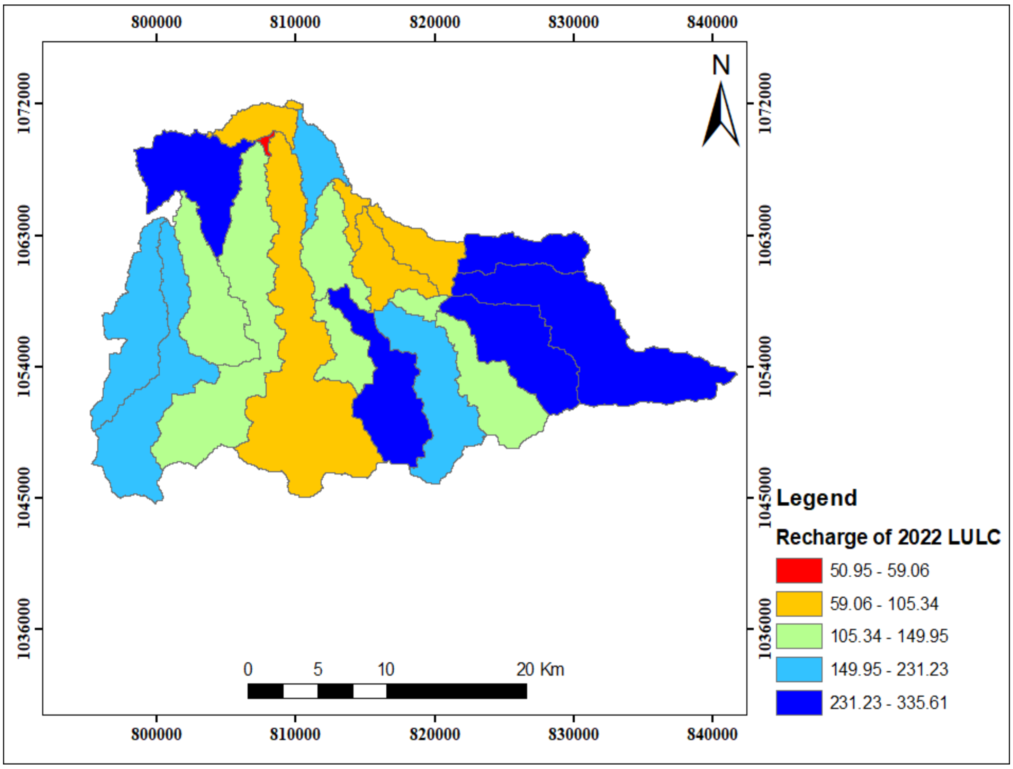
The spatial impact of land use/ land cover change on groundwater recharge of Dire Dawa watershed is shown in the figure 4.7 below for each historical LULC maps. The groundwater recharge for the 2000-year LULC map range from 97.31 to 338.45 mm/year, for the 2010 LULCmap the recharge ranges from 21.78 to 335.67 mm/year, and for the 2022 LULC map the recharge ranges from 50.95 to 335.61 mm/year. The maximum recharge recorded around easte nd north western part of the watershed, and the lowest recharge recorded at central and northernpart of the watershed.



(a)



(b)



(c)

Figure 4. 9 The Spatial groundwater recharge for the three historic period (a 2000, b 2010, andc 2022) LULC maps.

4.6 Impact of land use/land cover change on groundwaterrecharge in the study area

In this study we evaluated the effect of land use land cover change on the groundwater recharge in Dire Dawa Watershed, it can be concluded that Dire Dawa Watershed has experienced significant LULC change over the past two decades. Among the six LULC classes agricultural land, and built up shrublands, and Forest were found to be the most importantly modified LULC units during the study period (2000-2022).

Relative change assessment results depict that area under agriculturalland and built-up area is expanded by 49.18%, and 22.6 % respectively at the expenses of otherrevealed Land use/landcover class. The shrub land and forest decreased by 56.39%, and 28.8%respectively as compared from 2000 to 2022 historic land use/ land cover maps.

The change indicates that recharge is decreased by 20 % from 2000 to 2022, 5.17% from 2010 to 2022, and 25% from 2000 to 2022. Surface runoff is amplified by 15 % from 2000 to 2010, 5% from 2010 to 2022, and 10% from 2000 to 2022

CHAPTER5: CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

This study evaluated the effect of land use land cover change on the groundwater recharge in Dire Dawa Watershed, Ethiopia, using satellite data with ERDAS envision software and a SWAT model coupled with GIS. In order to identify and examine the dynamics of land cover in the study watershed, LULC maps (2000, 2010, and 2022) were created using remote sensingcombined with GIS. In order to evaluate the effect of land cover dynamics on the groundwaterrecharge of this watershed, the SWAT model was principally calibrated and validated for hydrological modeling.

The maximum likelihood supervised classification algorism, and Google earth-assisted accuracy assessment was performed by ERDAS Imagine coupled with GIS software to detect a change in Land use/land cover in the watershed. Image classification revealed Land use/landcover maps with six Land use/landcover types of three historical periods 2000, 2010, and 2022. The overall accuracy and kappa coefficient results were above the acceptable threshold values (>85%). Relative change assessment results depict that area under agriculturalland and built-up area is expanded by 49.18%, and 22.6 % respectively at the expenses of otherrevealed Land use/landcover class. The shrub land and forest decreased by 105.39%, and 28.8%respectively as compared from 2000 to 2022 historic land use/ land cover maps.

From the LULC change analysis result, it can be concluded that Dire Dawa Watershed has experienced significant LULC change over the past two decades. Among the six LULC identified, agricultural land, and built up shrublands, and Forest were found to be the most importantly modified LULC units during the study period (2000-2022).

The change in groundwater recharge during the steady period is highly associated with the landuse/landcover changes. The change indicates that recharge is decreased by 20 % from 2000 to 2022, 5.17% from 2010 to 2022, and 25% from 2000 to 2022. Surface runoff is amplified by 15
% from 2000 to 2010, 5% from 2010 to 2022, and 10% from 2000 to 2022. The change in Landuse/landcover in the watershed was attributed to the conversion of shrubland, and forest lands to agricultural land, and built-up area.

5.2 Recommendation

According to the research results, the following major recommendations are made.

- This study serves as a foundational contribution to the ongoing exploration of water resources, particularly for those involved in water resource studies. It underscores the critical relationship between land use and land cover in the study area, emphasizing itssignificant impact on groundwater recharge. For sustainable urban development in DireDawa, future land use activities must align with and consider local hydrological conditions.
- The findings from the SWAT model reveal a concerning trend: a rapid decline in groundwater recharge within Dire Dawa city. This signals an urgent need for the government to diversify its water supply sources for upcoming projects, moving awayfrom a heavy reliance on groundwater.
- In light of these results, it is imperative for the government to proactively address the diminishing groundwater recharge. Implementing strategies such as artificial recharge methods and refining land use practices can play a pivotal role in enhancing local groundwater volumes. By prioritizing these measures, the government can contribute to sustainable water resource management and ensure a resilient water supply for the future

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APPENDIX1

Summary of climatological parameters

Summary of mean monthly rainfall at different metrological stations (mm)

	Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
CFSR1	2000-2022	8.38	14.80	70.02	103.72	58.44	44.76	122.35	210.64	108.24	36.95	21.08	13.74	813.13
CFSR2	2000-2022	9.00	12.16	72.21	110.21	63.34	45.90	114.68	210.22	113.83	37.14	20.80	13.59	823.09
MelkaJebdu	2000-2022	11.02	11.33	77.61	133.64	80.06	65.94	148.46	254.13	135.98	55.21	25.07	14.51	1012.96
Dire Dewa	2000-2022	12.50	12.59	73.83	138.84	97.32	76.29	147.08	230.33	160.28	61.87	29.69	16.79	1057.43
CFSR3	2000-2022	12.50	12.59	73.83	138.84	97.32	76.29	147.08	230.33	160.28	61.87	29.69	16.79	1057.43
Kulibi	2000-2022	17.35	18.12	91.19	191.79	136.52	111.52	227.39	301.56	233.25	85.11	38.38	24.21	1476.40
Kersa	2000-2022	18.21	16.47	91.49	186.62	139.91	116.37	216.91	286.78	239.45	94.02	41.12	25.86	1473.21
Dengego	2000-2022	18.32	17.71	86.11	178.65	142.26	116.84	205.64	264.38	244.68	97.28	42.48	27.40	1441.75
	Average	13.41	14.47	79.54	147.79	101.90	81.74	166.20	248.55	174.50	66.18	31.04	19.11	1144.42

Summary of mean monthly temperature at different metrological stations (^{0}c)

	Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
CFSR1	2000-2022	8.38	14.80	70.02	103.72	58.44	44.76	122.35	210.64	108.24	36.95	21.08	13.74	813.13
CFSR2	2000-2022	9.00	12.16	72.21	110.21	63.34	45.90	114.68	210.22	113.83	37.14	20.80	13.59	823.09
Melka Jebdu	2000-2022	11.02	11.33	77.61	133.64	80.06	65.94	148.46	254.13	135.98	55.21	25.07	14.51	1012.96
Dire Dewa	2000-2022	12.50	12.59	73.83	138.84	97.32	76.29	147.08	230.33	160.28	61.87	29.69	16.79	1057.43
CFSR3	2000-2022	12.50	12.59	73.83	138.84	97.32	76.29	147.08	230.33	160.28	61.87	29.69	16.79	1057.43
Kulibi	2000-2022	17.35	18.12	91.19	191.79	136.52	111.52	227.39	301.56	233.25	85.11	38.38	24.21	1476.40
Kersa	2000-2022	18.21	16.47	91.49	186.62	139.91	116.37	216.91	286.78	239.45	94.02	41.12	25.86	1473.21
Dengego	2000-2022	18.32	17.71	86.11	178.65	142.26	116.84	205.64	264.38	244.68	97.28	42.48	27.40	1441.75
	Average	13.41	14.47	79.54	147.79	101.90	81.74	166.20	248.55	174.50	66.18	31.04	19.11	1144.42

APPENDIX2

Summary of mean annual rainfall at different metrological stations (mm)

	Melka Jebdu	Dire Dewa	Kulibi	Kersa	Dengego
2000	26.12	23.54	19.25	19.89	19.89
2001	26.35	23.70	20.43	19.53	20.60
2002	26.92	24.14	21.13	20.17	21.13
2003	25.81	23.04	20.06	19.05	20.01
2004	25.68	22.91	19.94	18.94	19.86
2005	25.78	22.99	20.25	19.04	19.94
2006	27.48	24.43	21.80	20.73	21.42
2007	27.51	24.65	21.81	20.79	21.65
2008	26.84	24.10	20.99	20.08	21.09
2009	28.28	25.31	22.31	21.49	22.28
2010	27.78	25.00	21.76	20.99	21.97
2011	27.91	25.14	22.10	21.14	22.12
2012	28.02	25.23	22.06	21.22	22.18
2013	27.61	24.84	21.65	20.77	21.75
2014	28.10	25.37	22.17	21.34	22.37
2015	28.76	26.03	22.81	22.00	23.04
2016	28.28	25.51	22.33	21.52	22.51
2017	27.62	24.80	21.75	20.87	21.76
2018	27.21	24.40	21.33	20.44	21.36
2019	26.67	23.87	21.03	19.94	20.85
2020	26.98	23.56	22.15	20.12	20.99
2021	27.54	23.98	22.84	20.93	21.81
2022	27.91	24.23	23.01	21.54	22.09
Average	27.27	24.38	21.52	20.54	21.42

Summary of mean annual temperature at different metrological stations (mm)

	MelkaJebdu	Diredewa	Kulibi	Kersa	Dengego
2000	26.12	23.54	19.25	19.89	19.89
2001	26.35	23.70	20.43	19.53	20.60
2002	26.92	24.14	21.13	20.17	21.13
2003	25.81	23.04	20.06	19.05	20.01
2004	25.68	22.91	19.94	18.94	19.86
2005	25.78	22.99	20.25	19.04	19.94
2006	27.48	24.43	21.80	20.73	21.42
2007	27.51	24.65	21.81	20.79	21.65
2008	26.84	24.10	20.99	20.08	21.09
2009	28.28	25.31	22.31	21.49	22.28
2010	27.78	25.00	21.76	20.99	21.97
2011	27.91	25.14	22.10	21.14	22.12
2012	28.02	25.23	22.06	21.22	22.18
2013	27.61	24.84	21.65	20.77	21.75
2014	28.10	25.37	22.17	21.34	22.37
2015	28.76	26.03	22.81	22.00	23.04
2016	28.28	25.51	22.33	21.52	22.51
2017	27.62	24.80	21.75	20.87	21.76
2018	27.21	24.40	21.33	20.44	21.36
2019	26.67	23.87	21.03	19.94	20.85
2020	26.98	23.56	22.15	20.12	20.99
2021	27.54	23.98	22.84	20.93	21.81
2022	27.91	24.23	23.01	21.54	22.09
Average	27.27	24.38	21.52	20.54	21.42

APPENDIX 3

The Dire Dawa gauge station monthly discharge data.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	7.17	8.93	7.49	14.21	6.71	8.37	36.80	40.24	24.01	12.42	7.96	1.19
2001	6.89	11.99	14.71	5.91	4.35	14.71	40.89	45.78	12.04	9.91	2.86	9.56
2002	6.29	4.86	3.49	12.16	13.55	40.97	30.77	37.25	24.18	14.93	2.77	10.88
2003	7.27	3.17	4.34	5.74	4.99	27.16	38.06	28.51	35.00	10.67	5.98	9.30
2004	5.00	5.43	4.78	11.34	10.21	10.81	45.31	39.92	38.99	2.57	1.60	8.30
2005	5.28	5.74	7.09	8.57	7.99	8.93	42.22	41.96	22.15	8.28	8.12	5.08
2006	3.38	1.90	1.81	3.38	1.98	5.61	40.08	37.93	33.54	4.03	1.82	5.86
2007	6.18	2.82	2.46	2.14	6.18	21.22	36.04	43.53	40.00	6.71	4.86	8.86
2008	5.62	1.54	2.22	1.55	1.77	8.75	42.74	42.66	30.60	1.26	6.91	7.11
2009	4.02	1.46	0.99	2.05	4.15	6.56	43.33	47.35	47.83	6.64	6.80	8.20
2010	4.93	2.23	5.49	4.03	10.11	32.31	47.49	46.70	25.23	2.77	9.50	5.68
2011	5.09	2.27	3.39	3.20	2.15	5.59	44.02	33.35	27.13	3.42	1.56	6.22
2012	3.85	1.70	2.37	4.36	2.36	17.43	45.84	48.33	19.64	6.39	8.90	5.21
2013	3.20	1.66	1.01	6.60	2.87	13.24	27.00	32.87	19.81	2.74	9.70	5.44