Wetland Degradation Mapping and Evaluating Its Impacts On the Surrounding Environment, Using Geospatial Technique, A case Study in Geba Watershed, Southwest Ethiopia

Mintesnot Berhanu

A Thesis Submitted to
School of Earth Science

Presented in Partial Fulfillment of the requirements for the Degree of
Masters of Science (Remote Sensing and Geo-informatic)

Addis Ababa university
Addis Ababa, Ethiopia
May, 2019

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Advisor:

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School of Graduate Studies
Declaration

This is to certify the thesis prepared by **Mintesnot Berhanu** entitled as "***Wetland Degradation Mapping and Evaluating Its Impacts On the Environment, Using Geospatial Technique, A case Study in Geba Watershed, Southwest Ethiopia***." Is submitted in partial fulfilment of the requirements for the degree of master of science in Remote Sensing and Geo-informatics compiles with the regulations of the university and meets the accepted standards with respect to originality and quality.

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CBD	Convention on Biological diversity of Ethiopia
CSA	Central Statistical Agency
CWI	Compound Wetness index
CTI	Compound Topographic Index
DEM	Digital Elevation Model
DN	Digital Number
DT	Decision Tree
EGM	Earth Gravitational Model
EMA	Ethiopian Mapping Agency
ENVI	Environment for Visualizing Image
ERDAS	Earth Resource Data Analysis System
EROS	Earth Resources Observation and Science
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
EWNRA	Ethiopian Wetlands and Natural Resources Association
FCCs	False color composites
ISODATA	Iterative Self Organizing Data Analysis Technique Algorithm
GIS	Geographic Information Science
GTPs	Ground Truthing Points
LDCM	Landsat Data Continuity Mission
LIT	Terrain Correction
LPGS	Level I Product Generation System
LU/LC	Land-use/Land cover
MIR	Mid-infrared
MFD	Multiple Flow Direction
MNDWI	Modified Normalized Difference Water Index
MTSER	Mettu Town Socio-economic Report
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NGA	The National Geospatial-Intelligence Agency
NIR	Near-infrared
OLI	Operational Land Imagery
RGB	Red, Green, Blue
SRTM	Shuttle Radar Topography Mission

TM	Thematic Mapper
TOA	Top of Atmosphere
TWI	Topographic Wetness index
US EPA	United State Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization
WGS	World Geodetic Survey

Wetland Degradation Mapping and Evaluating Its Impacts On the Environment, Using Geospatial Technique, A Case Study in Geba Watershed, Southwest Ethiopia

Mintesnot Berhanu, MSc Thesis
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Abstract

Wetland is one of the world’s most significant ecosystems, threatened from both natural and human-induced activities. As a result, the overall objective of this study is to map, monitor, and evaluate the impacts of wetland degradation on the environment, the case of Geba watershed southwest, Ethiopia. Remote Sensing and Geographic Information System approach integrated with ground data calibration were used to evaluate and quantify wetland resources. To conduct this study Landsat Thematic Mapper (TM) images was acquired for 1985, 2000 and Landsat 8 Operational Land Imager (OLI) imagery for 2018. In addition, SRTM DEM was acquired from the archives of the United States Geological Survey (USGS) for the analysis. Three different approaches have been used for mapping and monitoring of wetlands. Pixel-based classification (Supervised classification), index-based classification (NDVI & MNDWI), SRTM Slope and (TWI)wetness index and image enhancement methods were used. The use of multi-spectral Landsat imagery, including SRTM DEM, combined with ground truth data and GIS produced acceptable results for the delineation and mapping of wetland degradation in the study area. The overall accuracy of the 3 aggregated wetland (1985, 2000 and 2018) in the study area was 86.66 percent with reasonable errors of omissions (7.54 percent) and low errors of commissions (13.33 percent). TWI and slope map enhance the detection of forested wetland in the study area. Based on the results, wetland areas of 31.115km^2 (14.53%), was converted to agricultural land in the period of 1985 to 2000. Similarly, in the same fashion from 2000 to 2018, 17.515km^2 (10.9%) of wetland converted to agricultural land. Hydro-chemical parameters indicate a significant difference in water quality of degraded and undegraded wetlands and there is a change in ground water table based deep-well data between drained and undrained wetland types. A considerable driving force for wetland degradation within the watershed was directly related to agricultural expansion and population increment. Climate variability has also its own impacts on the degradation of wetlands in the study area.

Keyword; *Wetland Mapping, Wetland Degradation, Geba Watershed, Geospatial, TWI, Water quality*

CHAPTER I

1. Introduction

1.1. Background

Wetlands are separating ecosystems which originate between dry land and water body zone which at least periodically wet during the growing season in most years or in arid regions during the wet phase of the hydrologic cycle and they range from permanently flooded areas to lands that are flooded or saturated for extended periods usually with some frequency (Ralph et al., 2015). Wetlands are among the most significant ecosystems on the earth and functioned as the kidneys of the earth, which play a vital role in conserving ecological service and functions (Junhong et al., 2013). Primarily Wetlands can provide essential environmental services including storing floodwater, reducing peak runoff, recharging groundwater, reaching aquifers, filtering impurities in water, acting as nutrient and sediment sinks, mitigating floods, climate regulation, carbon storage and providing a range of recreational opportunities (Kaplan and Avdan, 2017; Wu and Qiusheng, 2018). Ecologically, wetlands have high biodiversity and serve as breeding grounds and critical habitat for several species of plant communities, invertebrates, fish, and wildlife (Weng and Qihao, 2014). Wetlands are the main custodians of these valuable water resources and they act as 'banks 'from where water may be drawn, and groundwater replenished (Abebe Yilma, 2003).

Wetland is a generic term used to define the universe of wet habitats including marshes, swamps, bogs, fen, and similar areas. Wetlands are environments subject to permanent or periodic inundation or prolonged soil saturation sufficient for the establishment of hydrophytes and/or the development of hydric soils or substrates unless environmental conditions are such that they prevent them from forming (Tiner and Ralph, 2000). By 1991 over 60 countries had joined the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, adopted in Ramsar, Iran, in 1971 and known as the Ramsar Convention and takes a comprehensive approach in determining the wetlands which come under its mandate, developed the following definition. Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land, or where the land is covered by water. Wetlands are-

> "*areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed 6 m" (Ramsar Convention, 2016).*

Ethiopia possesses a great diversity of wetland ecosystems which are widely distributed in all climatic regions of the country with the exception of coastal and marine-related wetlands and extensive swamp-forest complexes, all forms of wetlands are represented in Ethiopia (Abebe Yilma and Geheb, 2013), and containing swamps, marshes, flood plains, natural or artificial ponds, high mountain lakes and micro-dams (CBD, 2009). Besides exhibits a wide range of geologic formations and climatic conditions which create numerous wetland ecosystems (Dagim Terefe, 2017). It is indicated that the wetland in Ethiopian is distributed in different parts of the country, in almost all ecological and altitudinal ranges. A comprehensive inventory of wetland in Ethiopian is not yet done but, Wetlands are estimated to cover about 2% of surface area of the country (Tadessse Amsalu and Solomon Addisu, 2014; Dagim Terefe, 2017; Mengesha, Tadlo Awoke, 2017).

Wetlands are a common feature of the landscapes in the highlands of South western Ethiopia, particularly Western Wellega and Illubabor (Afework Hailu et al., 2000). Wetlands are a small land cover areas but significant part of the resource base in Illubabor and nearly all households in one way or another use wetland, directly or indirectly (Abebe Yilma and Geheb, 2013). The wetlands are vital natural resources, both in terms of their environmental functions and their products, which are used extensively by local communities (Afework Hailu et al., 2000).

Despite recognition of their many uses by people, their environmental services to humankind (e.g., flood storage, shoreline stabilization, carbon sequestration, and water-quality renovation), and their ecological significance, natural wetlands continue to be converted to other lands and subjected to pollution (Ralph et al., 2015). The loss of wetlands at international level which is considered to be more than 50% since 1900, has gained considerable attention over the past years (Gordana Kaplan, 2018). As the value of wetlands to society has become recognized, it is now found important to conserve these valuable resources (Ozesmi and Marvin, 2002).

Davison (2016) and Decleer (2016) estimated that the world had lost at least 50% of its wetlands during the 20th Century. The loss of these wetlands is devastating to several endemic species and particularly for wetland-dependent species (Bahilu Bezabih and Tadesse Mosissa, 2017). The loss and degradation of these critical resources (wetlands) need urgent mapping and monitoring of the resources, as well as determining potential restoration areas (Gerjevic, 2004).

Many wetlands in Ethiopia are considered vulnerable zones and some of the most exploited, mismanaged and lost their regenerating capacity (Alemayehu, 1996). The major threats to the biodiversity of the country are unsustainable utilization of natural resources like over-harvesting, deforestation, diversion of natural vegetation for agricultural intensification, forest fires, land degradation, habitat loss and fragmentation, invasive species, illegal trafficking of domestic and wild animals, poaching, wetland destruction and climate change, dam construction, pollution and other anthropogenic interventions (Leykun Abunie, 2003; CBD, 2009).

Alterations of the hydrological system of wetlands have significant physical, chemical and biological effects that can have significant ecological and socioeconomic implications at a wider scale and the consequences of wetland loss and degradation in Ethiopia are enormous and directly affecting the livelihood base of rural communities. These changes of wetlands have created numerous problems, including decrease and extinction of wild flora and fauna, loss of natural soil nutrients, water reservoirs and their subsequent benefits. They have affected various traditional occupations (Mosissa et al., 2017). The development of a management plan for Ethiopia's wetlands will need basic studies, including awareness, surveys, and inventories, which should be part and parcel of a wetland development program (Abebe Yilma and Geheb, K. (2003).

To better manage and conserve wetland resources, we need to know the distribution and extent of wetlands and monitor their dynamic changes (Wu and Qiusheng, 2018). The primary condition to help protect wetland areas is a thorough mapping and monitoring of the changes that affect them: past, present, and future. Remote sensing is one of the effective tools to perform both tasks by enabling rapid mapping of their situation both past and present. While images from the recent generations of Earth-observing satellite and sensors come in a wide range of spatial resolution up to about half a meter, historical data at medium resolution can provide a record of past situations and help determine an evolutionary trend (Maillard et al., 2012).

The combination of Remote Sensing and Geographic Information System approach integrated with in-situ measurement provides an advanced tool in detecting and identifying degraded wetland resources at regional and local scales. Therefore, in this study degraded wetland resources have been mapped, and Spatial relationship between wetland degradation and its hydrological and related impacts on the surrounding environment was assessed using Geospatial tools. Recent wetland degradation map was produced for future mitigation and management purposes in order to sustain the development at regional and national levels.

1.2. Statement of the Problem

Wetlands are among the vital natural resources and important productive ecosystems on Earth. Wetland plays a significant role in filtering and purifying polluted water as well as maintaining surface water and provide habitats for fauna and flora resources. According to Mengesha Tadlo (2017) wetlands are one of the most multi-functional ecosystems of the world that provide a range of economic, biological, ecological, social, and cultural functions and services to human beings.

Ethiopian is gifted with a various ecosystem in which miscellaneous flora and fauna resources are found. Such ecosystems are common in the western and Southern part of the country. For instance, in Illubabor, the land use record from the Ministry of Agriculture shows that 256 km^2 (1.6%) of the zone is covered by wetlands (EWNRA, 2001). If floodplains and seasonally flooded grassland are included, the total wetland area of Illubabor is estimated to cover about 4%−5% of the zone. According to Hagos Gebresllassie (2014), wetland resources contribute billions of birr to the people of Ethiopia every year in the form of clean water, pure air, soil formation and protection, crop pest control, and provision of food, fish, fuel, fiber, medicine, recreation, tourism, etc. The safety and security of water, which is a matter of survival, have linkages to both water quality and water quantity. Wetlands can store water and delay or reduce surface or subsurface water flows from developed areas, consequently removing or reducing the amount of pollutants to improve water quality (i.e., chemistry), and thus improving water quality of streams and lakes. These linkages and societal benefits are intertwined and must be understood for informed decision making (Ricardo et al., 2013).

Despite all those and other values, Ethiopian wetlands are under severe pressure and degradation. Due to improper extraction and misconceptions forwarded to wetlands, the health of the wetlands is continuously decreasing from time to time that put in doubt their existence soon (Zerihun Woldu & Kumlachew Yeshitela, 2003; Abebe Yilma and Geheb, 2003). Unregulated and unwise resource use from the wetland ecosystem, lack of appropriate policies and institutional setup that controls and regulates the proper utilization and management of the resource, among other problems, has resulted in a serious degradation of wetlands and wetland resources, and eventually led to their disappearance in Ethiopia (Amanuel Kumsa, 2015). In Oromia Regional State Illubabor zone, including southwest Regions of Ethiopia, where many and extended wetlands are found, there was no act of cultivation around the periphery of the wetlands before the entrance of the 20th centuries (Afework Hailu, 1998). Nowadays, the complete drainage and cultivation of wetlands become common phenomena throughout the area (Afework Hailu, 1998; Dixon and Wood, 2007). For instance, approximately one-third of the total valley bottom wetlands has come under cultivation for growing food crops from 1974 to 1983 (Afework Hailu, 1998). More severely from this, approximately 20% of the total wetlands in Illubabor have been cultivated each year between 1986 and 1998 and this intensity increased to 35% in 1999 (Afework Hailu, 2003). Assessing the vulnerability of wetlands to natural and human disturbances will enable wetland managers to identify wetlands at risk of degradation and loss on the landscape. This will improve wetland management and planning by government agencies and other stakeholders (Akumu et al., 2018).

The rapid evolution of geographic information system and remote sensing technology with increasing availability of geospatial datasets such as satellite data provides an opportunity for wetland classification and mapping, distribution pattern and vulnerability analysis (Akumu, et al., 2018). Wetland classification has attracted much attention amongst Remote Sensing experts for several reasons, including the numerous advantages associated with wetlands, the considerable global coverage of wetlands that can be estimated using Remote Sensing tools, and vulnerability of wetlands to loss and degradation that can be similarly estimated by application of Remote Sensing methods (Sahel et al., 2017).

As a result, Quantifying Wetland type, extent, distribution, condition and vulnerability to degradation is a vital input for mitigation and management efforts. For this study, Remote Sensing and Geographic Information System approach integrated with ground data calibration and validation will be used to quantify and monitoring wetland resources. In this study wetland degradation mapping and its impacts on the corresponding natural resources of Geba watershed was studied for monitoring and mitigation action using multi-temporal satellite series images with ground data and, the result can be used as an input information basis for management activity, decision and policy makers in order use sustainably.

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of this study is to map and evaluate impacts of wetland degradation on the environment, the case of selected wetland in Geba watershed southwest Ethiopia and the surrounding using GIS and remote sensing techniques.

1.3.2. Specific objectives of the research:

The specific objectives of the study are: -

- To map and quantify the changes that had happened to the wetlands and understand the major factors driving the changes.
- To map the land use and land cover of the study area.
- To evaluate wetland water quality in Geba watershed.

1.4. Significance of the study

The findings of this study were redounded to the benefits of Community considering a significant role of wetlands in alleviating flooding and filtering polluted water and also provide quantified information on Wetland degradation and its impacts. As a result, wetland degradation has been mapped and identified in terms of assessing its adverse impacts on socioeconomic activity, and surrounding environment including ways of its management for the purpose of sustainable development.

1.5. Scope of the study

This study was focused on wetland degradation mapping and evaluating its impacts on the surrounding environment using Geospatial Technique. The scope of the study was limited to Geba Watershed, Southwest Ethiopia.

1.6. Limitation of study

As a result of high clouds coverage and unclear weather conditions during the summer season in the study area, mapping variation of wetland inundation area was a major limitation using optical Landsat imagery due to their dependency to the weather situation.

1.7. Thesis organization

This thesis was organized into Six chapters as follows: Chapter one contains the background of the study and provides a brief overview of the overall study undertaken. It also provides information on the study and gives a highlight of the significance of the study. Chapter two emphasize an overview of wetland resources and briefly describe the extent, importance, threats of wetlands in the study area. It also shows the application of GIS and remote sensing in wetland mapping and contains previous works related to optical remote sensing related to the study. Chapter three explains the datasets available as well as the method used to map wetland degradation. Chapter four delivers information on the results and discussion on the results related to previous works. Chapter Five shows conclusion and recommendations. And finally Chapter six contain reference lists.

CHAPTER II

2. Literature Review

2.1. Definitions of Wetland

Wetlands have been defined variously in several countries by scientists and natural resource agencies interested in specific functions of wetlands, e.g. habitats for water birds, animals, and potential land uses. There is no common wetland definition which was accepted by all domains or sectors. There are numerous different definitions of wetlands such as “bogs and fens” (peat-accumulating wetlands), “marshes” (herbaceous, frequently inundated wetlands), or “swamps” (forested wetlands), and there is no standardization of these terms (Mitra et al., 2005). Some of far and wide used definition of wetland are lands that are at least periodically wet during the growing season in most years or in arid regions during the wet phase of the hydrologic cycle (Ralph et al., 2015).

Wetland can similarly defined as universe of wet habitats including marshes, swamps, bogs, fens, and similar areas subject to permanent or periodic inundation or prolonged soil saturation sufficient for the establishment of hydrophytes and/or the development of hydric soils or substrates unless environmental conditions are such that they prevent them from forming (Tiner, 2000). According to Ramsar convention Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life in nature. They occur where the water table is at or near the surface of the land, or where the land is covered by shallow water. The Ramsar Convention takes a broad approach in determining the wetlands which come under its mandate and define wetland as;

“areas of marsh, fen, peatland or water, whether human-induced or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, including areas of marine water the depth of which at low tide does not exceed six meters” (Ramsar Convention Bureau, 2013).

In addition, The Ramsar Convention for the purpose of protecting coherent sites provides that wetlands;

> *“may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands” (Ramsar Convention Bureau, 2013).*

Two third of this world is surrounded by water bodies. Wetlands occupy an estimated amount of 6.4% of the earth's surface (IUCN Environmental Policy and Law Paper No.38). Wetlands similarly assist as vital sources of food, construction and fuelwood, raw materials for making household furniture, and medicine to rural communities. Poor rural households, particularly women, rely on wetlands for additional income to their families. Hence, wetlands contribute significantly to efforts aimed at poverty reduction and food self-sufficiency. Growing number of people in Ethiopia, in both rural and urban areas, depending on wetland resources for their survival (Tadesse Amsalu and Solomon Addisu**,** 2014).

2.2. Potential distribution of global wetland

During the past thirty years, the image of wetland has been transformed from one of undervalued, unutilized wastelands whose only utility lies in their conversion to alternative land uses. After researchers recognized as wetlands internationally important natural resources begun recognizing that wetlands perform an ecological, hydrological and socioeconomic function, which are a benefit to human population mainly in developing a world where local communities depend on this function (Dixon, 2003).

The most recent estimate of global inland and coastal wetland area is in excess of 12.1 million km^2, an area almost as large as Greenland (Figure 2.1). Of this, 54% is permanently inundated and 46% seasonally inundated. An estimated further 5.2 million km^2 are intermittently or occasionally inundated, but this is believed to include areas of former converted wetlands affected by extreme storm events. Around 93% of wetlands are inland systems, with 7% being marine and coastal – although this coastal estimate does not include several wetland classes such as nearshore subtidal wetlands (Ramsar Convention on Wetlands, 2018).

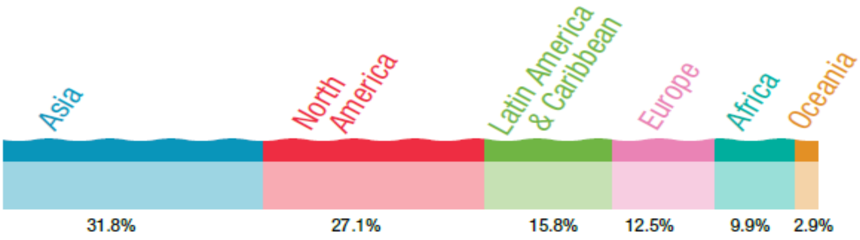


Figure 2. 1: Potential distribution of global wetland

2.3. Wetland distribution in Ethiopia

Ethiopia owns more than 58 different types of wetlands which provide enormous socio-economic and environmental values (Getinet Seid, 2017). Ethiopia possesses a great diversity of wetland ecosystems in different parts of the country including with the exception of coastal and marine-related wetlands swamps, marshes, floodplains, natural or artificial ponds, high mountain lakes, and micro-dams. These include alpine formations, riverine, lacustrine, palustrine and floodplain wetlands. Floodplains are found both in Ethiopia's highlands and lowlands, although they are most common in the North-Western and Western Highlands, Rift Valley and Eastern Highlands (CBD, 2009; Yilma Abebe and Geheb, 2003). Those wetlands provide enormous socioeconomic and environmental values and that attracts a number of users that benefit the local community directly or indirectly (CBD, 2009; Hagos Gebresllassie et al., 2014). Even though a comprehensive inventory of wetlands is not done yet (Tadesse Amsalu and Solomon Addisu**,** 2014) but According to Afework Hailu (2005) wetlands in Ethiopia estimated to cover about 2% of the country's land coverage.

Ethiopia's ecological diversity and climatic variation is to a large extent explained by its highly variable topography (Yilma Abebe and Geheb, 2003). Wetlands are distributed in different parts of the country almost in all ecological zones. The Dallol depression which is located at about 110m below sea level flourishes with wetlands such as Lake Afdera (salty lake), Swamps, lakes and riverine ecosystems are also distributed in central highlands, rift valley areas and mainly in the southwest borders of the country. In general, the southwest and western parts of the country are wetter than the southeast, east, and north (Hagos Gebresllassie et al., 2014). There are about 30 major lakes, 12 major river basins and over 70 wetlands that are located in different ecological zones of Ethiopia (CBD, 2009).

2.4. Environmental Values of wetlands

Wetlands are among the Earth's most creative ecosystems and produce an ecological equilibrium in the environment by preserving the integrity of life support systems for sustainable socio-economic development (Yilma Abebe and Geheb, 2003). Wetland eco-systems directly or indirectly provide goods and services for millions of people. The growth and development of all the organisms that require wetlands for life (Rajinikanth and Ramachandra, 2000). Ethiopia has a large natural and cultural variety with a big range of climates which result from its landscape and latitudinal position. As a result, much of the interior of Ethiopia is dominated by highland plateaus, these are interrupted by deep gorges draining into 12 major river valleys. The fantastic diversity of cultures and ecology is further mirrored by the diversity of fauna and flora. As a result, Ethiopia is a center of biological diversity with sizeable endemism (CBD, 2009). Water resource and wetland development need environmentally sound planning systems and to make room for long-term ecological productivity and the welfare of local communities (Yilma Abebe and Geheb, 2003).

People often view wetlands as wasteland. Wetlands are sometimes drained and used for development; others are polluted from dumping of wastes from various sources (e.g. industry, agriculture, household) (Mitra et al.,2005). Wetland ecosystems are mostly assumed to be less important than any other irrespective of the many services they provide and are viewed as free goods. Pressures to these wetland ecosystems include conversion to agricultural land, overutilization, unregulated management, siltation and construction of dams (CBD, 2009). The loss of wetlands can have both economic and environmental consequences. While rates of wetland loss are documented for the developed world, the limited study of these ecosystems in Ethiopia leaves majority with little to say (Dagim Terefe, 2017). Wetlands also play a critical role in maintaining the quality of the environment by absorbing and processing waste products. They serve to slow down storm flood, trap sediments and carbon sink, protect property damage in downstream and wastewater treatment. Studies also reveal that wetlands have a role in ameliorating unfavorable climatic variations (Tadlo Awoke Mengesha, 2017).

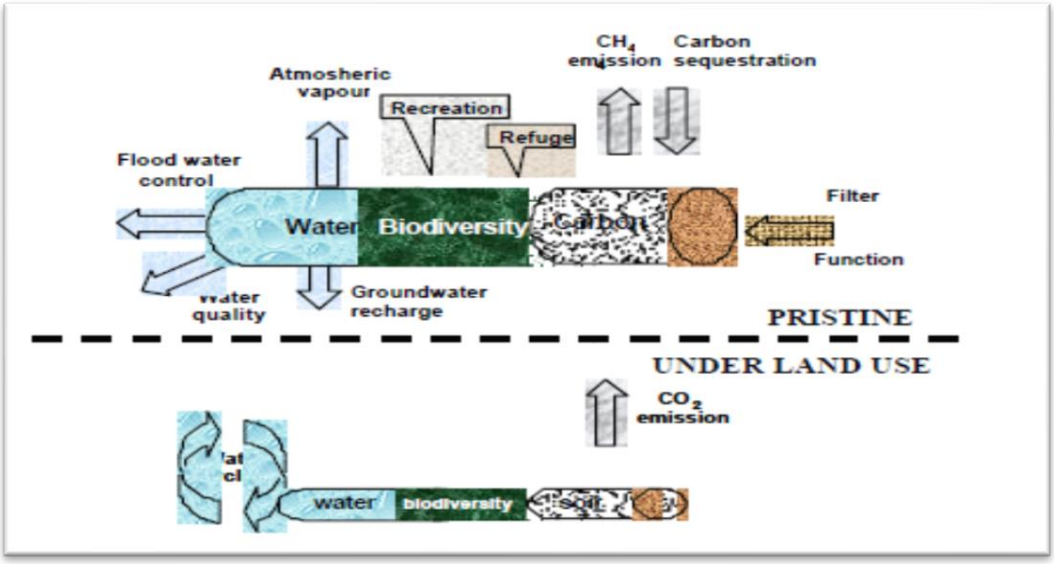


Figure 2. 2 : Schematic View of the Role of Wetlands in the Environment (adopted from Mitra et al., 2003).

Ethiopia's economic growth and development put growing demands on the river system and the basin's resources. Wetlands are key natural environmental assets providing crucial ecosystem services that support livelihoods and socio-economic development in the basin. As a result, the loss and degradation of wetland due to improper or unnecessary management of wetland in Ethiopia leads to a series challenge for the existence of Rivers and lakes (Dagim Terefe, 2017). According to Yilma Abebe and Geheb (2003), Wetlands are the main custodians of these valuable water resources. They act as 'banks' from where water may be drawn, and groundwater replenished.

Storage and sequestration of carbon by wetlands play an important role in regulating the global climate. Peatlands and vegetated coastal wetlands are large carbon sinks. Salt marshes sequester millions of tonnes of carbon annually. Despite occupying only 3% of the land surface, peatlands store twice as much carbon as the world's forests (Ramser, 2018).

2.5. Wetland Degradation and their consequence

Ethiopia is often referred to as the water tower of Africa mainly because of its wide variety of landforms and climatic conditions, creating an extensive wetland system throughout the country. Wetlands have their own positive impacts on the environment. While wetlands are the most productive ecosystems on earth; they are also the most threatened. Due to rapid growth in human populations, wetlands worldwide are suffering from serious degradation or loss as affected by wetland pollution, wetland reclamation, civilization, and land use changes, and so forth. Wetland degradation has potential influences on human health, biodiversity, regional climate, and regional ecological security (Junhong Bai et al., 2013).

In Ethiopia wetland destruction and alteration has been and is still seen as an advanced mode of development, even at the government level. This indicates that wetlands and their value remain little understood (Hagos Gebresllassie et al., 2014). The major threats to the biodiversity of Ethiopia are unsustainable utilization of natural resources (CBD, 2009). Ethiopian wetlands are currently being lost or altered by unregulated over-utilization, including water diversion for irrigation-based agriculture following intensive drainage, urbanization, dam construction, pollution, and other anthropogenic interventions. They have been converted to commercial, residential or industrial sites (Dixon, 2003; Yilma Abebe and Geheb, 2003). This poses describes major threat to the existence of wetlands in Ethiopia.

Convention on Biological diversity of Ethiopia 4th report describe; Wetland is getting lost as the wetlands are being converted to farmlands. Fogera marsh has been changed to the rice field, Sululta marsh is distributed to investors, ELFORA PLC has transformed Chefa wetland in South Wello to farmland, and these are only few examples of wetland degradation in Ethiopia. Lake Tana is loaded with silt and invasive water hyacinth because the wetland vegetation in the surrounding catchments was destroyed and used for agriculture, and the wetlands that were used to stop silt and plant nutrition that are discharged to the lake have been are converted to a rice paddy.

In Ethiopia, the recent total drying up of Lake Alemaya and the precarious existence of Lake Abijata are clear evidence of the looming danger on wetland ecosystem. (Tadesse Amsalu and Solomon Addisu, 2014). According to CBD (2009), wetland destruction or degradation and climate change result as a major threat to the biodiversity of the country and all these are related to the root causes of poverty in Ethiopia.

Wetland constitutes important features of the landscape and subject to constant change due to urbanization and in some cases has led to disappearance (Jianga et al., 2017). Degradation of wetlands and disturbance of their anaerobic environment lead to a higher rate of decomposition of a large amount of carbon stored in them and thus release greenhouse gases (GHGs) to the atmosphere. Therefore, protecting wetlands is a practical way of retaining the existing carbon reserves and thus reducing emission of carbon dioxide and GHGs (Adhikari, 2009).

Improper management of wetland will provide a potential sink for atmospheric carbon, they become a source of greenhouse gases. The role of wetland change of carbon in the global carbon cycle is poorly understood. Wetlands may affect the atmospheric carbon cycle in different ways, such as many wetlands especially boreal and tropical peatlands results in oxidation of soils due to water level let fall or improper mismanagement practice. In another way, the entrance of carbon dioxide into a wetland system is via photosynthesis by wetland plants giving it the ability to alter its concentration in the atmosphere by sequestrating this carbon in the soil. wetlands are also known to contribute to the release of methane to the atmosphere even in the absence of climate change (Adhikari, 2009).

Ethiopia is prone to desertification and recurrent drought, the effects of wetland loss could be more visible in complicating the situation locally. It can also affect hydrological cycle or rainfall patterns.

Rivers and streams may lose their strength. This will create a shortage of water and narrow opportunities for irrigation-based agriculture. Wetlands are a prominent shelter of aquatic and terrestrial biodiversity. Endemic fishes, birds and other life forms depend on wetlands. Hence, the loss of these wetlands is devastating to several endemic species and particularly to wetland-dependent species (Hagos Gebresllassie et al., 2014). As wetland degradation has become more severe and public awareness of wetlands has deepened, wetlands have become the focus of studies and of global concern (Jianga et al., 2017). Degradation of wetlands and disturbance of their anaerobic environment lead to a higher rate of decomposition of a large amount of carbon stored in them and thus release greenhouse gases (GHGs) to the atmosphere. Therefore, protecting wetlands is a practical way of retaining the existing carbon reserves and thus avoiding emission of carbon dioxide and GHGs (Adhikari et al., 2009).

2.6. Drivers of wetland degradation and loss

The wise use of wetlands requires a thorough understanding of the drivers of change so that the main causes of wetland degradation can be addressed. Wetlands continue to be degraded and lost through drainage and conversion, introduction of pollution and invasive species, extraction activities, and additional actions affecting the water quantity and frequency of flooding and drying (Ramser, 2018).

Remote sensing or modeling data can also be used for integrated assessment and measurement of a typology of drivers (Ramser, 2018). Around 65% of wetland disturbances are of human origin, while the remainder has natural origins. Out of this 65%, 73% of disturbances are thought to result from direct human actions, while the remaining 27% are believed to come from indirect sources (Dugan, 1990)

In Ethiopia Improper agricultural practices and expansions, continuous land degradation, urbanizations and industrialization, overutilization and unregulated management, absence of appropriate policy, lack of institutional arrangement, capacity shortage, high population growth rate increases and natural and ecological problems listed as the main drivers for wetland degradation and losses (Getinet Seid, 2017, Hagos Gebresllassie et al.,2014).

Application of the Remote Sensing in wetlands monitoring

According to Milne (1988), change is defined as an alteration in the surface of landscape. The alteration in the spectral reflectance recorded by the sensor that are related to germination and growth and development will be detected by remote sensing instrument. In the spatial context, different types of change whereby spatial entities either become a different category, expand, shrink or alter shape, shift position, or fragment or coalesce also considered as a change (Coppin et al., 2004).

Not all detectable changes, however, are equally important. It is also probable that some changes of interest will not be acquired very well, or at all, by any given system. Of particular interest to the ecosystem scientist and/or manager are first and foremost vegetation disturbances caused by short-term natural phenomena such as insect infestation, fire, and flooding, and changes resulting from human activities, e.g. resource exploitation and land-use conversion. While the natural phenomena are likely to be temporary and may in some cases even be self-correcting, evidence of anthropogenic activities generally remains much longer (Coppin et al., 2004).

An important contribution of environmental remote sensing to land resources analysis is its potential to identify and quantify changes that occur in land cover over an extended period of time. Recently the use of Remote sensing Digital change detection encompasses the quantification of temporal phenomena from multi-date imagery that is most commonly acquired by satellite-based multi-spectral sensors significantly used in ecosystem detection and monitoring (Milne, 1988). Up to now, nearly all remote sensing data sources including aerial photography, multispectral and hyperspectral sensors, light detection and ranging (LIDAR), synthetic aperture radar (SAR), and interferometric SAR (InSAR) are employed to map and characterize wetlands especially at local scales. (Gong and Niu, 2018).

A common problem in environmental management, particularly in less developed countries, is the inadequacy of information on current and changing environmental conditions and the available resource base (Haack, 1996). Satellite remote sensing can be especially appropriate for wetland inventories and monitoring in developing countries rather than conventional ground-survey techniques, where funds are limited and where little information is available on wetland areas, surrounding land uses, and wetland losses over time (Butera 1983; Stacy et al 2002).

According to (Stacy et al., 2002), satellite remote sensing data and its spatiotemporal capability have been many advantages in mapping and monitoring wetlands seasonally or yearly. Satellite remote sensing can also provide information on surrounding land uses and their changes over time. Current information on the uplands surrounding wetlands is important because land use practices in uplands cause loss of wetland functions, goods, services, and values.

Wetland identification, mapping, and analyses are often done by means of remote sensing, a tool offering well-documented advantages including a synoptic view, multi-spectral data collection, multi-temporal coverage, and cost-effectiveness. In addition, anyone who has conducted field research in wetlands is well aware of the difficulty in making *in-situ* measurements. The technology has been used extensively because remote sensing seems to be one of the only practical ways to study environments that can be difficult to access or traverse (Rundquist et al., 2001).

Remote sensing has been used to study all wetlands, however, marshes (wettest to driest), deciduous forested wetlands, evergreen forested wetlands, and scrub-shrub types of wetlands difficult due to a spectral mixture of wetland reflection with other land use and cover types. Conversely, the use of multi-temporal data to improve classification accuracy of wetlands and the combination of two dates of imagery allowed separation of emergent and floating vegetation (winter and spring) and flooded emergent vegetation and open water (fall and winter) (Stacy et al., 2002).

The first wetland map of China which has the accuracy of nearly 90% was also developed primarily from manual interpretation of Landsat imagery (Gong and Niu, 2018). While this method generally has high accuracy, it is time-consuming (Gallant, 2007). Computerized classification methods usually comprise supervised and unsupervised approaches. Supervised classification uses training samples to train classifiers to recognize different classes. The advantage of this method is the ability to specify the desired class types (Gong and Ziu, 2018).

2.7. Satellite Sensors used in wetland identification and classification

The launch of the United States' first Earth resources satellite (ERTS 1; now called the first Landsat satellite—Landsat 1) on July 23, 1972, offered a new technology for remote sensing of wetlands (Tiner et al.,2015). Landsat MSS, Landsat TM, SPOT, AVHRR, MODIS and Indian Remote

Sensing Satellite (IRS) Linear Imaging self-scanning Sensor (LISS-II) are common type of Earth observational (EO) satellites that collect data imagery used for wetland classification and its spatial-temporal dynamic change system that have been used to study wetlands (Butera, 1983; Rundquist et al., 2001; Stacy et al., 2002; Ghobadi et al., 2012). In addition, with the release of Sentinel 2A and 2B which is part of the Copernicus Program managed by the European Community and European Space Agency (ESA), customs by integrating 17 remote sensing spectral indexes and decision tree (DT) method to map Small Inner Marsh areas using Sentinel 2A images from Summer and Winter seasons and satisfactory results obtained in order to classify wetland ecosystems (Simioni et al., 2018).

2.8. Spectral reflectance of Wetland Vegetation

Even remotely sensed data that are best suited to create a wetland map are only as good as the methods used to transform that image or group of images into a map. The methods used to create a map or categorize pixels into different groups (e.g., swamp versus marsh) are broadly referred to as image classification (Tiner et al., 2015). Most computer classification techniques, including maximum likelihood, minimum distance to means, unsupervised clustering, and parallelepiped methods, are dependent on different spectral responses of wetland vegetation types for classification. Spectral reflectance studies have been useful for determining which wetland vegetation types are spectrally separable and which bands and dates are best for wetland discrimination (Stacy et al., 2002).

2.9. Remote sensing classification techniques used for wetland identification

Recognition that image data exists in sets of spectral classes, and identification of those classes as corresponding to specific ground cover types, is carried out using the techniques of mathematical pattern recognition or pattern classification and their more recent machine learning variants (Richards and Jia, 2006).

Classification is the process of developing interpreted maps from remotely sensed images. As a consequence, classification is perhaps the most important aspect of image processing to GIS. Digital image classification in remote sensing contains a grouping of pixels of an image to set of classes, such that pixels in the similar class are having like properties and process of developing interpreted maps from remotely sensed images. As a consequence, classification is perhaps the most important aspect of image processing to GIS (Eastman, 2003; Erasu Duguma, 2017). The common type of image classification is based on the detection of the spectral response patterns of land cover classes (Erasu Duguma, 2017). Both supervised and unsupervised classification technique (Hybrid classification method) has been used in land use classification process the study area.

2.9.1. Pixel-based classification

Both unsupervised and supervised pixel-based classifications have been used by different researches for separating wetlands from other land use types, monitoring, and mapping of wetlands (Kaplan and Avdan, 2017).

2.9.1.1. Supervised Classification

In unsupervised classification, pixels are grouped based on the reflectance properties of the pixels and the created groups are called "clusters". The supervised classification needs to be done by selecting representative samples for each land cover class, and the classification is based on the spectral signatures defined by the user (Tiner et al., 2015; Kaplan and Avdan, 2017). The most common supervised classifiers are minimum distance, parallelepiped, and maximum likelihood. Minimum distance classifiers assign pixels to a particular class based on a pixel value's proximity to a simple average of each class type (Tiner et al., 2015). The maximum likelihood decision rule, implemented quantitatively to consider several classes and several spectral channels simultaneously, forms a powerful classification technique (Campbell and Wynne, 2011).

According to (Steven and Freek, 2005) basis of the maximum likelihood classification, and other related probabilistic classifiers which may be used in the same way, is the probability density function, which may be derived from, equation 1.

$$p\,(x_k|i) = \frac{1}{\sqrt{2\pi}\,\sqrt{|M_i|}}\exp\left(-\frac{1}{2}D^2\right) \text{ --- (2.1).}$$

where $p(xk|i)$ represents the probability density function for the pixel k with the data vector xk as a member of class i, Mi is the variance-covariance matrix for class i and $D2$ is the Mahalanobis distance between the pixel k and the centroid of class i. The Mahalanobis distance may be calculated from,

$$D2 = (xk - vi)^{T}\, Mi^{-1}\, (xk - vi) \text{----------------------------- (2.2)}$$

where *vi* is the mean vector for class *i*. The calculated Mahalanobis distance may be converted to a typicality probability by reference to a chi-squared distribution (Steven and Freek 2005). maximum likelihood classification uses the training data as a means of estimating means and variances of the classes, which are then used to estimate the probabilities. Maximum likelihood classification considers not only the mean, or average, values in assigning classification but also the variability of brightness values in each class (Campbell and Wynne, 2011).

2.9.1.2. Unsupervised classification

Unsupervised classification can be defined as the identification of natural groups, or structures, within multispectral data (Campbell and Wynne, 2011). In unsupervised classification, pixels are automatically grouped into statistically similar categories. Similar statistical groupings are clustered and stratified by class types according to image analyst interpretation or mathematical correlations (Tiner et al., 2015). According to (Campbell and Wynne, 2011) advantages of unsupervised classification (relative to supervised classification) can be enumerated as no extensive prior knowledge of the region is required, Opportunity for human error is minimized and Unique classes are recognized as a distinct unit in unsupervised classification.

2.9.2. Index based classification

A number of relatively simple processing steps can be used to produce inputs for decision trees or create wetland maps directly. These procedures include thresholding using one input band and the creation of ratios using multiple input bands. Thresholding is a simple yet powerful technique that works best when classes occupy distinct ranges of image values (Tiner et al., 2015). For classifying different land covers, a number of researches have been made through the years and most of the studies use different indexes for distinguishing wetlands from other land covers. For more successful extraction of wetlands, a combination of the pixel-based and index-based method was used. Normalized Difference Vegetation Index (NDVI) gives information related to wetlands and information about the vegetation presents in the wetlands. Correspondingly Normalized Difference Water Index (NDWI) used for monitoring the open water bodies (Kaplan and Avdan, 2017). The most obvious method of change detection is a comparative analysis of spectral classifications for two consecutive periods produced independently (Singh, 1989). In this context, it should be noticed that the change detection map of two consecutive images will only be generally as accurate as of the product of the accuracies of each individual classification (Stow et al., 1980). A post-classification detection method algorithm was employed in order to perform land use/cover change detection which is a pixel by pixel-based method comparison. Landsat Classified image pairs of two different study period data were compared using cross-tabulation statistical analysis in order to determine qualitative and quantitative characteristics of the land use land cover changes for the periods from 1985 to 2018 using ERDAS Imagine 2015 (Weng,2001).

2.9.3. SRTM Semiautomated wetland delineation

According to Moore (1991), Topographic attributes can be divided into primary and secondary (or compound) attributes. Primary attributes are directly calculated from elevation data and include variables such as elevation and slope. Compound attributes involve combinations of the primary attributes and are indices that describe or characterize the spatial variability of specific processes occurring in the landscape. A series of hydrologically related primary topographic attributes, such as slope, specific catchment area, aspect, and profile curvature, can be derived from elevation data for each and every element as a function of its surroundings can be easily estimated using the computer-based method. Based on Shuttle Radar Topography Mission (SRTM) 90m resolution data all primary (Flow direction, Flow accumulation, slope, upslope and catchment area) and Secondary attribute (TWI) were derived.

2.10. Application of GIS in wetland change detection

Geographic Information System (GIS) is another widely used technique in wetlands analysis. Modern GIS gives users the ability to conduct visual and quantitative analysis involving multiple kinds of digital spatial data, including remotely sensed imagery (Shi, 2013).

2.11. Difficulty in Monitoring Wetlands

It is not an essay task to map and classify wetlands from the sky due to wetlands are not unified by a common land-cover type or vegetation form in the way that forests are populated with trees, grasslands with grasses, and shrublands with shrubs. Interrelations among environmental dynamics and potential wetland land covers and conditions result in an ever-changing variety of energy responses that make it highly challenging to train algorithms that can map wetlands with levels of accuracy and consistency sufficient for monitoring. This is evidenced by the myriad ways in which researchers have approached remote mapping of wetlands and the lack of consistency in results (Gallant, 2015).

Chapter III

3. Materials and Method

3.1. Description of the study area

3.1.1. Location

The study area is located within - Geba river watershed that constitutes Baro River basin in Ethiopia. In terms relative location the study area is found in the southwestern Ethiopia at around 600 km from Finfinne/Addis Ababa. The area is bounded by 7°45'00"−8°36'00"N latitude and 35°20'00"−36°11'00"E longitude. The study area approximately covers 7,125. 35 km^2 (Figure. 3.1). The Geba watershed is situated in the Southwestern part of the country and it remains as one of the most fertile and least exploited areas in Ethiopia (Dixon, 2003). This study area is mainly characterized by tropical montane evergreen rainforest. The present study focused on this area valley bottom wetland degradation mapping due to severe degradation of the wetlands in the watershed.

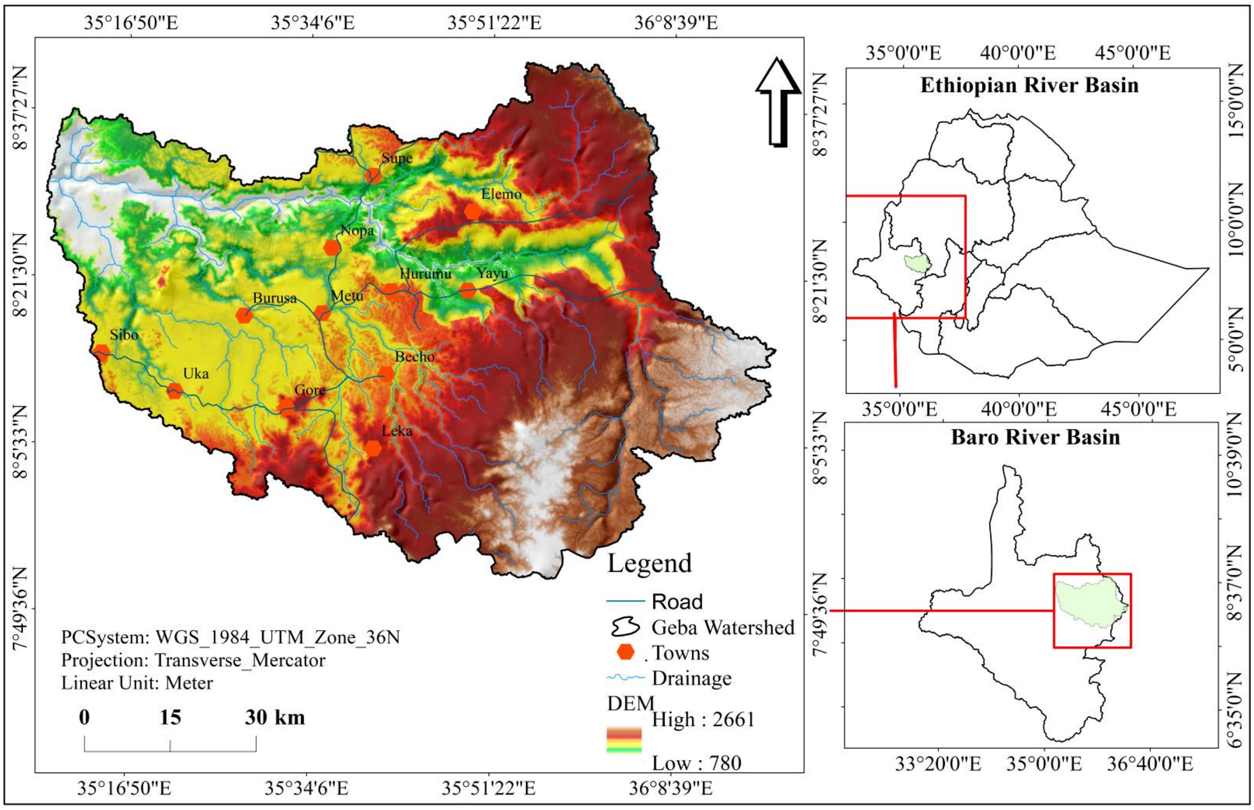


Figure 3. 1: Location map of the Study Area

3.1.2. Geology of the study area

Geology of the watershed is represented primarily by Basalt underlain by Precambrian formation constituting the basement. The majority of the study area covered by Oligocene flood basalt (Figure 3.2). Those geologies give rise to sandy or sandy loamy soils. Wetlands of the watershed formed on Oligocene flood basalt bedrock with those formed in watershed with a mixture of olivine-pyroxene and rarely large plagioclase phyric, amygdaloidal basalt and recent quaternary sedimentary bedrock. The Precambrian basement (Basement complex) forms typically landscape characterized by a sharply crested or rugged mountainous terrain whereas that of the basalt is more hilly and undulating terrain (Tadessse Amsalu and Solomon Addisu, 1994; Dixon, 2003). The southwestern highland valley bottom wetlands are develop through time in response to changing external geological, geomorphological and climatic conditions. The formation of ancient impermeable quaternary and tertiary bedrock in the study area could plays significant role in the formation of wetlands.

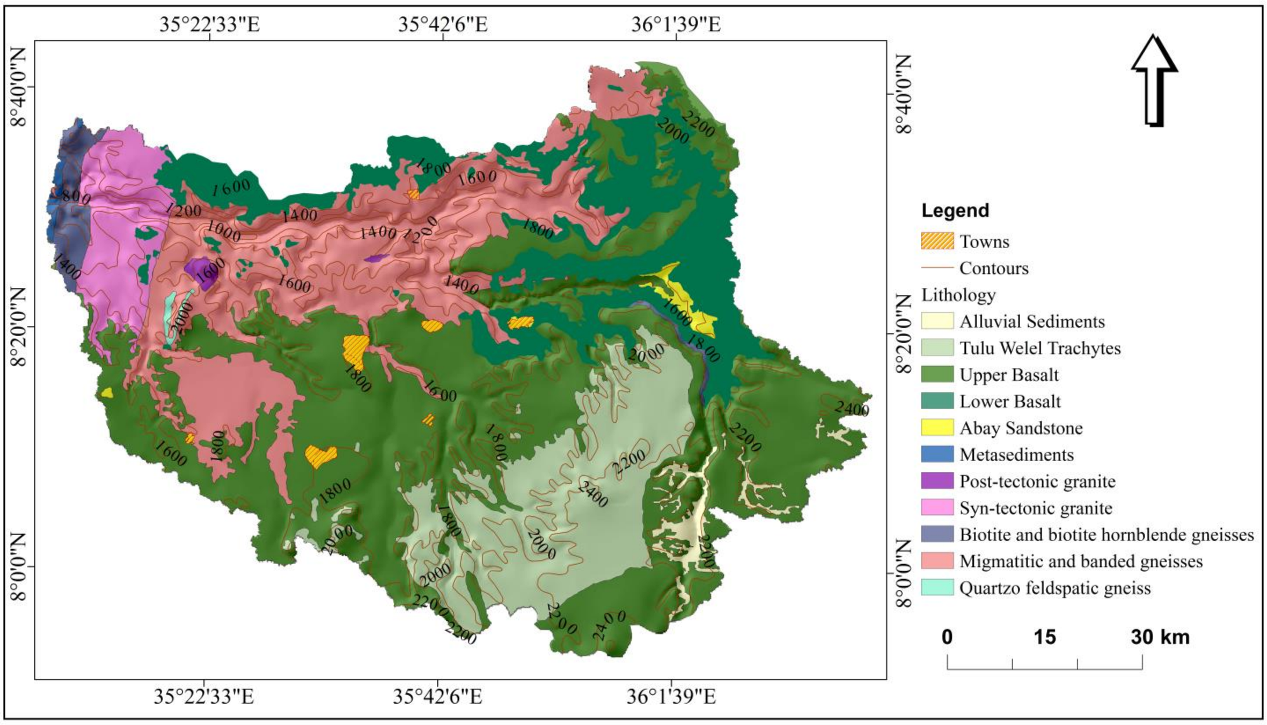


Figure 3.2: Geological map of the study area (Partially adopted from Asfawossen Asrat, 2018)

3.1.3. Topography

Topography of the study area is generally categorized as a highly incised plateau and dendritic drainage systems (Afwerk Hailu 2001). The altitude ranges from 780m a.m.s.l. at the bottom of the valley and 2661m a.m.s.l. in the mountain's areas (Figure3.3). The terrain in the study area is mainly plateau that is dissected by rivers and streams. In general, the elevation in the hinterland increases from southwest to northeast. The landscape of the hinterland which is the result of internal and external forces involved in landscape formation includes plateaus, valleys, and hills. There are many rivers, streams or small rivers that commences from these highlands and flow across the town and they are good sources of water for domestic uses. However, during high rainfall season the town and the surrounding area vulnerable to flooding by rivers(MTSER, 2004).

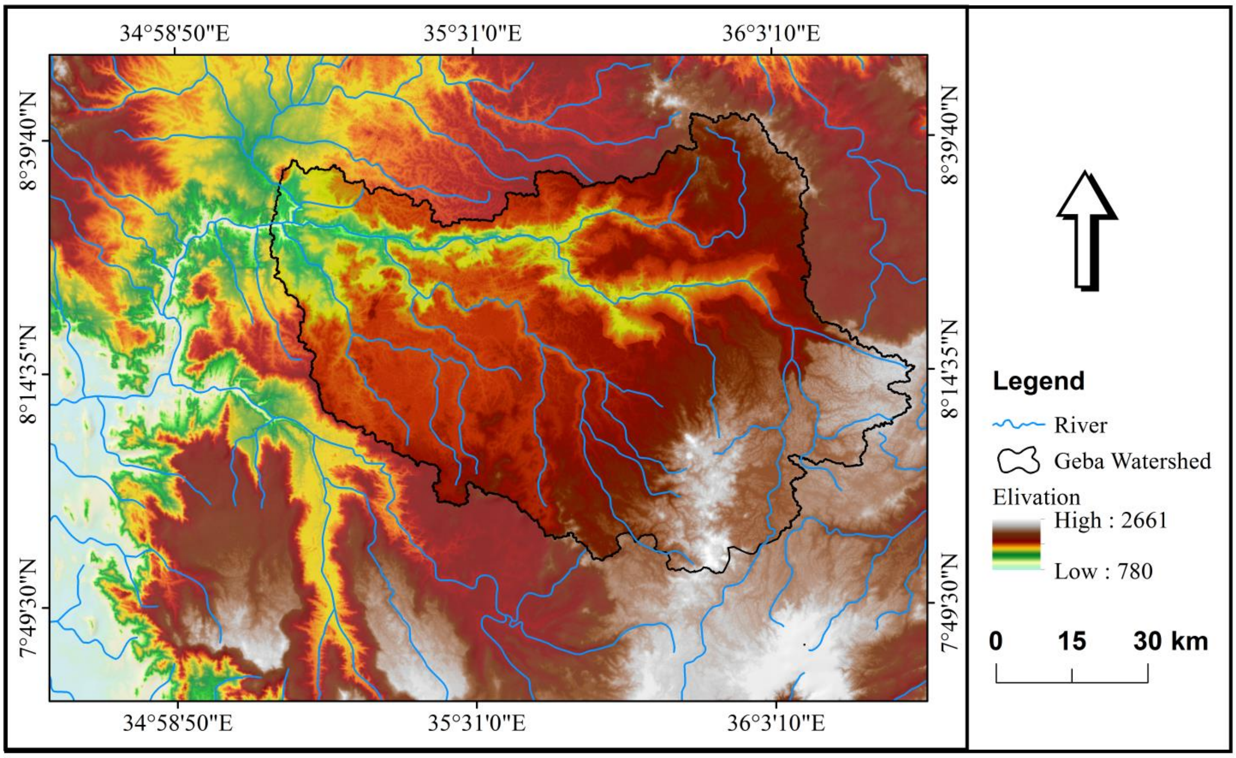


Figure 3. 3: Physiography map of the study area

3.1.4. Soil Types and Distribution

According to FAO classification, the hinterland is endowed with six major soils types (Figure. 3.4). These are Dystric and Eutric Cambisols, Dystric Nitosols, Lithosols and Orthic Acrisols (MTSER, 2004). The soils in the wetlands within the study area are mainly dystric gleysols being composed of recent alluvial or fine colluvial deposits and show hydromorphic properties. The texture of these soils varies from silt loam to silty clay loam (Wood and Dixon, 1999). The presence of different soils in the hinterland is a potential for practicing agriculture, it supports different natural vegetation and also, they are used for construction purposes (MTSER, 2004).

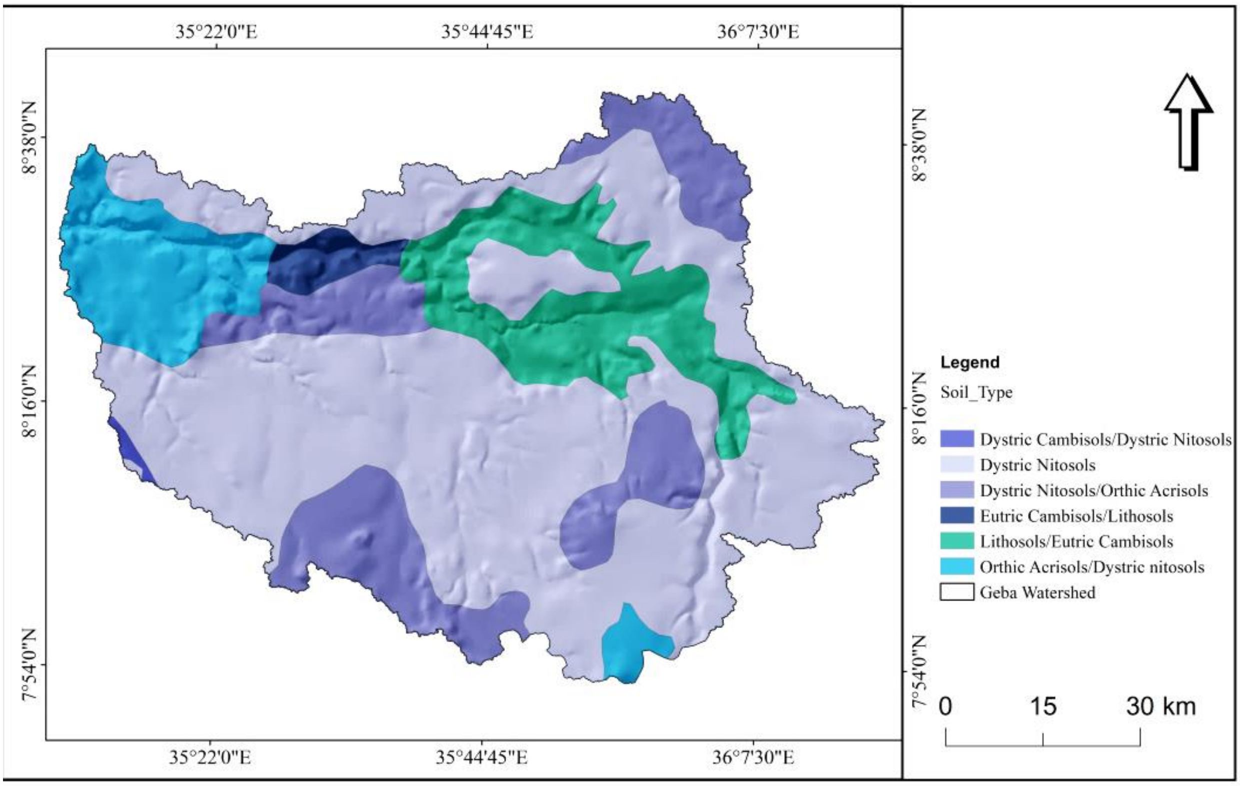


Figure 3. 4: FAO Soil type map for the study area

3.1.5. Climate

In Ethiopia, latitude and altitude are the two most important that controls of the elements of the climate. Similarly, in the Geba watershed, the climate is influenced by altitude and latitude. Based on the vertical altitudinal variation in the hinterland there are three major agro-climatic zones which are Kolla (lowlands), Woindega (midlands) and Dega (highlands). The vertical altitudinal variation creates a suitable condition for growing of different crops that range from warm to cool thermal zone (Mettu Town Socio-economic spatial study report, 2004).

3.1.6. Rainfall

Based on Metrological data from Ethiopian National Meteorological Agency (NMA), Geba watershed receives an average annual rainfall that exceeds 2000 mm in a year. The distribution of rainfall throughout the year is seasonal (Dixon, 2003) with the dry season from November to February which receives less than 5mm of rainfall. The monthly mean rainfall in the study area steadily increases from March and April from about 5mm to 80mm in May, June, July, August, September, and October. July, August, and September- experience the highest amount of average monthly rainfall. The average annual rainfall amount in the study area results in the unimodal pattern even though there is small fluctuation in different stations. Bure the lowest elevation station receives the smallest amount of rainfall (Figure 3.5).

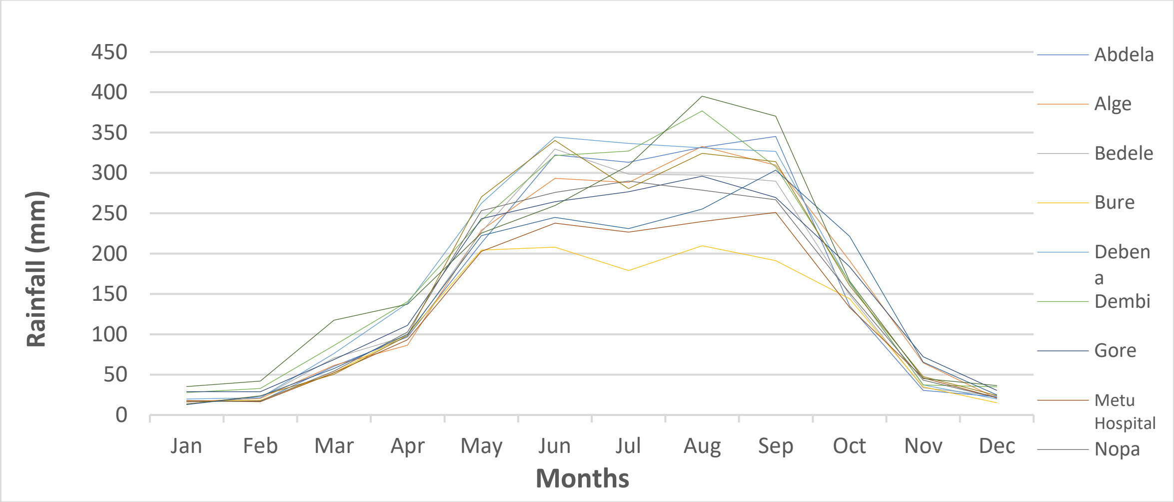


Figure 3.5: Seasonal and Spatial distribution of rainfall (1985–2018).

3.1.7. Temperature

The temperature of the watershed varies from month to month. The highest temperature stirring in January, February and April. The average monthly temperature ranges from 17.1^0c to 20.2^0c. Based on observation from Ethiopian Meteorological data the annual variation of temperature in Mettu is very small due to humid climatic characteristics. The lowest temperature of the town occurs during the summer season (Figure 3.6).

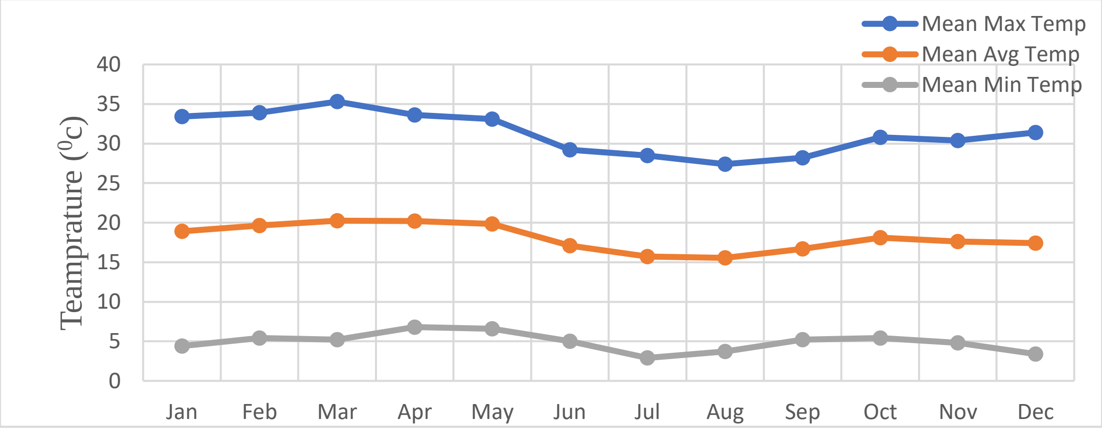


Figure 3. 6: Monthly mean temperature

3.1.8. Natural Vegetation

The climax vegetation of most of the highlands in Ilu Aba boor is tropical montane, evergreen rainforest (broad-leaved natural vegetation regions) which is a direct reflection of the climate of an area. In this natural vegetation region, the dominant species are Arundinaria (Leman) and Aningeria (Kerero), Baphia, croton macrostachyus Sapium ellipticum and Olea forests are the major climatic climax natural vegetation (Dixon, 2003, MTSER, 2004).

3.1.9. Demographic characteristics

According to the official Ethiopian government census that was carried in 2007, the total population of Ilu Aba Bora Zone was 1,271,609 persons of which 636,986 were males and 634,623 females (CSA,2007). As the result of migration and governmental relocation programmers the ethnic compositions of Illubabor is diverse (Afework Hailu 2000; Dixon, 2003).

3.2.Datasets

The qualities of overall input data can affect the result of the overall accuracy and findings of scientific research. Especially, geospatial data collected by both ground surveying and remote sensing methods require special attention on the quality of the data. Most Ethiopian geospatial data provided by different organization are distributed without any appropriate metadata information. As a result, before collecting and using the data, it's highly recommended to identify the quality of dataset and production purpose. For the purpose of this study, both primary and secondary data were used for this study(Table 3.1).

Table 3. 1: Description of data

No	Data	Spatial resolution (m)/scale	Source
1	Landsat (TM and OLI)	30	USGS, Earth explorer
2	SRTM DEM	90	USGS, Earth explorer
3	Topographic map	1:50,000	Ethiopian Geospatial Agency
4	Water quality data	-	Laboratory test
5	Filed GPS Data Collection		

3.2.1. Remote Sensing data

The primary Geospatial datasets that are used in this research work included imageries collected by Landsat time series satellite sensors of 1985, 2000 and 2018 with 15-year interval were selected for analysis. The study area covered by two Landsat scene of 170/054 and 171/054 path and row respectively. and Landsat sensors can provide multispectral imagery with finer spectral and better temporal resolutions, which are essential for classifying wetland vegetation types and analyzing wetland water dynamics. (Wu, 2018). All optical Landsat imagery was collected from the USGS Earth Resources Observation and Science (EROS) Archive Center (https://earthexplorer.usgs.gov) and which comprised of the Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) was used. The spatial resolution of 30m Landsat imagery Level 1T - Terrain Corrected and there is no need for rectification and ortho rectifications. More Detailed characteristics of the sources of data or the study are shown in (Table 1). All images are predominantly cloud-free. One of the advantages Landsat imageries is its free availability of the data.

3.2.2. Landsat Thematic Mapper

The advanced multispectral scanner sensor of Landsat thematic mapper ™ was carried out on Landsat 4 and 5. Landsat 5 was launched from July 1982 to until November 2011. Thematic mapper ™ are sensed in seven multispectral bands; band six thermal infrared with a spatial resolution of 120 to 30 m spatial resolution of the visible and infrared region with the approximate scene size of 170 km. The detail and more description of thematic mapper summarized in (table 3.2).

Table 3. 2: Descriptions of Landsat Thematic Mapper

Landsat 4 & 5	Bands with description	Wavelength (µm)	Temporal resolution (days)	Spatial Resolution (meters)
Thematic Mapper (TM)	Band 1-Blue	0.45-0.52	16	30
	Band 2-Green	0.52-0.60	16	30
	Band 3-Red	0.63-0.69	16	30
	Band 4-NIR	0.76-0.90	16	30
	Band 5-Shortwave IR (SWIR) 1	1.55-1.75	16	30
	Band 6-Thermal	10.40-12.50	16	120
	Band 7-Shortwave IR (SWIR) 2	2.08-2.35	16	30

TM bands 6 was originally acquired at 120 m spatial resolution, but products are resampled to 30 m pixel resolution. Landsat TM scene was mostly processed through the level 1 Product Generation System (LPGS), Processed to full precision Terrain correction and L1T Terrain correction.

3.2.3. Landsat Operational Landsat Imagery

Formerly the Landsat Data Continuity Mission, (LDCM) is the most recently launched satellite on February 11, 2013, Landsat program provides repetitive medium-resolution multispectral data of the earth. It acquired data in 11 bands; from bands 1 to 7 and 9 are a multispectral band, and band 8 is panchromatic while band 10 and 11 are a thermal band. The approximate scene size is 170 km north by south and 183 km east-west. (Table 3.3) shows a brief description of OLI and TIRS.

Table 3. 3: Landsat 8 OLI and TIRS description

Landsat 8	Bands with description	Wavelength (µm)	Temporal resolution (days)	Spatial Resolution (meters)
Operational Land Imager (OLI)	Band 1-Ultra Blue (coastal/aerosol)	0.43-0.45	16	30
	Band 2-Blue	0.45-0.51	16	30
	Band 3-Green	0.53-0.59	16	30
	Band 4-Red	0.64-0.67	16	30
	Band 5-NIR	0.85-0.88	16	30
	Band 6-Shortwave IR (SWIR) 1	1.57-1.65	16	30
	Band 7-Shortwave IR (SWIR) 2	2.11-2.29	16	30
	Band 8-Panchromatic	0.50-0.68	16	15
	Band 9-Cirrus	1.36-1.38	16	30
	Band 10-TIRS 1	10.60-11.19	16	100
	Band 11-TIRS 2	11.50-12.51	16	100

3.2.4. SRTM data

Along with optical sensor Shuttle Radar Topographic Mission (SRTM), DEM data were used. SRTM 90 m Resolution Digital Elevation Model data have increasingly been incorporated into the wetland mapping. Importantly SRTM 3 Arc Second DEM is primarily used to generate precise information on surface elevation and compute various topographic metrics, which serve as essential wetland indicators. More detailed Product Specifications of SRTM DEM are shown in (Table 3.4).

The 90m resolution SRTM Digital Elevation Model (DEM) was used and downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/). The Shuttle Radar Topography Mission (SRTM) was flown aboard the space shuttle "*Endeavour*" from February 11-22, 2000. The National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA) participated in an international project to acquire radar data which were used to create the first near-global set of land elevations (https://www.usgs.gov).

Table 3. 4: SRTM DEM Specification **(**USGS SRTM Mission Summary)

Projection	Geographic
Horizontal datum	WGS84
Vertical datum	EGM 96 (earth gravitational model 1996)
Vertical units	Meters
Spatial resolution	3 arc-seconds for global coverage (~90 meters)
Raster size	1-degree tiles
C-band wavelength	5.6 cm

3.2.5. Field Observation

Based on potential resources of wetlands three kebeles of the study area were visited in the month of February and March. Ground Truthing Points (GTPs), Wetland Water sample and photos of existing land cover types and wetlands were collected during the field work using handheld GPS (Global Positioning System) and digital camera in order to enhance the classification of satellite image and wetland mapping.

3.2.6. Ancillary data source

Meteorological data such as monthly temperature and average monthly rainfall were acquired from Meteorological Agency of Ethiopia. Demographic data of the study area were collected from the Central Statistics Agency (Table 3.5).

Table 3. 5: Meteorology data description

Data type	Year	Source
Rainfall	1985-2017	Meteorological Agency
Temperature		Meteorological Agency
Population data		Central Statistics Agency

3.3. Software

To achieve the overall objectives of the study the following software packages were used to analyses spatial data and satellite imagery and Microsoft office packages: office such as MS-excel, MS word, and MS power point were used as their desires. All software were listed in (Table 3.6)

Table 3. 6: Software used

Software	Application
ArcGIS 10.5	Image processing and Map Preparations
ENVI 5.3	Image preparation and pre- processing
ERDAS IMAGINE 2015	Image classification
Google Earth Pro 7.1.5.1557	Validation
TauDEM (Terrain Analysis Using Digital Elevation Models)	DEM Processing

3.4. Data Analysis and Method

Different standard remote sensing image interpretation and processing techniques have been used in this study. In addition to remote sensing imagery, integrated ancillary data were used in the mapping of wetland degradation and its impacts on the surrounding environment were analyzed. wetland water quality assessment has been done in the laboratory.

Different Remote sensing techniques analysis were used for classifying and separating wetlands from surrounding land covers types. Both indices and pixel-based image classification method were done respectively. Index based classification where done using Landsat thematic mapper and Operational land imagery. Slope and Topographic wetness index were calculated from the SRTM 90m Digital Elevation Model, respectively. At the same time, semiautomatic delineation of the wetland has been used using image enhancement and direct digitization of wetland from enhanced multispectral imagery.

Afterward, field collected data and Slope of the study area integrated with semiautomatic classification were used for accurate mapping of wetland. Supervised classification method was used for the classification of land use land cover map of the study area.

3.4.1. Image Preparation

As described under the dataset and sources section table (1) two Mosaic images were used for this study (Landsat Thematic Mapper and Operational land imagery of 1985, 2000 and 2018). Firstly, Landsat imagery used for this study were downloaded from the USGS Earth Explorer (https://earthexplorer.usgs.gov) website in the form of GeoTIFF data format. Before image mosaicking, radiometric and atmospheric normalization were conducted for all scene. Then after Image mosaicking of two scenes covering the study area was possessed using ArcGIS mosaicking tool. Dry season images of January and February was selected for the acquisition of an image when the study area receives the lowest amount of average annual rainfall which results in free or the smallest amount of cloud cover. Satellite Imageries belonging to the same time of the year may reduce problems from Sun angle differences and vegetation phenology changes (Singh, 1989).

3.4.2. Radiometric Correction

Radiometric normalization of multi-dates imageries is the acute stage and is a basic requirement for change detection. The reflectance values measured by the sensors are not the pure representation of the values reflected by earth surface features due differences in atmospheric absorption and scattering due to variations in water vapor and aerosol concentrations of the atmosphere at disparate moments in time temporal variations in the solar azimuth angles, and sensor calibration inconsistencies for separate images factors. Multi-date image datasets require that images obtained by sensors at different times are comparable in terms of radiometric characteristics (Coppin et al., 2004; Erasu Duguma, 2017). The difference in radiance values between two dates is taken as an indicator of change Differences in illumination, differences in atmospheric conditions, differences in sensor calibration, and differences in the registration of the two images changes due to changes in the object scene should be large relative to radiance changes due to other factors for good signal-to-noise ratios (Singh, 1989). Generally, the objective of the radiometric correction procedure is to convert satellite generated digital accounted to ground reflectance that is absolute surface reflectance and ENVI 4.3 used to calibrate Landsat imagery.

Data continuity requires consistency in the interpretation of image data acquired by different sensors. Calculation of radiance is the fundamental step inputting data from multiple sensors and platforms onto a common radiometric scale (Chander et al., 2007).

3.4.3. Conversion to at a Sensor radiance

Radiometric correction has to be done before directly extracting information from satellite imagery. The Radiometric Calibration of Landsat image was performed using gain and offset of the sensor provided under metadata of satellite product and the digital counts were converted to at a sensor radiance values by removing error caused by imaging instrument (Chander et al., 2009).

$$\left(\frac{\mathrm{LMAX}\lambda - \mathrm{LMIN}\lambda}{\mathrm{Qcalmax}-\mathrm{Qcalmin}}\right)(\mathrm{Qcal} - \mathrm{Qcalmin}\ \text{ð Þ} + \mathrm{LMIN}\lambda) \text{------------------------} (3.1)$$

Where, Lλ= Spectral radiance at the sensor's aperture [W/ (m2 sr μm)], Qcal= Quantized calibrated pixel value [DN], Qcalmin= Minimum quantized calibrated pixel value corresponding to LMINλ [DN], Qcalmax= Maximum quantized calibrated pixel value corresponding to LMAXλ [DN], LMINλ= Spectral at-sensor radiance that is scaled to Qcalmin [W/ (m2sr μm)], LMAXλ= Spectral at-sensor radiance that is scaled to Qcalmax [W/ (m2sr μm)].

3.4.4. Conversion to TOA reflectance

Next, at-satellite radiances must be converted to surface reflectance by correcting for both solar and atmospheric effects (Chavez, 1996). A reduction in scene-to-scene variability can be achieved by converting the at-sensor spectral radiance to exoatmospheric TOA reflectance. In order to remove and correct the cosine effect of different solar zenith angles due to the time difference between data acquisitions and variation in the Earth-Sun distance between different data acquisition dates TOA reflectance of the Earth is computed (Chander et al., 2009). Finally, TOA reflectance with a correction for the sun angle is given by the following formula: (equation 3.2)

$$\left(\frac{\mathrm{L}\pi * \lambda * \mathrm{d2}}{\mathrm{ESUN}\lambda * \cos\theta\mathrm{s}}\right)\text{---} (3.2)$$

where, ρλ= Planetary TOA reflectance [unit less], π= Mathematical constant equal to ~3.14159 [unit less], Lλ= Spectral radiance at the sensor's aperture [W/ (m2 sr μm)], d= Earth–Sun distance [astronomical units], ESUNλ= Mean exoatmospheric solar irradiance [W/ (m2 µm)], θs= Solar zenith angle [degrees] θSZ is local zenith angle; $\theta SZ = 900 - \theta SE$.

3.5. Data Processing Method

3.5.1. Wetland Degradation Mapping

Wetland is among the most difficult ecosystem to classify using remote sensing data due to their high spatial heterogeneity and temporal variability (Ozesmi and Bauer, 2002). Sizes and shapes of wetlands vary greatly, as do the diversity of plant species and vegetation structures and types (e.g., open water, submerged plants, floating-leaved plants, emergent herbaceous vegetation, woody shrubs, and forest). Water levels fluctuate daily and seasonally, which can confound spectral classification, and many wetland plant species are spectrally similar to one another, which makes separation of unique signatures difficult, particularly when only a few broad spectral bands are available for classification (Lane et al., 2014) Despite these limitations, the remotely sensed multi temporal and multispectral imagery from Landsat, SPOT, and other major data sources (Ozesmi and Bauer, 2002), have a long history of use in wetland mapping applications and improves the classification of wetlands, as does ancillary data such as soil data, elevation or topography data. (Lane et al., 2014).

Additionally, GIS and remote sensing techniques can facilitate wetland identification and delineation by analyzing a combination of wetland indicators such as hydrology, vegetation, and topographic position (Lillesand, 2004). These wetland indicators can be represented as various wetland indicator layers in a GIS environment, which can be overlaid or integrated to identify areas where there is a high probability or potential that wetlands may be present (Wu, 2018).

In this study, image enhancement and both Semi-automatic pixel-based and index based classification were used in order to identify and delineate wetland extent through multitemporal and multispectral Landsat Series imagery and Digital Elevation Model (SRTM 90m). The general work flow of the proposed research methodology in this study was briefly labeled in the following flow chart diagram presented in (Figure 3.7).

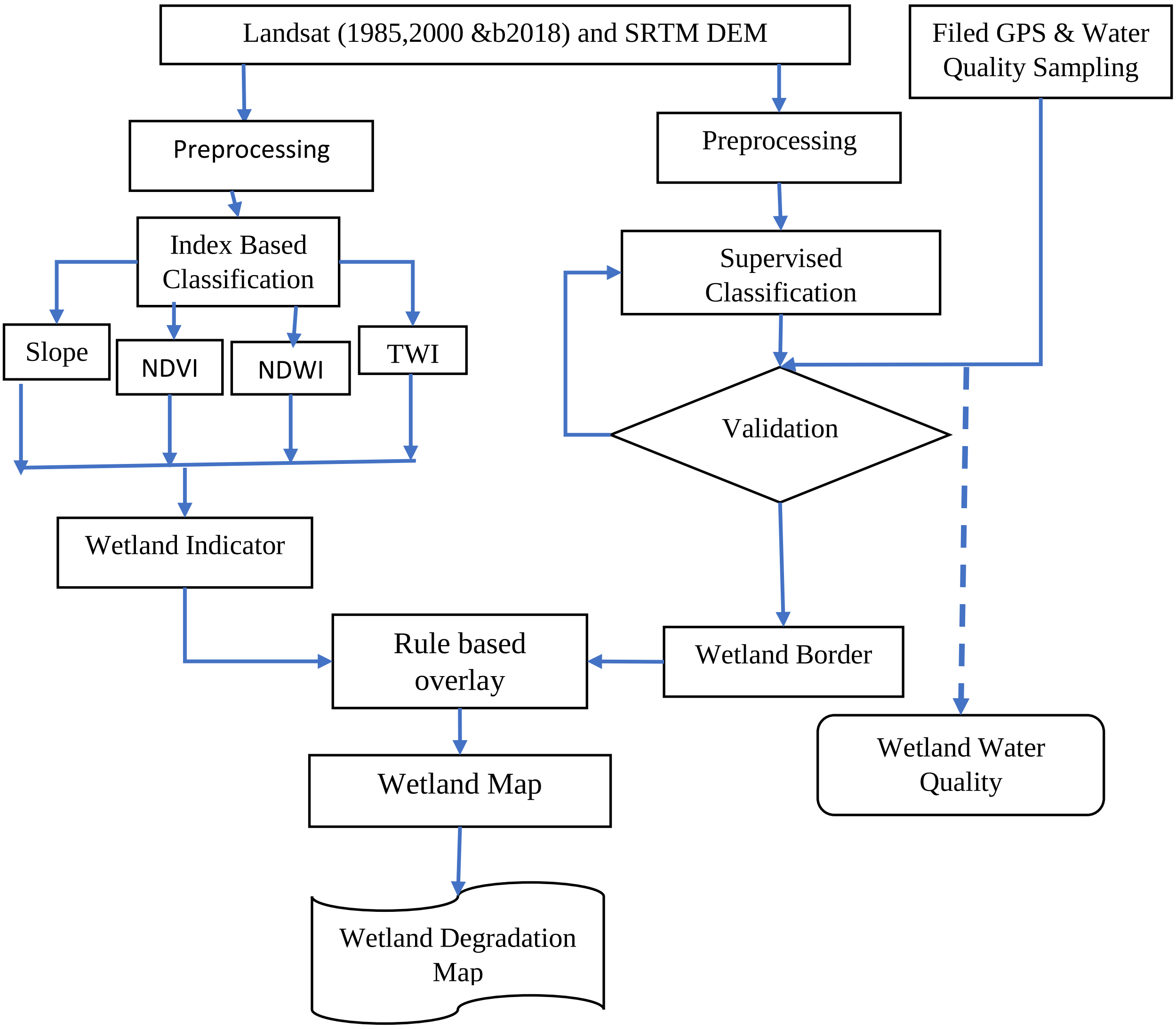


Figure 3. 7: Work Flow chart

3.6. Pixel-based classification of Wetland

3.6.1. Land-cover classification method

According to Dodge & Congalton (2013), Image classification described as a grouping of pixels within an image into categories with similar pixel characteristics and these are called classes or \themes. The resulting “thematic map” typically reflects land cover or land use. With the intention of identifying a degraded wetland area and monitoring supervised classification method will be used. They are pixel-based classification methods solely based on spectral information of image data. The supervised classification was done by selecting representative samples for each land cover class based on the spectral signatures defined by the user. In this case, based on maximum likelihood classification algorithm five different classes were identified; Agricultural fields, forest, Bush/Shrubland, Wetland, Gumro tea plantation, and urban/settlement. Due to the limitation of Landsat spatial resolution capability small water bodies which are rivers, streams and spring were not included in the classification classes.

Level I land use land cover classification system were used and it was adopted from United State Geological Survey (USGS) land use land cover classification system for remote sensing data were used (James, 2013). In the classification, urban or built-up land class include residential, commercial, mixed urban and rural area areas. Cropland, nurseries and other cultivation area classified as Agricultural land except for Gumro tea plantation farm and coffee forest. Due to the spectral similarity of Tea plantation farm with Wetland areas Gumro tea plantation farm classified as one class to minimize spectral mixture with wetland classes. Similarly, coffee forest cropland areas were classified as Forest lands. This is due to, traditionally, wild coffee Arabica were produced by managing and monitoring natural forests and it’s difficult to identify coffee forest land use types using medium resolution spectral reflectance values. Tropical montane, evergreen rainforest (broad-leaved natural vegetation regions and plantation trees classified under forest classes. The more description of land use land cover types presented in (table 3.7). Iso-clustered unsupervised classification algorithm classification carried out before fieldwork data collection in order to understand the general land use types of the study area. This is because unsupervised classification is automatic and requires little knowledge of the study area (Adane Mezgebu, 2016).

Table 3.7. Land-use and land-cover classes descriptions

Land-use class	Description
Agricultural land	including crop fields, Fallow land, sandy, rocky and bare soil
Wetland	including papyrus, forested and grassy wetlands
Tea Plantation	Gumro Tea Plantation Farm
Urban	Including urban, rural settlements and Asphalted roads.
Forest	Economic forests such as timber and fuel woodland other natural forests.
Shrubland	Scattered trees and bushland

Then after field data collection supervised classification technique using maximum likelihood algorithm has been done. The first step in undertaking a supervised classification is to define the areas that will be used as training sites for each land cover class (Eastman, 2003). Signature values have been defined on the original image by integrating high-resolution satellite images from Google Earth Pro. ERDAS IMAGINE 2015 and Google Earth Pro 7.1.5.1557 software were used to classify the image and define training sites respectively by linking the imagery displayed in Viewer to Google Earth Pro. The capability of Google Earth Pro to view map or imagery over time were used to define historical Thematic Mapper (TM) Landsat imagery. Although unsupervised classification and information from the elder peoples in the study area were used to classify the former Landsat imagery. There are six land use a land cover types namely: Forest, Agriculture, Shrub-land, Wetland, Tea Plantation and Urban area in the study area. A total of 300 ground truth point (GTP) were collected from 2018 classified LULC types using a hand-held Global Positioning System (Garmin GPS 72). A total of 150 ground truth data from each Land use land cover type were used to define training areas form recent Landsat 8 operational land imagery (OLI) imagery and the remaining 150 GTP were used for accuracy assessment.

3.6.1.2. Class smoothing process

The classification procedure usually leaves use with a small number of isolated, generally poorly classified or unclassified, pixels that are often located at the boundaries between two clearly assigned areas. The value of applying small kernel smoothing filters to reduce in-class spectral variability and enhance between-class spectral separability (Tottrup, 2013). Post classification smoothing with a majority filter is essential to reduce unnecessary detail and further improve the classification accuracy. Filtering comprises conveying isolated pixel to the leading class within which it lies (Erasu Duguma, 2017).

The use of pre-classification image smoothing could suppress the influence of in-class spectral variance while enhancing the between-class spectral separability. A smoothing filter reduces the in-class spectral variability by averaging the pixel values inside a sizeable kernel moved throughout the image (Tottrup, 2013). Generally, for mapping purposes, a very common post-processing operation was applied to generalize the image and remove these isolated pixels (Eastman, 2003).

3.7. Automated and semi-automated methods of wetland boundary delineation

Different automated and semi-automated wetland classification algorithm was used in order to enhance and map wetlands. The semi-automated methods involved: (i) image enhancement, (ii) display of enhanced images in red, green, blue (RGB) false color composites (FCCs) to highlight wetland boundaries, and (iii) digitizing the enhanced and displayed images and delineate wetlands from non-wetlands. The process is described in detail below. Additionally, different types of index-based classification of wetland were used for wetlands mapping such as (iv) Normalized Difference Vegetation Index (NDVI), (v) Normalized Difference Water Index (MNDWI), and (vi) Topographic wetness index (TWI), (vii) slope and (viii) (Kulawardhana et al, 2007 and Islam et al., 2008).

3.7.1. Normalized Difference vegetation index (NDVI)

Often vegetation indices can be useful for highlighting wetlands. The vegetation indices can be used in the visual interpretation of wetland boundaries and extents or used in a classification algorithm to map wetlands (Ozesmi and Bauer, 2002). NDVI derived from Landsat ^{TM} and Operational Land imagery ^{OLI} were used to highlight and detect wetland vegetation in the study area. NDVI is calculated from surface reflectance in red and near-infrared (NIR) wavelengths (Equation. 3.3) as NDVI = (NIR − red)/(NIR + red) (Dong et al., 2013 and Lane et al., 2014).

$$NDVI = \frac{NIR-Red}{NIR+Red} \text{---} (3.3)$$

Where, NIR = Reflectance in Near Infrared (Band 4 and Band 5 for Landsat ^{TM} and Landsat ^{OLI}), Red = Reflectance in Red (Band 3 and Band 4 for Landsat ^{TM} and Landsat ^{OLI}).

3.7.2. Modified Normalized Difference water index (MNDWI)

The modified NDWI (MNDWI) is proposed by (Xu, 2006) can enhance open water features while efficiently suppressing and even removing built-up land noise as well as vegetation and soil noise. The NDWI is modified by substituting the MIR band for the NIR band. The modified NDWI (MNDWI) can be expressed as follows: MNDWI was used to extract wetlands from Landsat imageries. The modified normalized difference water index (MNDWI) can reveal subtle features of water more efficiently than the NDWI or other visible spectral bands and the MNDWI can remove shadow noise from water information. So in this study, we selected MNDWI for open water extraction.(Dong 2013; Xing, 2014 and Jones, 2015). MNDWI calculated as (Equation 3.4).

$$MNDWI = \frac{Green-MIR}{Green-MIR} \text{---} \quad (3.4.)$$

where, MIR = Reflectance in middle infrared band such as Landsat ^{TM} band 5 and Landsat ^{OLI} band 7, Green = Reflectance in Green (Band 2 and Band 3 for Landsat ^{TM} and Landsat ^{OLI} Respectively).

3.8. Digital Elevation Model (DEM) based Surface Hydro-processing

The most common digital data of the Earth's surface is raster digital elevation models (DEMs), and because the flow of water is determined by the terrain it has become more common to use DEMs for the analysis of hydrological processes. Usually, there are a number of steps which have to be followed for performing a specific task. The following flowchart shows the sequence of steps for the Primarily and secondary key hydrological parameter functionality (https://www.ian-ko.com/ET_Surface/userguide/ets_hydrological_functions.htm). The overall hydrological modeling process is shown in (Figure 3.8).

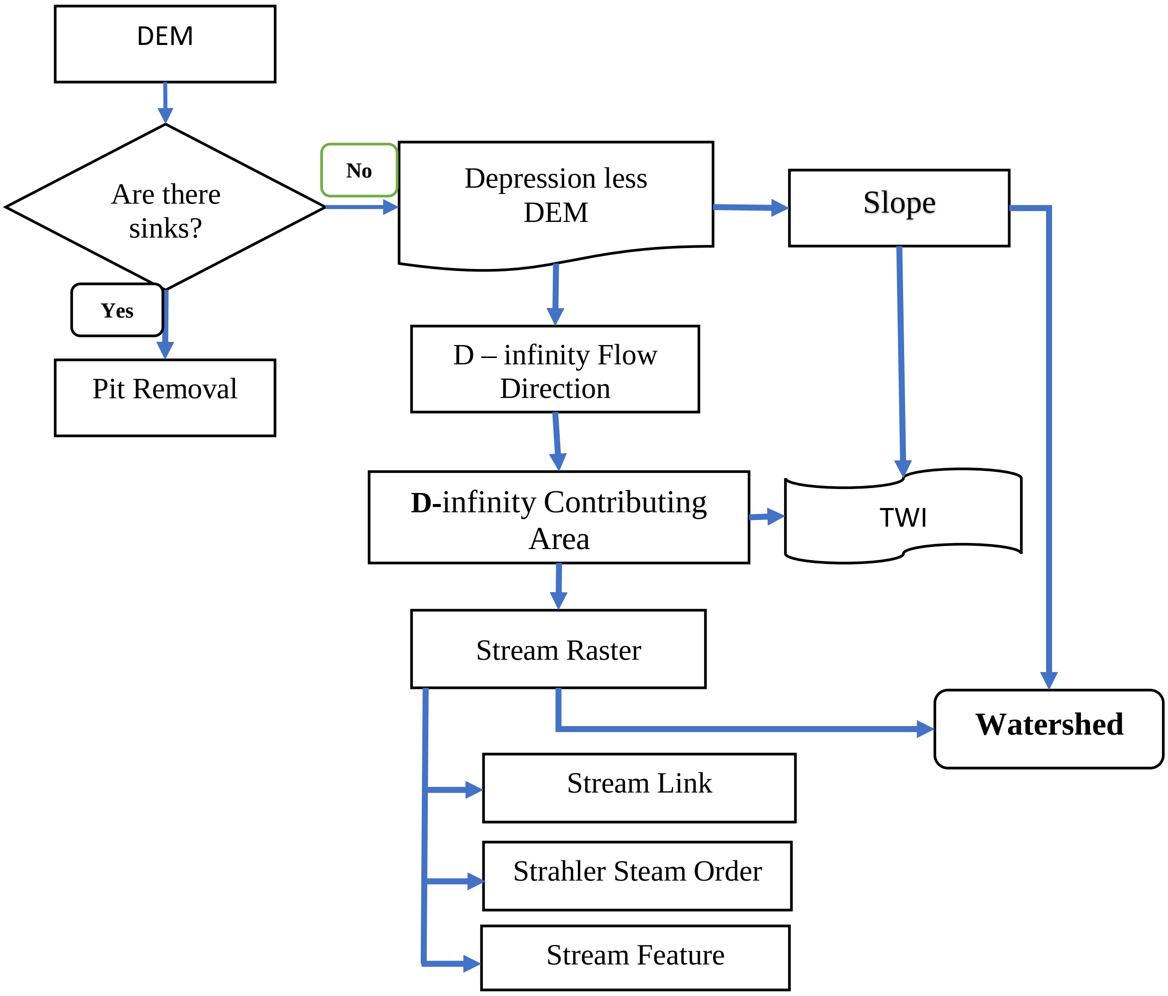


Figure 3. 8: Surface Hydrological Functions Flow Chart

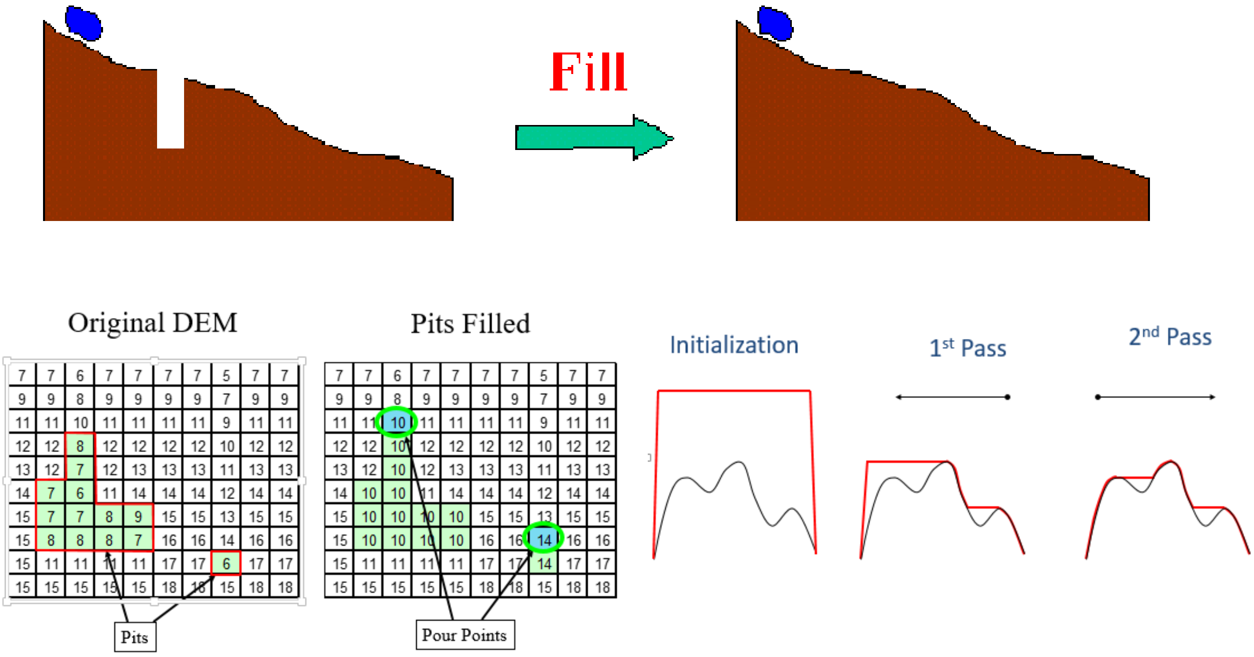
3.9. Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) is an ordered array of numbers that represents the spatial distribution of elevations or topography above some arbitrary datum in a landscape. It describes the “elevation” of the ground surface, exclusive of man-made structures, vegetation, or any other objects above ground (Croneborg et al., 2015). It may consist of elevations sampled at discrete points or the average elevation over a specified segment of the landscape, although in most cases it is the former (Moore et al., 1991). Thematic maps of both primary and secondary key Hydrological parameters attribute of DEM, slope(%), drainage, flow direction, flow accumulation, stream order, Topographic Wetness index (TWI) and the watershed boundary of the study area was derived from SRTM DEM 90 m. The drainage system was delineated using SRTM DEM data by using appropriate algorithms, as described by (Islam,2008), in TauDEM version 5.1 ArcGIS plugin and following a set of topographical functions. The process involved such as (i) Filling sinks, (ii)

Generation of flow direction, (iii) Generation of flow accumulation, (iv) Generation of stream network, (v) Derivation of Slope. Derivation of TWI and the automated approaches used delineate valley wetland were briefly discussed below.

3.9.1. Pit Removal/Fill DEM

DEM creation results in artificial pits/depressions in the DEM or landscape, as a result, before using the DEM, it is recommended that the data must be pre-processed. A pit is a set of one or more cells which has no downstream cells around it and unless these pits are removed they become sinks and isolate portions of the watershed (figure 3.9). Pit removal is the first thing done with a DEM and Pits in the DEM were filled by raising the values of cells in depressions to the value of the depression's spill point using TauDEM ArcGIS plugin tool (Jenson, 1991; Tarboton et al., 1991)



Original DEM

7	7	6	7	7	7	7	5	7	7
9	9	8	9	9	9	9	7	9	9
11	11	10	11	11	11	11	9	11	11
12	12	8	12	12	12	12	10	12	12
13	12	7	12	13	13	13	11	13	13
14	7	6	11	14	14	14	12	14	14
15	7	7	8	9	15	15	13	15	15
15	8	8	8	7	16	16	14	16	16
15	11	11	11	11	17	17	6	17	17
15	15	15	15	15	18	18	15	18	18

Pits Filled

7	7	6	7	7	7	7	5	7	7
9	9	8	9	9	9	9	7	9	9
11	11	10	11	11	11	11	9	11	11
12	12	10	12	12	12	12	10	12	12
13	12	10	12	13	13	13	11	13	13
14	10	10	11	14	14	14	12	14	14
15	10	10	10	10	15	15	13	15	15
15	10	10	10	10	16	16	14	16	16
15	11	11	11	11	17	17	14	17	17
15	15	15	15	15	18	18	15	18	18

Figure 3. 9: Pit Removal diagram adopted from Tarboton et al…and Planchon, O., and F. Darboux (2001), a fast, simple and versatile algorithm to fill the depressions of digital elevation models, *Catena* (46), 159-176.

Generally, the purpose of filling raw DEM data is, to improve the accuracy of the data by removing peak, pits (sinks) and flat areas to maintain continuity of flow to the catchment outlet. Sinks and peaks in a DEM are often errors due to the resolution of the data or rounding of elevations to the nearest integer value (Demisachew Yilma, 2018).

3.9.2. Derivation of D-infinity Flow Direction Algorithm

One of the sources to deriving hydrologic features of a surface is the ability to determine the direction of flow from every cell in the raster. The calculation of "a" in the In(a/tanβ) topographic wetness index requires an analysis of flow pathway to determine the total upslope area ***(A)*** entering a grid element, together with an effective contour length *(L)* orthogonal to the direction of flow, from which a = A/L (Quinn and Beven, 1991).

According to Yang et al., (2005), the calculation flow direction using the D-8 algorithm has disadvantages arising from the proximity of flow into only one of eight possible directions, separated by 45°. There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction (D8) flow model and follows an approach presented in Jenson and Domingue (1988). This produces very unrealistic results especially producing striped artifacts on very gentle and long lower slopes. In the single flow direction algorithm, it is normal to assume that the contour length is equal to the grid square length and that the slope angle is the greatest slope angle for any downslope direction (Quinn and Beven, 1991).

In this study a new method D-Infinity Flow Direction algorithm was used for the determination of flow directions and accumulation areas in Digital Elevation Models (DEM), using TauDEM hydrological ArcGIS plugin tools. The D-Infinity Flow Direction algorithm was proposed by Tarboton (1997) in a strength to compute contributing area more accurate on divergent hillslope area and it can allow all of the confusing situations that can occur in real topography (sometimes restoring to the D-8 Method) while much other Multiple Flow Direction (MFD) methods cannot (http://hydrology.usu.edu/taudem/taudem5/help/DInfinityFlowDirections.html). Map of d-infinity flow direction was showed in (figure.3.10).

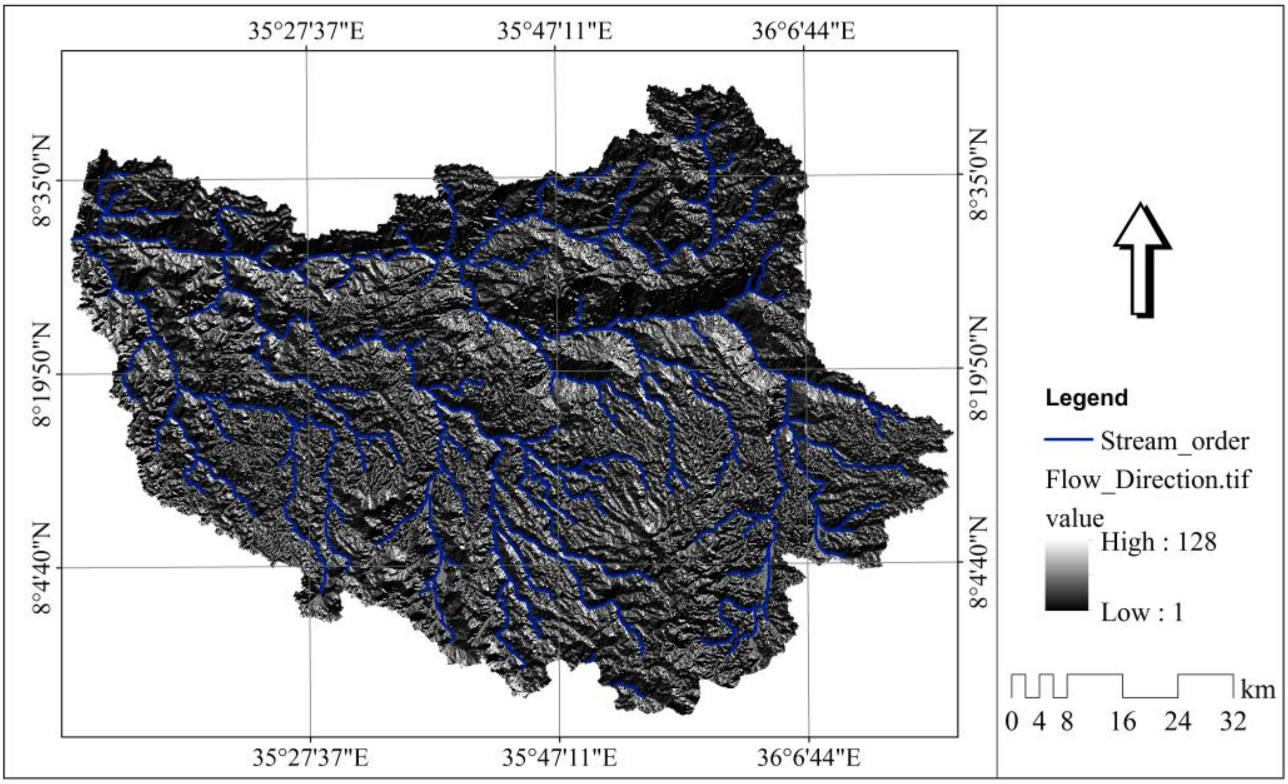


Figure 3. 10: Flow direction map

3.9.3. Derivation of D-infinity Contributing Area

Flow accumulation or D-infinity contributing area raster generated using the D-infinity algorithm (Tarboton, 1997). A grid of specific catchment area is the contributing area per unit contour length using the multiple flow direction D-infinity approach. The contributing area of each grid cell is then taken as its own contribution plus the contribution from upslope neighbors that have some fraction draining to it according to the D-infinity flow model. The calculation of the contributing area uses single and multiple flow direction methods. According to Tarboton, (1997) the new procedure overcomes the problems of loops and inconsistencies that plague plane-fitting methods and performs better than the D-8 algorithm. D-infinity contributing area was mapped based on D-infinity algorithm using TauDEM DEM analysis tools incorporates the DEM analysis tools (Yang et al., 2005). D-infinity flow accumulation map showed in (Figure 3.11).

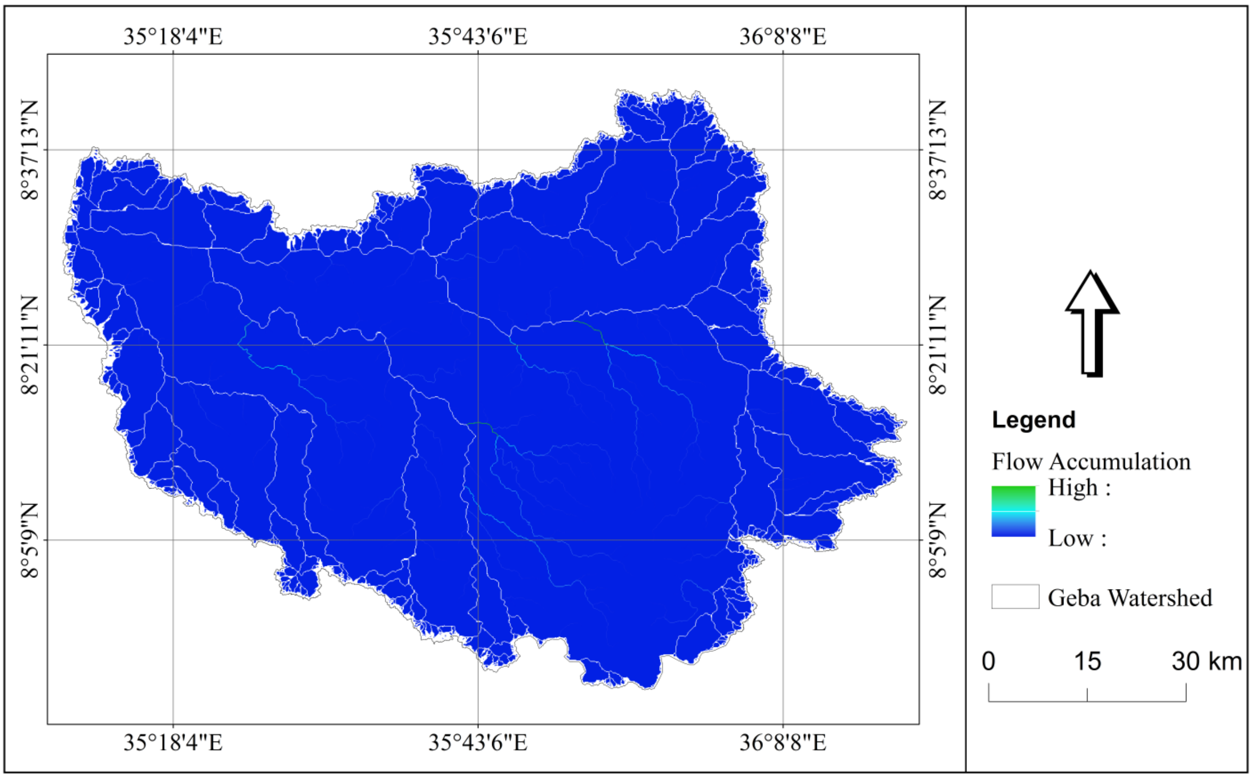


Figure 3. 11: D-Infinity Flow Accumulation map

3.9.4. Stream Network

Stream networks can be delineated from a Digital Elevation Model (DEM) using the output from the Flow Accumulation tool but in this study, D-infinity Contributing Area was used to delineate stream network. D-infinity Contributing Area is the simplest form is the number of upslope cells that flow into each cell. By applying a threshold value to the results of the Flow Accumulation tool using either the Con, a stream network was delineated (https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/identifying-stream-networks.htm).

3.9.5. Derivation of Slope

The slope can be defined as the rate of maximum change in the elevation (Z) for each Digital Elevation Model (DEM) cell values. Slope identifies the steepest downhill slope for a location on a surface. Wetland is extremely dependent on slopes. Wetlands form on flat areas or shallow slopes, where perennial water lies at or near the land surface, either above or below. Wetlands tend to form where surface and groundwater accumulate within topographic depressions (EPA, 2008). Based on topographic conditions are favorable and sufficient, long-term favorable sources of water exists. As a result, lowland wetland identified based on favorable presence of land surface depression in the watershed along hillsides where there is a change in slope. This is as a result of the slope of any area affect runoff of surface water. Finally, Semi-automated delineation of wetland using SRTM derived slope threshold values was investigated. Threshold values of less than three percent (5%) slope values used for wetland identification. Slope map derived from SRTM 90m DEM shown in (Figure 3.12).

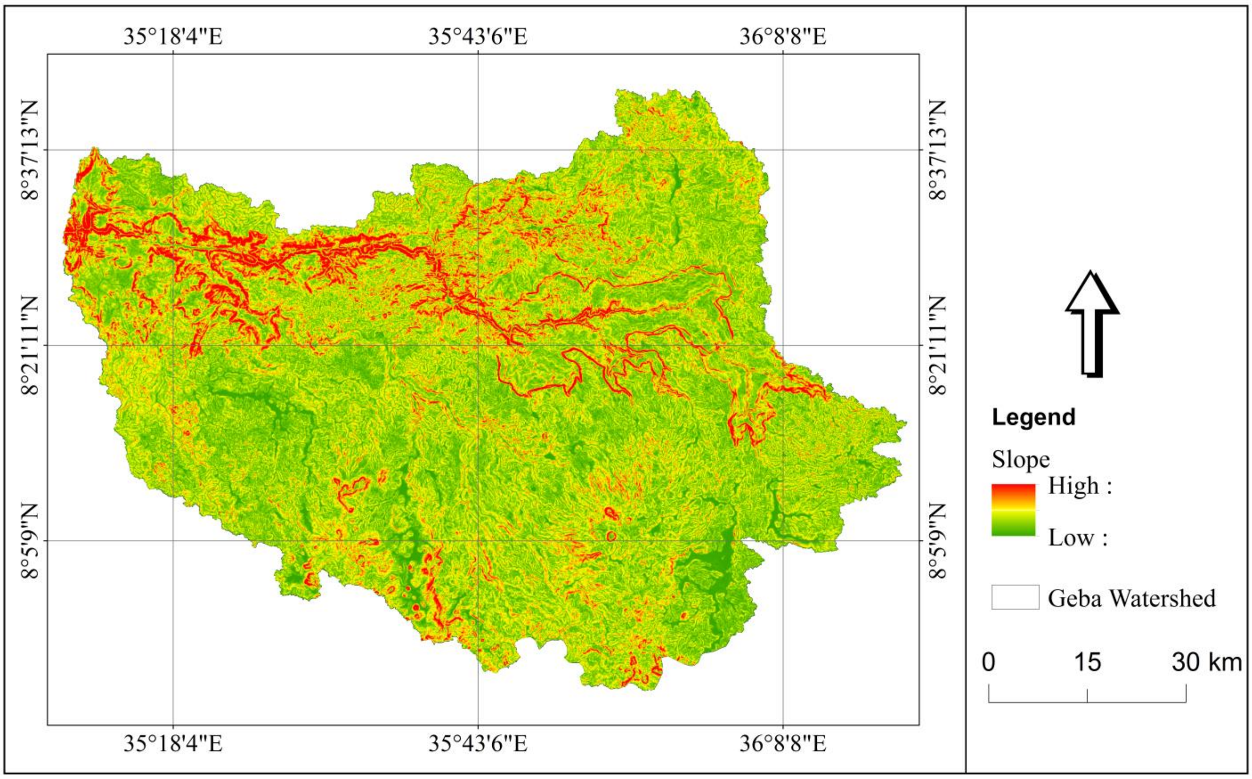


Figure 3. 12: Slope map

3.9.6. Derivation of TWI

Wetlands are easily confused with other upland land cover types such as forests, agriculture, and shrubland. As a result spectral signatures of wetland fusions with upland land cover types which are motioned in above (Ozesmi and Bauer, 2002). As a result, to improve the classification and mapping of wetland TWI were used to reduce the error of commission with upland land covers since the occurrence of wetlands strongly depends on the topographic conditions of a region. Compound Topographic Index (CTI) is a steady state wetness index (also named Topographic Wetness Direction Index) and it is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow (Yang et al., 2005). Compound Topographic Index was calculated from the D-Infinity algorithm was used in the TWI and Slope map which directly derived from DEM (Beven and Kirkby, 1979 and Gessler et al., 1995): The TWI was defined by Beven and Kirkby (1979) as (equation 3.5).

$$TWI = \ln\left(\frac{As}{tan\beta}\right)\text{-- (3.5)}$$

where, *As* is the specific catchment area expressed as m^2 per unit width orthogonal to the flow direction [(flow accumulation + 1) * (cell size)], and β is the slope angle expressed in radians.

3.9.7. Accuracy Assessment

One of the most very important steps in remote sensing image mapping and classification is an evaluation of mapping/ or classification accuracy assessment. It is used for understanding the classified results and employing the results for decision-making. The digital photographs Land use and the land cover type and GPS data were collected by field analysis and were used to verify the accuracy of the land cover classification. Classification accuracy assessment was conducted by collecting 250 in situ ground truth points (GTP), which were systematically distributed throughout the study areas in the accessible parts. Following equations were used to derive percentage accuracies, errors of omissions, and errors of commissions: (Equation 3.6;3.7;3.8) (Kulawardhana 2007).

$$\text{overall accuracy } (\%) = \left(\frac{\text{Total no.of GT points of class 'X' that falling on class 'X'}}{\text{Total no.of GT points of class X}}\right) * 100 \text{ ------Equ.(3.6)}$$

$$\text{Error of omission } (\%) = \left(\frac{\text{Total no.of GT points of class 'X'not falling on class 'X'}}{\text{Total no.of GT points of class X}}\right) * 100\text{----- Equ. (3.7)}$$

$$Error\ of\ commission = \left(\frac{\text{Total no.of GT points of other classes falling on class 'X'}}{\text{Total no.of GT points of class X}}\right) * 100\text{----- Equ. (3.8)}$$

3.10. Hydro-Chemistry of Wetland Sampling and Testing

3.10.1. Wetland water quality analysis

Hydrochemistry can be used to interpret the general occurrence of the various constituent's in natural waters, controlling factors and the relation of these constituents to water use (Abera Taye, 2007). Water quality is an important factor in managing wetlands. Water quality in wetlands is affected by the type of soil, vegetation, topography, water quantity, climate, groundwater and surface water chemistry, and hydrology (https://www.aswm.org/wetland-programs/water-quality-standards-for-wetlands).

The study area wetland water quality valuation in systematically selected three valley wetland were studied. Based on the systematic selection of wetlands transects walk was set up within wetlands and the characteristics of water quality in different topographic position has been assessed. Wetland water Samples from those selected wetlands were analyzed in the laboratory for properties like PH, Turbidity, color, absorbance, fluoride, potassium, manganese, nitrate, chlorine free, chlorine total.

Chapter IV

4. Results and Discussion

In this paper, different methods have been used for mapping wetlands. Remote sensing data from satellite images, Digital Elevation Models and field survey data were used in mapping and separating wetlands from other upland areas. Three different approaches have been used for mapping and monitoring of wetlands. Pixel-based supervised classification, index-based classification (NDVI & MNDWI), SRTM wetness index and image enhancement methods were done.

4.1. Supervised classification

Different classification maps produced for Geba Watershed using supervised classification method. Supervised classifications were performed for separating the valley wetlands from the other land cover types. Based on the results using supervised classification of Landsat Thematic mapper of 1985, 2000 and 2018 of Landsat Operational land Imagery it was possible to delineate the extent and boundaries of wetlands in the study area. As a the result the extent and boundaries of Geba watershed was mapped using maximum likelihood algorithm. Mapping of wetland based on supervised classification is shown in (figure:4.1, 4.2 and 4.3) for the study period of 1985,2000 and 2018.

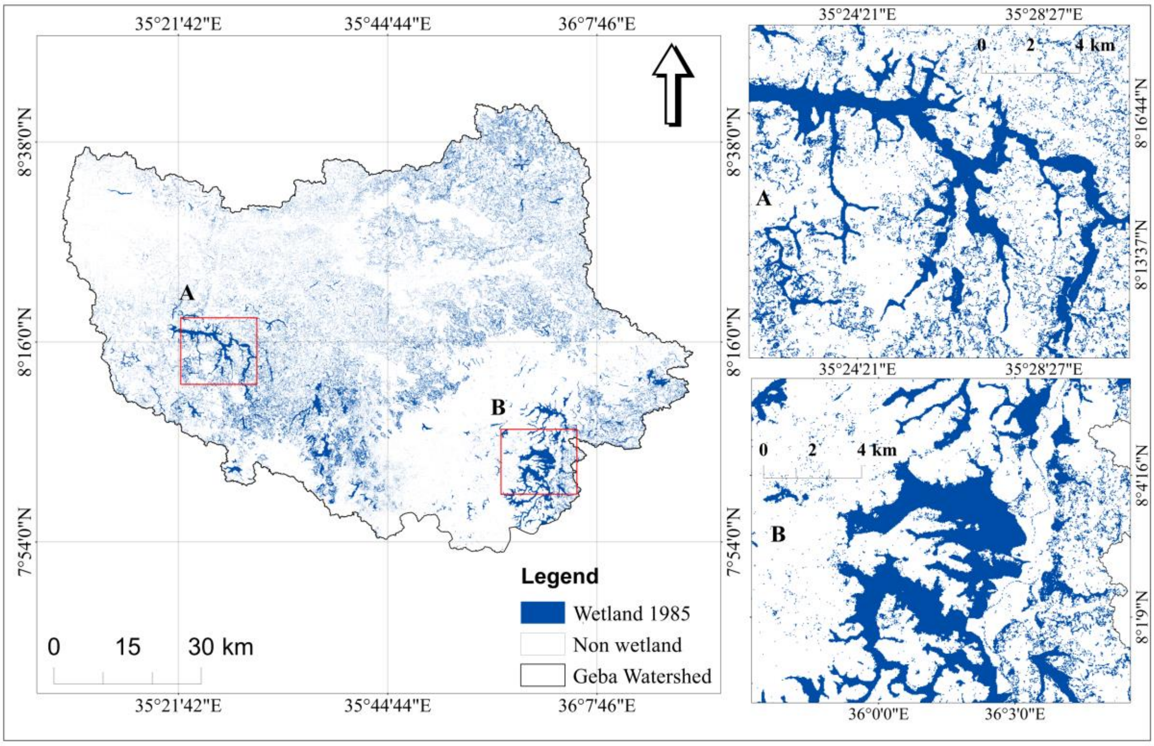


Figure 4. 1: Wetland Cover in 1985

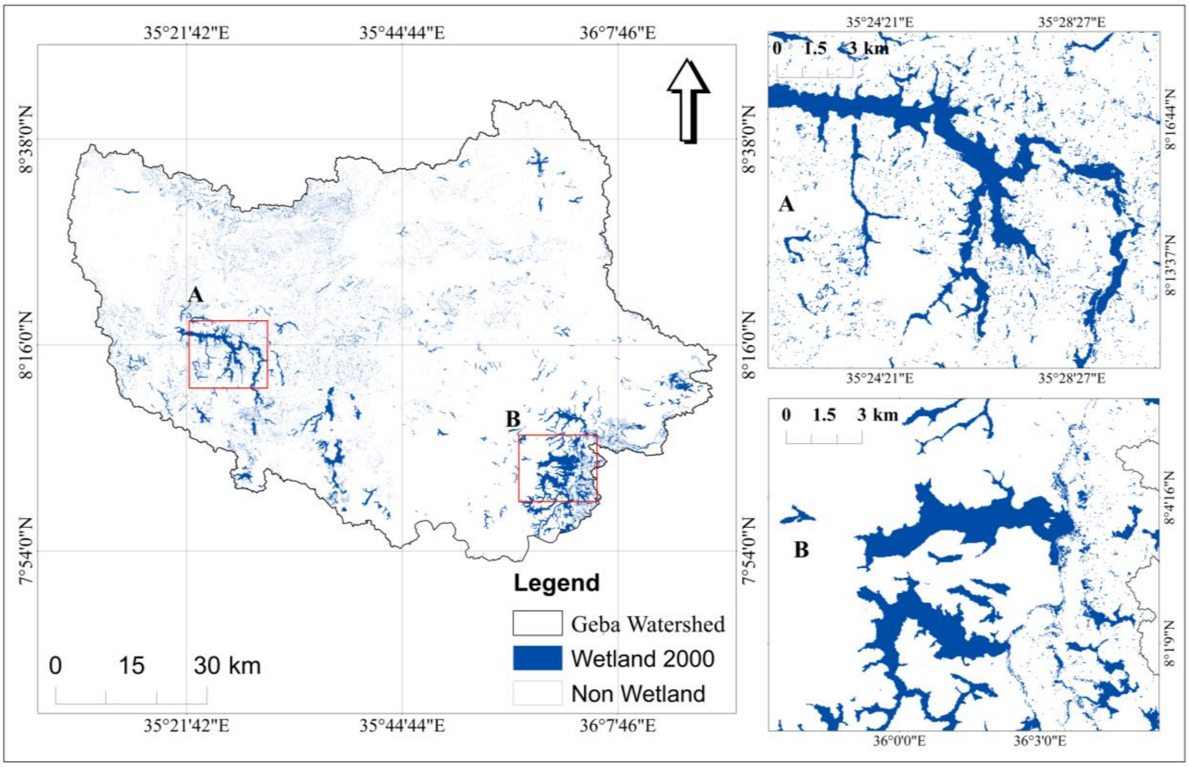


Figure 4. 2: Wetland Cover in 2000.

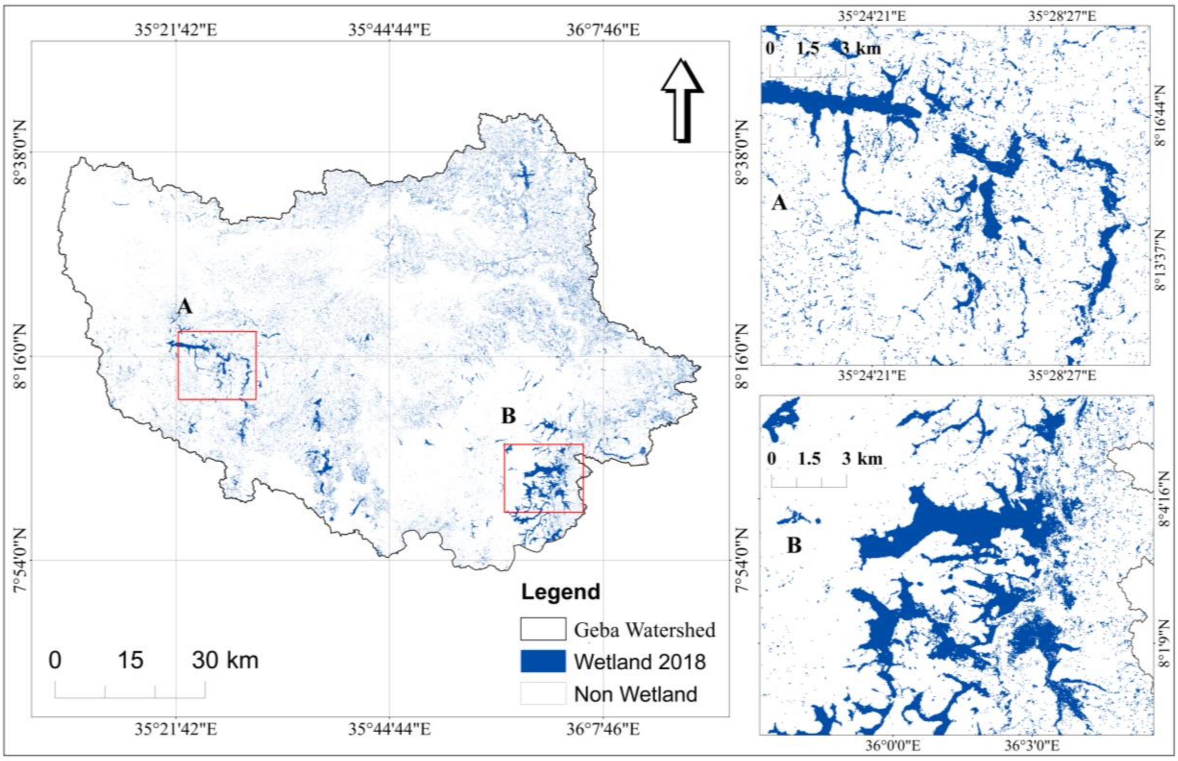


Figure 4. 3: Wetland Cover in 2018

The most commonly used multispectral satellite sensors for wetland mapping include Landsat MSS/TM/ETM+/OLI, AVHRR, SPOT and Sentinel-2, sensors can be found in (Ozesmi and Bauer (2002); Klemas (2011); Lang et al., (2015)). The use of multi-spectral satellite was essential for wetlands mapping. (Baker 2006). However, wetland remote sensing techniques reviewed by (Klemas, 2011) mentioned Medium-resolution sensors, such as Landsat TM, miss some of patchy wetlands and produce too many mixed pixels and increasing errors. In this study also wetland spectral mixing with other land cover areas was observed. The supervised classification methods, using maximum likelihood algorithm was the common classification algorithm in mapping wetlands by different scholars with satisfactory results. As example, using supervised classification maximum likelihood algorithm wetland maps of Sanjiang plain of Northeast China were classified with the overall accuracy of 86.57% (Niu and Zhang, 2013). In classification of Landsat image maximum likelihood algorithm were used and acceptable results were obtained in this study.

4.2. Index based Classification

4.2.1. Normalized Difference Vegetation and Water Index (NDVI and NDWI)

In the present study, the finest of these indices (NDVI and NDWI) provided only an accuracy of less than 19% with high levels of errors of omissions and commissions. The indices were also unsuccessful in delineating forested wetland areas and the wetlands of seasonal occurrence. With a number of iterations, threshold values of NDVI and NDWI were done to extract wetland from other land covers. It is insignificant to extract wetlands from agricultural and other land covers using NDVI and MNDWI. High resolution google earth imagery and filed data collected using GPS were used to assess the accuracy of NDVI and MNDWI. Therefore, the wetlands delineated using NDVI and MNDWI approaches showed very low accuracies. When the accuracies have increased the errors of omissions or commissions spread to unacceptable levels. As a result, the hypothesis to extract wetlands in the study area using Pixel based classification (NDVI and MNDWI) were failed and the major limitation was identified. Map of NDVI and MNDWI based on threshold values of -0.25<NDVI>0.10 and -0.15<MNDWI>0 were presented in (figure.4.4). (Tiner, 2015) explains mapping and separating wetlands from the other land cover has been difficult without using the inclusion of field measurements, Digital Elevation Models, due to the medium spatial resolution of the Landsat imageries. A high level of error of omissions and commissions were observed while validating the accuracy of the maps. In the past studies, NDVI and MNDWI is being widely used for mapping wetlands (Li et al, 1998; Hogg et al, 2006; Islam, 2008; Xu and Hutchinson, 2011; Ya Liu et al, 2015).

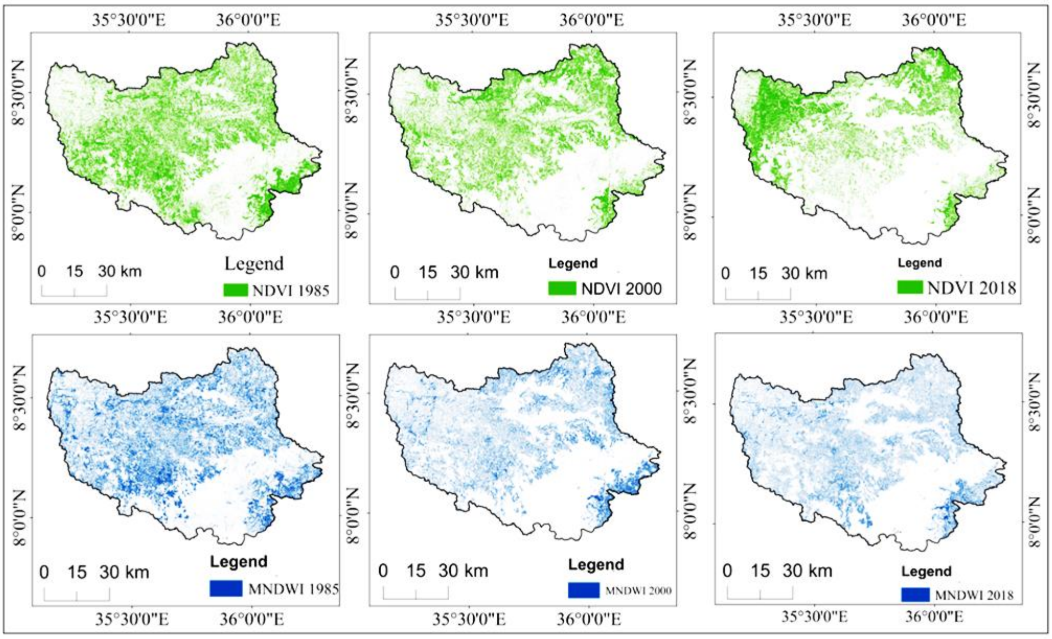


Figure 4. 4: Map of NDVI and MNDWI for the period of (1985,2000 and 2018).

A strong correlation between NDVI and MNDWI wetlands were observed in different studies (Islam, 2008; Kaplan and Avdan, 2017). Therefore, the method was mainly used to map wetlands, classify wetland types and also used as an indicator of wetlands in different studies. But, in the current study, the finest of these indices provided only accuracy of less than 19 percent. As an example, a study presents the capabilities of Sentinel-2 for mapping and monitoring of wetlands studied by (Kaplan and Avdan, 2017) in Sakarbasi wetland located Eskisehir, Turkey was successfully mapped wetland with NDWI threshold values of -0.15 successfully extracts pixels that contain wetland water. Wetland within West Songnen Plain, Northeast China as delineated by (Dong,2013) showed well discriminate wetlands from other land-covers and study performed well in detecting and mapping wetlands. However, in our attempts to delineated wetlands using similar threshold values of NDVI (<-0.25) insignificant accuracy of wetland mapping within the watershed. Findings of the study by Kulawardhana et al., (2007) showed the best of these NDVI indices provided only accuracy of less than 30 percent with high levels of errors of omissions and commissions. A primary cause for this is attributed to rugged topography with exception to few areas in different parts of the watershed. Some studies showed that topography significantly affects

VIs in rugged mountainous area (Verbyla et al., 2008; Veraverbeke et al., 2010; Wang et al., 2012). For example, Deng et al. (2007) observed that the NDVI and the Normalized Difference Infrared Index (NDII) showed a significant correlation (r^2) ($p = 0.001$) with topography variables such as slope and the cosine of the aspect. The elevation of watershed ranges from 780 to 2,661 meters with an altitudinal variation of 1,881 meters. Similarly, the area has the highest rainfall in Ethiopia, up to 2000 mm over a teen month rainy season (Dixon and wood, 2001) and the natural vegetation is tropical montane rainforest. As a result, the highest amount of rainfall in the study area (monomodal rainfall pattern) exerts seasonal control on vegetation greenness which my lead to similar spectral reflectance of wetlands with other land cover types.

According to Islam, 2008 NDVI and NDWI were used in mapping wetland within elevation of the Ruhuna basin that varies from sea level to 2350m. The rainfall in the basin is bi-modal with precipitation from the two seasons each year and the mean annual rainfall is 1574mm, while the monthly average ranges from 48 to 274mm. Furthermore, The Macquarie Marshes are in the low reaches of the Macquarie-Bogan River catchment of the Murray-Darling Basin in semi-arid Australia studied by (Xu and Hutchinson, 2011) with a mean annual rainfall of >700 mm, compared to <500 mm within the Marshes was used to map marsh wetland using NDVI and NDWI Successfully. However, as compared precipitation and landscape of those study to the present study area, Geba watershed experienced monomodal rainfall throughout the year as a result wetlands vegetation looks similar to uplands with similar vegetation cover. Even when, the lowland vegetation is characteristically different from uplands, the difference in spectral reflectivity may not be consistently significant over space. The watershed is generally referred to as the all year rainfall region because it receives rainfall throughout the year. Study area found in the wettest part of the country where the average annual rainfall exceeds 2000 millimeters. Generally, variation in precipitation amount and topography of the study area resulted in inaccurate wetland mapping using with NDVI and MNDWI in the study area.

4.3. Digital Elevation Model (DEM) Surface Hydro-processing extracting of Slope and TWI

4.3.1. Wetland Derived from Slope

Many depressions represented in the DEM are actual valley wetland areas with seasonal to permanent inundation. Topography, which strongly determines water movement patterns provides detailed topographic information. Slope was used as a complimentary data to extract the wetland area in this study. If the slope threshold values are too small, some wetlands will be labeled as other land cover types, whereas a value of slope threshold that is too large, some other land cover areas will be levelled as wetlands. As a result, the selection of the appropriate slope threshold is very helpful. Different threshold values were used for identification of wetlands within different studies based on topography, data type and nature of the landscape. For example, (Ozesmi 2002 and Zhang, 2017) threshold value of less than 5 degrees were considered as a wetland, (Islam 2008) the SRTM DEM slope of less than 1% also helped in delineate higher order wetlands, rapidly and accurately. Additionally, (Ji, 2015) used a threshold of less than 9 percent in urban wetland detection. Selection of proper slope threshold values in this study was done using different iteration method. Threshold values of higher accuracy were selected. Therefore, based on the accuracy assessment 5 percent slope threshold were used for the study area. The study result showed that terrain analysis using SRTM topographical data can produce potential maps for wetlands. The automated method of wetland delineation was investigated with a threshold of less than 5% percent. The slope values less than 5 percent were identify and delineate upland and valley wetlands in the study area (Figure 4.5). Moreover, the SRTM slope threshold of less than 5% was successfully delineated higher-order wetland boundaries which have greater than 3km^2. however, small types of wetland which is less than 3km^2 were misclassified with slope map. The wetlands were delineated using the semiautomated methods with an accuracy of 65% as determined using google earth data. Accuracy assessment of automated classification will be discussed in the next part.

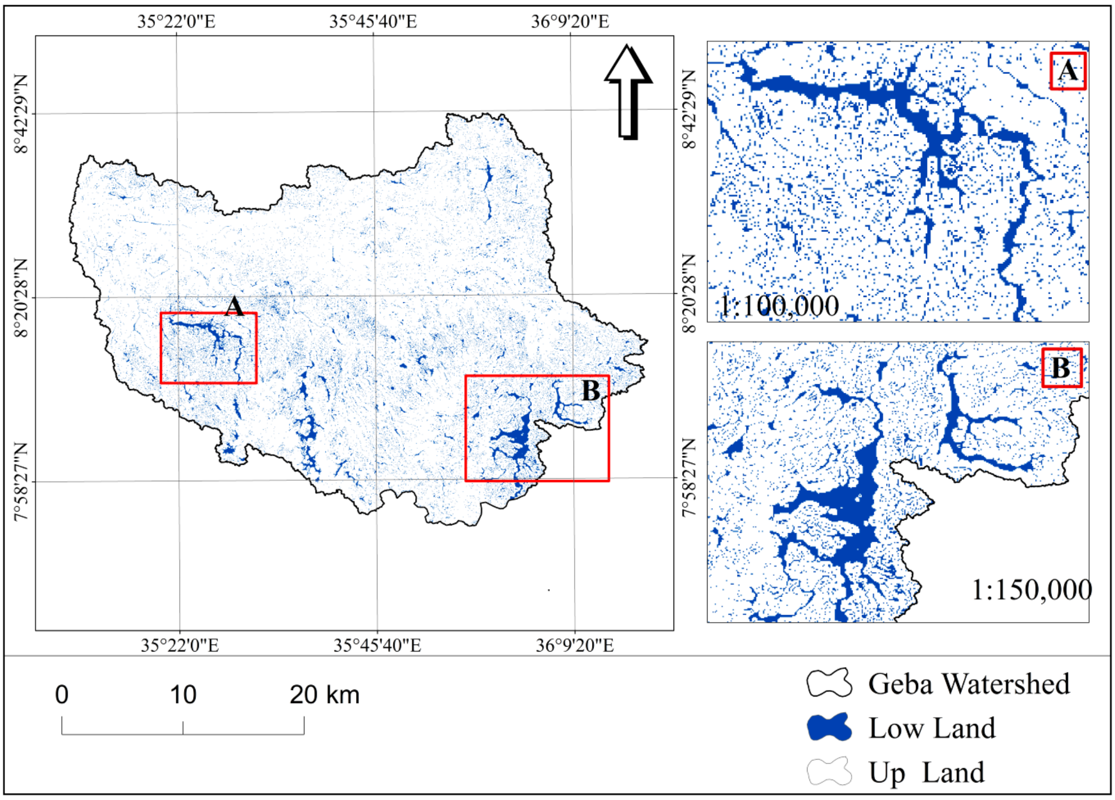


Figure 4. 5: Reclassified Slope map

4.3.2. Topographic Wetness Index (TWI)

Topographic wetness index was used as additional method in mapping of wetland in the study area. TWI was calculated for the whole watershed (Figure 4.6). The result showed that the TWI perform better than NDVI and NDWI for the detection of wetland in the study area. Larger wetland area was identified with better accuracy while smaller wetlands were invisible. TWI maps with its respective wetland threshold were considered as a detected wetland. Thus, the percentage of pixels that were well predicted was compared to the total of pixels of the potential wetlands mapped using supervised classification.

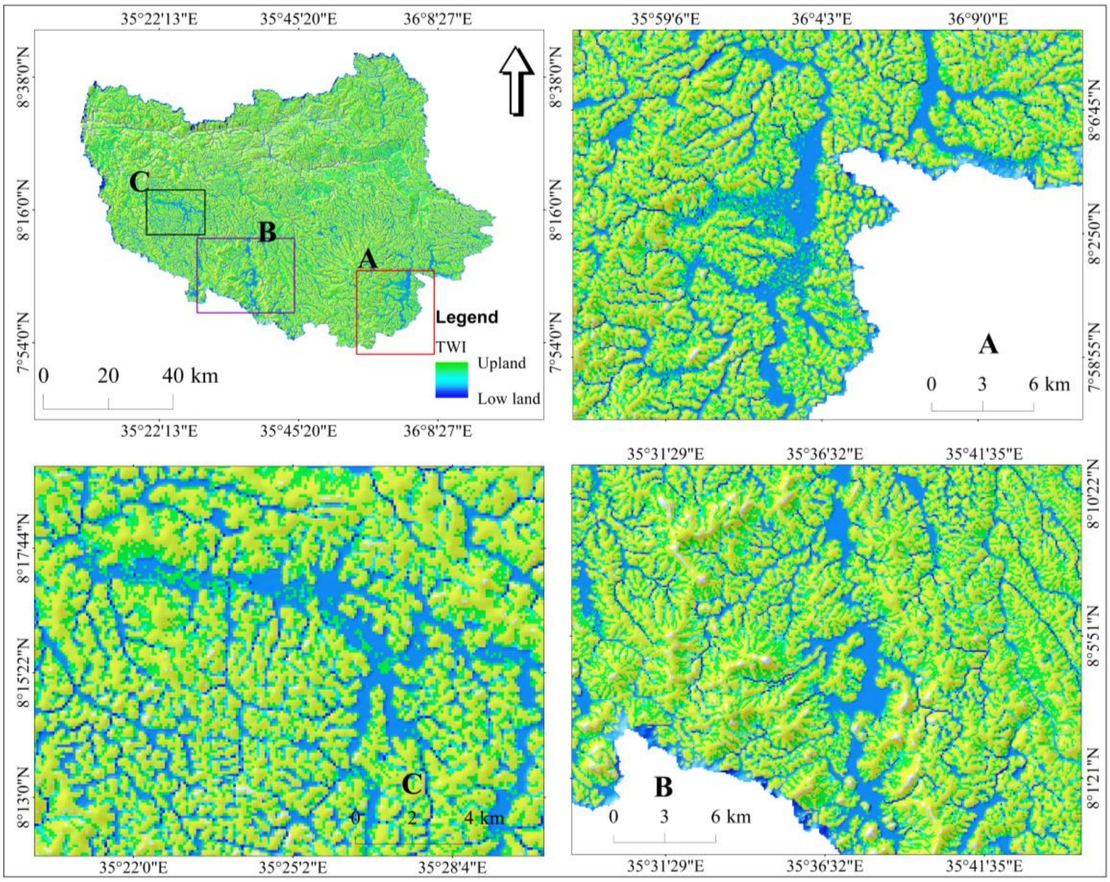


Figure 4. 6: Topographic Wetness Index map

Ethiopia Bisrat and Belete Berhanu (2018) stated Topographic Wetness Index (TWI) was used to represent the spatial distribution of water flow and water stagnating across the study area and the Normalized Difference Vegetation Index (NDVI) was used to detect surface water through multispectral analysis. According to (Wu, 2017) high-resolution LiDAR based DEMs have been used to derive TWI and facilitate forested wetland mapping. The enhanced FD8 TWI provided good prediction of wetland location but could not predict periodicity of inundation. Normalized relief provided good prediction of inundation periodicity but was less able to map wetland boundaries (Lang 2012).

4.4. Wetland Mapping

Finally, based on automated and pixel-based extraction and classification of wetlands were successfully done. The combination of Automated and pixel-based classification methods consisted of Slope and TWI separate wetlands from other upland land areas. Since wetlands will more likely to occur on the plane/level topographic surface, knowledge of topography is key in determining the existence of wetlands in a given area. TWI was overlaid with Wetland map in order to identify topographically wet areas. The main challenge for the detection of wetland within densely vegetated areas is to differentiate dry upland forests from forested wetlands in the study area. However, using TWI upland forests were eliminated and detection of the forested wetland was enhanced. But TWI not entirely eliminate upland areas from the forested wetland, as a result, digitization was done by enhancing wetlands using false color Infrared color combination. As an example using TWI and slope map derived from SRTM DEM detected seasonal forested wetland in the study area and validated using field activity. Photo captured during field survey are presented in (Figure 4.7). TWI, slope and classification maps were then combined according to the rule that pixels with a slope less than 5 percent, wet in classification map and pixel which fall under TWI threshold value were considered as wetland and the other pixels were coded to upland. The land cover classification map was used to generate the wetland boundaries. For example, pixels classified as forest in the classification map were re-coded to forest wetland if they overlapped with a wetland threshold with TWI and slope. Those pixels coinciding with upland were coded as non-wetland. The final wetland classification map was validated based on field data and Google earth data. Consequently, The design of decision rules is a critical part of the rule-based method. Since almost all wetlands occur on flat areas or isolated depressions surrounded by upland, classified wet areas from supervised classification, slope, and TWI were used to constrain the extent of wetlands. Combining the information from Landsat TM /OLI, TWI and Slope, successfully map wetlands in the study area.

Figure 4. 7: A photo captured during field survey which displayed seasonal forested wetland

Finally, Based on an index derived from SRTM DEM and classification of Landsat Imagery were integrating using knowledge-based decision rules within an ArcGIS software Wetland map of the study area were effectively mapped. Wetland maps for the study period of 1985, 2000 and 2018 were shown in (Fig.4.8, 4.9 and 4.10). The overall accuracy of Wetland mapping was validated using filed collected and Google earth data

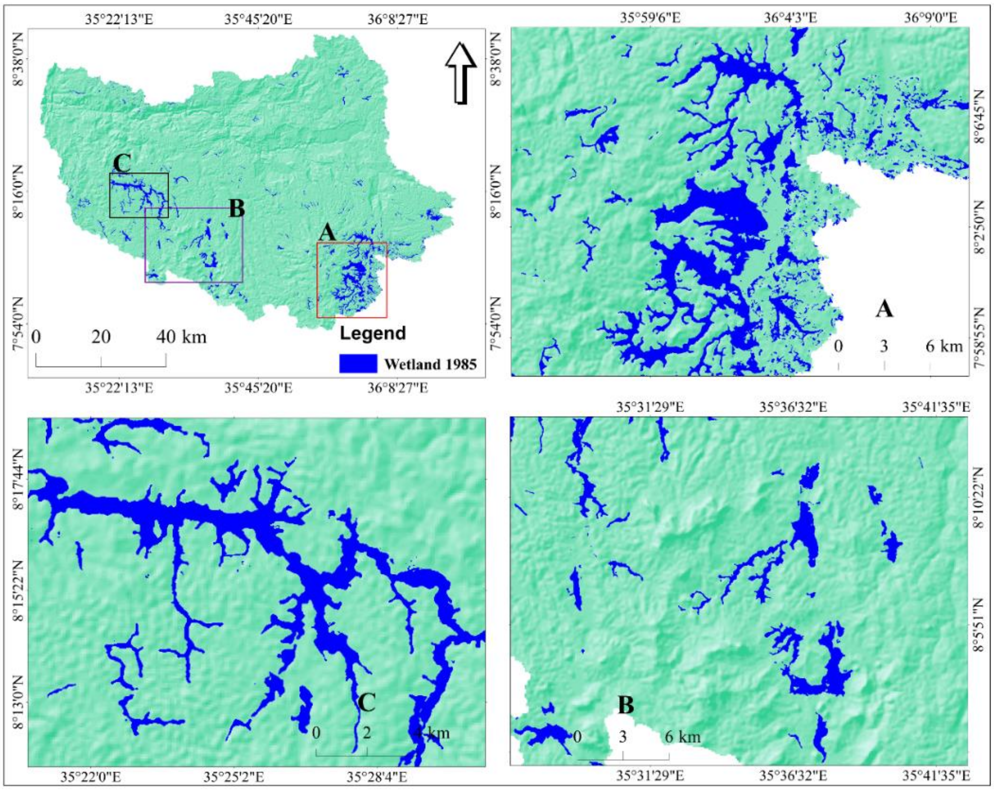


Figure 4.8: Wetland maps of Geba watershed during 1985

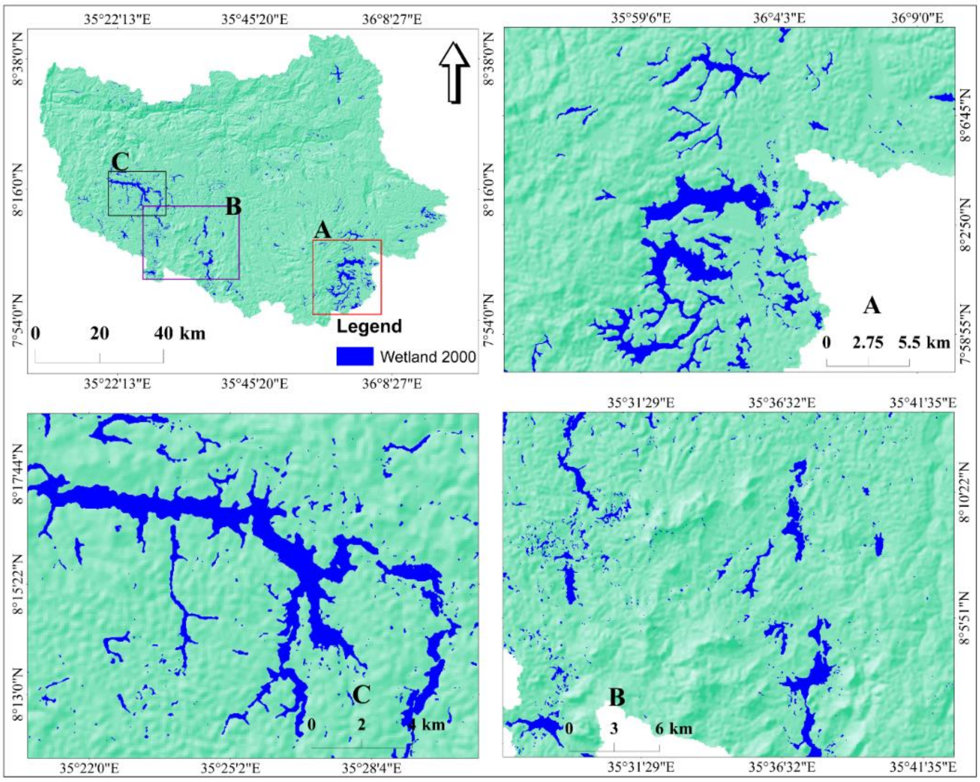


Figure 4. 9: wetland map of Geba watershed during 2000.

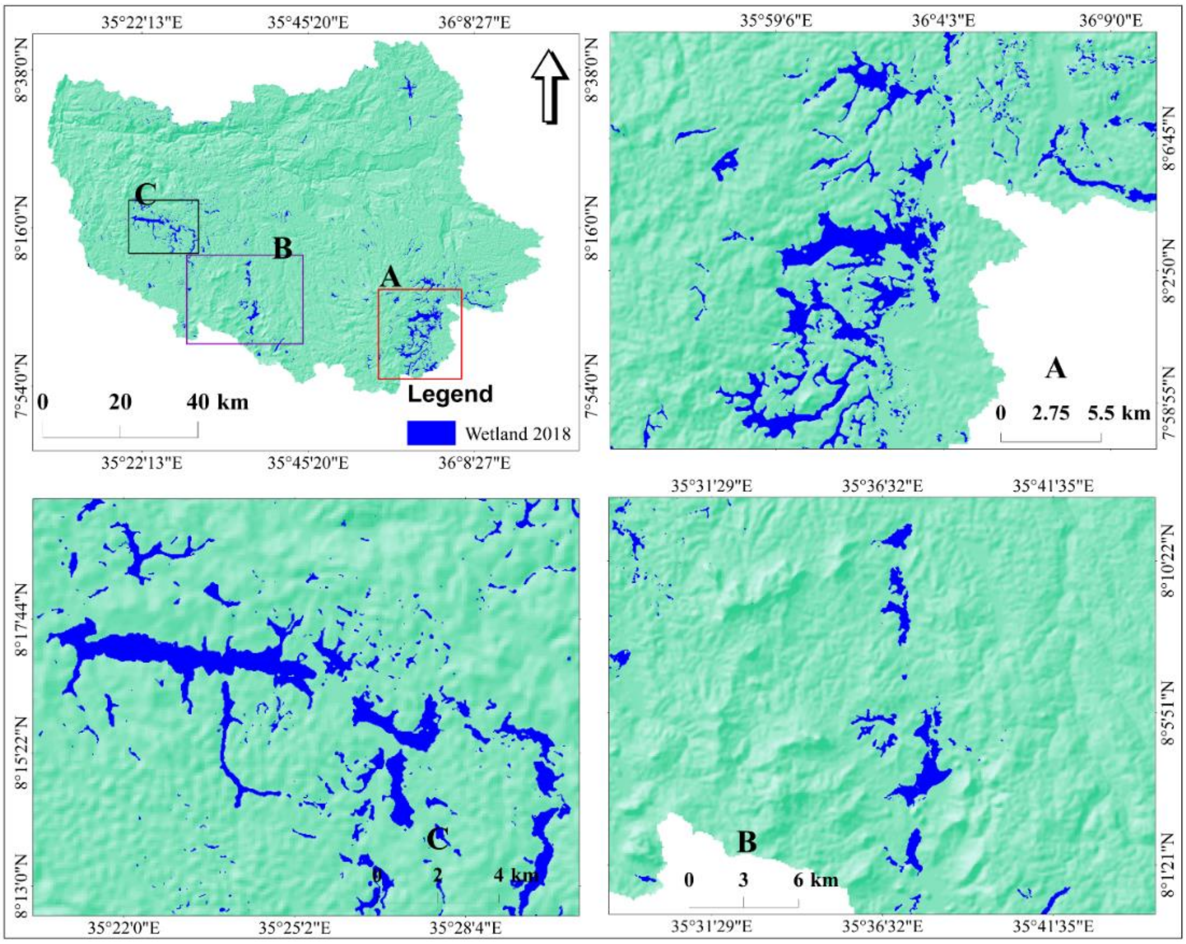


Figure 4. 10: Wetland Maps of Geba watershed of 2018.

Table 4. 1: Automated methods of delineating wetlands. Accuracy of Landsat indices and SRTM derived slope and TWI threshold for delineating wetlands.

Index for automatic delineation	threshold value	Accuracy (%)	Commission error (%)	Omission error (%)
NDVI - (-1 to + 1)	-0.25 – 0.1.0	19	21	81
NDWI- (-1 to + 1)	-0.15 – 0	17	23	83
SRTM-derived slope (%)	<=5%	65	53	35

The existence of valley bottom wetlands in Geba watershed is a result of the undulating topography combined with the high rainfall promotes the natural formation of wetlands through the accumulation of runoff and the high ground water table (Dixon,2002). The elevation of the study ranges between 1500-2600m amsl with a higher frequent variation of the landscape. Most of the valley wetland land covers vegetation known as locally as cheffe (Cyperus latifolious), grasses and forested wetlands were the dominant types of wetland vegetation types. A potential hotspot location of the wetland was identified and some of them are Enago, chebere, Tulube wetland, Hamuma and Wangegnye wetlands were some of wetland in the watershed. Most of the study area wetland called by the name of standing kebele names of the wetlands. Enago and Wangegnye wetlands were commonly dominated by grasses cyperus latiolious wetland vegetation type. Vegetation types of Enago and Wangenye wetlands were shown in (Figure.4.11).

Figure 4.11: Vegetation types of Enago and Hamuma wetland

4.5. Mapping and quantification of wetland degradation

Wetland degradation is becoming a severe problem in southwest Ethiopia because of the pressure on wetlands from different sectors of society. Wetlands within the study area has been experiencing huge losses over the last 33 years. Detailed wetland losses have been consecutively captured between 1985, 2000 and 2018 as presented in (Figure.4.12). Spatial change in surface area and shape over a long period of time were considered as wetland degradation. Areas of all wetland classes in the study area for the year 1985, 2000 and 2018 were quantitatively analyzed. Wetland disturbance through cultivation and vegetation clearance alters wetlands functionality leading to their degradation.

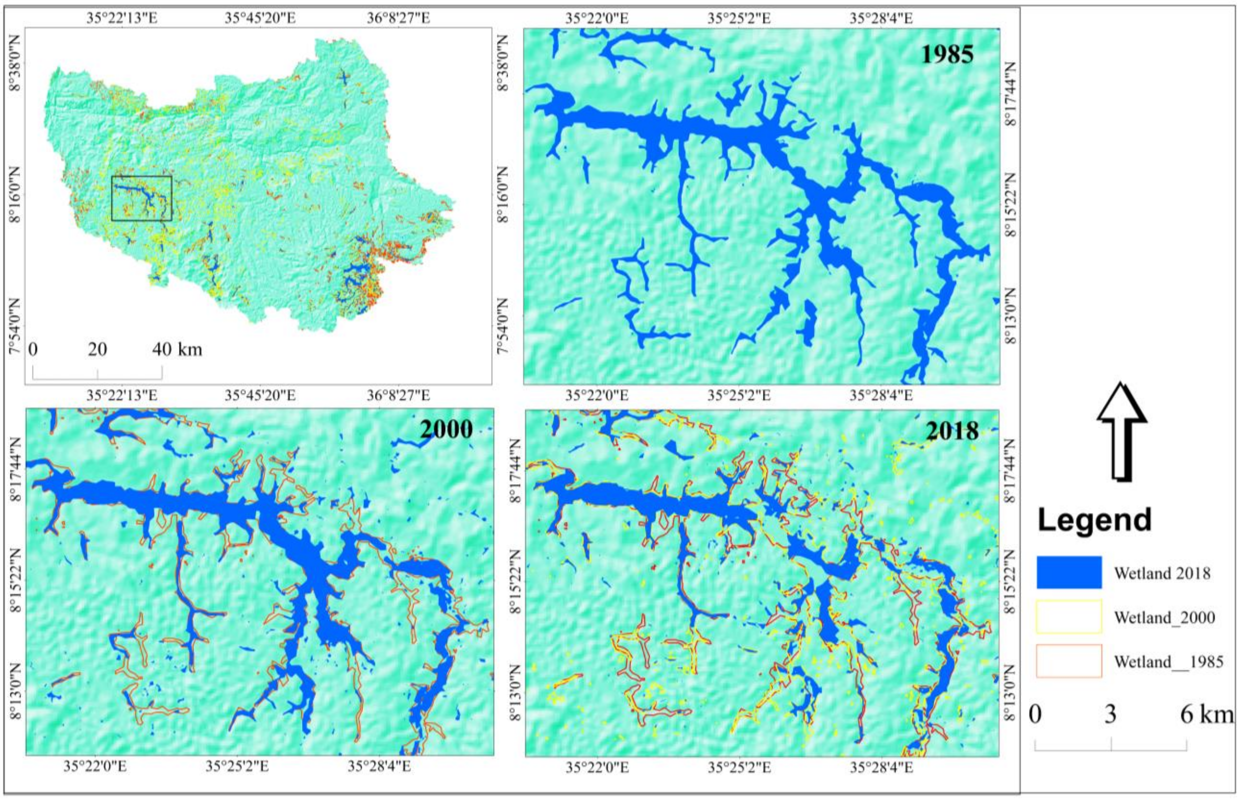


Figure 4. 12: Wetland degradation map of 1985, 2000 and 2018.

The total wetland area in the watershed accounted 214km^2, 160km^2 and 127km^2 for the period of 1985, 2000 and 2018, respectively. The detailed degradation map of wetland classes within the study area is presented in (Figure 4.13; 4.14) show the degradation and loss of wetland.

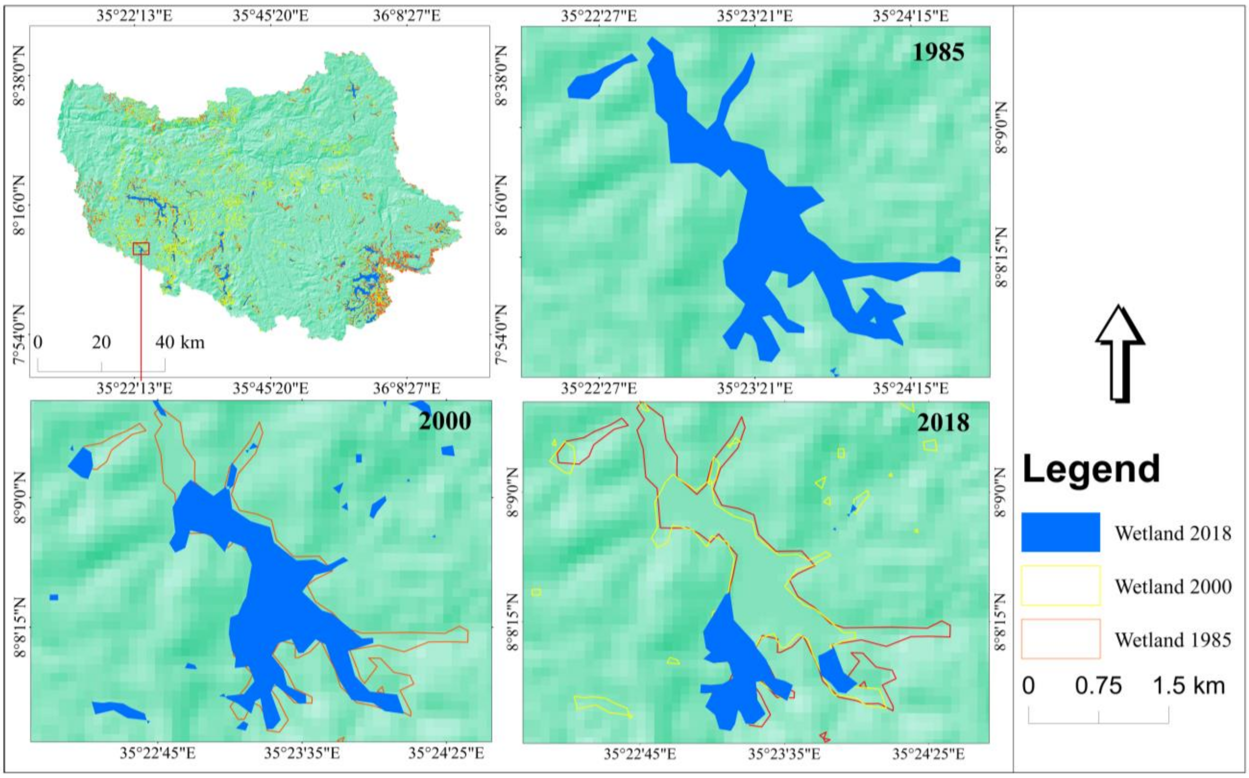


Figure 4. 13: Wetland degradation map

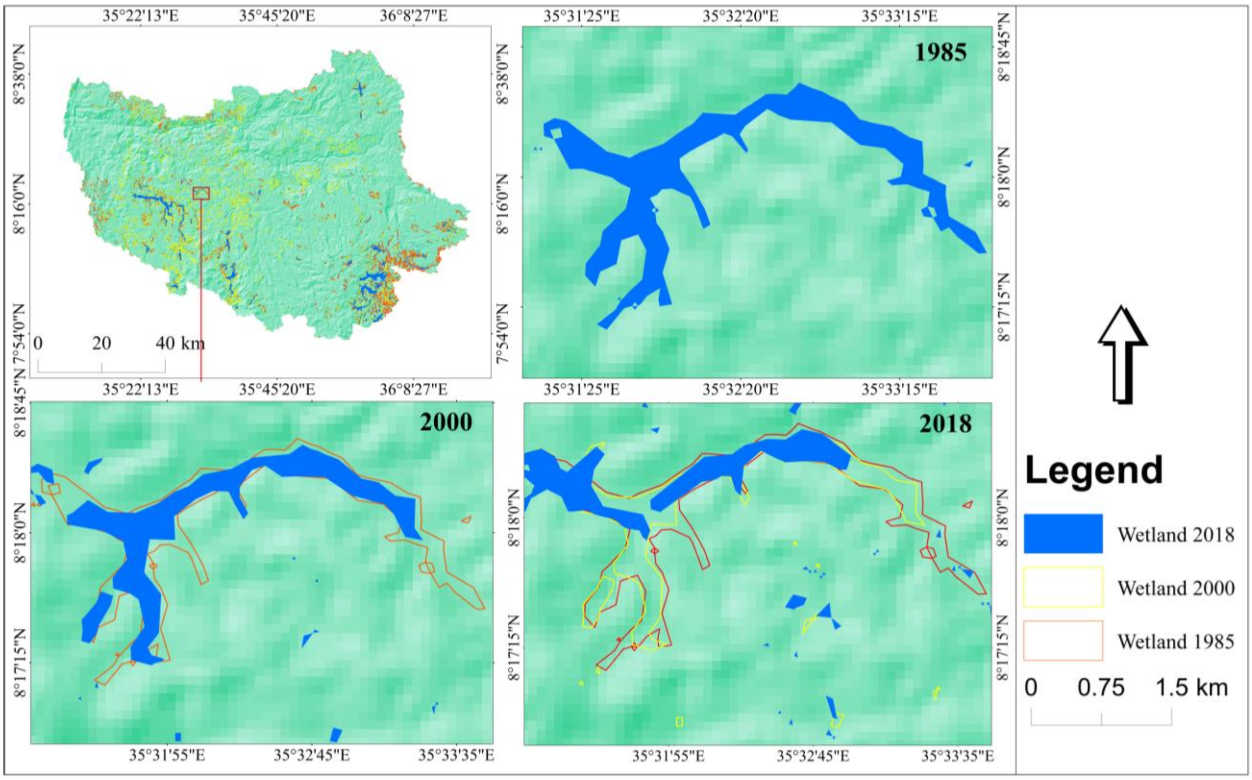


Figure 4. 14: Wetland degradation map

Wetland degradation mapping from multi-temporal image analysis revealed a significant loss of wetlands area during 1985–2018 in the area. (Figure 4.15) shows that 214 km^2 of the area was covered by wetland in the year 1985. This coverage was reduced to 160km^2 by the year 2000. The total wetland cover degraded during 2000 and 2018 amounts to 33km^2. The wetland area was reduced by 59.34% between the years 1985 and 2018. From the amount of 214km^2 in 1985, about 87km^2 was degraded by the year 2018.

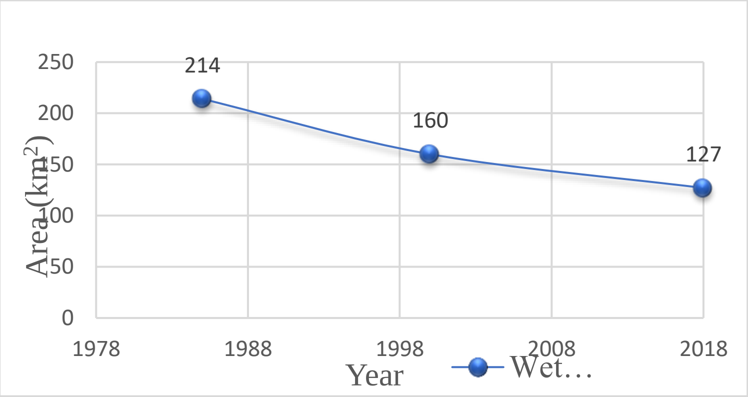


Figure 4. 15: Wetland Degradation for the period of 1985,2000 and 2018

The accuracy assessment for all of the used methods has been made by comparing the results with high-resolution images from Google Earth and field collected data. Systematically, 150 hundred random points was used. The ground sample points (Figure 4:16,4:17:4:18 and Table 4) was overlaid on wetland maps to determine the classification accuracies and errors of each class. The overall accuracy of the 3 aggregated wetland (1985, 2000 and 2018) in the study area was 86.66 percent with reasonable errors of omissions (7.54 percent) and low errors of commissions (13.33 percent).

Table 4. 2: Accuracy Assessments Results

Class	GTP	Error		Overall Accuracy (%)
		Commission (%)	Omission (%)	
Wetland 1985	100	16	11.3	84
Wetland 2000	100	12.66	6.66	87.33
Wetland 2018	100	11.33	4.66	88.66
Aggregated	300	13.33	7.54	86.66

Note:

1. Accuracy = Percentage of wetland area falling inside wetland boundary;
2. Commission = Percentage of wetland area falling outside wetland boundary;
3. Omission = Percentage of wetland area not mapped as wetland by specific threshold;

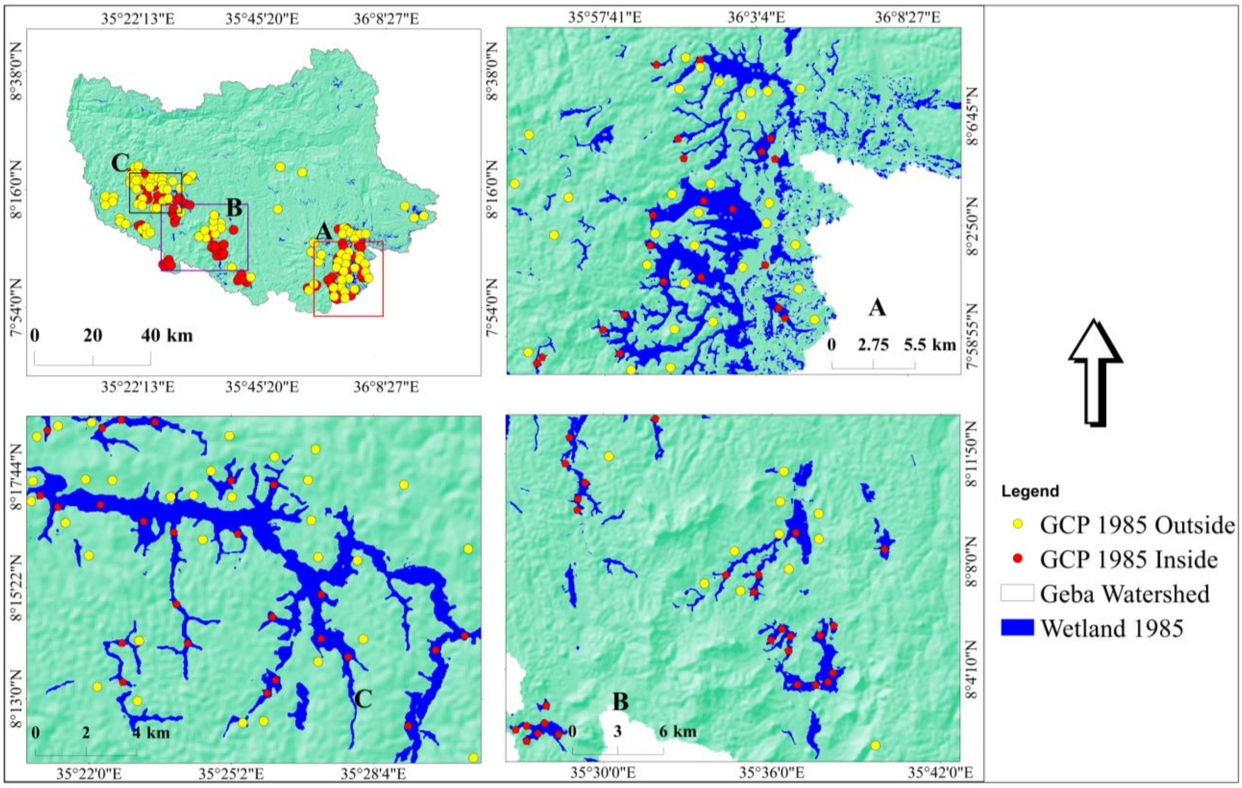


Figure 4. 16: wetland Ground Truth point projected from Google Earth Pro (1985)

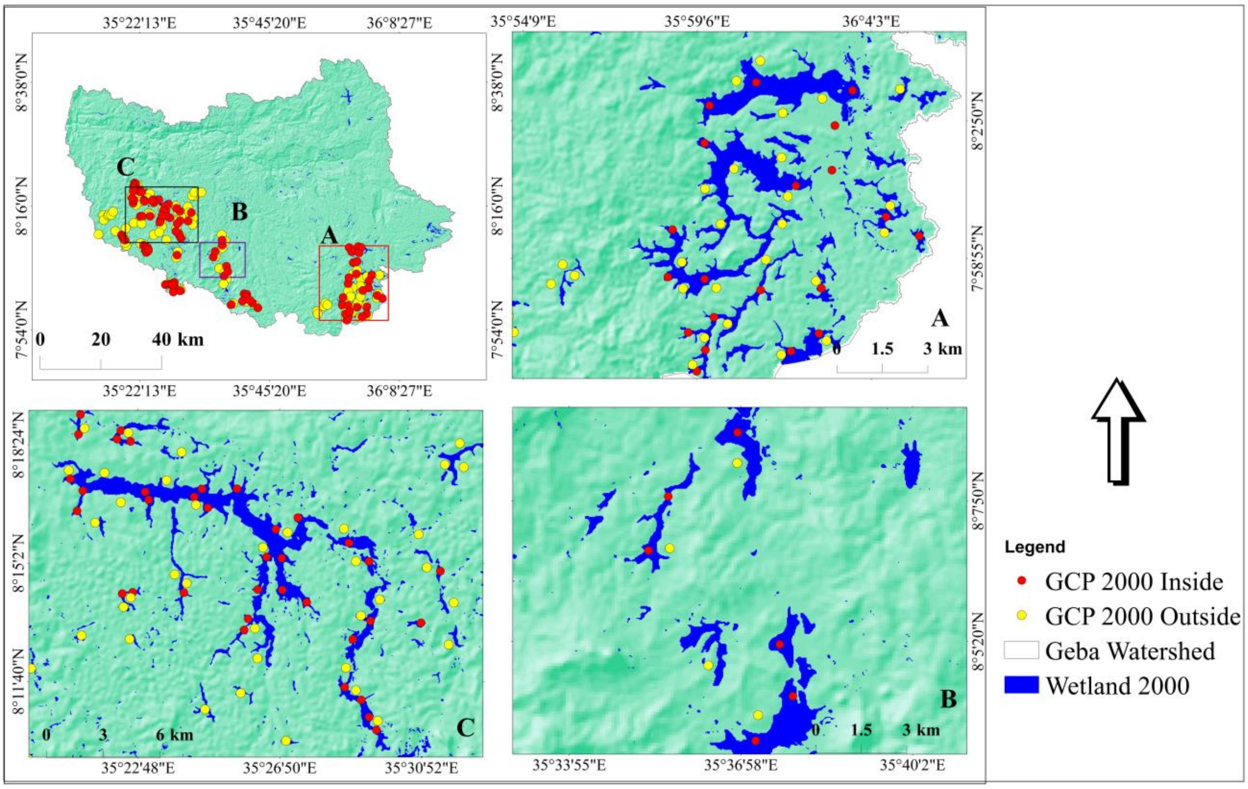


Figure 4. 17: wetland Ground Truth point projected from Google Earth Pro (2000)

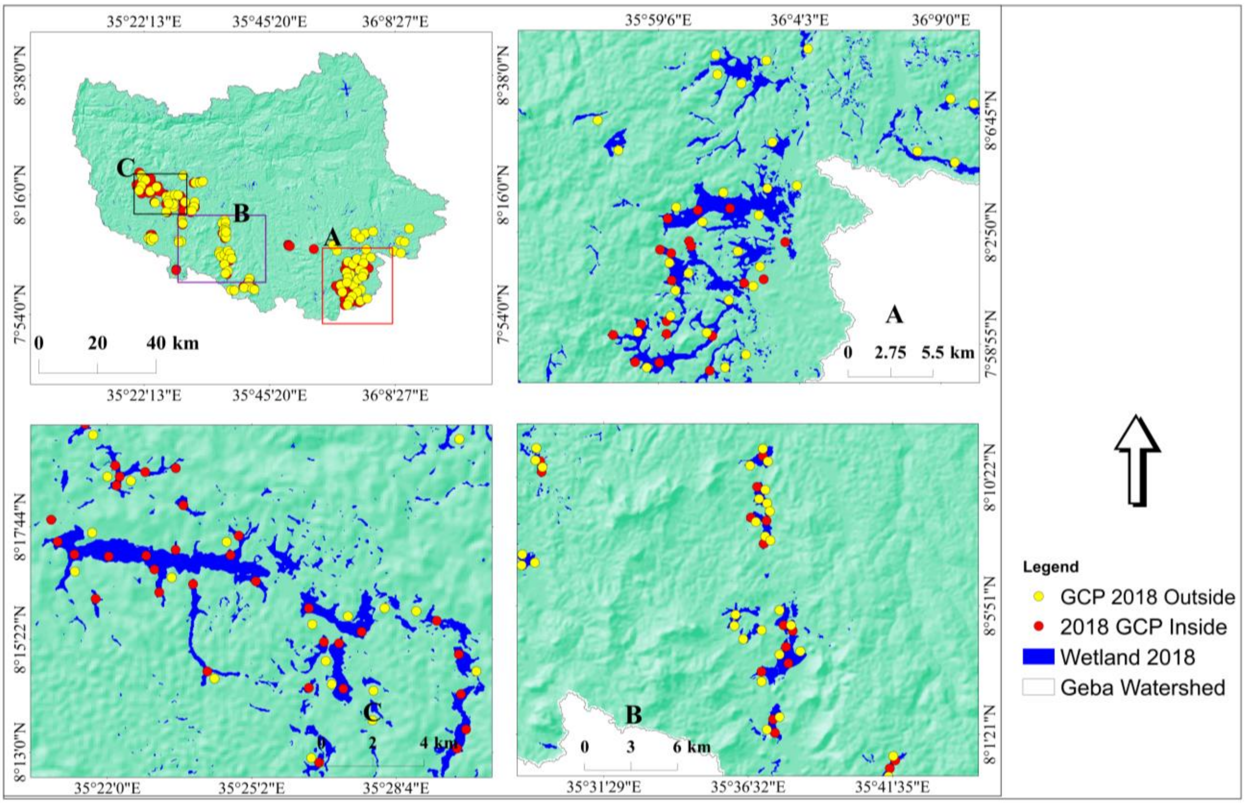


Figure 4. 18: Ground Truth point of wetland partially projected from Google Earth Pro (2018)

4.6. Impact of wetland degradation in hydrology

Major river and lake systems, together with their associated wetlands, are fundamental parts of life interwoven into the structure and welfare of societies and natural ecosystems (Leykun Abunie, 2003). Indirectly wetland ecosystem provides hydrological function in regulating the water balance in the watershed. Major rivers within the watershed which are Birbir, Geba, Dabena, Sor and Keber rivers are tributary rivers of Baro riverine basin. Most of these rivers are punctuated by numerous valley bottom wetlands that occur in both their upper and lower courses. the main sources of all rivers in the watershed start from wetland ecosystem see (Figure 4.19).

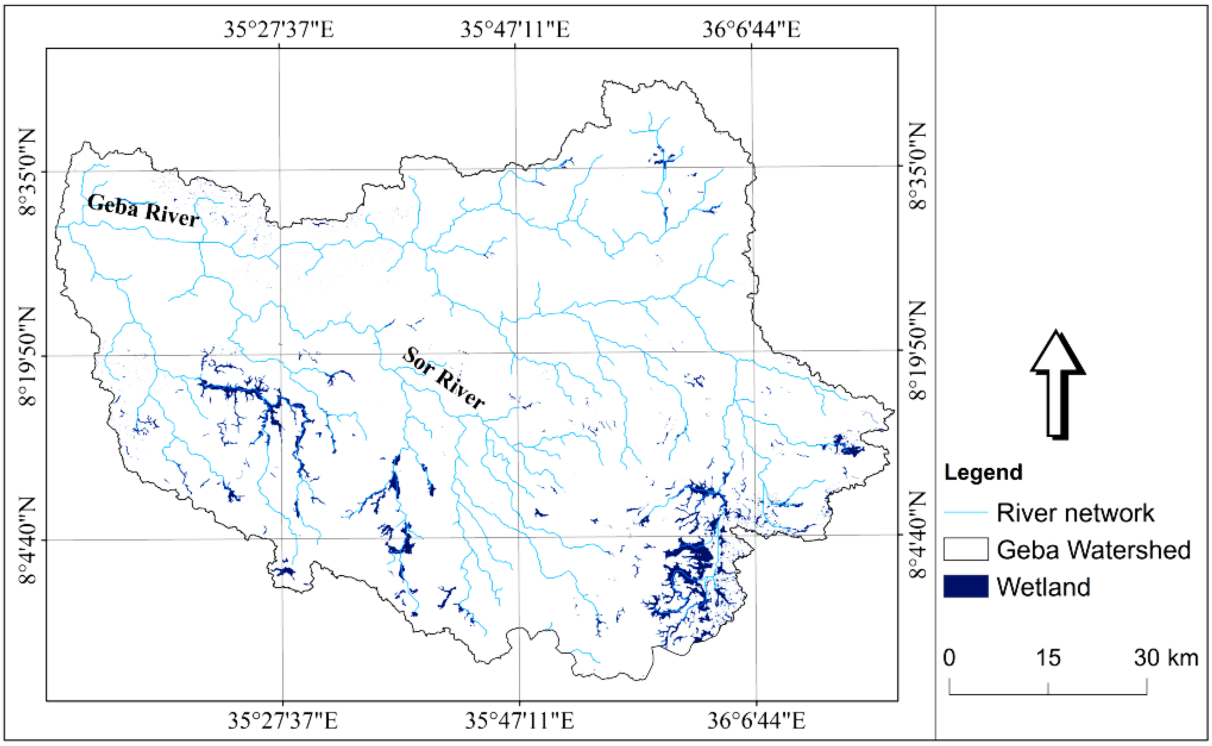


Figure 4. 19: Wetland interaction with stream network

The existence of rivers within the watershed as well as the surrounding area is determined by hydrological function of wetlands. As the wetland within a watershed degrades it will have a significant and direct impact on hydrology of the watershed. Generally, the survival of rivers with in the study area depends mainly on the existence of wetland. Dixon, (2002) had monitored water table wetlands of Illubabor. Monitoring was conducted on ten to twelve deep wells within each wetland on weekly base. The hydrologic analysis of the well data showed that lowering of the wetland water table observed in the degraded and cultivated wetlands and also reduces the rate of water movement through the wetlands. Analysis of degraded or cultivated wetlands verses undrained wetland observed temporal variability and change in height in weekly wetland water table (Figure.4.20 and 4.21). Dixon, (2002), indicated environmental degradation on wetlands unable to provide their full range of function and that has implication for food security in the study area and the availability of water to local communities, both around wetlands themselves and downstream.

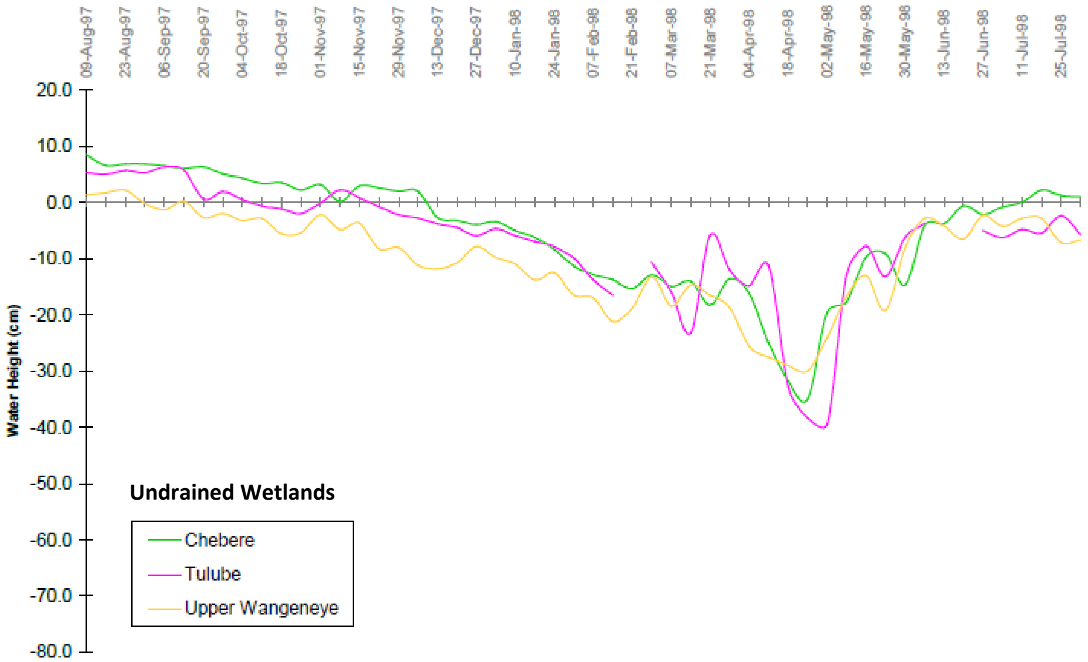


Figure 4.20: Mean weekly water table elevation in the undrained wetlands (August 1997-July 1998) adopted from (wood and Dixon, 2002).

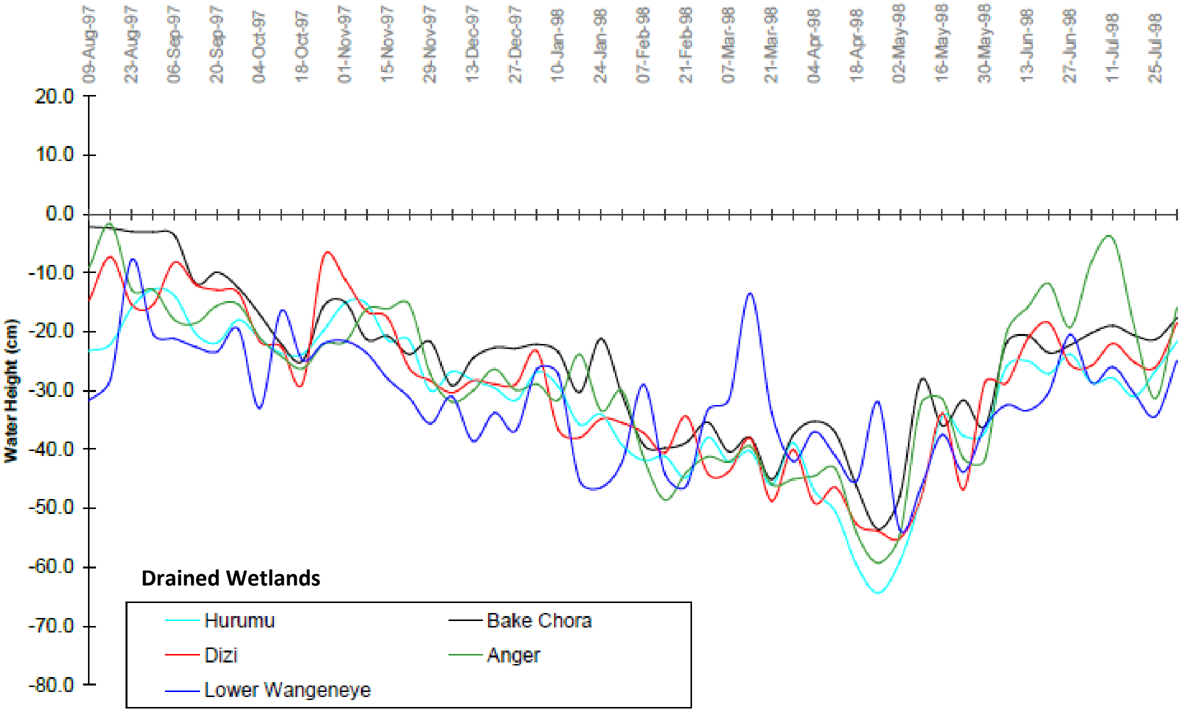


Figure 4.21: Mean weekly water table elevation in the drained and degraded wetlands (August 1997-July 1998) adopted from (wood and Dixon, 2002).

There is a significant difference between wetland water levels of cultivated/degraded wetlands and undrained wetlands. Hence over cultivation and draining of wetlands within the watershed have a direct impact on water level of the wetland. Additionally, alterations of the hydrological regime of wetlands have significant physical, chemical and biological effects that can have significant ecological and socio-economic implications at wider scale (Bahilu Bezabih and Tadesse Mosissa, 2017). The complete drainage of wetlands in Illubabor Zones, south west Ethiopia has led to a number of ecological and economic problems. Some of these are immediate and clearly linked to drainage, such as the scarcity of thatching reeds, vegetation change, lowered water tables, reduced accessibility and provides unsafe water (Wood and dixon 1996).

4.7. Driving-Forces Analysis

Human-induced and climate variability speed up the degradation of wetland significantly. This study investigated the major driving causes of wetland degradation by comparing climate variability (decreased in precipitation, temperature increment, moisture content, and wind speed) and human-induced factors (population increment, urbanization, large scale farming and conversion of wetland with other land covers) were analyzed statistical correlation between human-induced factors and natural driving force.

Wetlands within the study area had experienced huge losses to mixed farming over the last 33 years. This is due to the fact that much of the State Government’s and the Federal Government of Ethiopian policies in the past 2 decades that focused on agricultural expansion as an economic strategy to sustain food security in the country. Based on an informal interview with the local people wetland farming was the dominant activity for a long period of time within the study area. In the study area,, wetland farming practiced which called “Bone framing” which means farming of crops during the winter season (December, January, and February) which cause the main driving forces wetlands degradation. Wetland in the study area was considered as wetlands by the farmers if there are no cultivation activities on it. In another side, population increment and urban expansion play a very significant role in the degradation of wetlands. The statistical analyses of wetland driving forces were discussed as follows by categorizing human-induced and natural factor as the cause of wetland degradation.

4.7.1. Human-induced factor

4.7.1.1. Wetlands Versus Other LULC

As the classification of Landsat 8 of 2018 which have 30m spatial resolution images showed that in the study period of 2018 Forests and Agricultural land were the dominant land use land cover types. Forest and Agricultural LU/LC types together accounted for 6167 km^2 (87.07%) of the total area of the study area in 2018 (table 4.3). Land-use/land-cover maps quantified land cover area was shown in (Figure 4.22). wetland landcover was cover only 127km^2 in 2018.

Table 4. 3: Land-use and land-cover areas for the years of 2018

	2018	
	km^2	%
Urban	24.1367	0.340744
Tea plant	20.8846	0.294833
Wetland	127.000	2.397789
Forest	3647.34	51.49046
Shrub land	700.836	9.893887
Agricultural land	2520.48	35.58228

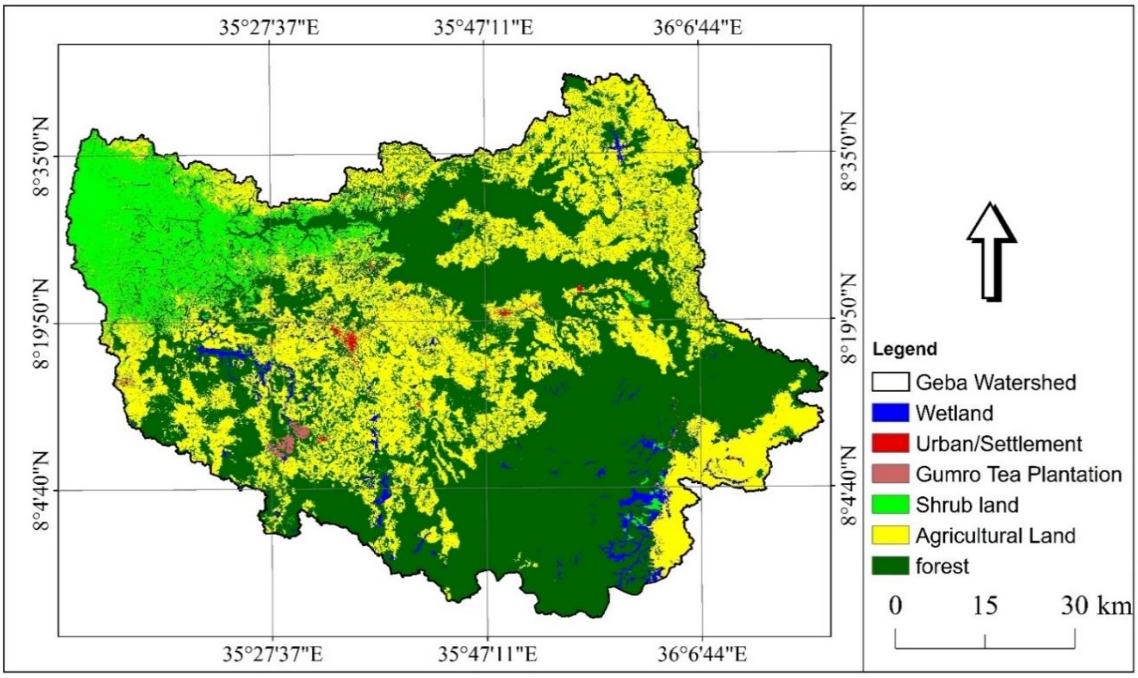


Figure 4. 22: land-use land cover map of 2018

According to wetland change matrix obtained from land-use land-cover map of 2018, the majority of wetland area 31.115km^2 (14.53%), converted typically to agricultural land in the period of 1985 to 2000. Conversion of wetland to agricultural land was nonstop between 2000 and 2018 of the study period. Similarly, In the same fashion with the first-period change matrix results, the majority of wetland land 17.515km^2 (10.9%), converted typically to agricultural land. Wetland change matrix was shown in (table 4.4 and 4.5). Accuracy assessment of Land Cover classification of 2018 were showed in (table. 4.6).

Table 4. 4: Wetland change matrix versus other land-use and land-cover areas.

Change in square kilometer (km^2)	Wetland	urban	Tea plantation	Shrub	Agriculture	Forest
Wetland conversion 1985-2000	160	0.4201	1.9111	2.580	31.115	17.975
Wetland conversion 2000-2018	127	1.525	2.8011	1.4909	17.515	10.33

Table 4. 5: Wetland change matrix versus other land-use and land-cover areas.

Change in percent (%)	Wetland	urban	Tea plantation	Shrub	Agriculture	Forest
Wetland conversion 1985-2000	74.76	0.19	0.89	1.20	14.53	8.39
Wetland conversion 2000-2018	79.04	0.94	1.74	0.92	10.90	6.42

Table 4. 6: Accuracy Assessment of land cover classification

	User Accuracy	Producer Accuracy	Overall accuracy
Urban	93.75	76	84.8484
Wetland	88.77	86.45	
Forestry	88.54	85	
Shrub Land	85.56	84.69	
Agriculture	81.91	84.61	
Tea Plantation	86.31	88.17	

Geba watershed wetland ecosystems was under most pressure from dryland farming restricted to the local communities. The inland wetland systems of Study area, which are in poor condition as a result of agricultural activities, water diversion and drought. Wetland cultivation and degradation which was practiced in the watershed dominated by cultivation of different vegetable's, maize, teff and sugarcane were more common among the rural ranchers. (Figure 4.23) shows the correlation between wetland degradation versus agricultural land change. Agricultural change matrix for 1985,2000 and 2018 were extracted from Supervised classification map.

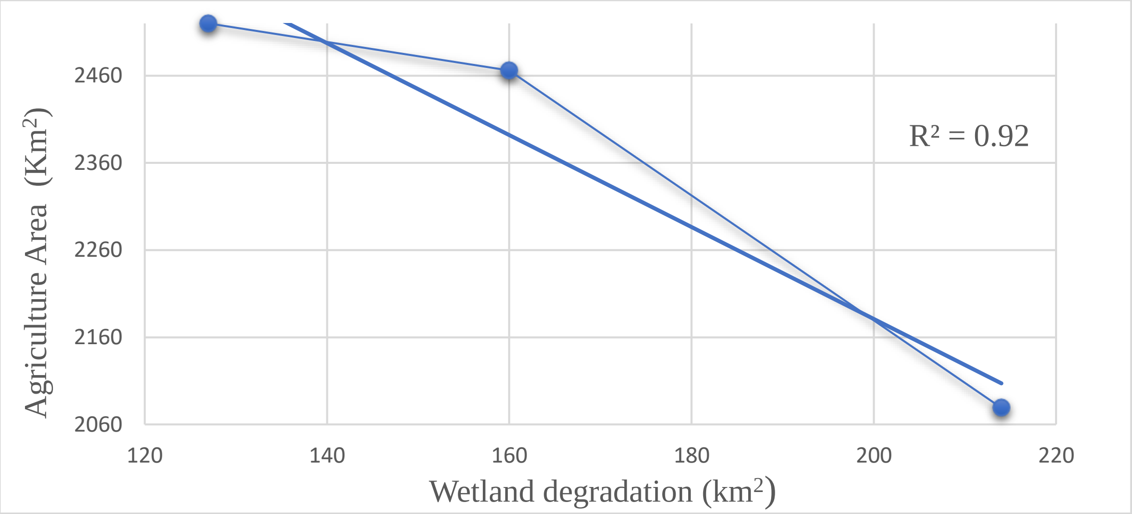


Figure 4. 23: Wetland degradation versus Agricultural land change

Previous study Report of the wetlands policy briefing workshop done by (Wood and Afework, 2000) described that wetland cultivation has been practiced in the Illubabor zone at least for about eight decades. About 70% of the farmers of study area have cultivated wetlands at least once a year. The amount of wetlands cultivated in the zone between 1988 and 1998 varied from 7% in Chora Wereda to 75% in Algae Wereda while the ten year zonal average for wetland cultivation in Illubabor is 23 % of the total wetland area. Also, Solomon Mulugeta (2004) indicated the continuous wetland cultivation, has in the recent past led to the severe degradation of many wetlands and even to the complete drying up of certain wetlands in the zone. The cultivation of wetlands is still going on in the study area. Food insecurity owing to pests and crop storage problems, land shortages for cultivation and grazing owing to coffee planting on uplands, land reform in 1975 giving more people access to wetlands and encouraging use listed as the main drivers of wetland degradation in Illubabor zone. The high lands of south west Ethiopia (Illubabur) and swamps of Awash valley are good examples to where the farmers are engaged in producing more than seeing sustainable use of the resources (Dixon 2002; Dixon and Wood 2007). Field photo capture of wetland cultivation and draining (figure 4.24).

Figure 4. 24: Wetland cultivation and draining

4.7.1.2.Demographics factors

The analysis above shows that wetlands were lost to Agriculture (see table.4.4 for detail) and that the farming population and agriculture area in the plain kept increasing during 1985–2018. Population increase in the study areas has a significant impact on wetland degradation as compared to natural driving factors. Many studies have proved that there is a direct correlation between population increase and wetland degradation Dixon, (2003); Song, (2014); Sica (2016) ;Chen (2018;). Wood and Halsema, (2008) reported that shortage of cleared land for upland cereal cultivation owing to coffee expansion and population growth, the latter being partly a result of in-migration and resettlement the major drivers of wetland degradation in southwest Ethiopia. A series of threats to these valuable resources as high population pressure and other excessive natural resource exploitation in wetland drainage basins mentioned in Proceedings of a seminar on the resources and status of Ethiopia's wetlands edited by (Yilma Abebe and Geheb, K., 2003).

4.7.2. Natural driving factors

4.7.2.1. Rainfall pattern

Analysis of Rainfall Spatio-temporal variability of the study watershed was done based on rainfall data obtained from Ethiopian Meteorological Agency. Metrological station nearer and in the watershed were used. The highest amounts of rainfall were recorded in the month of June to September, months of December, January and February the lowest amounts of rainfall was recorded for the period of 1985-2018 (Figure 2.25). Based on the analysis of rainfall pattern the highest rainfall peak were obtained between Jun and September. As a result, the watershed experienced a monomodal rainfall pattern.

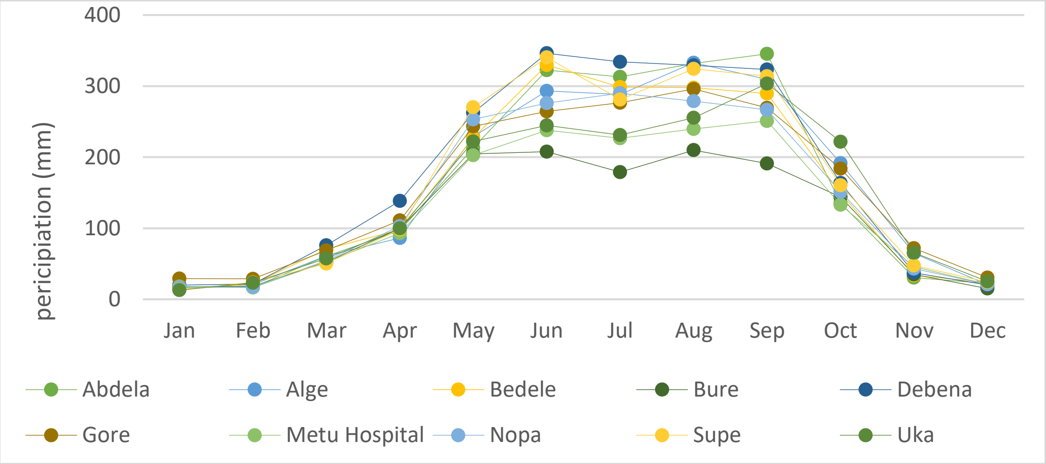


Figure 4. 25: Spatially variation of Rainfall pattern

4.7.2.2. Spatial and temporal variation of rainfall

Temporal variation of rainfall can be shown by plotting rainfall with time for the station. Based on consecutive plotting of rainfall data in the watershed with the different meteorological station were analyzed. Generally, the spatiotemporal variation of the rainfall data shows a decreasing trend. As a result, commonly the watershed valley wetland formation mainly depends on rainfall amount decreasing trends of rainfall pattern can be attributed to wetland degradation. Temporal variation of selected watershed areas was presented in (Figure 4.26).

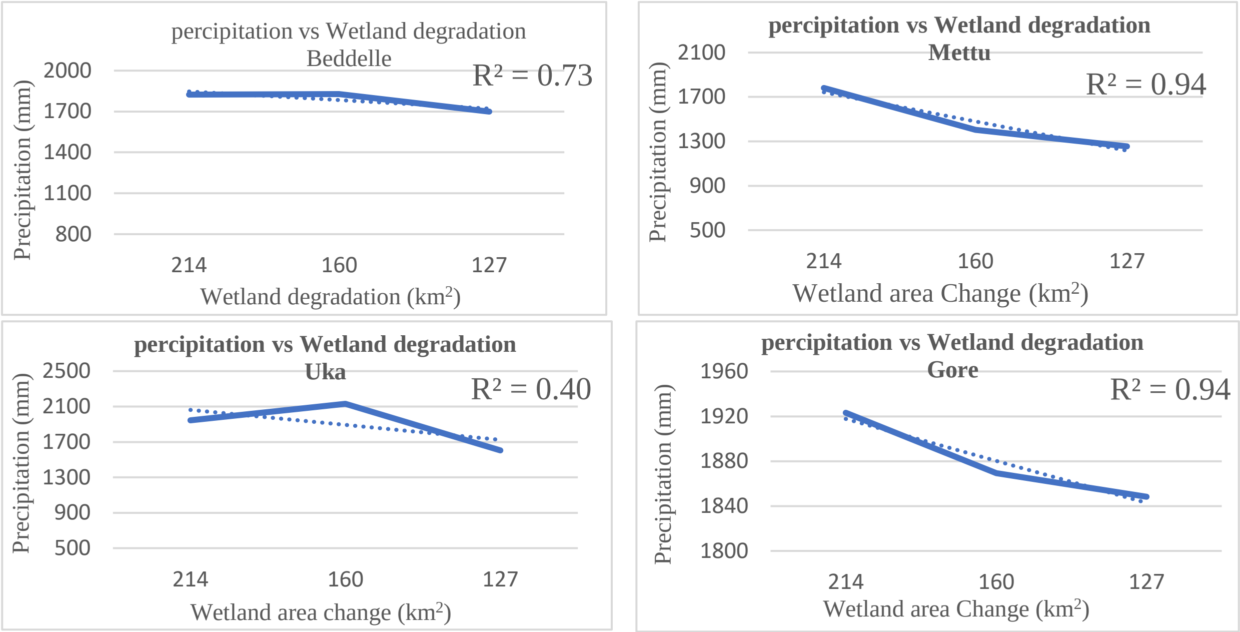


Figure 4. 26: precipitation and wetland degradation of the selected metrological station within the watershed.

4.7.2.3. Impact of precipitation on wetland degradation

The change rates of precipitation per metrological station inside and nearby the watershed 1984–2018 were calculated. Based on all station average annual precipitation values significant correlation between the rate of precipitation and the change in wetland area were analyzed, a linear regression model was set, change in precipitation and wetland degradation positively correlated with r^2=0.8185 for (1985–2018); The rate of change in precipitation and the change rate of wetland was positively correlated. The changes in precipitation had it is own impact on wetland degradation. as example correlation between precipitation and wetland declination were showed in (Figure.4.27) of some metrological station within the watershed boundary.

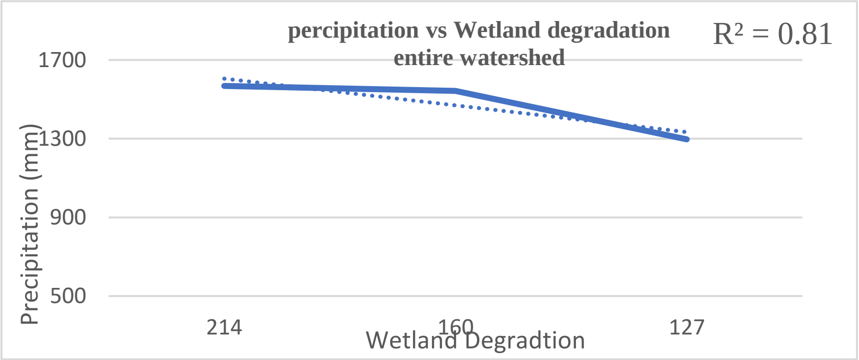


Figure 4. 27: correlation of Precipitation and wetland degradation.

4.7.2.4. Impact of Temperature

The degradation and loss of wetlands in Ethiopia seem to progress faster than in other ecosystems. Wetlands will be affected by a change in temperatures and consequence in modifications of the hydrologic cycle. The amount of water vapors in the atmosphere is directly related to temperature. The higher temperatures lead to an increase in vaporization. The change rates of maximum temperature, minimum temperature, mean temperature per metrological station inside and nearby stations from 1985 to 2018 were calculated, respectively.

As shown in the following Temporal variation of annual temperature varies considerably in the watershed. Consequently, increment trends of temperature were recorded with time. This may attribute to environmental or wetland degradation. Mean monthly minimum, mean monthly maximum and an average temperature of the watershed temperature is given in (Figure 4.28; 4.29) and (Table 4.7).

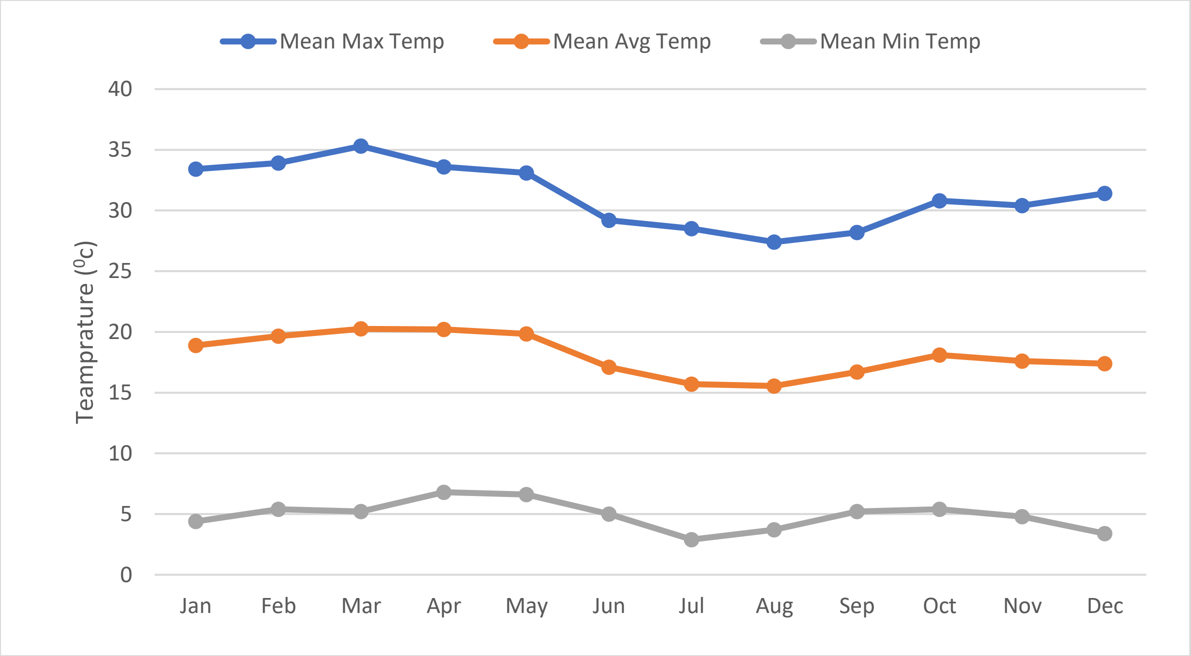


Figure 4. 28: Mean monthly minimum, mean monthly maximum and an average temperature of the Geba watershed

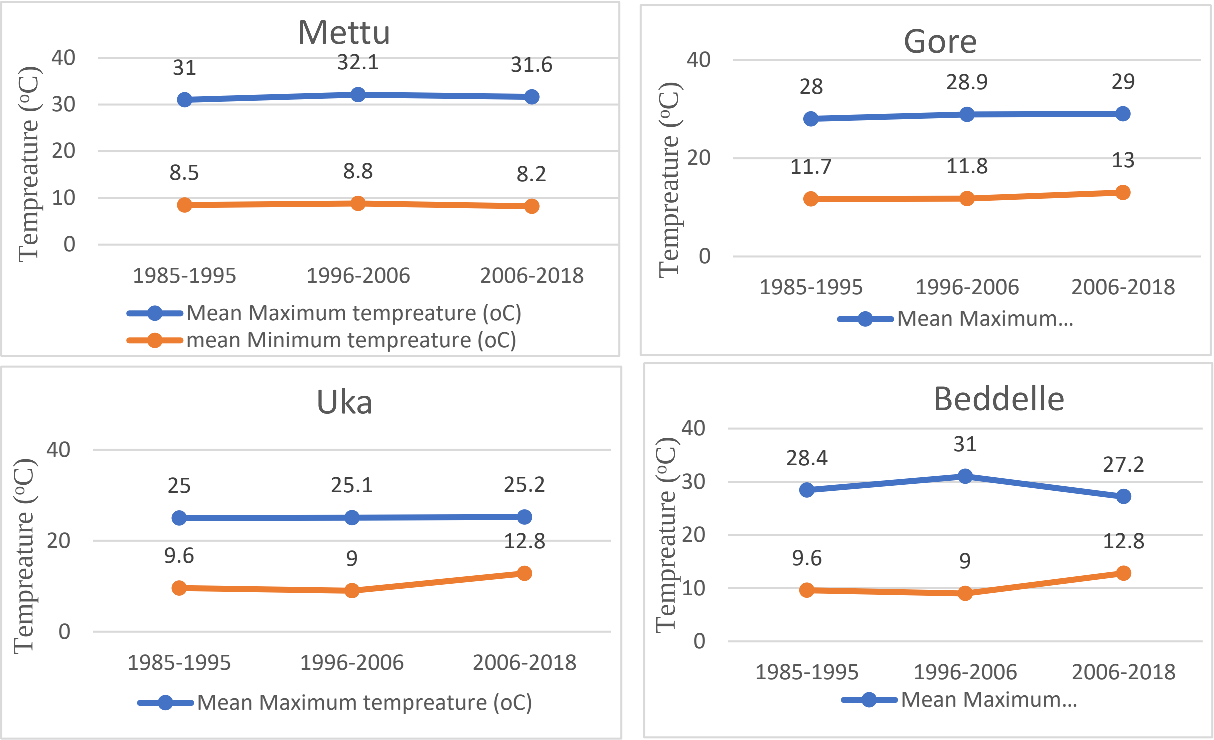


Figure 4. 29: Annual mean maximum temperature of Different station

Table 4. 7: Mean monthly temperature (1985-2018)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max Temp	33.4	33.9	35.3	33.6	33.1	29.2	28.5	27.4	28.2	30.8	30.4	31.4
Mean Avg Temp	18.9	19.6	20.2	20.2	19.8	17.1	15.7	15.5	16.7	18.1	17.6	17.4
Mean Min Temp	4.4	5.4	5.2	6.8	6.6	5	2.9	3.7	5.2	5.4	4.8	3.4

Pearson correlation between average temperature and the change rate of wetland were done. Simple linear person correlation between average temperature within and nearby the watershed and total wetland degradation were inoperative. correlated with the change rate of wetlands, a linear regression model between them result in $r^2 = 0.243$. There is no direct relationship between wetland degradation and change in temperature within the watershed (Figure.4.30).

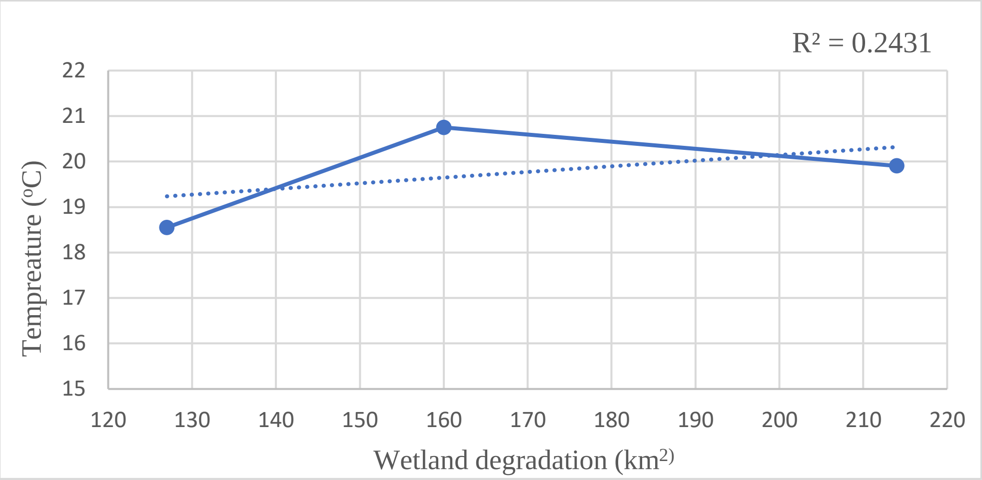


Figure 4.30: Correlation of Temperature and wetland degradation

Generally, a significant driving force of wetland degradation within the watershed directly related to agricultural expansion and population increment were identified with simple linear correlation statistics. Precipitation variability and decrement through time also has an important impact on wetland loss because of valley bottom wetland in the study area mainly results from high precipitation and highly incised terrain formation. Pearson correlation between natural and anthropogenic factor obtained r^2=1, r^2=085 and r^2=0.243 for Population increment, precipitation decrement and Temperature variation respectively. (Afwerk Hailu, 1998) mentioned that wetland function is influenced by rainfall through spring and river flow and (Dixon, 2003) testified the occurrence of valley bottom wetlands in the southwest Ethiopia result of the high rainfall and highly incised terrain which is host to poorly drained depression.

4.8. Wetlands as protected areas

Some wetlands are found inside protected areas in study area. Some organizations within the watershed protected and improve wetland management as being achieved through the inclusion of these areas within protected areas. As example “Bishari Park” in Mettu Town result from Rehabilitation of wetlands by Mettu town Beshari prison center (Figure.4.31). Hence, the park provide endless popular recreational activities, such as boating, birdwatching and presence of many fascinating lifeforms makes the wetlands especially enjoyable. Bishari park not only contains or provide recreational value, but also substantial economic valu

Figure 4. 31: Mettu Beshari Recreation wetland park

4.9. Hydro-Chemistry of Wetland Water Quality Assessment

The wetland water quality assessment has been calculated by using standards of drinking water quality recommended by the World Health Organization (WHO) (table 4.8). The results of the Hydro-chemical parameters of the different samples of degraded Hamuma Wetland , undrained Enago wetland and wangegnye wetland water quality was analyzed are as shown in (Tables 4.9 and 4.10) respectively. The following Hydro-chemistry parameters, namely PH, Turbidity, color, absorbance, fluoride, potassium, manganese, Nitrite nitrogen, Nitrate Nitrogen, chlorine free, chlorine total, Transmittance and Concentrations. The variations of the above Hydro-chemistry parameters observed among the different water samples were all within the recommended standards.

Table 4. 8: WHO Drinking water standards and unit weights. (All values except PH and electrical conductivity are in mg/l)

S/n	Parameters	Standards	Unit
1	PH	6.5-8.5	-
2	Color	15	TCU
3	Turbidity	5	NTU
4	Chlorine	5	Mg/l
5	Chlorine total	250	Mg/l

6	Fluoride	1.5	Mg/l
7	Manganese	0.1	Mg/l
8	Nitrate nitrogen	50	Mg/l
9	Nitrite nitrogen	3	Mg/l
11	Potassium	10-50	Mg/l

Table 4. 9: Water quality for Enago wetland

S/N	Parameters	Sample 1	Sample 2	Sample 3	Average
1	PH	7.55	7.45	7.15	7.383
2	color	11 mg/L pt	over range	14 mg/L pt	12.5
3	Turbidity	7 FTU	5 FTU	0 FTU	4
4	chlorine	0.23 mg/L Cl_2	0.15 mg/L Cl_2	2.561mg/L Cl_2	0.98
5	chlorine total	0.28 mg/L Cl_2	0.90 mg/L Cl_2	0.060mg/L Cl_2	0.41
6	fluoride	Under Range	1.06 mg/L F	0.75 mg/L F	0.90
7	Manganese	0.003 mg/L	0.016 mg/L	0.0081 mg/L	0.009
8	Nitrate nitrogen	0.028 mg/L N	0.038 mg/L N	0.605	0.22
9	Nitrite nitrogen	0.019 mg/l N	0.205mg/LN	0.1375mg/LN	0.12
11	potassium	4.9 mg/L K	12.0 mg/L k	15.45 mg/L k	10.78
12	Transmittance	9.6	17.3	13.76	13.55
13	Concentrations	1.1	0.8	2.35	1.41
14	absorbance	1.016	0.76	0.472	0.749

Table 4. 10: Water quality for Hamuma wetland

S/n	Parameters	Sample 1	Sample 2	Sample 3	Average
1	Ph	7.45	8.35	7.15	7.98
2	Color	210 mg/l pt	280 mg/l pt	196 mg/l pt	228.6
3	Turbidity	10 ftu	30 ftu	15 ftu	18.33
4	Chlorine	0.77 mg/l cl_2	4.00 mg/l cl_2	0.077 mg/l cl_2	1.61
5	Chlorine total	0.75 mg/l cl_2	3.90 mg/l cl_2	2.99 mg/l cl_2	2.54
6	Fluoride	0.60	Under range	Under range	0.6
7	Manganese	Overrange	Over range	Over range	Over range
8	Nitrate nitrogen	0.014 mg/l n	Over range	Over range	0.01
9	Nitrite nitrogen	0.081 mg/l n	Over range	Over range	0.08
11	Potassium	2.8 mg/lk	0.97 mg/lk	5.0 mg/lk	2.92
12	Transmittance	19.6	9.8	14.52	14.64

13	Concentrations	2.058	1.45	2.89	2.132667
14	Absorbance	0.27	0.22	0.97	0.595

Table 4. 11: Water quality for Bake Chora wetland

S/N	PARAMETERS	SAMPLE 1	SAMPLE 2	SAMPLE 3	AVERAGE
1	PH	7.15	7.25	7.15	7.18
2	color	50 mg/L pt	50 mg/L pt	15mg/L pt	38.33
3	Turbidity	3 FTU	7 FTU	4 FTU	4.6
4	chlorine	0.35 mg/L Cl_2	0.68 mg/L Cl_2	0.35 mg/L Cl_2	0.46
5	chlorine total	0.31 mg/L Cl_2	0.75 mg/L Cl_2	0.31 mg/L Cl_2	0.45
6	fluoride	0.070	Under Range	0.01	0.04
7	Manganese	0.05 mg/L	0.01 mg/L	0.43 mg/L	0.16
8	Nitrate nitrogen	0.081 mg/L N	Over range	0.081 mg/l N	0.081
9	Nitrite nitrogen	0.014 mg/L N	Over range	0.014 mg/L N	0.014
11	potassium	2.8 mg/L K	0.97 mg/L K	5.07 mg/L K	2.94
12	Transmittance	8.7	7.7	18.85	11.75
13	Concentrations	3.5	0.25	0.35	1.36
14	absorbance	1.77	0.05	1.675	1.165

The quality of water deals with its chemical and physical constituents. Wetland water contains many chemical species in the dissolved state. Hamuma Degraded and cultivated wetlands contain lots of organic matter. Based on the result from hydro-chemistry analysis the effluent from agricultural land goes through a wetland and moderate difference in qualities of water compared to undrained/or uncultivated wetlands was observed. As example the following parameters was compared with Degraded and undegraded wetlands type in the study area.

The values of average of pH for the Enago, Hamuma and bake Chora was ranged from average 7.45 to 7.55 , 7.15 to 8.35 and from 7.15 to 8.01 for surface wetland was obtained respectively. As the result cultivation on wetlands the raise of PH values to 7.98 of degraded Hamuma wetland obtained which is at a maximum limit of WHO water quality standard. However partially undrained Enago wetland results average PH values of 7.3. The result of excess of agricultural fertilizers/ pesticides nearby wetland and cultivated wetland increases the value of leached chemical pollutants to Hamuma Degraded wetland represented by the nitrogenous pollutant chemicals. The average values of Enago and Bake Chora partially undrained wetland was ranged from 0.22 and 0.12 mg/N respectively. However, the average values of drained Hamuma wetlands was over ranged values of Nitrate nitrogen and Nitrite nitrogen was verified.

Additionally, in terms of Color and turbidity A significant difference was recorded between degraded/or cultivated wetlands and undrained wetlands within the watershed. The average values of water color for the undrained Hamuma and Bake Chora 19 and 38.33 mg/l pt was verified which acceptable water quality based on WHO standards. But, a very significant average value of color was observed in cultivated degraded wetland 228.6 mg/l pt. The values of average of turbidity for un cultivated Enago was recorded 4NTU and Bake Chora Surface wetland water samples was obtained 4 values and acceptable based on WHO water quality guideline standard. But, again a very weighty difference of turbidity between drained and undrained wetland was observed. Based on the result average turbidity values of 18NTU was verified in cultivated and drained hamuma wetlands.

Generally, wetland degradation was significant impact on the surface wetland water qualities. Wetland distraction as a result of draining, cultivating and grazing activities by local community leads the hydrologic and water quality functions of wetlands in question and there is a significant difference in water quality of degraded and undegraded wetlands.

Chapter Five

5. Conclusion and Recommendation

5.1. Conclusion

In this study applied remote sensing and Geospatial techniques were used to identify and map wetland degradation in Geba watershed, Southwest of Ethiopia. The main objective was to map degradation of wetlands which have been under several pressure from anthropogenic and natural driving factors for 3 periods of years. Previously, in the study area, wetland mapping efforts were mainly based on conventional field data collection and verification, which are consuming task, labor-intensive and limited accuracy where achieved. This research makes has largely improved the previous wetland inventory and results by using geospatial tool in mapping wetlands of study area. Since the first multispectral Earth resources satellite was launched on July 23, 1972, and data became publicly available, the science of wetland mapping and monitoring using satellite imagery has been emerging rapidly. As, the result the technological advances of GIS and remote sensing technologies and freely available open sources software have provided wetland mapping science with improved GIS tools and remotely sensed imagery with an increasing spatial, temporal, and spectral resolutions.

The current study acquired the use of multi-spectral Landsat imagery, including SRTM DEM, combined with ground truth data and GIS produces satisfactory results for the delineation and mapping of wetland degradation in the study area. Landsat imagery, nevertheless, is insufficient to provide the required details and resolution for wetland degradation mapping. Consequently, a combination with SRTM DEM has increased the accuracy of wetland mapping. However, 90m resolution of SRTM DEM is insufficient to provide the desired accuracy and required a detailed map of wetlands. As a result, by complementing field surveys with remote sensing imagery and SRTM DEM acceptable results of wetland degradation mapping was obtained. The supervised classification gave good results about the wetlands location and boundaries with some mixing with forested wetlands. However, mapping wetlands using index-based NDVI and MNDWI methods was not successful in deriving information about the contents of the wetland areas. Rugged topographic variation and monomodal rainfall pattern throughout the year makes the wettest vegetation condition. As a result, it is impossible to extract wetlands using NDVI and MNDW index for the study area.

The results of wetland detection were mapped with desirable accuracy, indicating that the approach semi-automated method has a great potential in delineating and mapping wetlands using Landsat and SRTM data through semi-automated techniques has been verified.

Natural and human (anthropogenic) activities are the main causes for the loss and degradation of wetlands in the Geba Watershed. The total area of wetlands is on a decline in the study area during the period of 1985–2018. In the year 1985, wetland covers was 214 km^2 of the watershed. As a result of anthropogenic and natural factors, the wetland cover in the watershed has reduced to 160km^2 by the year 2000. The total wetland cover within Geba watershed degraded during 2000 and 2018 amounts to 33km^2. Therefore, the wetland area had degraded by 59.34% between the years 1985 and 2018. From the amount of 214km^2 in 1985, about 87km^2 was degraded by the year 2018. The major driving forces of wetland degradation result from anthropogenic activities towards the wetland like conversion of wetland to farmland, population increase, draining and grazing were the major human-induced activities on the wetlands.

Wetland change produces a great impact on the surrounding environment, mainly influenced hydrological variation and water qualities. The changes in the groundwater table of the study area is attributed to wetland area change. Based on the weekly measurement of groundwater table inside the watershed a significant difference in the level of groundwater table recorded on degraded wetlands.

The degraded wetland maps that have been generated in the present study advance our understanding of current use, transformation dynamics in wetlands and may provide the quantitative basis needed to guide and predict future wetland uses and its impacts towards surrounding natural resources. Correspondingly, it will also be useful for monitoring the activities and changes occurring in the wetlands for their effective management.

5.2. Recommendations

This study recommends that the following should be considered in future studies and wetland mapping so that the accuracy is improved:

- It is recommended that those who are interested in mapping and monitoring of wetlands using semi-automated methods may use Landsat and SRTM data combined.

- Based on the results obtained through this study, mapping of wetland using NDVI and MDWI had no significant output compared with pixel based classification. Further research- is recommended to determine the maximum achievable enhancement using high resolution multispectral and LiDaR DEM data.
- It is recommended to conduct further research on modelling approach to identify efficient and effective methods of wetland mapping in the study area.
- It is further suggested that regular water quality monitoring is required to see impact of wetland degradation on hydrology using surface and deep well measurements of water table and quality.

Chapter VI

6. Reference

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APPENDIX

Appendix I: population census of 1994

Zone/Woroda	Both Urban & Rural		
	Both sex	Male	Female
Darimu	95818	46899	48919
chora	84617	41558	43059
Dega	45423	22029	23394
gechi	83723	41322	42401
Yayu	83579	41316	42263
Metu	106294	52925	53369
Ale Wereda	73207	36050	37157
Bure	55193	27037	28156
Total			

Source: The 1994 population and housing census of Ethiopia results for Oromia region volume I part 1 Central Statistical Authority FDRE 1996 Report.

Appendix i: population census of 2007

Zone/Woroda	Both Urban & Rural		
Woroda	Both sex	Male	Female
Darimu	145070	72348	72722
chora	100506	49784	50722
Dega	39466	19504	19962
gechi	70478	35307	35171
Yayo	95518	48046	47472
Mettu	90736	45382	45354
Ale Wereda	64266	32034	32232
Bure	50841	25312	25529
Total	**656881**	**327717**	**329164**

Source: The 2007 Population and Housing Census of Ethiopia: Statistical Report for Oromiya Region; Part I: Population Size and Characteristics for the users. Published in 4/1/2012 Central Statistical Authority Apr-12.

Appendix ii. Accuracy Assessment of Land use classification (2018)

	Urban	Wetland	Forestry	Shrub land	Agriculture	Gumro tea plantation	Total	User Accuracy (%)	Overall accuracy
Urban	38	1	0	5	3	1	48	93.75	**84.8484**
Wetland	2	83	4	2	4	3	98	88.77	
Forestry	2	2	85	3	1	3	96	88.54	
Shrub Land	3	1	5	83	4	1	97	85.56	
Agriculture	3	4	4	3	77	3	94	81.91	
Gumro Tea Plantation	2	5	2	2	2	82	95	86.31	
Total	50	96	100	98	91	93	**528**		
Producer Accuracy (%)	76	86.45	85	84.69	84.61	88.17	504.93	**448**	

Hint; Hint: UA -user accuracy, PA- producer accuracy.

Overall Accuracy = (448/528)*100 = **84.84**

Number of samples = 528
Sum of Correctly classified = 448

Appendix iii: Monthly precipitation data (1985-2018)

Name	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean annual precipitation**
Abdela	17.86	17.15	60.46	96.72	213.05	322.24	313.07	331.87	345.28	135.20	30.42	22.63	**1906**
Alge	16.24	20.68	61.28	86.46	229.00	293.4	288.40	332.88	309.56	191.49	64.66	20.64	**1914.74**
Bedele	14.08	21.50	70.68	97.81	227.18	329.67	298.39	297.52	289.71	148.94	33.75	23.81	**1853.10**
Bure	16.84	18.30	52.33	99.97	204.39	207.90	179.14	209.78	191.17	144.04	34.85	15.12	**1373.88**
Debena	19.96	21.5	75.97	138.64	262.44	346.07	334.26	329.06	323.39	163.44	37.08	20.4	**2072.26**
Gore	29.04	28.82	68.80	111.15	243.40	264.49	276.7	296.02	269.47	183.87	72.08	30.61	**1874.51**
Metu	17.96	16.41	52.34	93.22	202.78	237.73	226.72	239.70	251.08	133.22	45.94	21.21	**1538.36**
Nopa	16.44	17.31	54.43	102.75	253.29	275.88	289.93	278.66	266.87	151.06	43.19	21.17	**1771.03**
Supe	13.31	23.63	50.26	98.33	270.30	340.31	280.85	324.45	313.84	160.36	47.67	24.14	**1947.49**
Uka	12.86	23.256	57.59	99.91	222.11	244.80	231.23	255.34	303.50	221.52	65.64	25.01	**1762.82**

Sources. Ethiopian Metrological Agency

Appendix iv: Monthly maximum and minimum Temperature (1985-2018)

Name	**Elevation**	**Geogr1**	**Geogr2**	**element**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	Oct	Nov	**Dec**	**Annual**
Alge	1880	35.66667	8.533333	TMPMAX	32.0	31.2	30.9	31.0	27.5	28.8	26.3	26.3	25.1	26.2	26.6	28.3	**32.0**
Beddelle	2011	36.33333	8.45	TMPMAX	28.8	30.7	30.4	31	29	26	24.2	24.5	27	26.7	26.7	27.8	**31**
Bure	1750	35.1	8.2333	TMPMAX	31.4	32	31.8	30.6	29.2	25.7	26	24.6	24.8	26.5	28.6	29.6	**32**
Dembi	1925	36.45	8.066667	TMPMAX	30.2	30.9	31.1	29.9	28.3	26.8	25.4	26.3	26	27.3	30.1	30.9	**31.1**
Gore	2033	35.53333	8.1333	TMPMAX	27.5	28.9	29	29	26	23.6	22.6	22.9	23.7	25.2	25.4	26	**29**
Metu	1711	35.56667	8.283333	TMPMAX	32.5	33.2	34.1	33.6	31.1	28	25.9	26.7	27.8	29.2	30.1	30.8	**34.1**
Nopa	1744	35.6	8.4167	TMPMAX	32.8	33.9	35.3	33.5	33.1	27.6	26.9	26.7	27.6	29.7	30.4	31.3	**35.3**
Supe	1600	35.66	8.52	TMPMAX	33.4	33.9	34.8	33.4	31.4	29.2	28.5	27.2	28.2	30.8	30.4	31.4	**34.8**
Uka	1666	35.35	8.18	TMPMAX	30.9	32.2	32	32.1	31.5	26.9	27.3	27.4	27.4	28.4	29.1	30.6	**32.2**
Mean Monthly Max Temperature					**33.4**	**33.9**	**35.3**	**33.6**	**33.1**	**29.2**	**28.5**	**27.4**	**28.2**	**30.8**	**30.4**	**31.4**	
Alge	1880	35.66667	8.533333	TMPMIN	10.2	11.9	13.9	14.5	14.3	13.7	10.8	12.1	11.9	13.3	13.9	12.8	**10.2**
Beddelle	2011	36.33333	8.45	TMPMIN	10.1	11.2	12.6	13.2	12.2	12.5	12	12.1	12	11.3	10.6	9.6	**9.6**
Bure	1750	35.1	8.2333	TMPMIN	13.6	14.7	14.9	15.3	14.1	14.2	14.2	14.2	13.8	7.5	6.1	14.1	**6.1**
Dembi	1925	36.45	8.066667	TMPMIN	4.4	5.4	5.2	6.8	6.9	7	6.4	6.3	5.2	5.4	4.8	3.4	**3.4**
Gore	2033	35.53333	8.1333	TMPMIN	11.7	12.7	13.3	13.3	11.8	12.2	12.1	12.4	12.4	12.7	12.4	12.8	**11.7**
Metu	1711	35.56667	8.283333	TMPMIN	6.2	5.4	6.6	9.2	7.5	6.3	2.9	3.7	8.7	7.3	6.1	5.6	**2.9**
Nopa	1744	35.6	8.4167	TMPMIN	9.4	11.3	11.8	12	11	8.4	9.3	10.4	8.3	10.4	10.7	9.8	**8.3**
Supe	1600	35.66	8.52	TMPMIN	8.2	7.6	7.4	10.4	9.8	11.6	12.1	11.8	11.2	11.1	10.1	8.4	**7.4**
Uka	1666	35.35	8.18	TMPMIN	4.7	7.9	9.2	7.8	6.6	5	10.6	10.6	10	9.8	8.5	7.6	**4.7**
Mean Monthly Min Temperature					**4.4**	**5.4**	**5.2**	**6.8**	**6.6**	**5**	**2.9**	**3.7**	**5.2**	**5.4**	**4.8**	**3.4**	

Sources. Ethiopian Metrological Agency

Appendix v. Field photo for Hamuma and Engo Wetland, Ilu Aba Boor (Feb, 2019)

Addis Ababa University

School of Earth Sciences

Name of student	Mintesnot Berhanu Tilahun
Id No	GSR/3609/10
Stream	Remote Sensing & Geo-informatics
Thesis Title	Wetland Degradation Mapping, Monitoring and Evaluating Its Impacts on The Surrounding Environment, Using Geospatial Technique, A Case Study In Geba Watershed, Southwest Ethiopia

FORMAT FOR THESIS ORIGINALITY TEST REPORT

No	Particulars	Test I		Test II		Test III		Test IV		Test V		Average	Remark
		Originality(%)	Plagiarism (%)	Originality(%)	Plagiarism (%)	originality(%)	Plagiarism (%)	originality(%)	Plagiarism (%)	originality(%)	Plagiarism(%)		
1	Abstract	100	-	-	-	-	-	-	-	-	-	100	
2	Introduction	100	-	-	-	-	-	-	-	-	-	100	
3	Literature review	97	3	98	2	100	-	-	-	-	-	98.33	
4	Methodology	100	-	100	-	100	-	-	-	-	-		
5	Result and Discussion	100	-	100	-	100	-	-	-	-	-		
6	Conclusion and Recommendation	100	-	100	-	100	-	-	-	-	-		
7	Overall Thesis											98.33	

	Name	Signature	Date
Student	Mintesnot Berhanu Tilahun		
Advisor	Dr. Tesfaye Korme		

DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a Degree in any other university and that all sources of materials used for the thesis have been duly acknowledged.

Mintesnot Berhanu Tilahun

Signature ____ Date____________________

School of Earth Science

May, 2019

This thesis has been submitted for examination with my approval as university advisor.

Advisor:

Dr. Tesfaye Korme

Signature __________________________ Date ___________________________