ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTEMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

GIS AND REMOTE SENSING BASED ANALYSIS OF POPULATION AND ENVIRONMENTAL CHANGE: THE CASE OF JARMET WETLAND AND ITS SURRUONDING ENVIRONMENTS IN WESTERN ETHIOPA

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ADDIS ABABA UNIVERSITY

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DECELARATION

This is to certify that the research work presented in the thesis entitled "**GIS and remote sensing based analysis of population and environmental change: The case of Jarmet wetland and its surrounding environments in western Ethiopia"**. I declare that the work recorded in this thesis in my own, and no part of the work here has been submitted for any other degree or qualification in any university.

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LIST OF ACRONYMS

AOI	Area of Interest
CIA	Central Intelligence Agency
CSA	Central Statistical Agency
DEM	Digital Elevation Model
DCDC	Decision Center for a Desert City
DN	Digital Number
EMA	Ethiopian Mapping Agency
ENVI	Environment for Visualizing Image
EPA	Environmental Protection Authority
EPE	Environmental Policy of Ethiopia
ERDAS	Earth Resource Data Analysis System
EROS	Earth Resources Observation and Science
ESDI	Environmental Satellite Data and Information
ETM+	Enhanced Thematic Mapper Plus
EWRP	Ethiopian Wetland Research Program
FAO	Food and Agricultural Organization
FCC	False Color Composite
FGD	Focus Group Discussions
FGDC	Federal Geographic Data Committee
GCPS	Ground Control Points
GDP	Gross Domestic Product
GIS	Geographic Information System
GLCF	Global Land Cover Facility
GLOVIS	Global Visualization Viewer
GPS	Global Positioning System
GSE	Geological Survey of Ethiopia
HoAREC	Horn of Africa Regional Environmental Center
ISODATA	Iterative Self Organizing Data Analysis Technique Algorithm

ITCZ	Inter Tropical Convergence Zone
IUCNS	International Union for the Conservation of Nature and Natural Resources
LULC	Land Use/ Land Cover
MEDaC	Ministry of Economic Development and Co-operation
MoFED	Ministry of Finance and Economic Development
MSS	Multi Spectral Scanner
NASA	National Aeronautics and Space Administration
NMSA	National Meteorological Service Agency
0c	Degree Celsius
PCA	Principal Component Analysis
RMSE	Root Mean Square Error
RS	Remote Sensing
SRTM	Shuttle Radar Topographic Missions
TCC	True Color Composite
TM	Thematic Mapper
UNEP	United Nations Environmental Program
UNPD	United Nations Population Division
USDA	United State Department of Agriculture
USDOS	United State Department of State
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WBISPP	Woody Biomass Inventory and Strategic Planning Project
WCED	World Commission on Environment and Development
WGS	Worldwide Geodetic System
WRS	Worldwide Reference System

ABSTRACT

Wetlands are one of the crucial natural resources. They provide invaluable biodiversity resources, aid in water quality improvement, support ground water recharge, help in moderating climate change and support flood control. Environment is in the other hand, where we live and something we are very familiar with our day to day life. The change of those natural resources are a result of population growth, unwise use of natural resources, lack of conservation policy implementation and unsustainable cultivation. GIS, Remote Sensing and GPS were a useful tool for wetland and environmental change analysis and to improve on the classification accuracy. This study investigate population and environmental change of Jarmet wetland and its surrounding area change analysis over the period of 1972 to 2015. The purpose of this study was to show land use/ land cover change of Jarmet wetland and its surrounding environment over years as a response to population growth. For this purpose multi-temporal satellite imageries (Landsat MSS 1972, TM1986, ETM+ 2000, 2005 and 2015 and SRTM 2000) were obtained and used for LULC change analysis, elevation analysis and change detection analysis. ERDAS Imagine 2010, ARC GIS 9.3, Global Mapper11, ENVI 4.7, and DNR Garmin softwares were used to process the image data and accuracy assessment analysis. The result of LULC showed that there is spatial reduction in wetland, forest, Shrubland and grassland in the period of 43 years (1972-2015) by -1,722.8 ha, -296.2 ha, -1,718.7 ha and -661.9 ha respectively, due to increase in the farmland and plantation area as a response to overpopulation, lack of environmental policy implementation and irresponsible for natural resource degradation. The accuracy assessment of LULC change are done for recent satellite image showed that the overall accuracy 84.06% with Kappa index 75.19% this means this classification is accurately classified and handle greater than 75% of error. Depend on the problem of selection and generalization we can't achieve accuracy 100%. Finally, this study suggests that create strictly natural resource conservation law, stopping illegal expansion of farmland, educating society about the value of natural resource especially wetland and create a source of income for society rather than farming.

Keywords: *GIS, Remote Sensing, Jarmet and others wetland change, Environmental change, population growth, LULC change, Change Detection analysis, Accuracy Assessment Analysis*

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Many definitions for wetlands have been proposed and utilized over the years (Ramsar Convention, 1971; Mac *et al*., 1998) and these definitions have been developed for various purposes, such as research studies, general habitat classifications, natural resource inventories and environmental regulations. But, no universal definition of wetland exists up to wetland protection law implemented. Before the beginning of wetland protection laws in 1960s wetlands were broadly defined by scientists working in specialized fields (Lefor and Kennard, 1977). A botanist's definition would emphasize on plants; soil scientists would focus on soil properties, hydrologists' definition would emphasize of the water table and geographers and environmentalists' definition would emphasize the function and services of wetlands. Wetlands are useful natural resources and usually attract different types of wildlife and birds. They are also a fragile ecosystem that could irreversibly degrade with human impacts. The united states geological survey(USGS) (1992) defined wetland as a general term applied to land areas which are seasonally or permanently water logged, including lakes, rivers, estuaries and fresh water marshes, an area of low lying land submerged or inundated periodically by fresh or saline water. Although, many definition are proposed for the factor of population growth on wetland and environment of surrounding area.

According to UNPD (2009) the world's population are nearly one billion in 1800 and currently it has grown approximately to 7 billion. The recent estimation of population projection suggested that the world population will rise somewhere between 7.5 and 10.5 billion by 2050, depending on changes in national level fertility and mortality rates. When the population increases over years at the same time the wetland and the earth's ecosystems, that support peoples livelihoods and wellbeing are rapidly degrading. Increases in human population size have dynamic, nonlinear impacts on the wetland and environment, with feed backs, thresholds and synergies amplifying risk and spending wetland and environmental change or degradations beyond the rate of population growth (Harte, 2007).

Thomas Malthus (1978) says in his statement ‘‘the power of population is indefinitely greater than the capacity of the earth to produce subsistence for man’’. This shows as if the number of population grows the natural resources and environments are degraded. Because, if the population increases in number the populations carrying capacity on natural environment also increases. Although, population growth and human activity placing unprecedented and unsustainable demand on wetland and surrounding environments. Increasing demand for natural resources, the intensification of agriculture, the productions of hazardous waste, rapidly growing populations and globalizing economy and urbanization, all have contributed to wetland and environmental changes (DCDC, 2007).

The outcomes of the impacts of human on wetlands are manifested through land use/ land cover changes. Because, land use/ land cover changes are especially agricultural extensification converts and ultimately degrades natural habitats and wetland resources. Habitat degradation not only threatens biodiversity, wetland and environments; it also disrupts the soils natural regulatory functions, resulting in soil erosion, reduced water holding capacity and nutrient depletion, as well as wetland change and other forms of natural environment degradations. Although, wetland is an inherently dynamic system which can be created, modified, and destroyed by a range of natural processes, the direct and indirect consequences of human activity are the main causes of wetland and environmental change and loss worldwide (Williams,1991). Degradation on wetlands includes habitat loss and fragmentation, resource extraction, drainage and reclamation, pollution and so on.

The change of wetlands has created numerous problems including decrease and extinction of wild flora and fauna, loss of natural soil nutrients, water reservoirs and of their subsequent benefits. They have affected on various traditional occupations, socioeconomic conditions and cultural activities.

According to Finlayson and Moser (1991) wetlands occupy of about 6 percent of the land surfaces of the world, or approximately 890 million ha but an estimate of 50% of world's wetland may have been altered or lost in the last 50 years (Dugan, 1993). In tropical and sub-tropical areas conversions of wetlands to alternative land uses have accelerated wetland loss since the 1950s and agriculture is considered the principal cause for wetland loss or change (Moser *et al*., 1996). Africa is the best known for its savannas and hot desert, 1% of its surface area (345,000km^2) is covered by wetlands. In an Ethiopian context, more than 85% of population live in rural areas and depend on agriculture for employment. The total land area of Ethiopia is 113,000,000 hectares or 1,130,000 km^2. Out of which 2 – 3.5 % is covered by high forests, whereas wetland constitutes only 1.15% (13,699km^2), 23.1% covered by Shrublands and 12.8% covered by savanna and grasslands. Ethiopian highlands produce in excess of 110 billion meter cubic of water, of which 74% flows into rivers draining into Sudan, Egypt, Kenya and Somalia (EPA, 2004; WBISPP, 2005). On the other hand, the recent data on forest resources of Ethiopia reported in FAO (2010) puts Ethiopia among countries with forest cover of 10-30%.

Extensive loss of wetlands has occurred in many countries throughout the world (Mitsch and Gosse link, 1993). Ethiopia is one of the world countries known by loss of environments and wetlands. In many countries like Ethiopia, local economies depend on wetlands for fisheries, reed harvesting, grazing, drinking ground water, irrigation and recreation. A large number of Ethiopians depend on wetland resources for their survival **(**Wood and Dixon, 2002**).** The causes of wetland degradation include the conversion of wetlands for intensive irrigation agriculture, the expansion of human settlement, industrial pollution, pesticides and fertilizers and water diversion for drainage and the construction of dams. Wetland conversion often results in water depletion, the displacement of populations, the destructions of traditional production systems, habitat degradation, salinization, increase of water borne disease and other adverse ecological impacts (WCED, 1987).

The study area, Jarmet wetland is located in western part of Ethiopia and was claimed to have high diversity of wildlife, birds and surrounded by high forests. Currently, the area of the wetland has reduced and there are no wildlife life (except the most common ones such as hyena and common jackals). The surrounding high forest was replaced by agriculture and only remnant mature trees are scattered across the study area. Although the underlying factors can be anticipated, there is no recorded and quantified data to understand the original extent of the wetland and its current size. Second, there is no data that depict which land use type was converted to which. Third, the amount of the high forest surrounding the wetland is unknown. Fourth, there are also smaller wetlands which are part of Jarmet wetland and their status over years are also not known.

For the present study Geographic Information System (GIS) and remote sensing technologies are used for analyzing population and environmental changes of Jarmet wetlands and its surrounding areas. GIS and remote sensing data are appropriate tools for analyzing and monitoring of wetland distribution, change area and spatio-temporal dynamic multiplicity. Remote sensing has many advantages for analysis of wetland and environmental changes and also provides information on surrounding land use and their changes over time. Landsat MSS, TM and ETM+ are a common data type for wetland classification and analysis of its spatial and temporal dynamic change. This study attempt to investigate five multitemporal and multispectral Landsat images between 1972, 1986, 2000, 2005 and 2015 from USGS (Landsat GLCF) Path 170/Row 053 and path 182/ row 053 for analysis and detect changes happened in this study area. Remote sensing data are the basis of GIS which has the function of collecting, storing, managing, analyzing and describing all or part of the data which regards to spatial and geographical distribution , Global Positioning System (GPS), on the other hand can identify exactly the change of location, time and speed of any kind of object (Wang *et al*.,2008). The satellite based remote sensors are low cost, affordable GIS tools for effective analysis and detect the wetland and environmental change in surrounding areas as a response.

Traditionally, wetlands and environments are delineated, analyzed and mapped by using ground survey. However, the surveys are difficult and time consuming (Yasouka *et al*., 1995). Remote sensing is one of the technologies that can provide cost and time effective solutions to mitigate these problems (Gold berg, 1998). In addition, remote sensing technologies can supply the following information for analysis of wetland and environmental change; (1) areal extent of wetland and environments of surrounding area (2) identify the wetland and environmental resources change as to type (3) characterize the general wetland land use/land cover type and (4) identify spectral analysis of remote sensor data **(**Lyon and Mc carthly, 1995).

1.2 Statement of the Problem and Justification

In rural Ethiopia, natural resources are the basis of the livelihoods of local communities. People usually use various services of these natural resources and also change their nature through, e.g., expansion of agriculture. Wetlands are important ecosystem that support various components of natural resources. According to Cowardin *et al.*, (1979), wetlands are valuable land resources that fulfill diverse natural, social and production functions. They also provide a range of ecosystem services. This means wetlands are used as transitional lands between terrestrial and aquatic systems that provide many goods and services including flood water retention, water quality maintenance, wildlife habitat, and soil erosion control. Wetlands are essential ecological features in any landscape. In their natural condition, wetlands supply numerous economical, ecological and cultural benefits to local communities, including water protection and unique opportunities for education and recreation (Rai, 2008; Liu *et al*., 2010; Olhan *et al*., 2010; Munyat, 2011). Holland *et al*., (1991) and Liu and Cameroon (2001) says wetlands are indispensable part of the global ecosystem. They support a high level of biological diversity and provide a host of services including primary and secondary productivity. They regulate water and nutrient flows and provide important habitats for wildlife. Cartney and Hera (2004) say that wetlands are important habitats because the heterogeneity in hydrology and soil conditions which they support results in broad variety of ecological niches, and they usually support enormous biodiversity.

They are, however, prone to changes due to population growth whereby their size and pristine nature change through time. As indicated in the background section of this paper, wetlands are a source of livelihood for many citizens in Ethiopia as elsewhere in different parts of the world. However, unregulated and unwise resource use from the wetland ecosystem, lack of appropriate policies and institutional setup that controls and regulates 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 (Afwork Hailu,2006). In Ethiopia, many wetlands are converted to farmland and sometimes used in uncoordinated way, due to lack of information on its environmental benefits (Deribe, 2008). Including some of the facts mentioned above and other associated problems, the wetlands in Ethiopia are severely degraded and have lost their natural characteristics, and converted into rough grazing lands where no more of their natural functions and benefits could be available for use (Dixon and Wood, 2003). The major causes for their disappearance is improper drainage, construction of deep drainage ditches, double cropping, growing of perennial crops and grazing after crop harvesting. The cultivation of eucalyptus (*Eucalyptus* on the wetland edges and also teff (*Eragrostis tef*) in the wetlands have reportedly contributed to the drying out of wetlands (Dugan, 1990).

Particularly, in Jarmet wetland and its surrounding there are no studies with regard to its current status, threats, or values of wetlands or even the need for their conservation and sustainable utilization. This wetland has been degraded over years due to human activities. It has been variously reported that population growth has created unprecedented pressure on natural resources (e.g., FAO, 2006; Lal, 2006). Jarmet wetland is also not an exception. In Jarmet wetland and its surrounding area human impacts were mentioned as major factor driving environmental changes and affecting the size and quality of the wetland. Population growth and agricultural practices are major forms of wetland and environmental changes of these areas. This wetland was surrounded by forests and claimed to be larger in size harboring a variety of wildlife such as Red Buck, wild pig, bush buck, wolf and leopard. It has been also used as nesting sites for migratory and resident bird species. Currently, this wetland is highly degraded, reduced in size and has lost its previous services. Although there are these claims of the pristine nature of Jarmet wetland, a study that aims at understanding the changes of the wetland and its surrounding environment with regard to land use and land cover dynamics is very important to propose conservation measures. With the advent of new tools such as GIS and remote sensing made it possible to carry out time series analyses of changes in the natural environment such as Jarmet wetland and its surrounding areas.

The pressure on the environment and wetland caused by human activities such as deforestation, over cultivation, over grazing, pollution and by natural events such as drought refers to environmental changes. Environmental changes are compounded by population growth, resulting in declining resources and higher demand and this will be a likely factor that intensifies conflict over the coming decades (UNEP, 2009).

1.3 Objectives of the Study

1.3.1 General Objective

The overall objective of this study is to assess the impacts of population growth on natural resource bases, with a focus on Jarmet wetland and the surrounding areas using GIS and remote sensing techniques and different datasets.

1.3.2 Specific Objectives

The specific objectives will be pursued in order to achieve the general objective of the study.
These are:-

- To assess the land use/land cover changes of Jarmet wetland and its surrounding environment over the study periods.
- The study investigates the trend and rate of LULC change of Jarmet wetland and its surrounding environments.
- To explore the causes of change detection of wetland and its surrounding environments of the last (43 years).
- To identify impact of land use/ land cover change of the wetland and its surrounding environments.

1.4 Research Questions

The central working of this research questions enable the assessment of changes and classification of Jarmet wetland and the surrounding environment from 1972-2015. Many researchers argue that the major causes of wetland and its surrounding environmental change are largely emanate from the interaction of humans with the natural environment. For this study, the research questions include:-

- What is the extent of Jarmet wetland change in terms of its size?
- What are land use/land cover trend in terms of the unprecedented change in the size of the wetland?
- Are the wetlands being converted for other land use purposes within the study area?
- What are the major derivers of Jarmet wetland and its surrounding environmental change?
- How people perceived changes in the Jarmet wetland and its surrounding forests in terms of wildlife, birds and other uses?
- What type of problems happened societies living close to the degraded wetland areas and surrounding environments?

1.5 Significance of the Study

Turner (1997) stated that most of the worlds environmental and wetland issues and global changes are attributed to population and land use changes. Population, wetland and land use change/dynamics influences and affects; climate change, loss of biodiversity, pollution, degradation, erosion and the sustainability of resource use. According to Kevin (2000**)** wetland and environmental change takes place under the influence of a number of driving forces such as, population, technology, political and socio-economic changes, climate changes and all at country level of spatial desegregation.

Hence, this study analysis the impact of population change on environmental dynamism of Jarmet wetland and its surrounding areas over the study periods. The causes of population dynamics and changes of wetland and environmental implications through direct and indirect observation by using remote sensing, GIS, GPS, questionnaires, interviews, focus group discussion(FGD), population and livestock data, satellite imageries and topographic map. The integration of remote sensing and GIS for the analysis of socio economic household survey data within an information system will makes possible for analysis of change detection and their dynamics over years. The findings of this study may reveal the major factors of population changes on wetland and other natural environments. Therefore, the significance of the present research may provide direction for protection (policy formulation), teaching populations the values of wetlands and other natural environments, to inform the importance of Jarmet wetland watershed for the country and create the way of conservations before destroyed, and design the future importance of wetland resources for population lives close to Wetlands, uplands, woreda and the country in general.

1.6 Limitation of the Study

In this study there was a major limitation as a result of resolution difference of Landsat images. Landsat image of 1972 was acquired with the multispectral scanner (MSS) which has spatial resolution of 60 meters, whilst the image 1986 was acquired with thematic mapper (TM) with spatial resolution of 30 meters. The remaining images of 2000, 2005 and 2015 were acquired with enhanced thematic mapper plus (ETM+). Those all have a spatial resolution of 30 meters. If different land use/ land cover found within 30 and 60 meter, it captured as one and give pixels depending on majority land coverage. This limitation was corrected for through image thinning of the 1972, it still prevented its use for projecting into the future so as to have a consistent result. Getting cloud free satellite images and sufficient previous researches on the study area particular and the country in general are another bottlenecks. In addition, there is no sufficient data for hydrology, soils, populations and livestocks in the study area. Although, at local level in the district there was no responsible officer in charge of environment/wetlands hence limited information was found. Furthermore, lack of published and unpublished research material at the study area woreda, lack of enough time, money, material and information.

1.7 Approaches used in the Study

The study area was delineated based on population and environmental changes of Jarmet wetland and its surrounding areas. The socio- economic activity of society, environmental constraints, food security, land use land cover changes, natural environmental resource factors, local development impacts are analyzed by using GIS, remote sensing and GPS technology. The land use land cover change, wetland and environmental change and the factors of these changes for the last 43 years were evaluated and analyzed from satellite images and ground surveys. By using GIS the areal extent of wetland and environments of surrounding area changes over years were analyzed. Using remotely sensed data for land use/ land cover change of wetland and its surrounding environments over years analysis, change detections analysis, image classification and accuracy assessment analysis. Using GPS for enhancing the ability to capture more detailed and timely information for the ground truth about the boundaries of wetland land cover class identification like; forest, grassland, shrubs, agricultural land, wetland and other natural resource of the area at various scales. In order to understand the possible causes of wetland and environment of surrounding area changes and address the issues (the main factors of degradations or changes) that enhance the change detection, land use land cover analysis in addition to socio-economic activities and natural factors of the area was assessed through primary and secondary data collections.

1.8 Thesis Organization

This study is composed of seven chapters. The first chapter deals with general background of the study and constitutes the introduction, statement of the problems, objectives of the study, research questions, approaches used in the study, limitations of the study and thesis organizations. Chapter two focuses on review of literature related to the topic. In chapter three, descriptions of the study area, geology, rainfall and temperature, soil, elevations, population and socio- economic activities are briefly described. Chapter four, devoted to research methods and sampling techniques used in the study, conceptual frame work, reconnaissance survey, data source and type (data collection) and analysis methods. Chapter five, devoted to spatial data processing and analyzing; satellite image preprocessing (geometric and radiometric correction, noise removal), satellite image processing, image classification and accuracy assessment. Chapter six, employed results and discussion of the main findings and data analysis in wetland and environmental changes over years, land use land cover change analysis over years, change detection analysis, trend and rate of wetland and its surrounding environmental change analysis, impacts of land use/land cover change, drivers of LULC change and nature of LULC change analysis. Finally, summary, conclusions and recommendation of the study are presented in chapter seven.

CHAPTER TWO

LITERATURE REVIEW

2.1 Values and Functions of Wetlands

Wetlands are important resource in sub-Saharan Africa that sustains rural livelihoods, particularly in areas with low or unpredictable rainfall, land scarcity or where uplands have poor soil characteristics and thus low potentials for agriculture (Dixon, 2002; Dixon and Wood, 2003). Wetlands are provides a variety of food sources and cover for nest sites of migratory birds. Wetlands are also a great use to humans because of the diverse natures of habitats they provide for different species (Turner and Jones, 1991). In many parts of the world, wetlands are used for recreation, cultivation, education and timber production. As such, wetlands provide areas for both consumptive and non-consumptive uses. Consumptive use involves hunting and fishing, while non-consumptive uses includes, bird watching and studying animals and plants. Wetlands are fulfill a range of environmental functions depending on their type and location. They provide valuable resources for rural communities especially in developing countries like Ethiopia.

The function of wetlands are the physical, chemical and biological process occurring in and making up on an ecosystem. Processes include the movement of water through the wetland in to streams or the oceans and the decay of organic matter. Only 2.6% of world's water is fresh **(**Illueca and Rast, 1996). The remainder is found in the oceans and brackish water. Only a fraction of world's fresh water is available for consumption because so much of it is locked up on polar icescapes and glaciers **(**Illueca and Rast, 1996). Fresh water resources are finite, but global consumption rates are known to increase 2-3% every year (Illueca and Rast, 1996). Wetlands are the main custodians of these valuable water resources. They act as ''banks'' from where water may be drawn and ground water replenished. Values of wetlands are ''estimate usually subjective, of worth, merit, quality or importance'' **(**Richardson, 1994**).** Wetland **''**values'**'** may drive from outputs that can be consumed directly, such as food, recreation, or timber and indirect uses.

Which arise from the functions occurring within the ecosystem, such as water quality, and flood compassable future direct out puts or indirect uses such as biodiversity or conserved habitats; and from the knowledge that such habitats or species exist (known as existence value Serageldin, 1993). Wetlands provide natural resources and services for humanity. The loss of ecosystem services of wetland can have economic and environmental consequences. Multiple authors acknowledge a vast variety of literature has been published attempting to give wetlands an economic values (Mitsch and Gosse link, 2000; Bendor *et al.*, 2008). Economically, wetlands support livelihoods providing numerous services and products to human kind. The main importances and functions of wetlands are given below;

1. Hydrological function: wetlands provide a number of important functions in regulating water flow through hydrological system. They slow the speed of water moving through system and act as natural reservoirs, storing large amount of water. This regulates the downstream flow, maintain it during the dry season and controlling flooding during the wet season. Wetlands recharge ground water and are important for maintaining the water table. All of these factors are extremely important for communities living and farming around or down stream of wetland. Large wetlands also can have an effect on rainfall, humidity, and stabilization of local microclimate through high potential evapotranspiration rates of dense wetland vegetation (Messele Fisseha, 2003).

1.1 Water balance: is a hydrologic functions of wetlands and it play a critical role in regulating the movement of water within watersheds as well as in the global water cycle (Mitsch and Gosse link, 1993). Wetlands store precipitations and surface water and then slowly release the water in to associated surface water resources, ground water and the atmosphere. Wetlands help maintain the level of water table and exert control on the hydraulic head (O'Brien and winter, 1988). The extent of ground water recharge by wetland is dependent upon soil, vegetation, site, perimeter to volume ratio, and water table gradient (Weller, 1981; Carter and Novitzki, 1981). Weller (1981) stated that researchers have discovered ground water recharge of up to 20% of wetland volume per season.

1.2 Climate control: climate control is another hydrologic function of wetlands. Many wetlands return over two-thirds of their annual water inputs to the atmosphere through evapotranspiration (Richardson and Mc carthy, 1994). Brinson (1993) observed that wetlands might also act to moderate temperature extremes in adjacent uplands.

2. Water supply: wetlands acts as reservoirs for the watershed and they release the water they retain (from precipitation, surface water and ground water) in to associated surface water and ground water. Forested wetlands, marshes, riverine and plaustrine wetlands have been noted to have significant water storage and ground recharge **(**Weller, 1981; Brown and Sullivan, 1988).

3. Flood protection: wetlands help protect adjacent and downstream properties from potential flood damage. According to Mitsch and Gosse link (1993), the value of flood controls by wetlands increases with; (1) wetland area, (2) proximity of wetland to flood waters, (3) location of the wetland (along a river, lake or stream), (4) amount of flooding that would occur without the presence of wetlands and (5) lack of other upstream storage areas such as ponds, lakes and reservoirs.

4. Erosion control: wetland plants hold the soils in place with their roots, absorb wave energy and reduce the velocity of stream or river currents. Coastal wetlands buffer shore lines against the wave action produced by hurricanes and tropical storm (Mitsch and Gosse link, 1993).

5. Regulation function: refers to the critical role wetlands play in regulating ecological and biophysical processes. Many regulating services that wetlands provide are related to their capacity to purify water, retain flood waters and provide a buffer to terrestrial areas at risk of flooding or pollution. Although, wetlands are helps as storage and recycling nutrient, human waste, organic waste, ground water recharge and discharge. Vegetations in wetlands can absorb strong winds and tides, making them excellent for shore protection.

5.1 Ground water recharge: wetlands may have an important influence on the recharge or discharge of ground water. Ground water recharge refers to the movement of surface water down through soil in to zone in which permeable rocks and overlying soil are saturate.

5.2 Ground water discharge: ground water discharge in contrast, refers to the movement of ground water out in to the soil surface. Although poorly understood, it appears that most wetlands are ground water discharge or through flow areas.

6. Carrier functions: wetlands provide services to human beings like, agriculture, irrigation, stock farming (grazing), wildlife cropping/resources, transport, energy production, tourism and recreation and human habitation and settlement.

7. Production function: wetlands give production functions for human beings such as, water, food, fuel wood, and raw materials for buildings.

8. Information function: wetlands give information functions like, research, education and monitoring uniqueness, rarity or naturalness and role in cultural heritage.

2.2 Threats of Wetland and Environments

Wetlands are the most productive ecosystems due to their functions and attributes. They are essential to wellbeing of Ethiopians as they contribute significant economic and social benefits to the country. Despite their high productivity and provision of many benefits; wetland and environments are still facing a serious threats (Abebe *et al*., 2003). Other problems that develop time include a decline in agricultural productivity in the cultivated wetlands which may eventually lead to reduce overall availability of land for crop production. In the same way as continuous cultivation of crops around wetland will dry it out, afforestation of land upstream of a wetland may reduce the amount of water in lower reaches of catchment, leading to a lowering of the water table and wetland drying.

Although, wetlands are dynamic ecosystems there changes are naturally over times as a consequences of processes which as erosion, sedimentation and coastal flooding. However, human activities either within wetland and environment or in the catchment in which they are situated can alter these natural processes or accelerate the rate of change, threatening the wetlands continued existence. Many wetland and environments have been extensively and irreversibly modified as humans try to increase agricultural productivity. One of the main impacts of disruption to wetland and environments of Jarmet is over extraction of water for intensive agriculture, overgrazing, pesticides and other agro chemicals can pollute the wetlands and other surrounding environments. Another threats of wetland and environments are population growth and demand for more food and greater economic development. Agriculture is not only the activity that damages wetlands and environments, population around wetlands and uplands often grow quickly, leading to pressure on natural resources.

According to Yilma Abebe (2003) wetlands and their values remain little understood and their loss is increasingly becoming an environmental disaster. While rates of wetland loss are documented for the developed world. The limited study of these ecosystems in developing countries like Ethiopia are little to say. The most threats of wetlands face results from their misuse many are also related to unsustainable resource extraction. Another important reason for their vulnerability is the fact that they are dynamic systems undergoing continual change (Barbier *et al*., 1996). As a result, many wetland are temporary features that disappear, reappear and re-create themselves over time (Barbier *et al*., 1996). Dugans (1990) claims that 65% of wetland disturbances are of human origin, while remainder have natural origins. Out of these 73% of disturbance are thought to result from direct human actions, while the remaining 27% are believed to come from indirect source.

Table 1. Causes of wetland loss (after Dugan, 1990).

Human actions		Natural causes
Direct	Indirect	
Drainage	Sediment diversion	Subsidence
Dredging	Hydrological alterations	Sea level rise
Filling	Subsidence	Land degradation
Conversion	Agriculture	Hurricanes and storms
Construction	Deforestation	Erosion
Discharge	Soil erosion	Biotic effects
Mining	Pollution	Earthquakes
Abstraction		

Source: Wetlands of Ethiopia, (2003)

The major threats of wetland of Jarmet and its surrounding area are human activities. The most or serious threats of this area are include the following.

- Unsustainable use of wetland resources through overgrazing, over cultivation, over abstraction of water for domestic use, agriculture and improper use of forest practices.
- Establishment of new human and livestock settlements in wetland areas.
- Cutting and burning of aquatic and other vegetation for, housing and commercial activities like a charcoal and fire wood.
- Lack of an operational national wetland policy and cross cutting sectorial policies.
- Limited funds where by wetland management institutions, lack adequate and continuous fund personnel for monitoring, management, and research and community awareness.
- Lack of community participations in management of various wetland resources in the woreda and countries in general. Generally, conversion of wetlands, agricultural encroachment, demographic pressures, over grazing and climate change are the major factors threatening wetlands.

2.2.1 Major Factors of Wetland Threat

There are several factors of wetland threat in the world. Those factors are;

1. **Reclamation and conversion of wetland**: conversion, drainage and reclamation of wetlands for agricultural development, human settlement and industrial development is one of the biggest threats to wetland and environmental change in the world wide.
2. **Over exploitation of wetland goods and services**: increasing human populations and changes from subsistence to commercial exploitation of wetland resources continue to exert increasing pressures on limited wetland resources, resulting in a decline of services and quality as well as quantity of products derived from wetlands.
3. **Demographic pressures**: population pressures is tightly interconnected with the growing needs of wetland for food resources and combined with a poor knowledge of the ecological functions of wetlands and environmental resources. Due to population pressure and subsequent demand for more resources to sustain in rural livelihoods, wetlands and environments are now under threat in Jarmet wetland and environments of surrounding areas. Also, high population pressure and urbanization in developing countries increases the demand for land encourage deforestation, pollution and degradations.
4. **Over grazing**: over grazing harms wetlands and environments through soil compaction, removal of vegetation and stream bank destabilization. Wetlands offer some of the best forage for livestock as well as a water source and cover. So livestock trends to spend disproportionately large time in wetlands.
5. **Agriculture**: wetlands often have fairly flat or areas of rich organic soil that is highly productive agricultural land if drained. For this reason many wetlands have been drained and converted to agricultural lands.
6. **Climate change**: the increases of temperature are causing polar ice to melt and sea levels to rise. This in turn is leading to shallow wetlands being swamped and some species are degraded. Yet at the same time, other wetlands, estuaries, flood plains and marshes are being destroyed through drought.

2.3 Policy Action for Conservation and Use of Wetland and Environments

In Ethiopia the majority of the societies depends on the agriculture for their survival. In Ethiopia agriculture has dominated about 45% of GDP, 85% of exports and 80% of total employment. Agriculture also have been the main source of the stagnation and variability in GDP growth. In the cause of agriculture many resources are threatened or degraded like; wetlands and other natural resources such as, forest, wildlifes, birds, soils and waters. In Ethiopia deforestation is estimated for expansion of rain fed agriculture vary from 80, 000 to 200,000 hectares per annum. In 1990 the accelerated soil erosion caused a progressive annual loss in grain production estimated to 40,000 tonnes, which unless arrested, will reach about 170,000 tonnes by 2010 (Mathew *et al*., 2011).

Livestocks play a number of vital roles in rural economy, but according to one estimate 2 million hectare of grassland will have been destroyed by soil erosion between 1985 and 1995. Land degradation estimated to have resulted in a loss of livestock production in 1990 equivalent to 1.1 million tropical livestock units. For the cause of those problems many environmental and wetland policy action are taken for the wise use of these resources in Ethiopia and at a worldwide (FAO, 2006).

Environment are the source or production function that supports the livelihood of millions who depend upon environmental resources and the sinks or pollution absorption and cleansing functions essential for human health and wellbeing. Although, our country is the most important biodiversity hotspots of the world, but also one of the most degraded. The country faces many environmental challenges including declines in soil fertility and water quality, loss of biodiversity, deforestation, soil erosion and wetland degradation. Much of Ethiopians population is dependent up on the environment as their principle source of income (HoAREC, 2011; USDOS, 2011; MCkee2007, and EPE, 1997).

The environmental policy in Ethiopia are prepared for a long period of time. In Ethiopia the first environmental policy laws are Fitha Nagest (the law of king) of the 13 century had rules which deal with environmental matters. This laws explains the proclamations on hunting of wild animals to oversight of radiations. The environmental policy and challenges of Ethiopia during the period of Italian occupation (1936-41) while there were rules that addressed aspects of environment, formal environmental decrees were rare (Bekele, 2008). The resource laws during Italian occupation focused on the economic potential of Ethiopia natural resources rather than their ecological values. During this period Italians issued over twenty forest decrees and implemented destructive forestry programs to fuel infrastructural development (Bekele, 2008). After the return of Ethiopian imperial government (1941-1975) policy focused on the development of agricultural sector for domestic consumptions and export; as a result national forest land was redistributed for conversion to agricultural land (Bekele, 2008). While the 1955 constitution introduced the principle of conservations, it took years for forestry policies to develop and even longer for any implementation to take place. The period of 1955-1968 is described by Bekele as ‘‘probably one of the most distressing phases in forestry management’’ in Ethiopia, where the high land forest estimated 1,937, at nearly six million hectares was reduced by almost 1.5 to three million hectares in early 1960 (Bekele, 2008,p.339).

In 1975, the militaristic Derg regime succeeded the imperial government drastically changing Ethiopian environmental management. Environmental policies produced during the Derg era (1975-1991) were ground in socialist ideologies of the regime (Bekele, 2008). The environmental policies of Derg regime were characterized by top-down management policies which, although they often incorporated extensive conservation and tree planting initiatives were ‘‘thousand hectares of lands belonging to communities and individual households came under plantation by force’’ (Bekele, 2008, p, 339) without regard for local participation or community empowerment. In 1991 or in the transitional government of Ethiopia most of the conservation and development activities in the environmental sectors were destroyed in protest against decades of top-down rule (Bekele, 2008; Keeley and Scoones, 2003).

In 1995, the Ethiopian environmental protection authority (EPA) was established as a response to Rio Agenda 21which emphasized ‘‘the necessity of integrating environment and development at policy planning and management levels for improved decision making’’ (Ruffeis *et al*., 2010, p, 31). In 2002 the establishment of independent environmental agencies at the regional level was codified in the establishment of environmental protection organs proclamation (McKee, 2007). The federal EPA has since assisted regional states in developing their own environmental conservation strategies, through provision of equipment, training and environmental education (MoFED, 2002). The second stage decentralization introduced by federal government in 2002 established the woreda (a local level of government roughly equivalent to a district) as a center of socio economic development. The stated goal of policy was bringing the government closer to the people and increasing responsiveness to local needs (Wemai, 2008; McKee, 2007; MoFED, 2002). However, there are many environmental protection policy are prepared by federal governments and environmental protection authority. Environmental policy is intended to introduce the environmental protection enacted in 2008 both at federal and regional levels. There are many numbers of environmental protection policy are written in the past and present by governments and other organizations for protection of environments, but the reality on the ground is inverse of those policy, because many natural resources are degraded in rural areas of Ethiopia especially in Jarmet and its surroundings. Others, such as rural development, policy appear to lack crucial policy elements, or have been criticized for promoting development interests over environmental protection (Bekele, 2008).

For many years, in Ethiopia wetlands have received little or no attention from the general public and particularly from decision and policy makers. Awareness within the general public as well as amongst policy makers on wetland issues is still very limited or localized to specific organizations. Ethiopian wetland research program (EWRP) in 1992-2000 in Illubabor zone undertook the most comprehensive study on wetlands. The project was under taken by Huddesfield University from UK in collaboration with Addis Ababa University, with back stopping under taken by International Union for Conservation of Nature and Natural Resources (IUCNS) eastern African regional office. Although, in Ethiopia national policy on wetland conservation and management, the issue of wetlands has been indirectly mentioned in various policies and legal frame works including the national water resource management policy, the federal environmental policy, the biodiversity management policy, agricultural and natural resource development policy and the land administration policy frame works are potentially helpful to introduce managements and conservation of wetlands and environments in the country, the reality on the ground shows that wetlands are being mismanaged and some of them are in state extinction and degraded (Tadesse Amsalu, 2012). To assure a sustainable wetlands and environments of surrounding area development and addresses the multiple interests of stakeholders, it seems rational either to strengthen and act in accordance with the existing policy frameworks or to initiate a national wetland conservations such as, the Ramsar convention that facilitate wetland conservation and sustainable utilization is also very important.

According to Ramsar convention (1987) brundtland commission the wise use of wetlands ̋ wise use of wetland is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches within the context of sustainable development’’. Also wise use of wetlands has been defined under the conventions’’ the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within context of sustainable development’’. Although, the wise use of wetland means sustainable utilization for the benefit of human kind in a way compatible with the maintenance of the natural properties of the ecosystem and sustainable utilization is understood as human use of wetlands so that it may yield the greatest continuous benefit for present generations while maintaining its potential to meet the needs aspirations of future generations.

Although, Ramsar convention secretariat (2007) the convention of wetlands came into force in 1975 and currently there are number of contracting parties, which are obliged to undertake four main activities including;

- Designating wetlands for inclusion in the 'list of wetlands of international important' and to maintain their ecological character.
- Developing national wetland policies, to include wetland conservation considerations with in their national land use planning, to develop integrated catchment management plans and in particular, to adopt and apply the guide lines for implementation of the wise use concept, which is sustainable utilization of wetlands for the benefit of mankind in a way compatible with the maintenance of the natural properties of ecosystem.
- Promoting the conservation of wetlands in their territory through establishment of natural reserves and to promotes training in wetland research, management and wardening.
- Consulting with other contracting parties about transfrointer wetlands, shared water systems, shared species and development aid for wetland projects.

In this way the Convention plays an important role in helping to prevent detrimental changes to wetland sites in states that are party to the Convention. Recognizing the value of wetlands in the livelihood of local communities as well as in sustaining a productive ecosystem and biodiversity, Ethiopia is in the process of developing a protocol consistent with the Ramsar Convention and also has drafted a National Wetland Policy awaiting approval of the law makers Wetlands for (Addis Ababa and Bahir Dar University, 2012). In Ethiopia the environmental protection authority (EPA, 2003) addressed, water resources, wetlands, land use and biodiversity issues and indicates the need integrate the rehabilitation and protection of wetland with the conservation, development management of water and biodiversity resources. Specially, article 3.4 of the policy element on water resource states the following:-

- To recognize that natural ecosystems, ‘‘particularly wetlands and upstream forests are fundamental in regulating water quality and quantity and to integrate their rehabilitation and protection into the conservation, development and management of water resources’’.
- To promote the protection of inter face between water bodies and natural environments such as, lands, soils, lakeshores, riverbanks, forests, grasslands and wetlands.

2.4 Classification and types of Ethiopian wetlands

Wetland type can be defined as the combination of attributes (e.g., physical, chemical, and biological) that make a particular wetland different from other wetlands. Wetlands as defined in Ramsar convention include all lakes and open water as well as different types of permanently or seasonally wet ground. If one takes into account all areas covered by this definition. According to Afwork Hailu (2007) Ethiopia hosts all types of wetlands that have been classified and listed in different parts of the world, except wetlands that are associated with coastal zones. However, due to lack of institutional setup and legal frame work with in the country, no systemic classification and inventory of wetlands has been undertaken. Some researchers and resource managers have tried to list names and location of limited number of wetlands with in the country and made rough estimates of the area coverage. The total wetland area coverage of Ethiopia are listed below.

Table 2. Areal extent of Ethiopian wetlands

	Region	Total land area (ha)	Wetland coverage (ha)	% out of total area of region	% out of total wetland area of the country
1.	Tigray	5,085,784	8,053	0.16	0.49
2.	Afar	9,526,567	131,000	1.38	7.98
3.	Amahara	15,764,744	431,695	2.74	26.29
4.	Oromia	35,961,996	397,853	1.11	24.23
5.	Somali	29,151,569	250,612	0.86	15.26
6.	Benishangul Gumuz	5,033,592	22,466	0.45	1.37
7.	SNNP	11,064,200	152,900	1.38	9.31
8.	Gambella	3,203,280	247,556	7.73	15.08
Total		114,791,759	1,642,135	1.43	100.0

Source: WBISPP (woody biomass inventory and strategic planning project, 2002).

Hunghes and Hughes (1992) have some attempt to group Ethiopian wetlands in to ten categories based on ecological zones, and also made their descriptions. On the other hand, Leykun Abunie (2003) has classified Ethiopian wetlands in to four major categories based on ecological zones, hydrological functions, geomorphologic formations and climatic conditions. He explained that the four categories in which he has classified are linked with the four major biomes, which also describe climatic conditions in Ethiopia. The four wetland biomes he tried to identify include;

- The afro tropical wetland system
- Somali Masai wetland system
- Sudano-Guinean wetland system
- Sahelian transitional wetland system.

However, such classification is based on location of wetlands and does not take into account the wetlands environment, wise use, changes and does not provide proper information for their conservations. There are many systems of analyzing, classifying, identifying the changes of wetlands and environments followed by various organizations and institutions depending on their source of water and nutrients (river, lake, ground water or rainfall) according to their hydrological regime (e.g. permanently or temporarily flooded, permanently waterlogged and many other classification criteria could be envisaged (e.g. soil type, vegetation type and structure, livestock type and other natural and manmade resources as well. Ethiopia has diverse types of wetlands in various origins and different parts of the country. A wide range of wetland types, which are the result of the cumulative effect of many environmental variables, exist in Ethiopia.

Table 3. Major types of Ethiopian wetlands

Types of wetlands	Area per km squares	Percent [%]
Fresh water lakes	5,766.6	31
Saline lakes	1,170	9.5
Marsh lands	2,330	12.5
Seasonally inundated wetlands	8,720	47
Total	18,587	100

Source: Ethiopian environment protection authority (EPA, 2003).

Based on simplified classification versions used by the Ramsar convention, one can also classify the wetlands in Ethiopia in to three broad classes, including; fresh water, salt water and human made wetlands.

1. Fresh water wetlands

Most of the Ethiopian wetlands can be classified as fresh water wetlands. This in turns can be classified further as riverine wetlands (associated with temporarily and permanent fresh water marshes) and swamps and lacustrine wetland types (lakes and wetlands associated with lake systems). Depend upon the above idea I classify Jarmet wetlands as plaustrine wetland types because it is temporarily flooded only during the rainy season and it dries up in dry season. It also a riverine type of Wetland.

2. Salt water wetlands

There are limited salt water wetlands in Ethiopia. Examples, of salt water wetlands are wetlands of Dallol depressions in Afar region states.

3. Human made wetlands

Human made wetlands include; Koka, Gelge Gibe, Melkawakenna, Fincha, Alwero and other hydro power and irrigation dams. Further, municipal and small water reservoirs like dams built for various purposes, acquirers and wells.

In addition, Keddy (2000) classified the four main types of wetlands in a basic system of classification. Those are:-

Swamp (Carr): A wetland community dominated by trees with a developed leaf canopy, which have invaded from nearby areas into herbaceous marshes and fens, rooted in hydric soils, but not peat.

Marsh: A wetland community dominated by herbaceous plants, usually emergent through water and rooted in hydric soils, but not peat.

Bog (Schwingmoor): A wetland community dominated by sphagnum moss, sedges, ericaceous shrubs or evergreen trees rooted in deep, sometimes uncompacted peat

Fen: A wetland community usually dominated by sedges and grasses rooted in shallow peat, often with considerable water movement through the peat.

2.5 Population Growth Drives Wetland and Environmental Changes

The population of Ethiopia has increased from an assumed 16 million around 1950 to about 65 million at a turn of 20th century (Zeleke and Hurni, 2001**)** and almost 85 or 96 million and greater than today (CSA,2010 and CIA, 2015). According to Haile (2004) unsustainable population growth, particularly the western Ethiopian highlands which is the most densely population area contributed significantly to environmental degradation. Therefore, in the context of Ethiopian highland most studies pinpoint population pressures one of the major drivers of wetland and environmental change through destruction of Vegetations, water bodies, forests, wildlifes, lakes and wetlands mainly for agricultural expansion (Amsalu *et al.*, 2007; Bewket, 2002; Gebresamuel.*et al*.,2010; Zeleke and Hurni,2001).

The growing population is one of the most critical drivers at Jarmet wetland and environments of surrounding area changes, because the livelihood of almost the entire rural population of these area is dependent on mixed farming system (crop production and animal husbandry). Even, the urban populations especially, Jardaga town are made greater impacts on wetlands and other environments of surrounding area. Their impacts are; pollution of wetlands by thrown chemical detergents like; car batteries, burned fuels and garbage inside wetlands. Although, at the same time, the growing demand for cultivated land and settlements and trees for fuel (charcoal) and construction of house purposes aggregate the changes. Population growth coupled with lack of wise use of wetland and other environmental resources are affects the resources of surrounding areas. This leads to further fragmentations of land and intensification of environmental resources and subsequent reduction of following practice or abandonment fallow periods, ultimately expansion of cultivated land into forests, grazing lands and other marginal lands and wetlands. Which is a most common in western part of Ethiopia especially in the study area kebeles.

Another factors of wetland and environmental changes as a response to population growth at Jarmet wetlands are overgrazing and high livestock density in the deterioration of wetland and other natural resources. Those change is facing a critical problem due to several factors such as increasing population, demolished natural resources, environmental pollution and land use planning. As the major factors of wetland and environmental change of Jarmet indicators changes of landscape or topography, change of topsoil composition and changes in land use land covers. All these indicators are closely related to impact from intensive human activity including population growth.

2.6 Application of remote sensing and GIS for wetland and environmental analysis

Geospatial technologies as geographical information system (GIS), global positioning system (GPS) and remote sensing are the effective tools for wetland and environmental conservation, analysis, monitoring, planning and management through their various spatial, temporal and spectral characteristics. The applications of those systems encompasses the analysis, monitoring, mapping ,assessment of the changes and accurate data on different wetlands and environmental patterns, timely changes and their impacts such as; flooding, overgrazing ,pollutions, quality of water and other natural environments. Those applications are listed below.

2.6.1 Application of remote sensing for wetland and environmental change analysis

Many types of remote sensing have been used to study wetlands and environments worldwide. Prigent (2001**)** used satellite observation to find submerged wetlands and Harries *et al*. (2005) have applied large scale remote sensing methods to monitor near surface peat lands and hydrological conditions. Remote sensing as a definition is the science made at a distance from the objects, area or phenomenon under investigations. Although, remote sensing is not only a science both the science and art of obtaining information about an object , area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation**(**Lellisand and Kiefer,2004).

Remote sensing (satellite) imagery is available for most of the world since 1972. The multi date of satellite imagery permits monitoring, analyzing, detecting dynamic change of land scape environments and provide a means of major wetlands and environmental changes and quantify the rates of change (Joshi *et al*., 2004). The use of remote sensing is becoming increasingly frequent in environmental studies. In the 1970s and 1980s satellite images were mostly used in simple interpretations or as map back grounds **(**Merrifield and Lamar, 1975**)**. Remote sensing wetlands by satellite dates back to Landsat -1 launched in 1972.Work and Gilmer (1976) used Landsat 1-multi spectral scanner (MSS) imagery to inventory ponds and lakes. The interpretation and analysis of Landsat TM images since 1986, provided a comprehensive information of areas especially regarding the various land uses and associated environmental problems.

Classifying analyzing of wetlands and environmental change is the basic step for wetland analysis. After that the wetland changes can be detected from the classified image. Recently, digital classification of wetland from satellite image data has been widely used because these methods are less time consuming and the source data provide high temporal resolution and high accuracy in georeferencing procedures (Jensen, 1996; Coppin *et al*., 2004). Many data sets have been successfully used in wetland and environmental change analysis such as, Landsat data, topographic maps, rain fall maps, soil and vegetation maps, geological maps, but Landsat based classification is considered providing the greatest accuracies**(**Civco,1989; Hewitt,1990; Bolstad and Lellisand,1992) because of the sensitivity of Landsat bands. Landsat TM and ETM+ have similar seven bands but Landsat MSS have four bands. While ETM+ band 6 has higher resolution of 60m. Landsat 7 satellite also has newly added panchromatic band 8 with resolution of 15m.

Table 4. Landsat TM, MSS bands and wavelength ranges

Band	Region	Landsat (MSS)	Wavelength per micro meter of Landsat (TM) and ETM+	Resolutions(meters) for TM and ETM+
1	Blue- green		0.45-0.52µm	30m
2	Green		0.52-0.60µm	30m
3	Red		0.63-0.69µm	30m
4	Near IR	0.5-0.6µm	0.76-0.90µm	30m
5	Mid IR	0.6-0.7µm	1.55-1.75µm	30m
6	Thermal IR	0.7-0.8µm	10.4-12.5µm	120m
7	Mid IR	0.8-1.1µm	2.08-2.35µm	30m
8	Panchromatic	ETM+	0.52-0.90µm	15m
	Spatial	80m resolution		30m,120m for band6 TM and ETM+
	Radiometric	64bits		256bits
	Temporal	18days		16days
	First launched	1972		1982

Source: Lellisand and Kiefer (2004).

TM band 1 can detect designed for water body penetration, for coastal water mapping, for soil/vegetation discrimination, forest type mapping and cultural features identification. TM band 2 can detect designed to measure green reflectance peak of vegetation, for vegetation discrimination and vigor assessment. Also it is useful for cultural feature identification. TM band 3 is designed for sense chlorophyll absorption region or aiding in plant species differentiation. Also it is useful for cultural feature identification. TM band 4 is ideal for useful determining vegetation types, vigor and biomass content, for delineating water bodies and for soil moisture discriminations. The two mid IR bands on TM are useful for indicative of vegetation moisture content and soil moisture, useful for differentiation of snow from the clouds, useful for discrimination of mineral and rock types and sensitive vegetation moisture content. The thermal infrared band on TM is designed to assist in thermal mapping, for soil moisture and vegetation studies (Lellisand and Kiefer, 2004).

2.6.2 Application of GIS for wetland and environmental change analysis

Geographic information system (GIS) is a powerful computer based set of tools for collecting, storing, retrieving at will, transforming and displaying geographical referenced data from the real world for particular set of purposes. It allows for the integration of spatial and non-spatial data within system. GIS for wetland and environmental change analysis is used to explore the spatial relationships, patterns and processes of geographic, biological and physical phenomena.

The two primary methods of geospatial or (GIS) analysis include quantitative mapping and thematic mapping. A quantitative map shows how much of something is in a selected areas. It is spatial representation of numeric values such as, temperature, population density, elevation, pollution levels and so forth. Athematic maps demonstrates a specific features or concepts such as; judicial boundaries, soil types or flood zones. Geographic information system (GIS) is widely used techniques in wetland and environmental analysis. The application of these system for environmental and wetland change analysis are endless. Modern GIS gives users the ability to conduct visual and quantitative analysis involving multiple kinds of digital spatial data, including remotely sensed imagery. In most studies, Landsat data after classification combined with GIS data for future wetland analysis. Sader *et al*. (1995) used both supervised and unsupervised classification methods to map the Landsat data. Then ancillary data used like; topography, geology, hydrology and metrology for analysis of the changes. GIS data sources are used to model forested, riverine, plaustrine wetland and environmental change and their characteristics. With GIS different component layers can be overlaid to investigate relationship between individual wetland components. Classified images can be combined with addition shape files such as; permanent water bodies, farmlands, forests, settlement patterns, grasslands, shrubs, wetlands, plantation area soil types and population changes (Mahmud *et al*., 2011). These data provide extra information to detect the changes of wetlands and potential causes of changes. The national research council has identified geographic information system methods as a key element in future wetland management programs in 1993. GIS can be used to perform area calculations on classified images.

According to Abbasi and Abbasisi (2000) some of the capabilities of GIS which are utilized in environment and wetland change analysis briefly described below;

1. Delineation of land use and land cover

Land use and land cover of wetlands resources like: watershed/river basins can affect the quality of surface/ground water directly. For instance, if the presence of land cover in the form of forests dominates in a catchment, it would reduce the possibility of soil erosion. In case agriculture happens to be the most dominant land use, it would contribute agricultural inputs in the form of fertilizers and pesticides, soil sediments to the water resources as run off through filtration.

2. Overlay analysis; this feature of GIS can be highly useful in preparing new maps showing spatial distribution as well as interaction of parameters by overlaying selected maps. For example, a map of soil erosion index can be prepared by overlaying individual maps of digital elevation model (DEM) or three dimensional elevation which gives information on the slope of terrain, soil type and land cover(which provide clue to estimating erosion or loss).

3. Buffering; this features can be used for delineating the vulnerable areas or zones of high risk, or hotspots in the region (study area). It can also help in identifying an emerging new region around a known feature. For instance, if it is known that the regions which are within 0.5km of the wetland would be flooded; these regions can be delineated using the buffer tool.

4. View shading; a three dimensional elevation models (DEM) of a landscape of the region of interest enables viewing the elevation in different perspectives. The DEM can also have a better visual appeal compared to the tabulated data or conventional graphs.

5. Spatial analysis; the spatial data can be interpolated or extrapolated using several models such as nearest neighborhood and krigging. The spatial data can also be represented as line contours (elevation contours as a lines) or as regions (elevation contours as a regions) or as a grid (a map representing various data values as continuous gradient of colors).

6. Thematic maps; thematic maps represent numerical data in relation to the concerned area. The variability can been seen as it changes spatially. A side being more informative thematic maps also have better visual appeal compared to the tabulated data or conventional graphs.

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA.

The current study was carried out at Jarmet wetland and surrounding environments. Jarmet wetland is located in western part of Ethiopia and it lies between 9°52' 43".00N to 9°42'11".00N latitude and 36°57'31".00E to 37°05'50 ".00E longitude with an average elevation of 2,388 meter above sea level. This wetland is flooded during rainy season and gradually dries up. It is a part of Blue Nile watershed which encompass the Ethiopian renaissance dam. The total land coverage of the study area is 8,113 hectare or 81.13 km^2. Out of which coverage Jarmet wetland covers an area 291.0 hectares or 2.910 km^2. Its watershed length (Jarmet-Imane watershed) are 0.083 Km^2 coverage (Fig.1).

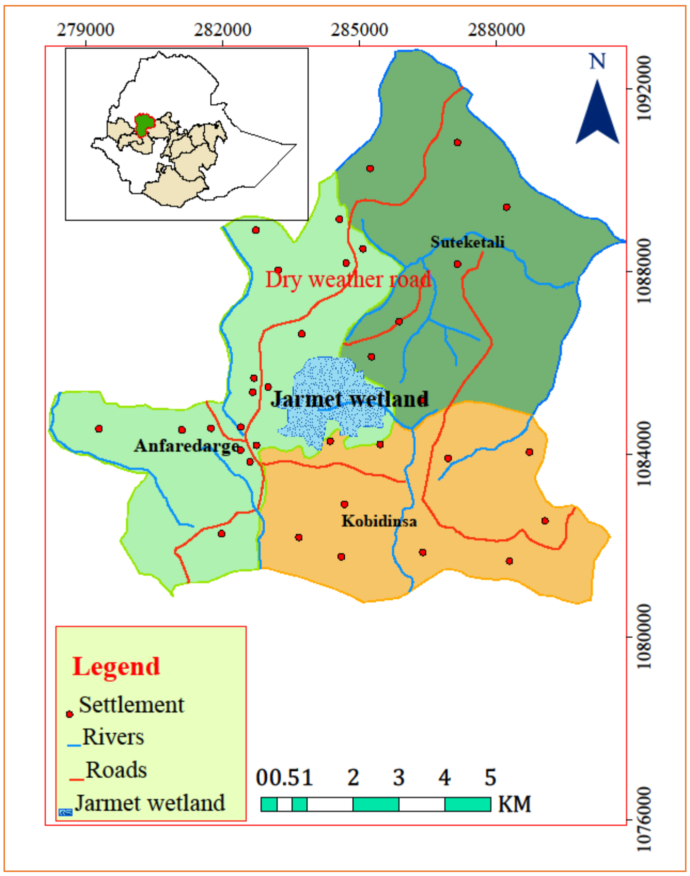


Fig.1. Location map of the study area.

These wetland is located in Horo Guduru Wollega Zone at about 45 km from zonal capital Shambu and 357 km far to west of capital city of Ethiopia Addis Ababa. In the south eastern this Wetland are fed by Jarmet river and Imane watershed and north western part of the wetland fed by Warabocho river and in western part of the wetland is fed by Dacce river. The boundary used for this study is delineated arbitrarily considering much larger area inside and outside wetland coverage which incorporates three kebeles and it share common boundaries with Anfaredarge, Kobidinsa and Suteketali. This Wetland is covered by grasses and wildlifes include different types of birds and livestocks. It also used as communal grazing of livestock and as major source of drinking water for Jardega town and population living its surrounding areas. The surrounding areas of this wetland are topographically varied and dotted with small hills and human settlements dominate the entire landscape.

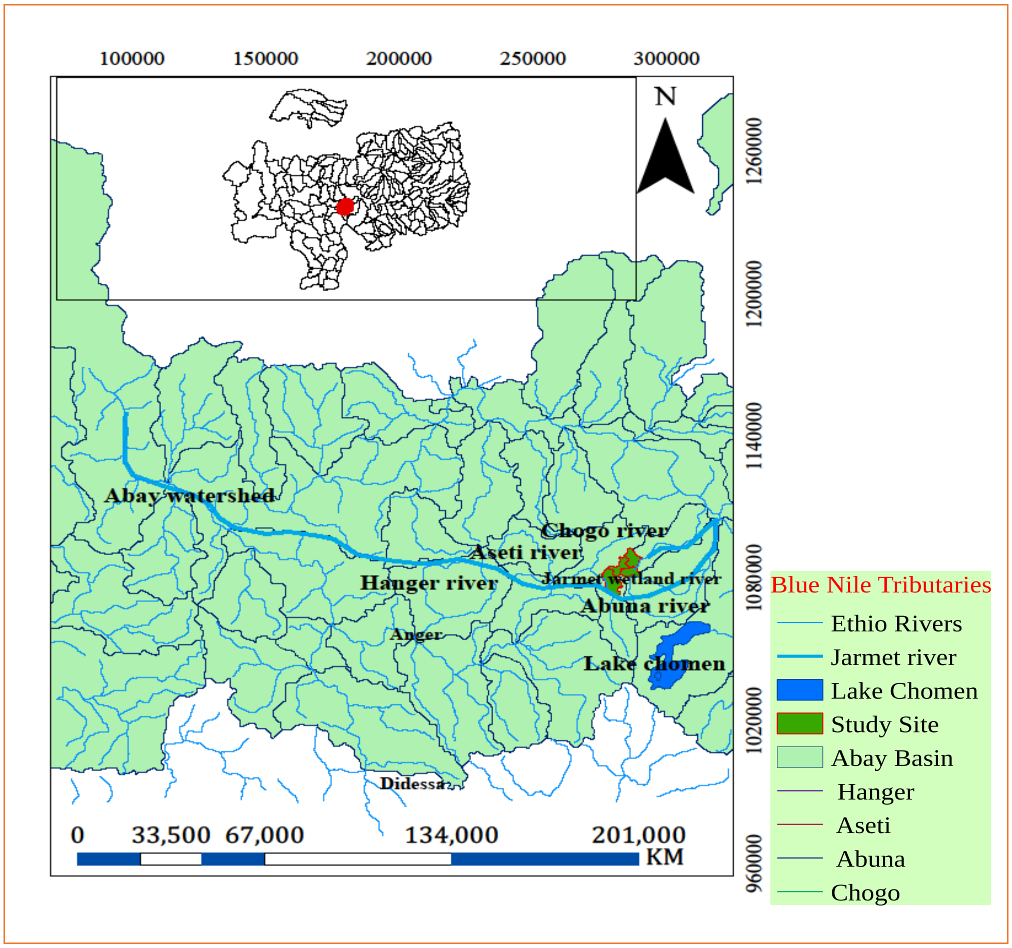


Fig.2. Tributaries of Blue Nile watershed.

Jarmet wetland is the largest of all wetlands in Jardega Jarte woreda. It contains large areas of wetland such as, flood plains, dambos and riverine system. Jarmet wetlands are marsh types of wetlands, because this wetland is a home of many kinds of plants and animals. As a result it is used to conserve birds and wildlifes before degradation. In addition, it is dambo type of wetland, because it acts like sponge, storing large quantities of water during the wet season and gradually releasing it during the dry season. Furthermore, it is riverine type of wetlands because these wetlands have important river called Jarmet which is part of Blue Nile watershed (Fig.2) above. Jarmet river flows to Imane river and which in turns flows to Abuna river. Abuna river flows to Aseti river which flows to Chogo river and Chogo in turns flows to Hanger river which is one of the biggest tributary of Abay River. According to this idea we understand that Jarmet Wetland river is a part of Blue Nile watershed and it helps as a one source of Blue Nile watershed and Ethiopian renaissance dam.

3.1 Climate

The climate of Ethiopia mainly controlled by the seasonal migration of intertropical convergence zone (ITCZ) which follows the position of the sun relative to the earth and the associated atmospheric circulation, in conjunction with the complex topography of the country (NMSA,2001). Climates can be classified according to the average and typical ranges of different variables, most commonly temperature and rainfall or precipitation. Accordingly, the present study, assessed temperature and rainfall data to determine the trend and spatio- temporal variability of climate in the study area. Rainfall and temperature are important factors in determining geomorphic processes, soil formation, wetland and environmental changes, human livelihood and biophysical environment in general at a given geographical environment. In addition, this area is classified within climatic zones of Degas and Woina Degas based on the Ethiopian climatic zoning system.

3.1.1 Rainfall

The rainfall data used for this study were collected from national meteorological service agency of Ethiopia. Monthly rainfall records from two stations namely; Alibo and Jarmet. Rainfall data are used for description of statistical parameters of average maximum and minimum rains of the study area within 25 years. As mentioned above station records were from early 1990 to present (2014). Then two rainfall records were analyzed at annual and seasonal time steps. The major rainy season is from May to August but there is relatively small rainfall during the month of March and April. The average annual rainfall is 3,457 mm in July and 2,633mm in August. In addition, in (Fig.3) below almost in this station the maximum peak rain is observed to be in July and August. The mean maximum monthly rainfall is recorded with the value of 411.9 mm, 406.3 and 393.1mm, 334.6mm in July and August respectively.

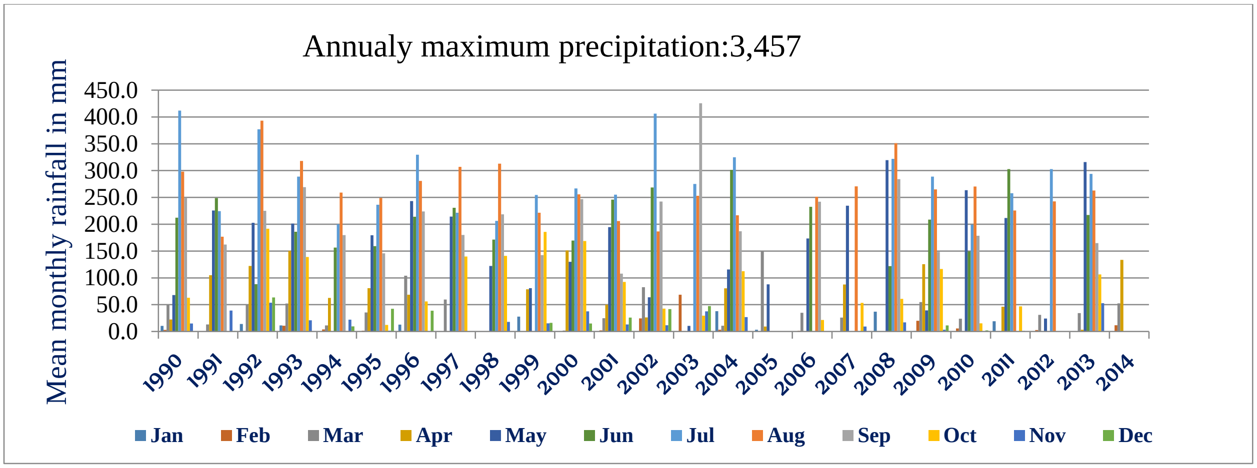


Fig. 3. Alibo mean monthly rainfall data from 1990 to 2014.

Furthermore, the (Fig.4) below revealed that Jarmet wetland get its maximum rain from May to August with mean monthly rainfall in millimeters (mm) 336.5, 321.0, 416.1 and 414.7 respectively. Hence, from figure 4, it is possible to say that Jarmet and its surrounding area get higher rain for long period of time starts from May to August. The study area receives in Alibo and Jarmet station annually maximum, 3,456.6, 2,042.0 mm and minimum 1,099.3, 1,222.8 mm total mean rainfall respectively. In both stations the analysis of monthly rainfall indicates that the rainfall pattern in the study area is predominantly bimodal (i.e., rainfall occurs over a continuous period of times, but dominated by two rain fall peaks). The first rain starts from March to April and the second from end of May to August. In general the wet season starts from May and end in August sometimes continuous to September.

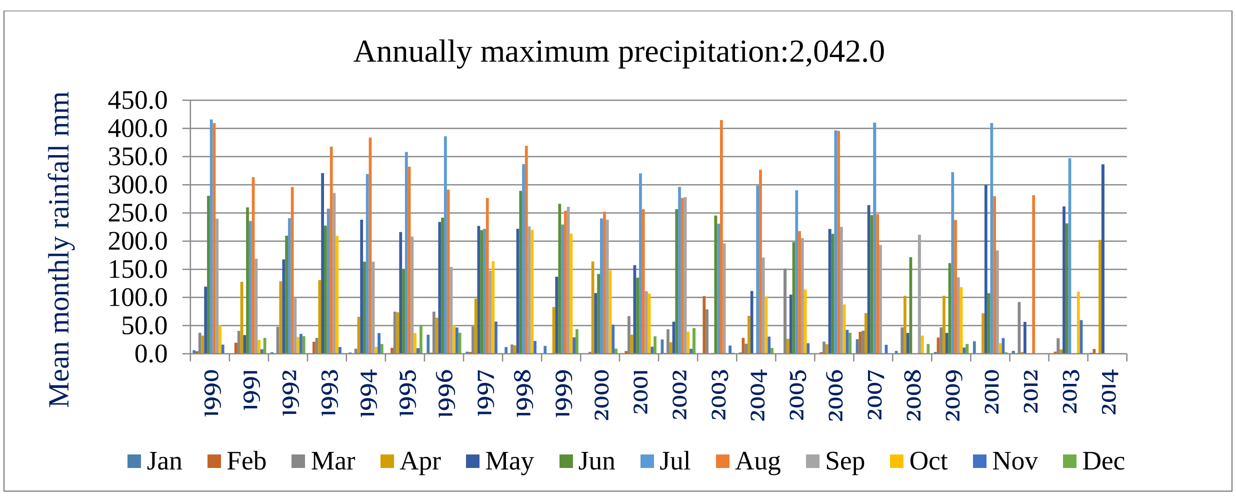


Fig .4. Mean monthly rainfall data of Jarmet from 1990 to 2014

3.1.2 Temperature

The temperature of the area is related with altitude. When altitude increases temperature decreases, because of the earth atmosphere heated upward from lowest level. In Alibo station the monthly mean maximum 27.7 ^{o}c in March and minimum temperature 11.9 ^{o}c in August of this station shows as an average temperature of the station recorded. In Jarmet station the mean monthly highest temperature is recorded from February to April with its average 26.6^{o}c and peak is 33.1 in February for this station. The mean monthly minimum temperature is recorded in August, December and January with its average 12 ^{o}c in Alibo station. The hottest months of the year is March with a monthly temperature maximum above 27.7^{o}c and coolest months of the year is August with diurnal variations between 11.9 ^{o}c minimum and 20.5 ^{o}c maximum.

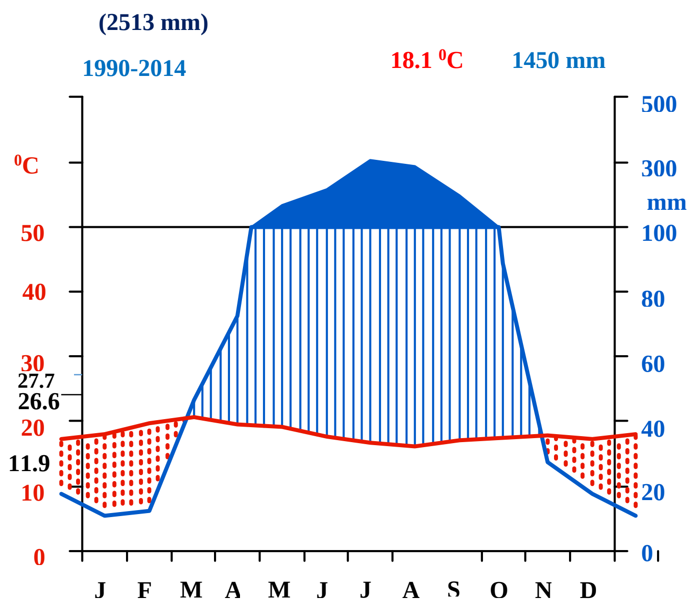


Fig.5 Average temperature and rainfall in both stations in 1990 to 2014

3.2 Geology of the Study Area

The main geological features of Western Ethiopia which includes the Nekemte map sheet NC37/9 is underlain by Precambrian rocks, Paleozoic, Mesozoic sedimentary rocks, quaternary schist and quaternary or rece unconsolidated sediments. The Precambrian rocks are divided into three N-S running zones; the western high grade gneisses, the central low grades volcano sedimentary belt and eastern high grade belts (Amenti, 1989). According to this map sheet Jarmet wetland and its surrounding area geology are Paleozoic, Mesozoic sedimentary rock and quaternary rock covers (Fig.6.).

3.2.1 Paleozoic sand stones

These types of sand stones are occurred in the study area kebeles at Anfaredarge in north western parts of Jarmet wetland at lower elevation where thick Paleozoic sand stone succession. This sand stone covers 1.91 km^2 (2.35 %) of the study area Kebele.

3.2.2 Mesozoic sand stones

The Mesozoic sand stones are occurred in the study site Kebele at Kobidinsa, Suteketali and Anfaredarge in southern, eastern and south western part of Jarmet wetlands. It covers 73.97 km^2 (91.2%) of the study area Kebele.

3.2.3 Quaternary soils

Quaternary soils occur in eastern and north eastern parts of Jarmet wetland at Suteketali Kebele and Jarmet wetland itself. This soil units consists of three types of sediments; black cotton soils, reddish sandy soils and fluvial soils. The major occurrences of fluvial sediments are along the banks of Jarmet river. It covers an area 5.21km^2 (6.42%) of the study area Kebele.

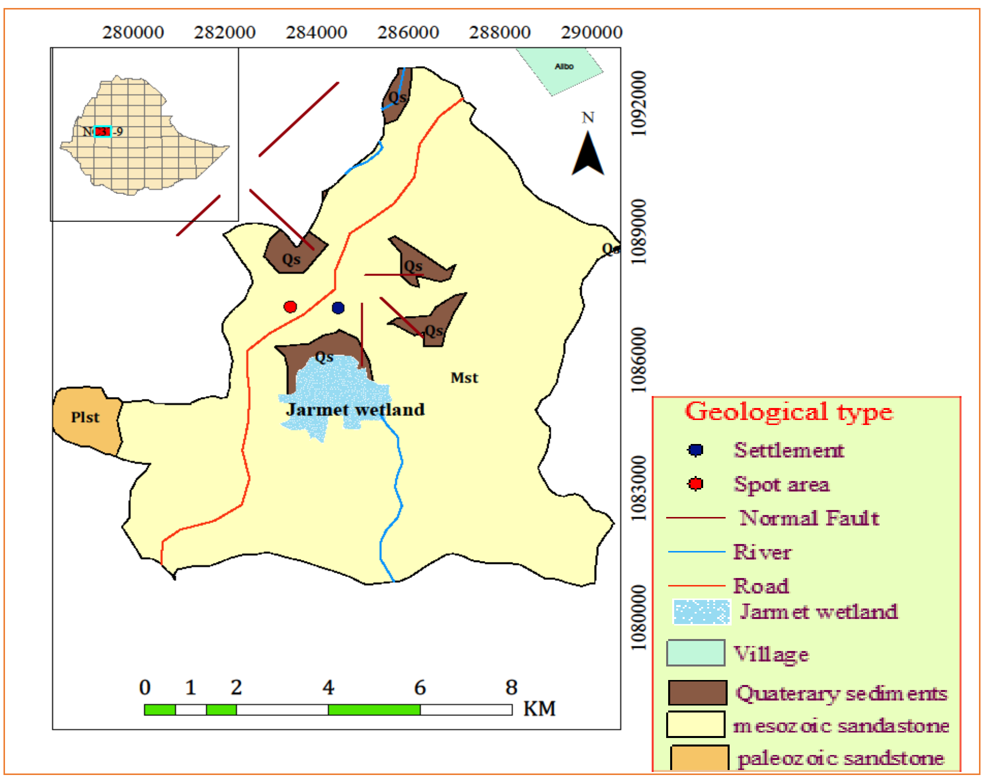


Fig.6. Geological Map of the study Area.

3.3 Soil, Vegetation and Wildlifes

3.3.1 Soil

The study area dominantly covered by two major soil types (Fig.7.). These are Haplic and Eutric lithosols and Haplic Phaeozems. In addition, it's surrounding small areas of Eutric and Vertic cambisols are found in the study site (FAO, 2003). Those alluvial soils are found at Jarmet wetland on plain areas along rivers and streams courses.

Lithosols (Haplic and Eutric): the FAO calls this soil lithosols, but USDA calls them orthents. These major soils occur on gently undulating lower foot slope ranges of 96.6 to 96.7 % of the study area. This soils are exceedingly shallow soils. They are often referred to as skeletal soils. It found in very steep, mountainous regions where erodible material is so rapidly removed by erosion the permanent covering of deep soil cannot establish itself. It covers 78.46km^2 of the study area.

Phaeozems (Haplic Phaeozems): these soil groups are formed on gentle to undulating topographic setting and are generally, well drained, deep, dark brown over dusky red. This types of soils are found in the north western part of study area at Anfaredarge Kebele. The area coverage by this types of soils area 2.63 km^2 (3.24 %) of the study area.

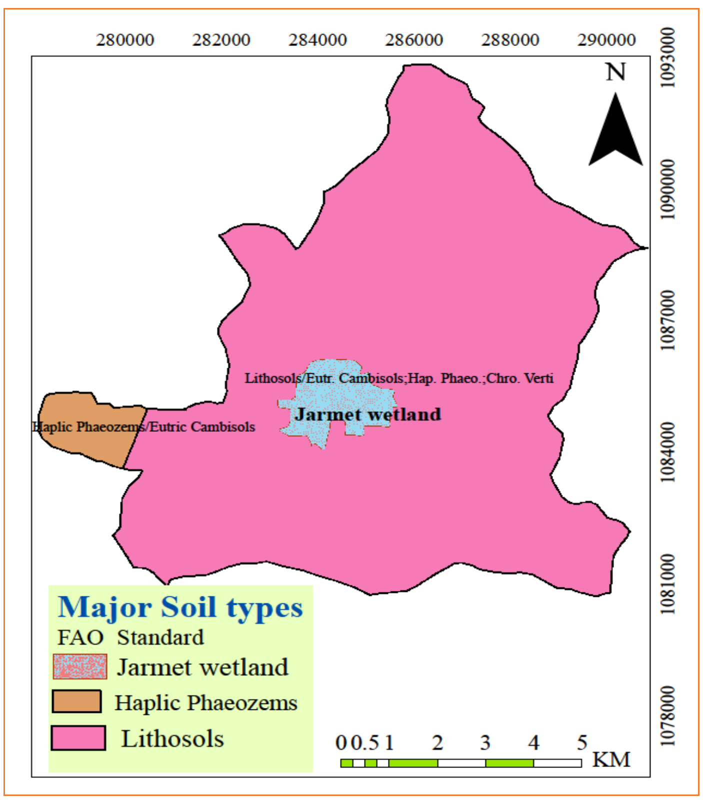


Fig.7. Major Soil types of the study area.

3.3.2 Vegetation

Vegetation means the assemblages of plant species and all ground cover by plants and the main elements of biosphere. Previously, the study area was a pristine wetland surrounded by ***moist afro-montane forest***. There are still mature individual plants of *Olea europea subs. cuspidata, Cordia Africana, Podocarpus falcatus, Ficus sycomorus, Phoenix reclinata, Syzygium guineense, Croton macrostachyus* and *Ficus vasta* scattered across the study area.

3.3.3 Wildlife

Wildlife is a collective name for animals that have not been domesticated or tamed and are usually living in natural environment. The wetland and the surrounding forest of the study area were once a home to a variety of animals. Animals such as reedbuck, leopard and wolf were once common in the wetland but now absent. Although their number is very much smaller compared to the disturbance of the wetland and forest, there are still colobus money, aardvark, wild pig, bush buck, rabbit and python in the remnant pockets of forests. Examples are marabou stork, harmerkop and white cheeked turaco are a common bird species in the area.

3.4 Elevation Data

Topography is important for wetland and its surrounding environment characterizations. The wetlands are topographically low lands and hence DEM data offers a fine opportunity to delineate low lands from up lands. Slope gradient (slope) and orientation (aspect) are primary attributes derived from digital elevation data. The elevation data of this study was derived from NASA shuttle radar topographic mission (SRTM), which was flown on board of the space shuttle mission in February, 2000. It was reprojected from spherical coordinate system (latitude and longitude) into geocover coordinate system (UTM Zone 37) and was used to derive a number of matrics by fitting a quadratic surface to digital elevation data for a 3x3 size window and taking the appropriate derivative using global mapper and Arc GIS software topographic modelling package. These include, contour, drainage and wetland boundary (Fig.8).

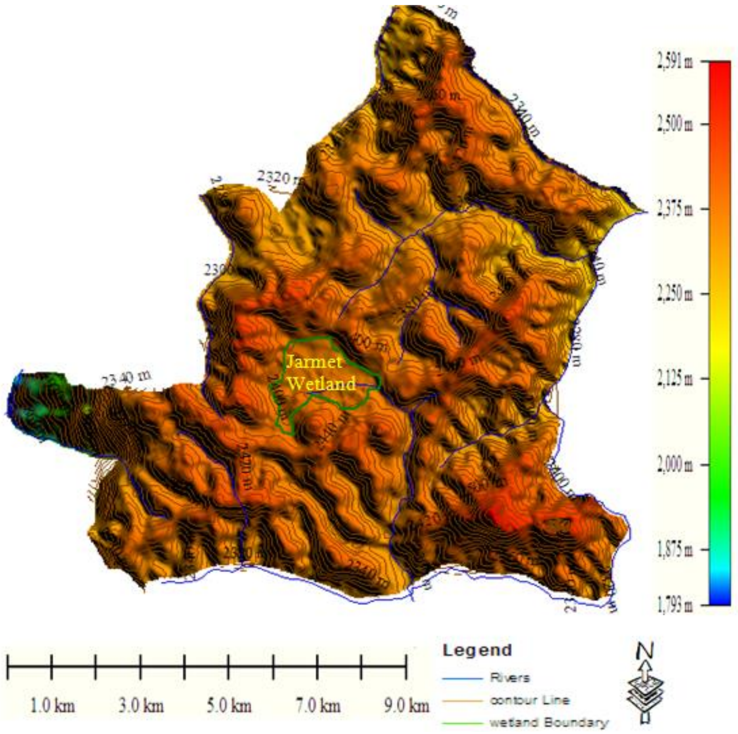


Fig. 8**.** Elevation map of the study area

3.5 Population

The population distribution of the study area is not uniform over years. A relatively dense population is observed in Suteketali kebeles. The settlement is highly dependent on the availability of waters, farmlands, fertile soils, and roads and proximate to the wetland area. The study area is dominantly in habited by Oromo ethnic group. There are also some Amahara people living in Anfare darge Kebele. Afan Oromo is the working language in the area. The total land area of the study site is 8,113 hectares and total population is 14,952. Hence, the crude population density of the study area is184.3 persons per km^2. Based on data CSA (2007 & 2010), topographic map of 1982/83 and the Woreda Agricultural Office (2011), the population of the area has increased between 1982/83, 2007 and 2013 (Fig.9.).

Furthermore, Table 4 given details of the population of the area.

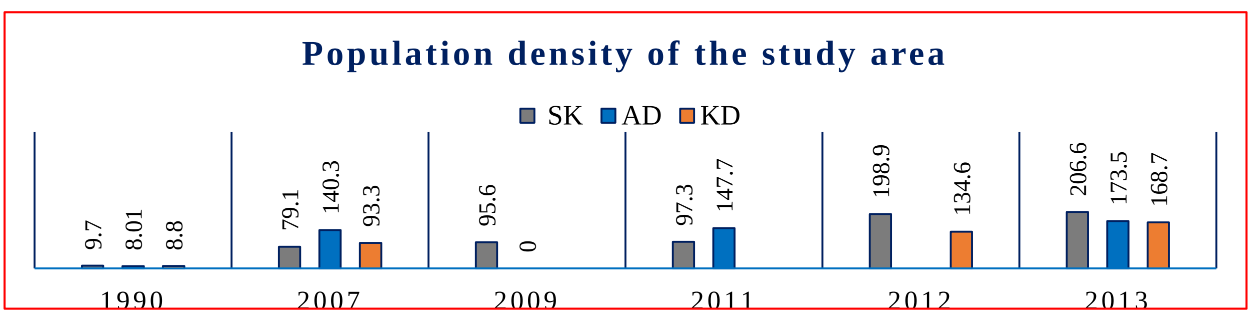


Fig.9. Population density of the study area

Table 5. Population density, household and housing units between, 1990, 2007 and 2013.

No.	Geographical area of rural kebeles	Year	Population_distributions			No. of households	No. of housing units	Land area(km²)	Population density per (km²)
			both sexes	Male	Female				
1	Suteketali	1982/3	786	370	413	244	271	30.105	9.7
2	Anfare darge	1982/3	650	300	350	202	224	25.513	8.01
3	Kobidinsa	1982/3	711	310	401	221	245	25.511	8.8
1	Suteketali	2007	2,382	1,241	1,141	439	420	30.105	79.1
2	Anfare darge	2007	3,579	1,708	1,871	742	727	25.513	140.3
3	Kobidinsa	2007	2,381	1,222	1,159	430	418	25.511	93.3
1	Suteketali	2009	2,879	1,512	1,367	1,325	426	30.105	95.6
2	Suteketali	2011	2,929	1,539	1,387	1,318	440	30.105	97.3
3	Anfare darge	2011	3,769	2,279	1,490	1,279	804	25.513	147.7
1	Kobidinsa	2012	3,433	2,234	1,168	1,165	480	25.511	134.6
2	Suteketali	2012	5,987	3,179	2,808	2,712	765	30.105	198.9
1	Anfare darge	2013	4,429	2,429	2,000	1,629	523	25.513	173.5
2	Kobidinsa	2013	4,304	2,170	2,134	1,824	558	25.511	168.7
3	Suteketali	2013	6,219	3,272	2,947	2,170	770	30.105	206.6

Source: CSA (2007, 2010, topographic map, 1990 and Woreda Agricultural Office, 2011)

3.6 Socio Economic Activity

The study area comprises of people from three kebeles with diverse socio economic activities. The diverse agro-ecological setting is a result of wide range of altitude and homogeneity of crop identities of kebeles makes the area support different livelihood systems. The economic base of the community in the area is agriculture (crop production and animal husbandry). However, agriculture seemed to dominate all other livelihood activities.

3.6.1 Agriculture

Agriculture is the mainstay of the Ethiopian economy. It generates over 45% of the GDP and 90% of the total export earnings of the country. It is also estimated that agriculture provides employment for about 85% of the labor force (MEDaC, 1999). The contribution of agriculture is obvious in rural kebeles of the study areas where it is one of the major economic activities and their employment. According to the agricultural bureau report (2011) of the woreda recorded about 4,205.7 ha, 380 ha, 48.3 ha, 1,285.4 ha, 1,396.6 ha, 482.5 ha, 82.75 ha, 11.25 ha of the study area was cultivable land, potential arable land, land reserved for future crop cultivation, grazing land, forests, wetland, barren and degraded land and other accounted for the remaining respectively. In the area during this periods agriculture is dominantly covered 51.8% of the study area. The farm size per households ranges from maximum 6 hectares and minimum 0.25 hectares. However, in the study area agriculture is characterized by mixed farming where farmers employ traditional technologies of farming over centuries.

3.6.1.1 Crop Production

A crop production is any cultivated plants that is harvested for food, clothing, livestock fodder, biofuel, medicine or for other uses. In the area population produce different type of crop for their livelihoods. The main crop types produced in the area are *teff, wheat, barley, maize, millet and sorghum from* ***cereals***; *horse beans, peas and haricot beans from* ***pulse.*** The additional crop type produced in the area are *coffee and chat from* ***permanent crops***. *Peppers, Ethiopian cabbage, head cabbage, tomato and pumpkin from* ***vegetables***. *Beet root, carrot, onion, garlic, ginger, potato, sweet potatoes from* ***root crops***. The ***local cash crops*** in the area are *Guizotia, coffee, chat, rapeseed, and linseed*. These oil seeds and cash crops are supplied to central markets in large quantities. All of those crops are the source of income for the population of the study area kebeles. The farmers of the study area practice traditional and modern method of maintaining soil fertility; the traditional are like fallowing, crop rotating and manuring. The modern methods are terracing, inter cropping and contour ploughing.

3.6.1.2 Animal Husbandry

Animal husbandry is a branch of agriculture concerned with the care and management of livestock. It deals with the feeding, breeding housing and health care of livestock for getting maximum benefit. Ethiopia has the largest livestock population in Africa and tenth in the world (FAO, 2006). In Ethiopia livestock covers 40% of gross agricultural outputs. Livestock are also the main sources of income and are closely linked to the social and cultural lives of Ethiopian population and the study area community. In the study area the major type of livestocks include, *cattle, sheep, goat, ass, mule, horse and oxen* are being reared as domestic and subsistence animals with traditional techniques and practices. In the study area Oxen are the sole sources of power for plowing while, donkeys are important animals for transportation of agricultural and non-agricultural products. Horses are dominantly used for human transport purpose. Livestock and livestock products play an important role in the socio-economic development of the study site kebeles. It helps as a source of security and supplementary cash income for rural agricultural households. It is the major source of livelihood for the population of the area through, dairy product (milk and yoghurt), land management (i.e. the grazing of livestock is sometimes used as control weed and under growth) and for fertilizers. In the area society used manure as natural organic fertilizers by spreading on their fields to increase crop yields. It is also used to make plaster for walls and floors and can be used as fuel for fires.

CHAPTER FOUR

RESEARCH METHODS AND SAMPLING TECHNIQUES

4.1 Research Methods

The land use/land cover change of Jarmet wetland and its surrounding area was analyzed using GIS and remote sensing techniques. For the purpose of the current study both primary and secondary data sources were used. Primary data source include semi structured questionnaire, key informant interview, focus group discussion and satellite images. This was complemented by a number of qualitative and quantitative techniques. Secondary data sources include population data, geological map, soil map, meteorological data and topographic map. Several investigations was conducted in selected three study kebeles in the form of questionnaire survey, GPS survey and visual observation was also made to verify satellite image information.

All collected and gathered primary and secondary data have been processed manually and using computer to manipulate the data in accordance with the objectives and guidelines of the research. The methodological steps employed in this thesis are shown in (Fig.10.) below. The workflow commences with data elaboration (1), which included, satellite image download, layer stacking, pre-processing and processing of raw material and creating LULC (land use/ land cover) classification plan and accuracy assessment. Following step (2) involved LULC mapping and analyzing, change detection and error matrix analysis and impacts of LULC change analysis. Finally, conclusion and recommendation of the study are conducted.

For this study many computer aided interpretation of images was conducted using ERDAS Imagine 2010, DNR Garmin5.1 and ENVI 4.7 softwares were used for satellite image processing for wetland and environmental change analysis, for change detection analysis, for land use land cover analysis and for accuracy assessment. Global mapper 11, 3DEM and ARCGIS 9.3, were used for GIS based DEM processing, MS excel was also used for analysis of meteorological data and population density.

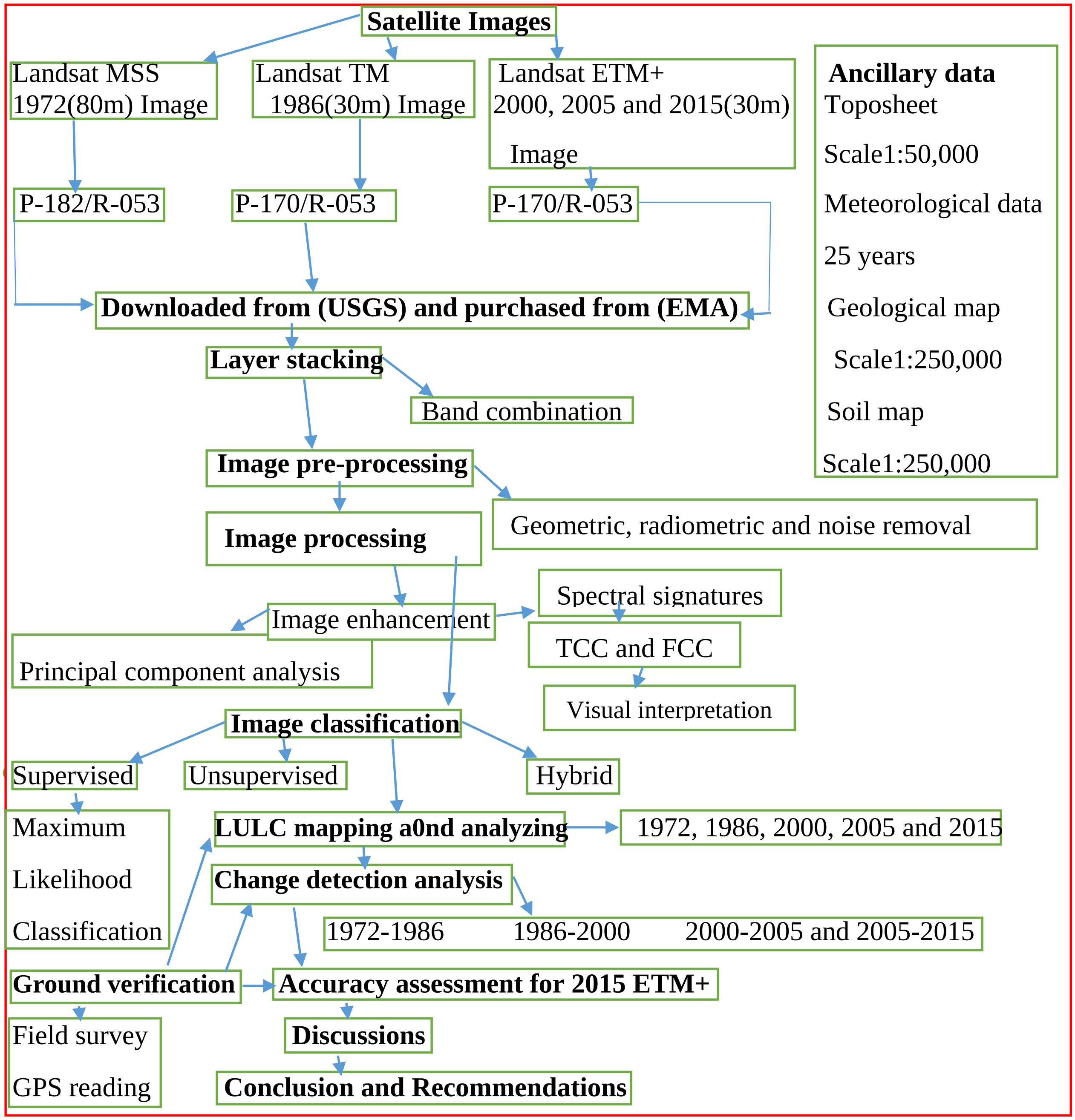


Fig.10. GIS and Remote Sensing methodology flow charts

4.2 Conceptual Frameworks

The conceptual framework of the study is given in (Fig.11) below. This figure shows the interactions of three major factors, namely, social factors, natural resource factors (environmental opportunities and constraints) and their ultimate outcome, local development.

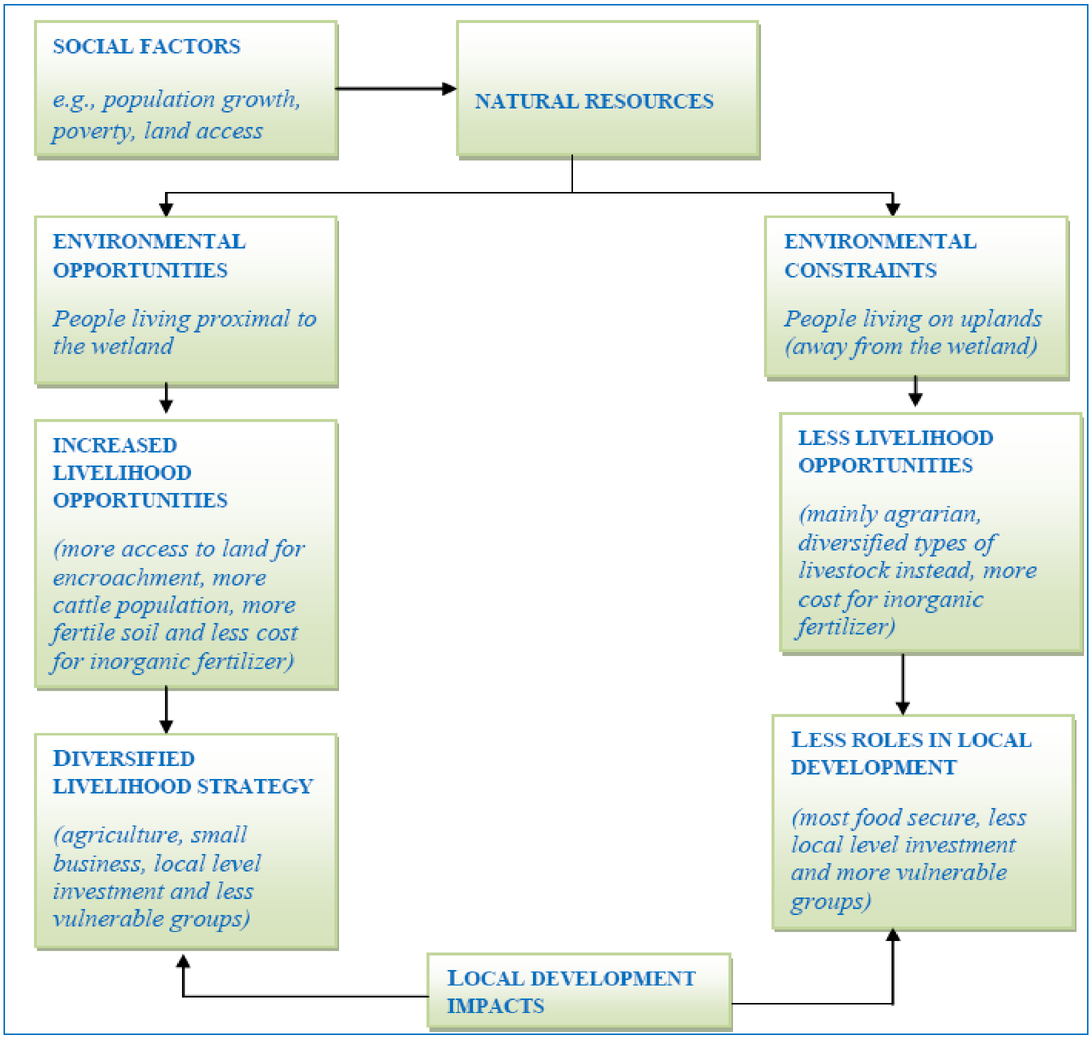


Fig.11. Conceptual framework of land use/land cover drivers.

4.3 Reconnaissance survey

Before collecting field data, a short reconnaissance survey was undertaken to understand the environmental and social settings of the study area. This survey was assist further refinement of the data collection tools and create a mental impression of the study area. A field reconnaissance survey taken (1-30 August 2014 and February 12-march 6, 2015) for selecting training sites and representative of different classes mapping. The 32 classes were interpreted and merged into 6 preliminary land cover classes during the initial field reconnaissance to create the land use/land cover map. Those land use/land cover classes are; wetland, plantation, farmland, grassland, Shrubland and forest. Although**,** field reconnaissance surveys will be conducted within the study areas to determine the major types of land use/land cover. Such data would be used in two aspects of the mapping of land use land/land cover. Firstly, it will aid in land use /land cover classification, by associating the ground features of a specific type of land use /land cover with the relevant imaging and spectral characteristics. Secondly, ground data will be used for accuracy assessment of the developed land use/land cover maps.

4.4 Sampling Techniques

The sample size of this study included 3 kebeles namely; Suteketali, Anfare darge, and Kobidinsa. Also, it includes 74 respondents selected by random and non-random sampling techniques. A land cover classification system was designed in which multisource land cover data were classified into 6 land cover types. Stratified random sampling, where each land cover category may be considered a stratum, is frequently used in such cases. In addition, descriptive research method and stratified sampling techniques were used to evaluate and describe the quality of classified images.

4.5 Data Type and Sources

In order to analysis of wetland and environmental change over years the Landsat 5 TM 1986, Landsat 7 ETM+ 2000, 2005 and 2015 images with 30m resolution and Landsat MSS 1972 with 80m resolution, were downloaded from the earth science data interface (ESDI) website produced by GLCF or USGS and purchased from EMA. Hand held GPS was also used for collecting and classifying land categories of the study area and delineating the boundary of wetland. In addition, for this study both spatial and non-spatial (attribute) data are used. The spatial data include topographical maps, SRTM data and satellite imageries. The non-spatial data include responses from questionnaires, field survey, focus group discussions and interviews.

4.5.1 Primary data source

A field work to the study area focuses on collecting socio-economic data and verification (ground truthing) of the preliminary outputs of the GIS. The following tools are used for collection of socio-economic data.

4.5.1.1 Semi-structured questionnaire

Semi-structured questions were developed to examine Jarmet wetland and environments of surrounding area over years. Were administered semi structured questionnaire among sixty (60) households randomly and non-randomly selected from within 2km to 5km distance from boundaries of the sampled wetland. This included 30 households selected from the wetland and 30 households from the uplands. The uniformity in the total number of local residents' questions was due to sparse settlements and limited access to settled areas in the sampled areas. Within the selected households, the surveys targeted all households especially the head of households, but for practical reasons in few instances those some were not at home. The most knowledgeable and agricultural experts of the kebeles participated.

For the conducting of each questionnaire the purpose of the study was explained each respondents as purely scientific and academic. Since, some respondents accessed wetlands and other natural resources illegally, some lacked knowledge about wetland and other natural environment use, some are for expanding agricultural land foster to food security and for increasing their incomes and others are lack of sufficient fertile land for administering their families. For those causes, wetlands and environments of the surrounding areas are extremely degraded. Respondents were in addition assured of anonymity and confidentiality and that participation was purely voluntary. All questionnaires were carried out in a common local language for each study sites.

4.5.1.2 Key informant interview

A total of 6 key informants (3 from the wetland and 3 from the upland) were selected. A guided field walk with each key informant was used to collect data on the status of the natural environment (mainly natural forests, e.g. grasslands, Shrubland, wetland and etc.) and extent of agricultural land use. GPS points was recorded to show this information on maps.

4.5.1.3 Focus group discussions (FGDs)

Focus group discussion (FGD) is a form of qualitative research in which a group of people were asked about their perceptions, opinions, beliefs and attitudes and contributes towards; wetlands and environmental changes of Jarmet and its surrounding areas. Focus groups have a high apparent validity-since the idea is easy to understand and the results are believable. In this study focus group discussion was used to collect data from 4 key informant farmers and 4 agricultural expert to assess, identify and collect data on the LULC changes and factors that drive these changes.

4.5.1.4 Boundary of the wetland

Each every corners of the current wetland were recorded using a Garmin GPS. These data was used to calculate the area of the existing wetland and detection of changes. The study seeks ground truthing, before the ground truthing map of the study area was printed and used as guide to locate and identify features both on ground and on the image data.

The geographic locations of the identified features on the ground was not defined. These were needs ground survey for delineating the boundary of wetland and its surrounding environments.

4.5.1.5 Satellite Images

All satellite images except those of year 1972 and 2005 were bought from the Ethiopian Mapping Agency. In order to compare the wetland and environment of Jarmet and its surrounding area change analysis many satellite image data of the area are used. Those satellite images are Landsat TM of 1986, ETM+ of 2000, 2005 and 2015 and MSS of 1972. All those images were georefenced to universal transverse Mercator projection of WGS84 coordinate system to Adindand zone 37 Clarke1880 spheroid.

Table 6. Characteristics of the spatial data used for land cover change mapping in the study area.

Size No.	Type	Format	Path/row	Spectral bands	Scene size	Date of acquired and source	Resolution s(m)
1.	Topographi c maps	Analogue	Sheet no.0937	______	_______	January1982 to october1983 EMA	1:50,000
2.L5	Landsat TM	Digital	170/053	1,2,3,4,5,7	185X185km	01-03-1986 USGS	30m
3.L7	Landsat ETM+	Digital	170/053	1,2,3,4,5,7	185X185km	01-04-2000 USGS	30m
4.L7	Landsat ETM+	Digital	170/053	1,2,3,4,5,7	185X185km	01-31-2005 GLCF	30m
5.L7	Landsat ETM+	Digital	170/053	1,2,3,4,5,7	185X185km	02-11-2015 GLCF	30m
6.L1-4	Landsat MSS	Digital	182/053	1,2,3,4	185X185km	12-09-1972 USGS	60m
7.	Geological maps	Analogue	Sheet no NC-37/9	----------	------------	August,2000 (GSE)	1:250,000

The scenes with worldwide reference system (WRS2) path 170/row 053 was acquired for Landsat TM and ETM+ images, whilst the scene WRS1 path 182/row 053 was acquired for Landsat MSS image with which fully cover of Jarmet wetland and environments of surrounding areas.

For this study, the dry season is the best period to detect the wetland and environments of surrounding area change, because in Ethiopian calendar satellite images taken from rainy season especially during June to December are very difficult for analysis. Because during this period everything is green and identification of wetland from grassland and vegetation cover from agricultural land and bare land from bush land are very difficult. For those reasons, satellite images were selected and downloaded during dry season December to march for clearly identify wetland and environments of surrounding area, to detect the changes and analysis of land use/land covers. But, for ground truth field survey is taken both in rainy and dry seasons for knowing and recording GPS point what is actually found on the ground.

4.5.1.5.1 Landsat Thematic Mapper (TM)

The Landsat thematic mapper (TM) sensor, first launched on Landsat 4 in1982, improved spectral, radiometric, temporal and spatial resolutions over Landsat multispectral scanner (MSS). For this study Landsat TM imagery used for wetland and its surrounding land cover mappings. The most important Landsat TM bands for wetland identification is band 5 because of its ability to discriminate vegetation and soil moisture levels. Landsat TM band 3, 4 and 5 are usually the best combination of bands for wetland and environmental change detection. In the Landsat TM more pixels are needed and some scientists believe that as many as 25 pixels are needed to be confident of certain classification units (FGDC, 1992). For these reason for present study 80 pixels were used for Landsat TM satellite images classification

4.5.1.5.2 Landsat Enhanced Thematic Mapper plus (ETM+)

Landsat ETM+ was launched in 1999. For this study Landsat ETM+ are used for wetlands and environmental change analysis band 5, 4 and 3 because it aids to high light and identify wetlands from other land covers. The combination of ETM+ band 4, 3 and 2 are displayed false colour composite (Red, green and blue) enhance wetlands depictions. ETM+ band 4 is the peak reflectance of green vegetation and ETM+ band 3 senses in strong chlorophyll absorption regions and strong reflectance region for soils and ETM+ band 2 is important for discrimination of vegetation.

4.5.1.5.3 Landsat Multispectral Scanner (MSS)

The oldest available data sets for the study area are Landsat MSS achieved data at EROS data center. This Landsat was first launched in 1972. The MSS onboard Landsat 1 had swathing pattern with an IFOV being 56 meters in the across- track direction and 79 meters in the along-track direction. This Landsat data are useful for this study and it uses for spectral discrimination of large vegetated wetlands. It also important for resampling and geometrical registering of satellite images by using false colour composite of satellite images band 3,2 and 1

4.5.2 Secondary Data Sources

Data on population of the study areas was collected from Central Statistical Agency (CSA) of Ethiopia. Enumeration areas will be targeted to ensure the quality of the data and its use for understanding changes in the wetland and the surrounding environment. Other secondary data such as spatial data of the study area was extracted from Ethio GIS. Topographic map of 1:50,000 scale was used as guide to identify features, which were used as ground control point for image referencing. In the absence of other historical land use/land cover information these maps proved to give an important insight about the historical situation in terms of land cover in better details than the historical imagery.

4.6 Data Analyses

Descriptive statistics as embedded in MS Excel was used to analyses of rainfall and temperature data. Landsat images was geo-referenced and the relevant bands also further analyzed in Arc GIS 9.3 platform to produce unsupervised and supervised land use changes. For this study, satellite data from the oldest (1972) to the present (2015) were used for land use change analysis of the study area. As a result, five sets of changes was compared. These are 1972 – 1986, 1986 – 2000 and 2000 – 2005, 2005-2015 and 1972-2015. ERDAS Imagine 2010, ENVI 4.7, Arc GIS 9.3 and Global mapper 11 were used for all image analysis and image processing. Landsat bands was used for wetlands and environmental classification analysis.

CHAPTER FIVE

SPATIAL DATA PROCESSING AND ANALYZING

5.1 Satellite Image Processing and Classification

5.1.1 Image Pre-Processing

Every raw remotely sensed image contains a number of artifacts and errors Mather (1999). For corrections of these errors image pre-processing is very important. Image pre-processing is sometimes called as image rectification or restoration and it used to correct image data from distortions or degradations that stems from image acquisitions process (Lellisand and Keifer, 2004). The image pre-processing procedures consist of radiometric, geometric and noise removal. Depending on satellite image acquisition and atmospheric problem of Landsat TM, ETM+ and MSS for this study geometric correction, radiometric correction and noise removal were used.

5.1.1.1 Geometric Correction

According to Lellisand (2004) the geometric correction process was normally implemented as two step procedure. First, the distortions that are systematic or predictable were considered. Second, those distortions that are essentially random or unpredictable were considered. In those of two methods for this study the random distortions and residual unknown systematic distortions were used for correcting and analyzing well distributed ground control points (GCPs) occurring in an image. In this study Landsat TM, ETM+ and MSS was imported and geocoded using ERDAS Imagine based on the provided image control points. Geometric registrations between those three Landsat images is expressed in terms of an acceptable total root mean square errors (RMSE), which represents a measure of deviation of corrected GCP coordinate values from the original (reference GCPs) used to develop correction model.

For the RMSE several authors recommended maximum tolerable limit of <0.5 pixels (Jensen, 1996), but others have identified acceptable RMSE values ranging from >0.2 pixel to <0.1 pixels, depending on the type of change being investigated (Townshend et al., 1992). For this study the RMSE of 0.002 was achieved. The orthorectification was done in the original Universal Transverse Mercator (UTM), datum WGS84 projection after which it was reprojected to geographic (datum; Adindand, zone 37 Clarke 1880 spheroid).

5.1.1.2 Radiometric Correction

As with geometric correction, the type of radiometric correction applied to any given digital image dataset varies widely among sensors (Lellisand and Kiefer, 2004). For this study, haze correction routines are often applied for Landsat MSS images with image acquired on 09-12-1972, because this satellite image have a few cloud for the correction of this cloud radiometric corrections were used in a great attention than other images. Haze represents the scattered path radiance, in the imagery and reduces image contrast. Haze compensation procedures are used to minimize the influence of path radiance effects of this satellite image. The effects of atmosphere up on remotely sensed data are part of the signal received by the sensing device. So, it was important to remove atmospheric effects. For such correction of this study the true color and gray pixel subtraction techniques used to remove haze from the top and left of satellite image of 1972. The other images of 1986 TM, 2000, 2005 and 2015 ETM+ were registered similar corrections according to the 1972 satellite images.

5.1.1.3 Noise Removal

Image noise is any unwanted disturbance in image data that is due to limitation in the sensing, signal digitization or data recording process (Lellisand, 2004). Noise can either degrade or totally mask the true radiometric information content of digital image. Hence, noise removal usually precedes any subsequent enhancement or classification of the image data. As with geometric restoration procedure, the nature of noise correction required in any given situation depends up on whether the noise is systematic (periodic, random, or some combination of the two). For this study, random or nonsystematic noise removal was used for handling the variation of pixel values (bit error) of satellite images. Also, it is used for restoration of an image to as close an approximation of the original scene as possible.

5.2 Image Processing

The first methods were subjected to principal component analysis (PCA) then apply clustering to the first principal component to classify and enhance the wetlands and environments of the surrounding areas. In the second method original remotely sensed satellite images were classified using unsupervised ISODATA algorithm and supervised classification method used. And these methods compared and used to analysis wetlands and environmental changes for estimate wetlands and environmental loss.

5.2.1 Image Enhancement

Image enhancement techniques is improve the quality of an image as perceived by human (Jensen, 1996). These techniques are most useful, because many satellite images where examined on a colour display give in adequate information for image interpretation. Enhancement operations are normally applied to image data after the appropriate restoration procedures have been performed. Noise removal is an important precursor to most enhancements. Without it, the image interpreter is left with the prospects of analyzing enhanced noise. Three techniques for digital image enhancement can be categorized as, contrast manipulation, spatial feature manipulation or multistage manipulation. For this study, multistage manipulation are used for identifying and analyzing vegetation and reduce the number of bands and apply clustering.

5.2.2 Principal Component Analysis

Principal component analysis is a pre-processing transformation that creates new images from the uncorrelated values of different images (Jensen, 1996). PC images may be analyzed as separate black and white images, or any three component images may be colour coded to form a colour composite. PC enhancement techniques are used in this study; for Jarmet wetland and its surrounding environment areas where little a priori information concerning on the satellite images.

5.3 Image Classification

The overall objective of the digital image classification procedures automatically classify all pixels in an image into land classes or themes (Lellisand *et al*., 2004). It is a powerful technique to drive thematic classes from multiband image data. It performed for extraction of distinct classes or themes, land use/ land cover categories from satellite imagery. Image classification method are divided into three method namely; supervised, unsupervised and hybrid. For this study among the various classification methods, supervised and unsupervised classification procedures are used for satellite image classification.

5.3.1 Unsupervised Classification

An unsupervised classification is theoretically better suited to application in a highly heterogeneous of wetland and its surrounding environment changes (Harvey and Hill, 2001). In the unsupervised classification, the image data is first classified by aggregating them into natural spectral grouping or clusters present in the scene. Then the image analyst determines the land cover from these spectral grouping the classified image to ground reference data (Lellisand and Keifer, 2004).There are several clustering method that can be used for unsupervised classification. The most common used for unsupervised classification method are the iterative self-organizing data analysis technique (ISODATA).The ISODATA classifier refines clustering by splitting and merging of clusters. For this study, the1972 MSS and 2015 ETM+ Landsat image was subjected to unsupervised classification to produce land use/ cover class classification. For this classification 6 land cover classes are produced by merging unknown distribution of pixel values in the image data. These land use/ land cover classification will be produced by using Arc GIS 9.3 and ERDAS IMAGINE 2010, before the field work. The true color composite (TCC) and false color composite (FCC) is used for assessing visualization of the land uses.

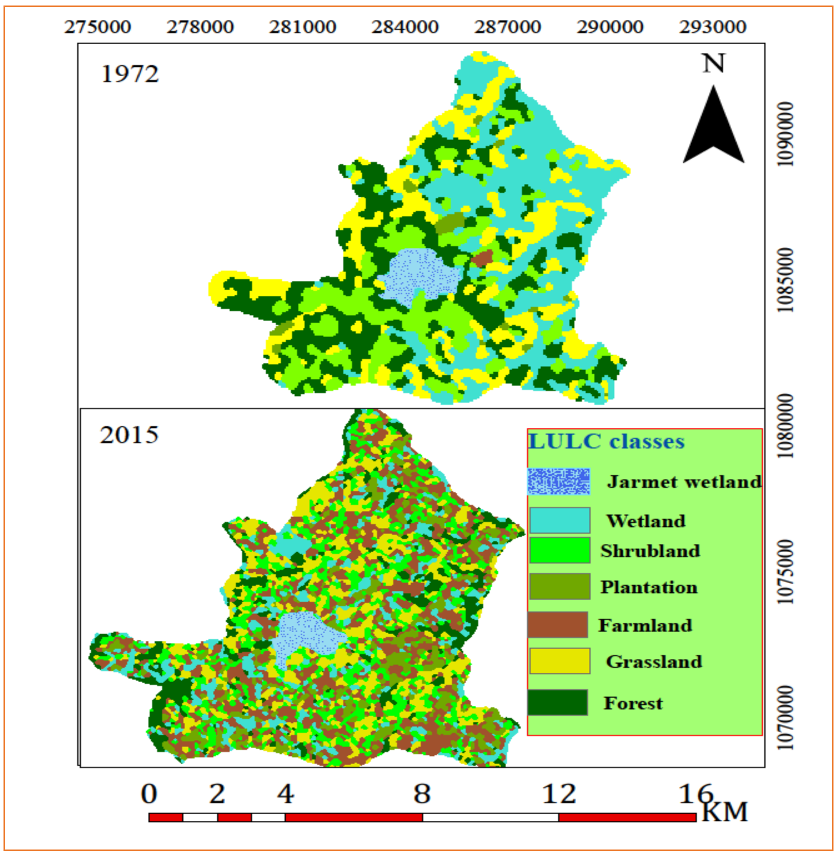


Fig.12. Unsupervised classification of Landsat MSS 1972 and 2015ETM+.

5.3.2 Supervised Classification

In the supervised classification system, the image analyst supervises the pixel categorization processes specifying numerical descriptors (groups of digital number (DN) values) of the various land cover type present in scene, to the computer algorithm. To do this representative sample site of known cover types, called training areas are used to compile a numerical interpretation key that describes the spectral attributes for feature type of interest (Lellisand *et al*., 2004). For the present study, Landsat MSS 1972, TM 1986, and ETM+ of 2000, 2005 and 2015 were independently classified using the supervised classification method of maximum likelihood algorithm. This method is the most common method and widely used for supervised classification in remote sensing image data analysis (Richards, 1995). In maximum likelihood classification assumes that for all classes and the input data in each band follows the Gaussian (normal) distribution function. A pixel has a certain probability of belonging to a particular classes. These probabilities are equally identifies and locates land cover types that are known a priori through combination of personnel experience interpretation of satellite images, map analysis and field works (Jensen, 2005). Accordingly, representative points thought to represent the various land cover classes were marked using Garmin GPS 72 during the ground truth survey. Over 294-337 ground truth sampling points 6 land use/ land cover classes are selected. Those classes are namely: wetland, plantation, shrubs, grasslands, forests and farmland. For each individual class classification 45 and above GPS points are taken. Then, the supervised classification spectral signatures are collected from specified locations in the imagery by digitizing various polygons overlaying different land cover types. These spectral signatures are used to classify all pixels in the scene. The 294-337 ‘ ‘user defined polygon” were selected from the whole study area by drawing area of interest (aoi). In this classification process, aoi function reduces the chance of underestimating class variance since it involved a high degree of user control. After the classification process, all signature sample points were grouped as class by ‘‘recode” function. Following this, supervised classification land use/land cover classification has been carried out using ERDAS Imagine 2010 and ENVI 4.7 software for time series satellite image of Jarmet wetland and its surrounding environmental change analysis.

5.4 Post Classification (Smoothing)

Classified data often manifest a salt and pepper appearance due to the inherent spectral variability encountered by a classifier when applied on a pixel by pixel basis (Lellisand and Keifer, 2004). For example, in this study many forest and shrubs are severe pixels scattered throughout a farmland maybe classified as farmland crops or vice versa. In such situation it is often desirable to “smooth” the classified output to show only the dominant classification one means of classification smoothing involves the application of statistical filter. In such operation a moving window is passed through the classified dataset and the majority class within the window is determined. A majority/minority filter is a logical applied on classified image that consists of label rather than quantized counts and its simplest form involves the use of filter window, usually measuring 3x3 centered on the pixel of interest (Mather,2004). Two filters were used to manage these problems are; recoding and statistical filtering.

5.4.1 Recoding: the Idrisi recode model was developed to semi-automate the recoding process. In the model for the current study extract the area of recoded pixels and recodes the pixels and burns them back into the classified images.

5.4.2 Statistical Filtering: the classification process can produce areas of isolated pixels that differ from the majority class. These isolated pixels are a result of the complexity of separating land cover signatures in satellite image, or can reflect the actual heterogeneity of land cover. For example, in this study plantation area pixels are scattered in wetland area. For this reason, statistical filtering are used for combine to the majority class by applying 3x3 window pixel.

5.5 Classification Accuracy Assessment

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of classification process. The accuracy assessment is essentially a measure of how many ground truth pixels were classified correctly. According to Edwards *et al*., (1998) accuracy assessment is a crucial step in classification in order to check for errors propagated by the way data acquired, analyzed and converted from one form to the other. In this study accuracy assessment was done for recent satellite image of Landsat ETM+2015 for which the ground truth data is likely corresponding. Error matrix is one of the most common methods of expressing classification accuracy (Congalton, 1991). An error matrix is square array of numbers set out in rows and columns which express the number of sample units (i.e. pixels, cluster of pixels, or polygons) assigned to a particular category relative to the actual category as verified on grounds. The column usually represent the reference data while, the rows indicate the classification generated from the remotely sensed data.

The LULC maps was performed by using satellite image and field data with the help of GPS. For this study 207 ground truth points are taken for accuracy assessment classification. Overall accuracy, user’s accuracy, producer’s accuracy and kappa statistics were then derived from the error matrices. Using the simplest descriptive statistics overall accuracy is computed by dividing the total correct (i.e. the sum of major diagonal) by the total number of pixels in the accuracy assessment. Producer's accuracy is computed by the total number of correct pixels in a category divided by column total. User's accuracy in the other hand, the sum of correctly classified pixels divided by row total. The k ("KHAT") statistic is a measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier (Jensen, 1996). Conceptually, Ḱ can be defined as

$$\acute{K} = \frac{\text{observed accuracy - chance agreement}}{\text{1 - Chance agreement}}$$

In reality, k usually ranges between 0 and 1.

The KHAT statistic is computed as

$$\acute{K} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} . x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} . x_{+i})}$$

Where,

r = number of rows in the error matrix

Xii = number of observations in row i and column i (on the major diagonal)

Xi+ = total of observations in row *i* (shown as marginal total to right of the matrix)

X·+i = total of observations in column i (shown as marginal total at bottom of the matrix)

N = total number of observations included in matrix

Table 7. Error Matrix resulting from classifying training Set pixels for Landsat ETM+2015

Classified data	**Reference data**						Row total	OE%	UA%
	SHL	GL	FR	PL	WL	FL			
SHL	1	0	0	1	0	0	2	87.5%	50%
GL	1	15	1	1	0	3	21	25%	71.43%
FR	3	1	22	1	0	0	27	24.1%	81.48%
PL	0	0	0	16	0	0	16	0%	100%
WL	0	0	2	0	15	1	18	11.8%	83.33%
FL	3	4	4	5	2	105	123	3.7%	85.37%
Column total	8	20	29	24	17	109	207		
CE%	50%	28.6%	18.5%	0%	16.7%	14.6%			
PA%	12.50%	75%	75.86%	66.67%	88.24%	96.33%			

Producer accuracy (PA) Users accuracy (UA) Overall accuracy (OA)

(Omission error) (Commission error) 1+15+22+16+15+105/207=84.06%

SHL=1/8=12.50% SHL=1/2=50%

GL=15/20=75%   GL=15/21=71.43%

FR=22/29=75.86%   FR=22/27=81.48%

PL=16/24=66.67%   PL=16/16=100%

WL=15/17=88.24%   WL=15/18=83.33%

FL=105/109=96.33%   FL=105/123=85.37%

Note**:** SHL= Shrubland**,** GL= Grassland, FR=Forest, PL= Plantation, WL=Wetland**,** FL= Farmland**,** [blue box] **=** correctly classified pixels**,** CE=commission error and OE**=** omission error

Khat analysis is;

$$\sum_{i=1}^{r} =1+15+22+16+15+105=174$$

$$\sum_{i=1}^{r} = (xi+.x+i)=(2.8)+(21.20)+(27.29)+(16.24)+(18.17)+(123.109)=15,316$$

$$\acute{K}=\frac{207(174)-15,316}{(207)^2-15,316} = \frac{20,702}{27,533} = 0.7519$$

Omission errors correspond to non-diagonal column elements (e.g., 2 pixels that should have been classified as "wetland" were omitted from that category). Commission errors are represented by non-diagonal row elements (e.g., 2 "forest" pixels plus 1 "farmland" pixels were improperly included in the "wetland" category). The current study revealed an overall accuracy of 84.06% with kappa index of agreement of 0.7519 this was reasonably good overall accuracy and accepted for subsequent analysis and change detection. Sabins (1997) says that accuracy levels of more than 80% are considered adequate enough for reliable classification of land cover types. User's accuracy of individual classes ranged from 50% to 100% and producer's accuracy for each individual classes ranged from 12.50% to 96.33%. Higher producer accuracy means more pixels on the original image were correctly classified for a given class in reference plots. Higher user accuracy means more pixels on the map were actually classified into a given class. Farmland, wetland, forest and plantation area had a very high user's accuracy and producer's accuracy, but plantation area are not have very high producer accuracy. Which shows this classification did well detect farmland, forest and wetland area. The producer's accuracy of Shrubland, grassland and plantation were low 12.50%, 75% and, 66.67% respectively. That probably due to the confusion between Shrubland, grassland and plantation cover types.

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.1 Results

6.1.1. Remote Sensing and GIS Analysis of LULC Types and their Areal Extent of Jarmet wetland and its surrounding area.

Land is a complex and dynamic combination of factors like: geology, topography, hydrology, soil, micro climates and communities of plants and animals that are continually interacting under the influence of climate and people activities (Hudson, 1995 in Ermias Aynekulu *et al*., 2006). From visual and digital interpretations of the satellite imagery, different land use/land cover categories were distinguished for this study. So that it will be possible to investigate changes that occurred since 1972 to 2015 of satellite imagery for Jarmet wetland and its surrounding environment.

Table 8. Land use/land cover classification Scheme

Number	Land use/land cover type	Descriptions
1.	Wetland	The area where the water table is near or above the land surface covered by marshes, swamps, bogs, rivers and streams.
2.	Forest	These areas are regions covered with big trees of different species, with little or no human activities.
3.	Farmland	These are areas use for growing agricultural crops and appeared cultivated during growing season.
4.	Shrubs	Areas covered with small shrubs, thickets and grasses with little or no trees are referred to as shrubs and its height is less than 5m.
5.	Plantation	All areas of eucalyptus plantation and temporary clear field stands a waiting replanting within in eucalyptus plantation.
6.	Grassland	Lands predominantly covered with grasses, fobs, and grass areas used for communal grazing.

This study has demonstrated population and environmental changes of Jarmet wetland and its surrounding environment analysis by using spatial and attribute data. The developed methodology is general enough that it could readily be extended to LULC mapping in the study area. The LULC of the study area had changed dramatically during the period of 43 years. Their areal extents of this LULC classes are given into their classification below. The total classified of the study area including Jarmet wetland are 8,133 hectare.

6.1.1.1 Land use/land cover classification for Landsat 1972

The land use/land cover classification for 1972 is given in Fig.13. Six land use/land cover types were recognized during this period. These are wetland (2,228.7 ha or 27.5%), Shrubland (1,956.2 ha or 24.1%) and grassland (1,638.5 ha or 20.2%), forest (1,587.600 ha or 19.6%), farmland (523.1 ha or 6.4%) and plantation (179.2 ha or 2.2%). The table 9 revealed that the majority of land cover during this period is wetland and the small land cover is plantation.

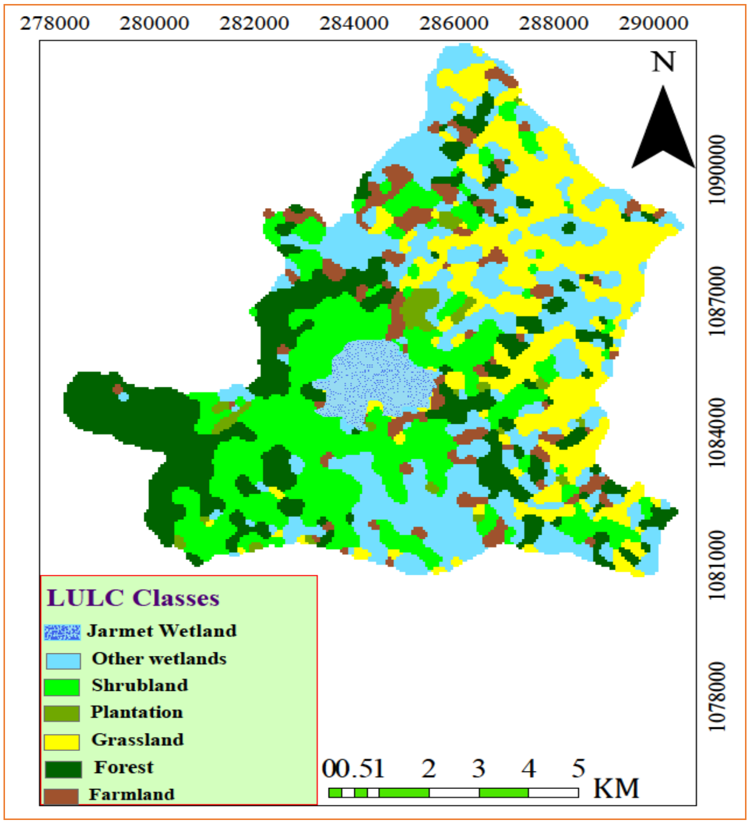


Fig.13. Land use/land cover map of the Study area in 1972

Table 9. Land cover classes of the study area in hectare and percent

S.N	LULC Classes	Area (ha)	Percentage (%)
1	Shrubland	1,956.2	24.1
2	Farmland	523.1	6.4
3	Plantation	179.2	2.2
4	Forest	1,587.6	19.6
5	Grassland	1,638.5	20.2
6	Other wetlands	1923.8	23.7
7	Jarmet wetland	304.9	3.8
8	Total	8,113.3	100.0

6.1.1.2 Land use/Land cover classification for Landsat 1986

The land use/land cover classification for 1986 from TM classified satellite image results showed that Grassland and forest accounting for 2,441.6 ha (29.7%) and 2,279.7 ha (28.1%) respectively. While, others like; Shrubland, plantation, wetland and farmland are; 693.4 ha (8.5%), 315.0 ha (3.9%), 991.4 ha (12.3%) and 1,442.2 ha (17.5%) respectively. Table 10 shows us most portion of the land use/land cover classes was Grassland during that period.

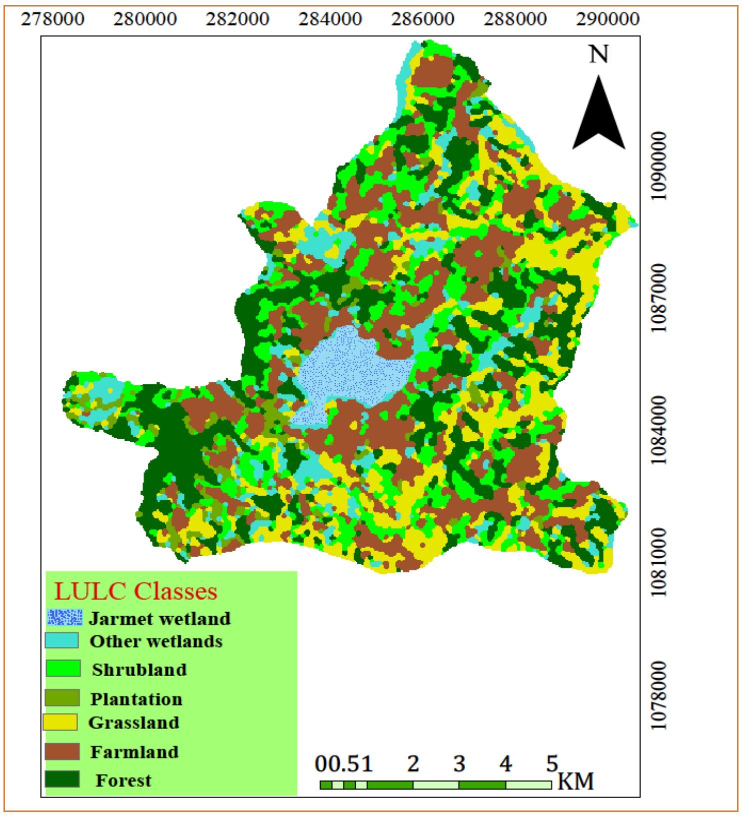


Fig.14. Land use/land cover map of the Study area in 1986

Table 10. Land cover classes of the study area in hectare and percent

S.N	LULC Classes	Area (ha)	Percentage (%)
1	Plantation	315.0	3.9
2	Forest	2,279.7	28.1
3	Shrubland	693.4	8.5
4	Farmland	1,422.2	17.5
5	Grassland	2,411.6	29.7
6	Other wetlands	686.5	8.5
7	Jarmet wetland	304.9	3.8
8	Total	8,113.3	100

6.1.1.3 Land use/land cover classification for Landsat 2000

The land use/land cover classification for 2000 from Landsat ETM+ classified satellite image for the study site kebeles including Jarmet wetland showed that Farmland and Forest on accounting for 2,495.5 ha (30.8%) and 1,932.3 ha (23.8%) respectively. While, Shrubland, grassland, wetland and plantation are, 1,518.4 ha (18.7%), 382.9 ha (4.7%), 1,435.8 ha (17.7%) and 348.4 ha (4.3%) respectively. During this period majority of the study area are covered by farmland and forest. Table 11 shows us land use land cover area extent of the study area.

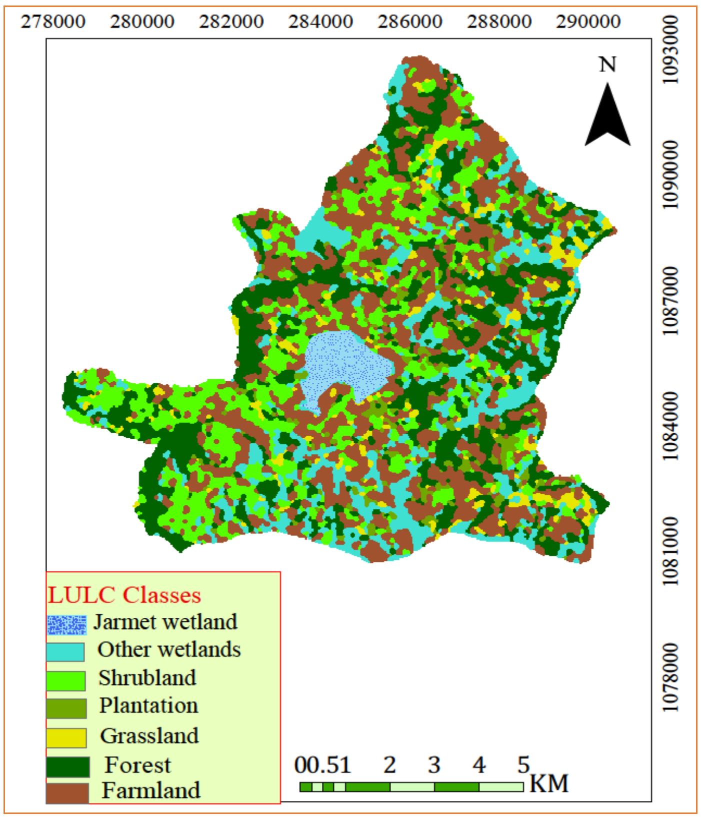


Fig.15. Land use/land cover map of the Study area in 2000

Table 11. Land cover classes of the study area in hectare and percent.

S.N	LULC Classes	Area (ha)	Percentage (%)
1	Shrublands	1,518.4	18.7
2	Grassland	382.9	4.7
3	Forest	1,932.3	23.8
4	Plantation	348.4	4.3
5	Other wetlands	1,200.8	14.8
6	Jarmet wetland	235.0	2.9
6	Farmland	2,495.5	30.8
7	Total	8,113.3	100.0

6.1.1.4 Land use/land cover classification for Landsat 2005

Furthermore, the land use/land cover classification for 2005 from Landsat ETM+ classified satellite image for the study area showed that Farmland, Forest and Grassland are accounting for 4,102.2 ha (50.6%), 1,496.6 ha (18.4%), 1,390.4 ha (17.1%) respectively. While, others like; Shrubland, wetland and plantation are, 263.3 ha (3.2%), 506.8 ha (6.3%) and 354.0 ha (4.4%) respectively. During this period half of the study area are covered by farmland.

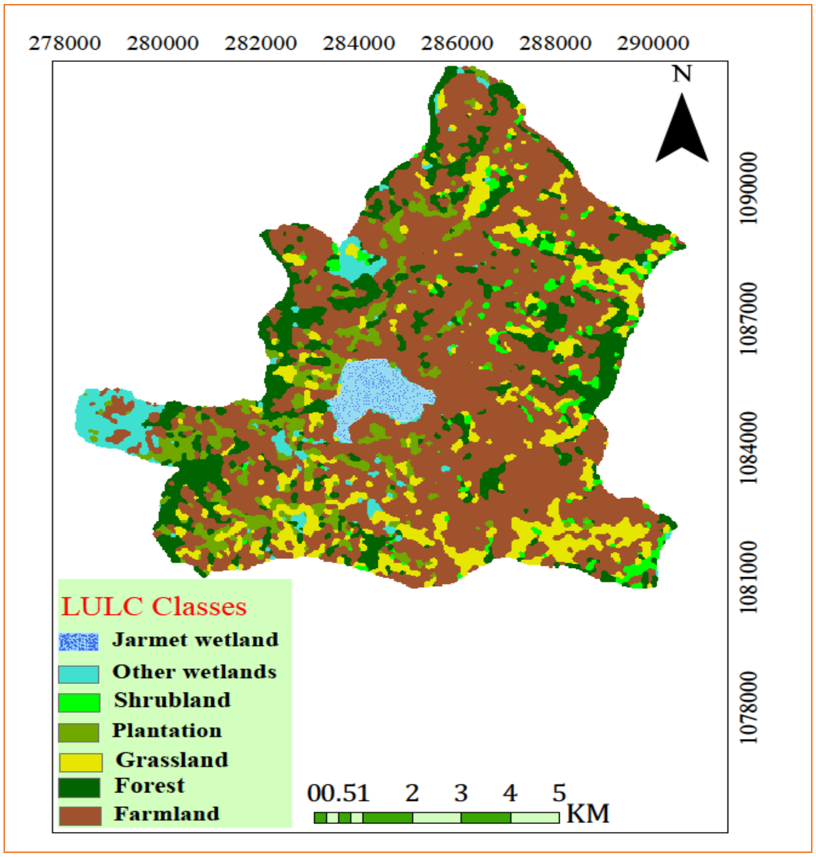


Fig.16. Land use/land cover map of the Study area in 2005

Table 12. Land cover classes of the study area in hectare and percent

S.N	LULU Classes	Area (ha)	Percentage (%)
1	Forest	1,496.6	18.4
2	Grassland	1,390.4	17.1
3	Plantation	354.0	4.4
4	Shrublands	263.3	3.2
5	Wetland	289.6	3.6
6	Jarmet wetland	217.2	2.7
7	Farmland	4,102.2	50.6
8	Total	8,113.3	100.0

6.1.1.5 Land use/land cover classification for Landsat 2015

The land use/land cover classification for 2015 from Landsat ETM+ classified satellite image showed that Farmland are dominated than any other land cover classes and it accounting for 4,510.8 ha(55.6%) . While others like; Shrubland, grassland, forest, plantation and wetland are, 237.5 ha (2.9%), 976.5 ha (12.1%), 1,291.4 ha (15.9%), 591.3 ha (7.3%) and 505.8 ha (6.2%) respectively. During this period the most portion of land cover classes are covered by farmland and forest, but others are slightly decreased. Table 13 shows us the land use/land cover classes and its areal extent for wetland and other land use types.

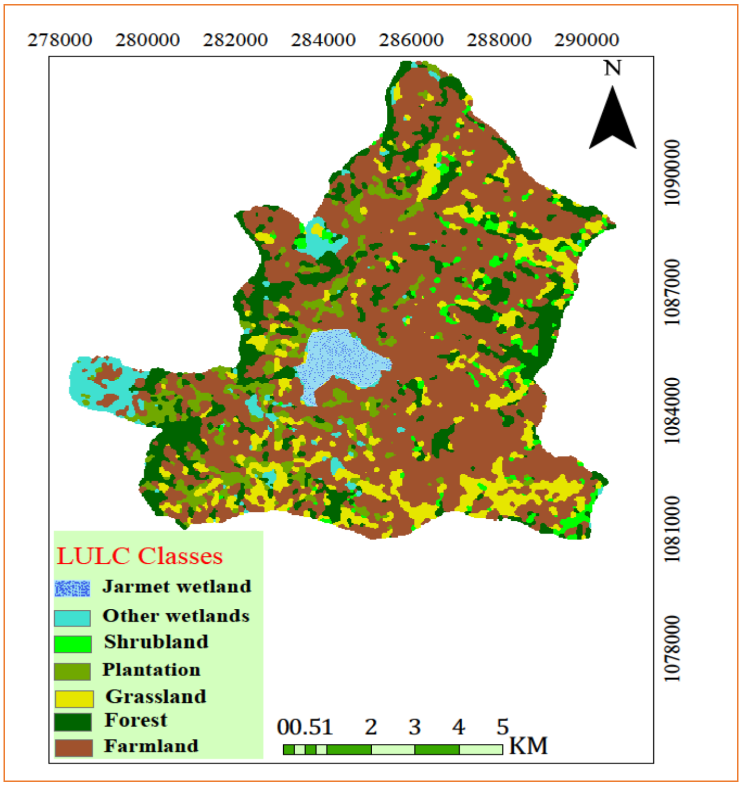


Fig.17. Land use/land cover map of the Study area in 2015

Table 13. Land cover classes of the study area in hectare and percent

S.N	LULC classes	Area (ha)	Percentage (%)
1	Shrublands	237.5	2.9
2	Grassland	976.5	12.1
3	Forest	1,291.4	15.9
4	Plantation	591.3	7.3
5	Jarmet wetland	214.8	2.6
5	Wetland	291.0	3.6
6	Farmland	4,510.8	55.6
7	Total	8,113.3	100.0

6.1.2 Land Use/Land Cover Change Detection From 1972-2015

Change detection plays a pivotal role at local and regional scale for land use/land cover change analysis of classified satellite image. Changes in land use/land cover can be categorized in to two types:-those are modification and conversion. Modification is a change of condition within the same cover type. While, conversion is a change from one cover to another. A common method for classified satellite image detecting is compare one satellite image to the other. For change detection of land use/land cover analysis for this study Landsat MSS of 1972, TM of 1986 and ETM+ of 2000, 2005 and 2015 are used. The statistics of land use/land cover were computed and summarized to detect the nature of major changes of Jarmet wetland and its surrounding environment within 43 years.

Table 14. LULC change statistics of Jarmet wetland and its surrounding environmental area between1972-2015.

Land use/ land cover classes	Land use/land cover change in hectare and percent								Total area Δ in (ha) 1972-2015	Area (%)
	1972-1986		1986-2000		2000-2005		2005-2015			
	Area (ha)	(%)change	Area (ha)	(%)change	Area (ha)	(%)change	Area (ha)	(%)change		
Farmland	+899.1	17.98	+1,073.28	22.58	+1,606.8	30.66	+408.408	31.62	+3,987.588	45.31
Grassland	+773.101	15.46	-2,028.711	- 42.68	+1,007.49	19.23	-413.828	-32.0	-661.948	-7.52
Wetland	-1,237.398	- 24.74	+444.478	9.35	-929.0	-17.72	-0.949	-0.07	-1,722.869	-19.58
Shrubland	-1,262.83	- 25.25	+825.0	17.36	-1,255.1	-23.95	-25.802	-1.99	-1,718.732	-19.53
Plantation	+135.801	2.715	+33.389	0.70	+5.611	0.107	+237.332	18.37	+412.133	4.68
Forest	+692.09	13.84	-347.4	-7.31	-435.71	-8.31	-205.165	-15.88	-296.185	-3.36

Note: The positive sign (+) means gain and the negative sign (-) indicates loss in areal extent.

The land use/land cover change detection equation was calculated by using this equation

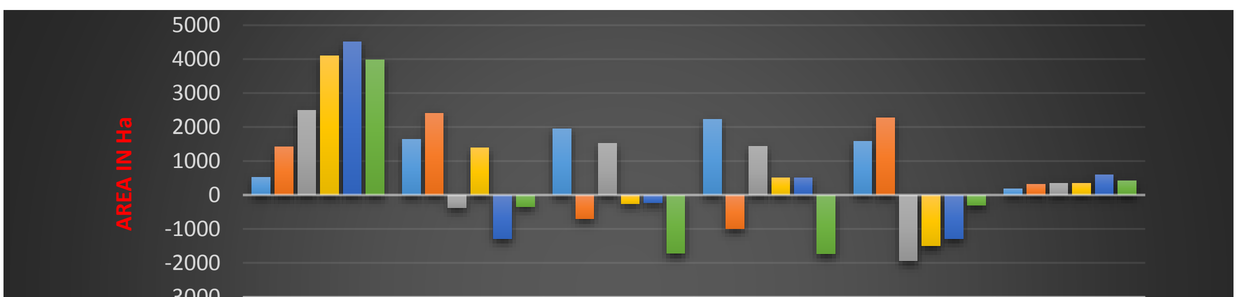
Change detection =(X-Y)/P

Where, X=recent area of land use/land cover in hectare

Y=previous area of land use/land cover in hectare

P= the percentage change within those years.

According to the results obtained, grassland, shrubland, wetland and forest are revealed negative sign of total area change which implies decline in the area. On the other hand, farmland and plantation have shown positive sign of total area change which implies increase in area coverage. The statistical table of change detection shows us the various proportions of losses and gains amongst the various land uses. Farmland and plantation was increased to in 1972:- 523.1 ha, 179.2 ha, to 1,422.2 ha, 315.01 ha in 1986, in 2000 they increased to 2,495.48 ha, 348. 39 ha, in 2005 the increment also continues to 4,102. 28, 354.01 ha and in 2015; 4,510.68 ha, 591.33ha respectively. This means, the farmland gaining from all land cover types except plantation. Plantation gain from Shrubland, grassland and wetland. Wetland and shrublands are recorded as the greatest loss than forest and grassland. The total losses of wetland and shrublands within 43 years are: -17.229km^2 (-1,722.9ha) and -17.187km^2 (-1,718.7 ha). The grassland and forest losses are equivalent (totally) in 1972-2015 are: -6.619km^2 (-661.9 ha) and -2.962 km^2 (-296.2 ha). This results reflects to us in the area the expansion of farmland and plantation activities are greater than other land use types in different periods.



	Farmland	Grassland	Shrubland	Wetland	Forest	Plantation
1972	523.1	1638.5	1956.21	2228.7	1587.6	179.2
1986	1422.2	2411.601	-693.38	-991.302	2279.69	315.001
2000	2495.48	-382.89	1518.38	1435.78	-1932.29	348.39
2005	4102.28	1390.38	-263.28	506.78	-1496.58	354.001
2015	4510.688	-1291.415	-237.478	505.831	-1291.415	591.333
Total area Δ(ha)	3987.6	-347.1	-1718.732	-1722.869	-296.185	412.133

Fig.18. Land use/land cover change in1972-2015.

Change in wetland area: it has been observed that from the Fig. 18 and table 14 the percentage change of land use/land cover of the wetland. The area of change recorded 24.7%, 9.3%, 17.7% and 0.07% percentage of change during the periods of, 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. This shows us wetland area decreased during 1972-1986 by -1,237.4 ha within 14 years, while, during 1986-2000 it shows increments by 444.5 ha within 14 years, in 2000-2005 it decreased by -929.0 ha within 5 years period and -0.95 ha decreased during 2005-2015 within 10 years. The total decreased area of the wetland for all years was -1,722.9 ha which -21.23% in the context of total land cover area. This result revealed that the majority of wetland coverage is changed to farmland and a few coverage of the wetland are changed to plantation area.

Change in forest area: the forest cover change of the study area is constituted 13.8%, -7.3%, -8.3% and -15.9% percentage of change during the periods 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. With, 692.2 ha, -347.4 ha,-435.7 ha and -205.2 ha as area coverage change during the same periods respectively. This revealed that the forest cover is directly change to farmland and it slowly change to Shrubland. The total forest cover change to other land uses within 43 years are: -296.2 ha or (3.36%) in context of total area.

Change in farmland area: farmland land use is another important land use of the study area and it showed highest change than other land use classes. Farmland area recorded 17.9%, 22.6%, 30.7% and 31.6% percentage of changes during the periods, 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. The area coverage of farmland increased within those periods are; 899.1 ha, 1,073.3 ha, 1,606.8 ha and 408.4 ha in 1972 to 2015 respectively. It was the largest expansion and had larger share than other land use types. This implies that farming expansion by converting other land covers like grassland, wetland, Shrubland and forest. The total gains of farmland from other land cover classes between 1972 and 2015 was 3,987.6 ha (49.3%) in the context of total land cover.

Change in Shrubland area: the land cover change of this class are not uniform in all years, because once it shows increasing and once it reveal decreasing. Shrubland area coverage recorded,-25.2%, 17.4%,-23.9% and -1.1% percentage of change during the periods, 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. The total Shrubland coverage increased and decreased within those periods are;-1,262.8 ha, 825.0 ha,-1,255.1 ha and -25.8 ha respectively. The total Shrubland cover change to other land cover during the periods of 1972 to 2015 -1,718.7 ha

(21.13%) in the context of total area. The majority of this cover change to farmland and a small cover of the Shrubland is change to plantation.

Change in plantation area: plantation for this study include eucalyptus trees. An areal extent of plantation of the study area shows a few increment for all years. The area coverage of this class are recorded, 2.7%, 0.7%,0.1% and 18.4 percentage of change during the periods of 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. The total area increased of plantation cover between those years are; 135.8 ha, 33.4 ha, 5.6 ha and 237.3 ha respectively. When we compare with other land covers it was the smallest land cover in that particular year (period). The total area coverage change or increased of plantation within all years are 412.1 hectare (5.07%) in context of total land cover area. This shows us eucalyptus trees were used as a source of income, for house construction, and for production of house hold materials for the study area societies.

Change in grassland area: within the started years grassland showed increases by 773.1 ha (15.5%) in 1972-1986 but, it decreased to -2,028.7 ha (-42.7) in 1986-2000, in 2000-2005 it shows increase by 1,007.5 ha (19.2%) within 5 years and in 2005-2015 it reduce to -413.8 ha (-32.0%). These results revealed that in the grassland area coverage showed very fast increments and decrements for all years. The total decline of grassland is 661.95 ha (8.14%) in context of total land cover area. The majority of grassland land cover is converted to farmland and plantation area.

6.1.3 Trend and Rates of Land Use/Land Cover Change (Dynamics)

The absolute, percentage and annual rates of land use/land cover change within the study area for the period of 1972-1986, 1986-2000, 2000-2005 and 2005-2015 and 1972-2015 was analyzed in Table 15.

The percentage change is calculated using the equation

$$\text{Land use/land cover trend (\%) change} = \frac{\text{observed change} \times 100}{\text{Sum of change}}$$

Annual rate of change= OC/(X2-X1) Where;

OC=is observed change X1= starting year and X2=is the ending year.

Table 15. Trend and rate of change analysis of LULC in the study area.

Land use/ land cover classes	Land use/ land cover change								Annual rate of change				
	1972-1986		1986-2000		2000-2005		2005-2015						
	Area (ha)	(%) Change	Area (ha)	(%) Change	Area (ha)	(%) Change	Area (ha)	(%) Change	1972 to 1986(ha)	1986 to 2000 (ha)	2000 to 2005 (ha)	2005 to 2015 (ha)	1972 to 2015 (ha)
Farmland	899.1	17.98	1,073.28	22.58	1,606.8	30.66	408.408	31.62	64.22	76.66	321.36	40.84	92.73
Wetland	-1237.398	24.74	444.478	9.35	-929.0	17.72	-0.949	0.07	-88.38	31.75	-185.8	- 0.095	-15.39
Grassland	773.101	15.46	-2,028.71	42.68	1,007.49	19.23	-413.828	32.0	55.22	-144.9	201.41	-41.38	-40.07
Shrubland	-1,262.83	25.25	825.0	17.36	-1,255.1	23.95	-25.802	-1.99	-90.20	58.93	-251.02	-2.58	-39.97
Plantation	135.801	2.715	33.389	0.70	5.611	0.107	237.332	18.37	9.70	2.38	1.12	23.73	9.58
Forest	692.09	13.84	-347.4	7.31	-435.71	8.31	-205.165	15.88	49.43	-24.82	-87.14	-20.51	-6.88

The above table indicated that LULC trend and rate of changes of the study area during the period of the study. It reveals a drastic decrease in the coverage of forest, wetland, grassland and Shrubland which contributed to concomitment increase mainly in farmland and plantation area. The forest cover annual increasing of the study area from 1972-1986, about 49.4 ha was increased by 13.8% rate per annum and from 1986-2000 about -24.8 ha was converted by 7.3% rate of change per annum. After 2000 years the forest coverage shows continuous decrease by -87.1 ha (-8.3%) and -20.5 ha (-15.9%) during the period of 2000-2005 and -6.88 ha during the period of 2005-2015 rate of change per annum respectively. This revealed that the forest decrease is as a result of population growth, unwise use of resource and the forest resources change to other land units.

The wetland cover of annual change is recorded,-88.4 ha (24.7%), -31.7 ha (9.3%), -185.8 ha (17.7%) and -0.09 ha (0.07%) rate of change per annum during the periods of 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. This results show that the lack of wetland conservation policy, overgrazing and lack of wise use resources are observed during field survey in the study area.

The trend and rate of conversion of grassland indicated that in Table (14) the grassland area coverage was increased to 55.22 ha (15.5%) in 1972-1986 and it decreased to -144.9 ha (42.7%) in 1986-2000, also it increased to 201.41 ha (19.2) in 2000-2005 and as well as, it decreased to-41.38 ha (32. %) in 2005-2015 rate of change per annum. Within 43 years about 8.15% of grassland was changed to other land covers. This result shows us the scarcity of farmland and illegal cultivation of grassland related to population growth and lack of land management in the area.

The trend and rate of farmland area expansion was recorded, 64.2 ha (17.9%), 76.6 ha (22.6%), 321.4 ha (30.7%) and 40.8 ha (31.6%) rate of increasing per annum during the periods of 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. The expansion of farmland is directly related to population growth, unsustainable agricultural activities, and illegal expansion of farmland and weak environmental conservation policy.

The trend and rate of change of Shrubland are; -90.2 ha (25.2%) per annum in 1972-1986. Although, there was, 58.9 ha (17.4%),increasing with annual increasing rate in 1986-2000 as well as, -251.0 ha (23.9%) decreasing in 2000-2005 per annum and -2.6 ha (1.9%) rate of change per annum during the periods of 2005-2015 respectively. This results revealed that the change of Shrubland is a factor of population growth, heavy livestock rate (overgrazing), expansion of farmland and lack of responsible organization for natural resource keeping in the area.

The trend and rate for expansion of plantation (eucalyptus) area coverage was, 9.7 ha (2.7%), 2.4 ha (0.7%), 1.1 ha (0.1%), and 23.7 ha (18.4%) increased rate per annum during the periods of 1972-1986, 1986-2000, 2000-2005 and 2005-2015 respectively. From 1972-2015 plantation are gain 4.7% from other land units. The results tell us eucalyptus tree are used as a source of income, fire wood, house construction and household material production in the area.

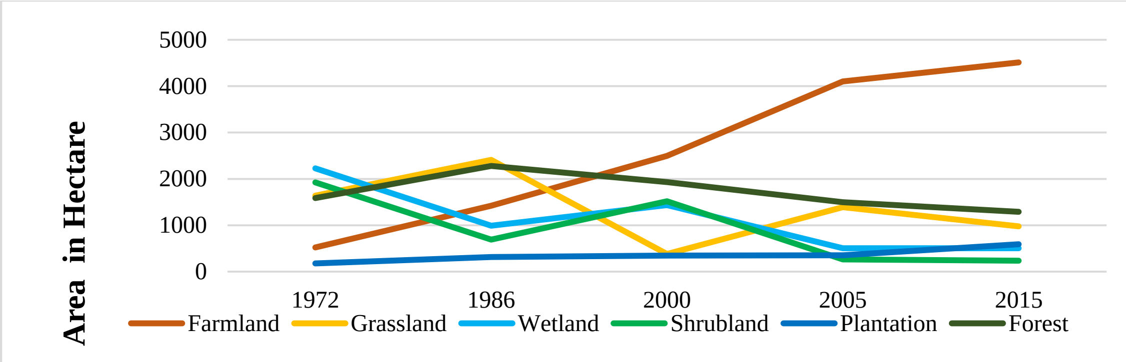


Fig.19. Land use/land cover trend of the study area in 1972-2015

6.1.4 Nature of Land use/Landover Change From 1972 to 2015

The nature of Land use/land cover change refers to the identification of 'what land use/land cover is changing and from what to what?' A post-classification comparison change detection technique revealed different trends in land use/land cover changes over the period from 1972- 2015. This information will reveal both the desirable and undesirable changes and classes that are "relatively" stable overtime. This information will also serve as a vital tool in management decisions. This process involves a pixel to pixel comparison of the study year images through overlay. The nature of changes has been examined in terms of areas of land use/land cover remained unchanged, gained from other classes and lost to other classes. The statistics on nature of changes for the study area during the periods 1972-2015 and 1986-2015 are presented as below (Table 16, 17 and 18).

6.1.4.1 Land use/Landover Change between 1972 and 2015

Between the years 1972 and 2015, the major land use/land cover changes were dominated by changes from wetland, Shrubland and grassland to farmland (Table 16).Quantitatively, 11.86 km^2, 11.53 km^2 and 10.52 km^2 of wetland, Shrubland and grassland respectively were converted to farmland (Table 16). These changes were attributed to population growth which forced the farmers to till and expand their lands in greater extent than before to cope up with the conditions and to sustain their life. In terms of land cover remained unchanged over the period of 43 years; 0. 28 km^2, 3.12 km^2, 5.67 km^2, 0.19 km^2, 2.61 km^2 and 3.71 km^2 were recorded for Shrubland, grassland, forest, plantation, wetland and farmland respectively. Overall, 15.58 km^2 (19.43%) of the total study area remained unchanged over the period of 43 years (1972-2015). The change detection matrix (Table 16) also indicates that there was gain in farmland and plantation area coverage by 1.67 km^2 (167 ha) and 1.41 km^2 (141 ha) respectively; whereas grassland, Shrubland, wetland and forest showed decrease (loss) by -6.41 km^2, -17.01 km^2, -17.13 km^2 and -2.94 km^2 in the same order.

Table 16. Change Detection Matrics of 1972 to 2015

	Initial State 1972														
	LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
Final State 2015	SHL	0.28	1.4	0.78	4.8	0.33	2.1	0.01	0.6	0.88	4	0.08	1.5	2.36	2.44
	GL	2.08	10.7	3.12	19.2	1.01	6.3	0.08	5	3.21	14.4	0.21	3.9	9.71	9.88
	FR	1.43	7.3	1.25	7.7	5.67	35.5	0.16	0.1	2.98	13.4	1.05	19.5	12.53	13.02
	PL	3.58	18.4	0.35	2.1	1.16	7.3	0.19	11.9	0.47	2.1	0.24	4.5	5.99	6.00
	WL	0.52	2.7	0.19	1.2	1.65	10.3	0.00	0	2.61	11.7	0.07	1.3	5.04	5.11
	FL	11.53	59.2	10.52	64.6	5.75	36.3	0 .16	0.1	11.86	53.3	3.71	69	44.54	44.93
	CCT	19.46	100	16.29	100	15.96	100	1.60	17.7	22.25	100	5.38	100	80.17	81.11
	CC	19.18	98.6	13.17	80.8	10.29	64.5	1.41	88.1	19.64	88.3	1.68	31.2		
	ID	-17.01	-87.4	-6.41	-39.3	-2.94	-18.4	4.39	2.7	-17.13	-77	39.54	734.9		

Note: Land cover categories: SHL: Shrubland, GL: Grassland, FR: Forest, PL: Plantation, WL: Wetland and FL: Farmland (blue) = unchanged area of land cover over the years, RT: Row total, CC: Class Change CT: Class total ID: Image difference CCT: Column Class total

6.1.4.2 Land use/Landover Change from 1986 to 2015

The second comparison made during 1986 to 2015 (table 17) also showed that 4.19 km^2 (42.3%) of wetland area was converted to farmland. During this period the unchanged class total area is 31.54 km^2 (38.9%). Similar to the period 1972 to 2015, farmland and plantation gained 10.25 km^2 and 2.92 km^2 of land area respectively. Regarding loss, 2.3 km^2, 5.45 km^2, 2.13 km^2 and 4.79 km^2 was recorded for wetland, grassland, Shrubland and forest respectively within 29 years. This is because of expansion of agricultural activity. Agriculture expansion is at the expense of grassland, forestland, and wetland and Shrubland contributing to the reduction of those land use/land cover types in the area. Some earlier studies in some area indicated that many households were abandoning unproductive grazing land and the increasing population pressures have an impact on natural resources degradation.

Table 17. Change Detection Matrics of 1986 to 2015

		Initial State 1986													
	LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
Final State 2015	SHL	0.28	2.1	0.80	0.5	0.71	4	0.08	2.2	0.31	3.1	0.23	1.1	2.41	2.43
	GL	0.76	5.6	4.34	28.9	1.52	8.4	0.45	12.5	1.40	14.1	1.31	6.3	9.79	9.82
	FR	2.27	16.8	0.84	5.6	7.92	43.6	0.21	5.8	0.82	8.3	0.63	3	12.71	12.95
	PL	0.66	4.9	0.44	3	1.02	5.6	0.69	19.1	0.47	4.7	2.65	12.8	5.94	5.97
	WL	0.63	4.7	0.43	2.9	0.54	3	0.46	12.7	2.67	27	0.23	1.1	4.97	5.07
	FL	8.86	65.5	8.09	54	6.33	34.8	1.71	47.4	4.19	42.3	15.64	75.4	44.82	44.96
	CCT	13.52	100	15.00	100	18.17	100	3.61	100	9.90	100	20.73	100	80.64	81.11
	CC	13.24	98	10.66	71.1	10.25	56.4	2.92	80.9	7.22	73	5.09	24.5		
	ID	-11.09	-82	-5.18	-34.5	-5.22	-28.7	2.35	66	-4.82	-48.7	24.23	116.9		

The figure below (Fig.20) summarizes the overall land use/ land cover change and the direction of change over a period of 43 years (1972-2015).

6.1.4.3 Land use/Landover Change from 2000 to 2015

On the contrary, during 2000 to 2015 LULC class change comparison in table 18 below shows that 0.3 km^2, 0.8 km^2, 5.1 km^2, 0.1 km^2, 2.2 km^2 and 16.2 km^2 were recorded as stable area for Shrubland, grassland, forest, plantation, wetland and farmlands respectively, within 15 years. Thus, 24.7 km^2 (30.4%) of all land cover remains unchanged during the period 2000-2015. Regarding gain, Farmland

and Plantation recorded 8.7 km^2 (87 ha) and 3.4 km^2 (34 ha). In terms of loss, wetlands, grasslands, Shrublands and forests recorded 2.8 km^2, 8.9 km^2, 2.1 km^2 and 0.8 km^2 respectively. The majority loss of those land cover are converted to farmland and plantation. Most of the forested land, Shrubland, wetland and grassland was converted to farmland by 47.4%, 56.3%, 46.1% and 46.1% respectively. On the other hand, those classes are also converted to plantation by 14.6 %, 3.5%, 7.7% and 5.7% between 2000 and 2015. The main causes of conversion is based on survey conducted, the community elders and agriculture expert of the area pointed out that at recently there is a government policy of land giving for landless and jobless population. The majority of land was given for those landless are from grassland, Shrubland and wetland, because those land classes in the area used as communal land and the values of those land cover classes at the area are unknown. Therefore, all of those reasons are the factor for expansion of farmland and degradation of other natural resources.

Table 18. Change Detection Matrics of 2000 to 2015

Final State 2015	Initial State 2000													
LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
SHL	0.3	2	0.2	5.1	0.7	3.6	0.2	5.7	0.6	4.2	0.5	2	2.4	2.5
GL	1.4	9.3	0.8	20.5	2.2	11.5	0.3	8.6	2.6	18.2	2.5	10	9.7	9.8
FR	1.8	11.9	0.5	12.8	5.1	26.6	0.5	14.3	1.8	12.6	2.9	11.6	12.7	13.0
PL	2.2	14.6	0.3	7.7	1.1	5.7	0.1	2.6	0.5	3.5	1.6	6.4	5.9	5.9
WL	0.8	5.3	0.1	2.7	0.8	4.2	0.1	2.6	2.2	15.4	1.0	4	5.0	5.1
FL	8.5	56.3	1.8	46.1	9.1	47.4	2.4	68.6	6.6	46.1	16.2	65.1	44.6	44.6
CCT	15.1	100	3.9	100	19.2	100	3.5	100	14.3	100	24.9	100	80.3	81.11
CC	14.9	98.7	3.0	76.9	14.1	73.4	3.4	97.1	12.1	84.6	8.7	34.9		
ID	-12.7	-84.1	5.9	151.3	-6.3	-32.8	2.4	68.6	-9.3	-65	19.8	79.5		

The slight difference in the row and column total is due to rounding errors

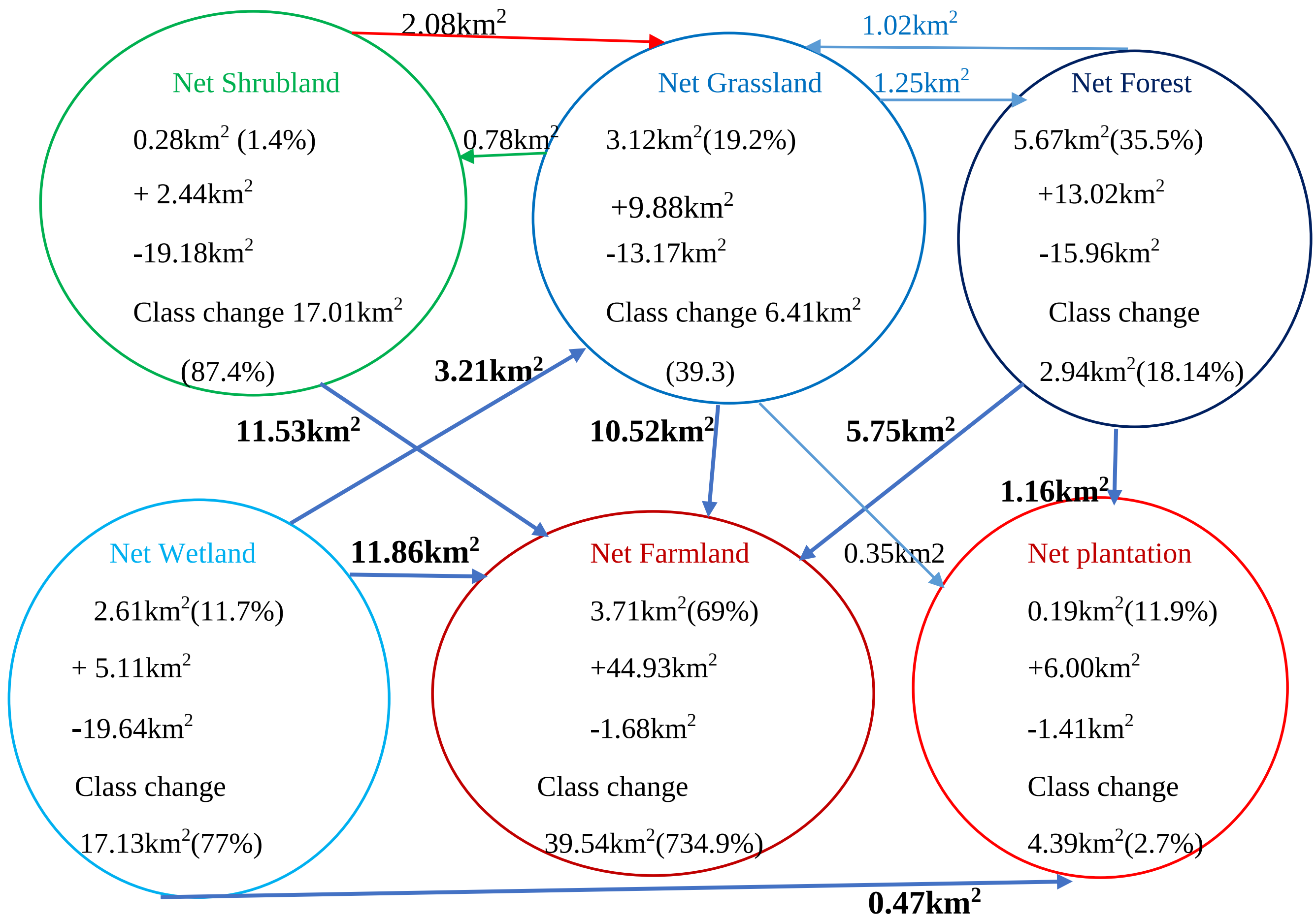


Fig.20.Land use/ land cover change analysis for 1972 to 2015

6.1.5 Drivers of Land Use/Land Cover Change

Land use/land cover change is always caused by multiple interacting factors. The mix of driving of land use change varies in time and space according to specific human's environment conditions. Several studies have examined the social and economic factors that drive land use/ land cover change. But the main cause for LULC change of this study can be divided into two categories. Those proximate (direct) and underlying (indirect) cause. The proximate causes of land use/ land cover for this study is related to modification of land by human at local level, individual farms, household levels and community. The underlying cause of this study related to economic, technological and institutional factors. The main driving force for LULC change of this study as information collected during field survey from the area and satellite image interpretation four main reasons are taken. These are: population growth (demographical factor), agricultural and forest prices, institutional factor and economic factor.

1. Demographic factors: the average number of people living a household has been increasing over time in the study site kebeles. Depending on population growth many farmers of the study area practice unsustainable farming methods as continuous cultivation results in loss of soil fertility and weed problems, which force them to move and clear forests, shrubs, grasses and wetlands for farming. Although LULC change processes occur at the interface of humans on environment by feed backs, synergistic effects and other system processes. Natural environment changes interact with population growth that cause land cover change. Between 1982 and 2013 the number of population of the area increased from 2,147 to 14,952. In the 2015 satellite image showed much of the study area covered by farmland and 3,987.7 ha (49.1%) of other land cover converted to agriculture when we compare with 1972. Therefore, population growth and expansion of agriculture is the main driver of land use/ land cover change at the study area.

2. Agricultural and forest product prices: a change in price of agricultural or forest products of the area can affect land cover change of the area. In the area during the period of 1972 the cost of one quintal Guizotia is 10-20 birr at present 1700-2000 birr. Although in 1972 the cost of one quintal charcoal and one stacked fire wood is 1-2 birr at present 100-150 birr in the area. The increasing of agricultural and forest prices are forced farmers to over cultivation and degradation natural resources like forest.

3. Economic factor: economic changes are increasing mediated by institutional factors, markets and policies, such as agricultural subsidies, that are enforced by local factor driving at and toward intensive agriculture and away from subsistence crop land of the area. For example, after farmers get better access to credit market (by road building and other infrastructural change), combined with improved agricultural technology and seed and secure land tenure can encourage forest, grassland, wetland and Shrubland conversion to cropland and plantation. Although, in the area Security of land tenure over land occupied by a household significantly increased the temptation of expanding unplanned farms towards the neighboring land covers. The land which was not demarcated and surveyed was normally not respected by the occupier and is likely to be abandoned and shift to another piece of land in the same neighborhood or anywhere else. This situation might have been the cause of poor land use practices and expansion of agricultural farms unnecessarily observed during the field survey in the area.

4. Institutional factors: land degradation and other environmental consequences of land use change in the study site are often the result of ill-defined policies and weak institutional enforcement and conservation strategies. This undermine local adaptation strategies such as, subsidies for road construction, agricultural production and forestry. In addition many people accessed farmland illegally by degradation of forests and other natural environments. Although, in the area there is no responsible organization for protection communal land as other natural resources. For this reason in the area many communal lands were changed to private land. Therefore, depend upon this idea it is possible to say institutional factors are as the other factors the main driving of land use/ land cover degradation.

6.6 Impacts of LULC Change of Jarmet Wetland and its Surrounding Environments as a Response to Population Dynamics

Land use changes are important aspect of global change has effect on regional water cycle, environmental quality, biodiversity and terrestrial ecosystem. Land use changes such as conversion of forest and wetland to agriculture due population growth are the main factor for changes of Jarmet wetland and its surrounding environment over years. Population growth and pressure is the main factor for LULC change, clearing forests, shrublands, grasslands and wetlands for agriculture and plantation, overgrazing , illegal land encroachment are the main causes for changes in hydrology (rivers), wildlifes, birdlife and vulnerable for flooding.

- Impacts on hydrology (rivers)
- Impacts on wildlife
- Impacts on birdlife
- Impacts on common trees
- Impacts on land degradation (flooding)

1. Impacts of LULC Change on Hydrology (Rivers)

Hydrology is the scientific study of movement, distribution and quality of water on earth. Land use/ land cover changes affected the hydrology of various rivers of the study area. Land cover changes of Jarmet wetland and its surrounding environment over years caused several problems of hydrology (rivers). This wetland and its surrounding area dramed by 7 major rivers in the past, but some rivers are dried up at present.

1. **Jarmet River:** is the largest river of the area. It is found in the western parts of the wetland in Anfaredarge Kebele. This river flows over the wetland to Imane river and it feeds the wetland ecosystem depended upon it during the periods of 1972-1986. But, after 1986 when the wetland sedges and forest patches removed the river changed its flowing direction to underground.

2. Badessa (Abayye) River: is found far from the wetland within 200m in the south western part of the study area. The river stands close to Jardega town and flows to Jarmet wetland. It is a source of drinking water for this town before and now. But, the power of the rivers before and after forest degradation slightly different. If this river is not protected it may dried up in about 5 year.

3. River of goda bollo: is found in the southern part of Jarmet wetland at kobidinsa Kebele. This river used as source of drinking water for the population and livestocks. Before 1986 this river used to flow all year round, but after land cover of the area changed the river started to dry in the dry season and flows only in the wet season.

4. Gindwac River: it is located in the south western part of Jarmet wetland all year round before 15 years as G.C., at present this river is changed to seasonal (i.e. it flows only in the wet season) but, it dried up in the dry season.

5. Borbor River: it's located in kobidinsa Kebele and used to flow all year round up to 2005 years. But, now this river changed to seasonal. It used only in wet season as drinking water for cattle.

6. Mujja River: this river is found in Anfaredarge Kebele before 1999 G.C, but after this years it is totally dried up.

7. Kistana River: is located in suteketali Kebele in eastern part of Jarmet wetland all year round during 1988 periods. After this year it dried up in summer season and it flows in winter season only.

Generally, the main factors responsible for changes on surface hydrology unsustainable farming activity in the area, plantation of eucalyptus trees close to the river and increasing demand for charcoal and firewood (forest degradation), wetland sedge and forest patch degradation, water diversion for irrigation and lack of strong natural resource conservation policy implementation.

Plate 1. Eucalyptus plantation surrounding wetland rivers

2. Impacts of LULC Change on Wildlifes

There have had been different kinds of wildlife lives in the study area in ancient time to present. They lived inside wetlands, forests, shrublands and grasslands before the land cover of the area changed. The type of wildlife that lived inside the wetland during 1972 to 1986 periods were red buck, bushbuck, pig, gazelle and etc. During this period this wetland are covered by sedges and forest patches. So, it was comfortable for those wildlifes living inside. But, after the wetland was burned all wildlifes migrated from the area except gazelle. Although there are another wildlifes that live in the forests, shrublands and grasslands include: Fox, hyena, leopard, ape, monkey, colobus monkey, rabbit and aardvark. But, after the land cover of the area changed Leopard and wildcat totally migrated from the area to other places, but a few others are found in the area.

Generally, the main reasons for wildlife migration and reduction in numbers are, LULC change in case of expansion of agriculture, hunting wildlifes and used as a source of income (e.g. Leopard skin), lack of wildlife protection law in the area and population growth. Therefore, this result revealed that the wildlifes found in the area endangered and great harm or imbalance situation.

3. Impacts of LULC Change on Birdlife

During the field survey several information was collected from elders related to birdlife resources of the area. The information collected from elders in the area showed there was a huge number of birdlife resources in Jarmet wetland and its surrounding environs. For example, there are a great variety of bird species that resides in the area during 1972 to present. The types of birds include, *little grebe(dab chick), great crasted grebe(pediceps cristatus), white breasted cormorant, African darter, harmerkop, goliath heron, black head heron, pink blacked pelican, marabou stork, African open bill, wolly-necked stork, black stork, blue winged goose, Egyptian goose, ruddy shelduck, yellow billed duck, black(northern) crowned crane, wattled crane, great snipe, African (Ethiopian) snipe, rose-ringed parakeet, and white cheeked turaco*. Out of these birds ***harmerkop*** is endemic to Africa and it is found in study area in the Jarmet wetland only. But, ***marabou stork** and **white cheeked turaco*** are migrated in the area before 10 years. Although *black headed heron, little egret, African sacred ibis, black stork,* ***wattled Ibis** and **blue winged goose (Cyanochen cyanopterus)*** *are endemic to Ethiopia*; *Egyptian goose and ruddy shelduck* are found only in wet season and they migrate in dry season after 20 years, presumably because of the merit of favorable food. But others are found all year round in the area of Jarmet wetland and its surrounding forests. The main reasons for migration of a few bird and changing their season of coming is degradation of Jarmet wetland sedge, river and forests. Because, of unsustainable agricultural activity and weak birdlife protection policy.








Plate 2. Birdlife of Jarmet wetland

4. Impacts of LULC Change on Common Trees

LULC changes of Jarmet wetland and its surrounding environments has led to common tree loss. There are many kinds of common trees that enriched the biodiversity of the study area site before destroyed. Unplanned agricultural activity, lack of nature and natural resource conservation in the area resulted in loss of many kinds of common trees like, *Podocarpus falcatus (Birbirsa), Pouteria altisssima (homi), Ekebergia capensis (sombo), Albizia schimperiana (Baha), Ficus vasta (Dembi)* and *Strereospermum kunthianum (Botoroo)* that were available all over the area, but now they are not observed. This is a great loss to forest biodiversity. Another common trees and shrubs like, *Ficus sur (Harbu),* Syzygium *guineense (Badessa)* and *acacia* in the area are also in vulnerable conditions.

5. Impacts of LULC Change on Land Degradation (Flooding)

Land degradation is broadly defined as any form of deterioration of natural potential of land that affects ecosystem integrity either in terms of reducing its sustainable ecological productivity or in terms of its native biological richness and maintenance of resilience. Land degradation is a serious problem in the study area Kebeles after natural resource of the area like, forest, wetland sedges, Shrublands and grasslands destroyed. Erosion is one of the main factor created related to land degradation. Soil erosion has several negative impacts on both human and natural resources. It impacts on food security as degraded land resources and soil resources associated agricultural productivity. In the study kebeles ***Darge and Darme*** are the main flood risk areas. Soil erosion problem of the area was generally connected with over cultivation, overgrazing and deforestation, but specifically to farming methods and management. The uncontrolled human activity in the area were rampant due to population growth, poor policy governing, agriculture and land use, forest degradation, low level awareness of sustainable land use, agriculture and overgrazing. Although the main reasons for flooding in the area is deforestation and altering water courses due to improper land use practices in the area. For this cause the forest cover of surrounding Jarmet wetland was cleared in the demand for more agricultural land need and for income supplementation by selling wood and charcoal.

Plate 3. Factors of land degradation condition of the study area

Generally, all of those factors are the main cause for biodiversity declining rapidly due to factors such as land use/ land cover change, over exploitation, unwise use of natural resource, weak conservation policy of nature and natural resources and population growth. The greatest human impact on biodiversity is the alteration and destruction of habitats, which occurs mainly through change of LULC, draining rivers, clearing land for agriculture, wildlife loss, birdlife loss, land degradation or soil erosion and common tree destruction.

6.2 Discussions

6.2.1 Main findings in this research

This section presents discussion of the results generated land cover maps from classification of Landsat images. It includes assessment of the recent map accuracy, analysis of the nature, extent and rate of land cover change maps and statistics, change detection analysis and LULC analysis of time series satellite image classification. Discussions of the analysis results focus on total wetland and others land cover loss and conversion between 1972 and 2015. The discussion then turns to examining the degree, trends, rates and patterns of LULC conversion or loss within the study area. Changes in wetland and other land cover classes and their gains and losses within 43 year periods are discussed below. The results of comparison of remotely sensed images in this study proved to be a good method in determining the changes in wetlands and other land covers over time. The spatial analysis of change detection and patterns, spatial transition of land use/land cover change analysis using spatial matrics and temporal patterns and configuration of land use/land cover changes are also presented in this sections.

Significant change has been detected in the Jarmet and its surrounding environs over years with highest rates. Firstly, the land use /land cover analyses through the use of remote sensing and GIS techniques shows that in 1972 the total areal extent of forest, wetland, Shrubland, grassland, plantation and farmland were 1,587.6 ha, 2,228.7ha, 1,956.7 ha,1,638.5 ha, 179.2 ha and 523.1 ha respectively.

In 1986 the research showed that wetlands and Shrubland decreased to -991.4 ha and -693.4 ha respectively; while cultivation(farmland), grassland, forest and plantation is increased to1,422.2 ha, 2,411.6 ha, 2,279.7 ha and 315 ha respectively. Thus, between 1972 and 1986 the four land use/land cover under investigation gain physical area of coverage. The main reasons for increasing of farmland are a result of extremely intensification of agriculture related to population growth than other activity, expansion of forest is as a result of degradation of Shrubland than forested land, increments of plantation especially, eucalyptus tree are a result of nonfood crop and largest source of income for the study site household, the increments of grassland is a result of the number of livestocks increasing, overgrazing and cutting shrubs and doing fence for protecting their crops from livestocks and used Shrubland as grazing land. The main causes for Shrubland and wetland degradation is population growth, taking Shrublands as invaluable resources, lack of knowledge in terms of the wetland and Shrubland use and burning of wetland ecosystem.

However, in 2000 farmland, Shrubland, plantation and wetland increased to 2,495.5 ha, 1,518.4 ha, 348.4 ha and 1,435.8 ha respectively; while forest and grassland decreased to -1,932.3 ha and -382.9 ha respectively. The main reasons behind the changes of grassland and forest are population growth, illegal expanding of new farmland, farmland scarcity and illegal eucalyptus plantation on common lands. In another string of agreements the USDA Forest Service (2004) holds that much of the pressure to convert forests to agricultural uses comes from increasing population growth and development demands.

Although, in 2005 this study revealed that farmland, plantation and grassland shows increasing in 4,102.2 ha, 354 ha and 1,390.4 ha respectively, while forest, wetland and Shrubland are decreased to 1,496.6 ha, 506.8 ha and 263.8 ha respectively. This results showed as, the wetlands, forests and Shrublands in the study area are not controlled by any authority and it is like ‘free area’ for any activity; hence, those inhabitants of the area that can work on farm moved in to produce mostly teff and Guizotia crops. In addition, the main causes for resource losses in the study area sites are population growth, illegal cutting of forest for energy especially charcoal and fire wood and weak environmental laws and policies. This is comparable to the findings made by Olson *et al.*, (2004) in Uganda.

Plate 4. Forest conversion to farmland and Shrubland conversion to grassland.

Furthermore, at present (2015) this study showed that farmland and plantation are increased to 4,510.8 ha and 591.3 ha respectively, while others like, Shrubland, grassland, wetland and forest decreased to 237.5 ha, 976.5 ha, 505.8 ha and 1,291.4 ha respectively. The reasons for farmland and plantation increasing during this period are eucalyptus tree are used as the main source of fire wood for both rural and urban populations, expansion of rural and urban settlement, increasing price of eucalyptus tree, increasing number of unemployment, expansion of irrigation, population growth, weak land management and environmental policy implementation, lack of wise use and irresponsible for natural resource conservation in the area. The results of this work correspond (similar) with the findings of a study done in Wetland uses/dynamics for agricultural purposes and its health implications in lower Ogun river basin, Lagos, Nigeria (2006).

The change detection of land use/land cover of Jarmet wetland and its surrounding environmental change revealed that during the period of 1972-1986 wetland and Shrubland showed dramatically decrease to -1,237.4 ha and -1,262.8 ha respectively, while farmland, grassland, plantation and forest increased by 899.1 ha, 773.1 ha, 135.8 ha and 692.1 ha respectively. This result indicated that population growth, increasing number of livestocks, burning of wetland sedges and forest patches, poor farming practices and overgrazing have led to land degradation along with negative impacts on the study area wetlands and Shrublands. The results of this study are similar to the studies by Copeland et al. (2010), Kangalawe and Liwenga (2005) and Ramsar (2009).

There was also serious land cover loss of grassland and forest during the periods of 1986-2000,by -2,028.7 ha and -347.4 ha respectively, while farmland, plantation, wetland and Shrublands are increased to 1,073.3 ha,33.4 ha , 444.4 ha and 825 ha respectively. These findings have revealed that household size (i.e. as information collected from elders; before 1986 in one Kebele the number of population lives only 100 households, but after 1986 it increased to 300 households), weak land use laws, illegal land taking, farmland scarcity, and illegal plantation of eucalyptus tree in the area are vital drivers of land use/cover of forest and grassland change.

In addition, the change detection statistics of this study revealed that farmland and plantation shows continuous increase during the period of 2000-2005 and 2005-2015 by 1,606.8 ha, 5.6 ha and 408.4 ha and 237.3 ha respectively, while forest, Shrubland and wetland decreased except grassland it shows increasing by 1,007.5 ha between 2000-2005 and decreased to 413.8 ha in 2005-2015. The area coverage losses of forest, Shrubland and wetland during the periods of 2000-2005 are 435.7 ha, 1,255.1 ha, 929 ha and in 2005-2015 205.1 ha, 25.8 ha and 0.94 ha respectively. Generally, this result revealed that wetlands, Shrublands, grasslands and forests is the most affected with more area been taken over by other land use/land cover. As shown in the study, more and more those land cover classes are being cut down either for plantation purpose or for cultivation. Although, lack of developing appropriate policies for wetlands and environments and unevenly distribution of eucalyptus tree, unsustainable agricultural activity and lack of strong relationship between agricultural assistant and rural population are the main factor for land use/ land cover change in the area. So, for conserving wetlands and other land cover classes must be covered under multiple sectors with no single sector being in overall charge.

Plate 5. Eucalypts and other plantation inside Jarmet wetland

The trend and rate of change analysis revealed that during the period of under investigation wetlands and Shrublands continuously experienced loss with all negative annual rates of change

(88.4 ha and 90.2 ha for 1972-1986. Grassland, farmland, plantation and forests are gains by 55.2 ha, 64.2 ha, 9.7 ha and 49.4 ha annual rate of change respectively within the same periods. The main reasons for wetland and Shrubland loss during this period is burning of wetland resources like sedge, forest patch and overgrazing the wetland resources and cutting shrubs for fence and expansion of agriculture. Although, political problem between governments of Ethiopia transition from (Derg and FDRE) for this reason there is a problem for environmental protection policy implementation, conservation and land management.

However, during the periods of 1986- 2000, 2000-2005 and 2005-2015 farmland and plantation shows increasing, others like; forest and wetland experienced loss, but Shrubland and grassland are gain between 1986-2000 and 2000-2005 respectively. The annual rates of gains of farmland and plantation for all years are; 76.6 ha, 321.4 ha, 92.7 ha and 2.4 ha, 1.1 ha, 23.7 ha respectively. The annual rates of loss of forest and wetland for the periods of under investigation 24.8 ha, 87.1 ha, 20.5 ha and 31.7 ha, 185.8 ha, 0.09 ha respectively. Regarding to grassland and Shrubland loss and gain during this periods Shrublands experienced gain between 1986 to 2000 with annual rate of change been 58.9 ha while after 2000-2005 and 2005-2015 the annual rate of Shrubland loss was-251.02 ha and -2.6 ha respectively. For grassland annual rate of loss and gain was recorded during 1986-2000, 2000-2005 and 2005-2015 was 144.9 ha loss, 201.4 ha gain and 41.4 ha loss respectively.

Generally, these result revealed that significant increase in agricultural activities and plantation in the study area during the period 1972,1986,2000,2005 and 2015. Therefore, the study findings have revealed that household size, weak land use laws, illegal land encroachment, farmland scarcity, and illegal plantation of eucalyptus tree were vital drivers of land use/cover change. On the contrary, increasing livestock activities and education levels turned out to be non-important drivers of land use/cover change. This type of results are got in one study done at Kirima Uganda (2000).

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary

In this paper we have presented the Jarmet wetland and its surrounding environmental change over 43 years due to population growth and natural factor. The long term land use change analysis was performed to detect, delineate and map the land use land cover dynamics over the study periods. Wetlands are defined by US fish and wild life service's(Cowardin *et al*.,1979) as lands that transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water and that have one or more the following attributes; **a**, at least periodically, the land supports predominantly hydrophytes, **b**, the substrate predominantly undrained hydric soils and the substrate is non-soil and saturated with water or covered by shallow water at some time during the growing season of each year. Each wetland is composed of a number of physical, biological and chemical components such as soils, water, plants and animal species, and nutrients. This wetland ecosystem structure (that is, the tangible items) yields benefits, which are of direct use value to humans. Here people are presently involved in cultivation of the wetlands for food crops production, some are for eucalyptus tree planting, drinking the wetland water and feeding their livestocks, and others are used for cultural and recreational sites. However, this research is interested in the use of these wetlands for agricultural, grazing of livestock, drinking ground water and plantation purpose. It should be noted that this use/conversion of wetlands for those purposes are the main factor for change of land use/land cover which can be study under this thesis.

7.2 Conclusion

This research work demonstrates the ability of GIS and Remote Sensing in capturing spatio-temporal data for Jarmet wetland and its surrounding environmental change analysis as a response to human population on land use/land cover change. The analysis of wetland and its surrounding environmental change over years are by using a time-series analysis technique of comparing remotely sensed images from Landsat missions.

The link between human development, illegal land taking, weak environmental conservation policy, unwise use of wetland and other land cover recession can be measured through image classification, given that data is available and affordable for researches. In addition, image quality is an important factor in classification accuracy, land use/land cover map, change detection analysis, cloud free imagery has been appropriate for clearly analysis of LULC changes of wetland and its surrounding environs. Considering wetlands are so valuable for humans, birdlife, livestocks and wildlifes. Also it was found that they are important for variety of birds species including endemic birds of Ethiopia and Africa. The change of these valuable resources has a great impact on biodiversity and wild life habitat through changing forest, grassland, Shrubland and wetland cover. However, the survival of the wetlands and associated ecological services and socio-economic importance is under threat by unsustainable farming practice.

The main purpose of this study was to detect the changes in Jarmet wetland and its surrounding environments over years and its factors. Furthermore, this research has attempted to detect the change of wetland areal extent of Jarmet and its surrounding environments using remote sensing approach and found that within forty three years. A comprehensive LULC map was developed for five distinct years. The LU/LC pattern of change different categories shows variation during the five year periods, 1972,1986,2000,2005 and 2015. During all of those years, forest, grassland, Shrubland and wetlands were degraded and almost lost by -296.2 ha, -661.9 ha, -1,718.7 ha and -1,722.8 ha respectively. Agriculture and plantation was expanded at the expense of forest, grassland, wetland and Shrubland degradation by 3,987.6 ha and 412.1 ha respectively. Change detection matrix table indicate that most of wetland was converted into agriculture (53.3%) and grassland (14.4%). This is because of both human activity, population growth, farmland scarcity, weak conservation and wise use policy implementation related to wetland and other natural environment.

In addition, land Use/ Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions. The effects of human activities are immediate and often radical, while the natural effects take a relatively longer period of time. The difference in increase by households and land cover change indicates the pressure on wetland, Shrubland, grassland and forest cover and related biodiversity. This implies that population pressure, institutional factor, economic development and increase the forest and agricultural product price is believed to be one of the major driving forces for the changes in the study area. In order to make relevant conclusions and recommendations of the area. Hence, in the case of this analysis, the major driving force to changes in LULC is increased population change.

Generally, as the wetland, grassland, Shrubland and forests future, that the outlook is not so good. Therefore, appropriate policies and education about sustainable land management practices and wise use of those resources and adopting necessary conservation measures are the best method for those natural resource save from degradation.

7.3 Recommendations

Wetlands and environmental resources provide means of livelihood for the people and all ecosystem depend upon it in the study area in particular and our country in general. In order to reduce the changes of wetlands and its surrounding environment over years and for creating the way of protection of natural resources from degradation and enable sustainable use of the resources, the following recommendations are suggested.

- ❖ Government organizations and society of those kebeles specifically and country generally must be give attention to the degradation of natural resources especially, grassland, wetlands, Shrublands and forests of the area.
- ❖ Additionally, depend on land use/land cover change those land class conservation and wisely use policy arena, the main challenge is still weak implementation of the policies concerning land use planning, creating capacitated institutions at various levels, land use conflicts, illegal cutting of trees, benefit sharing mechanisms in participatory forest and other land cover management, etc.
- ❖ Stopping illegal land taking and distribution of eucalyptus tree on common lands, fertile soils and close to rivers. Because, eucalyptus tree is a fast growing and voracious plant it absorb high moisture and soil nutrient. Although, these trees have the ability to loss soil fertility and drying rivers within a few years.
- ❖ Encouraging society for keeping wetland and other natural resources and teaching the values of those natural resource and their uses.
- ❖ Create a source of income rather than farming for jobless and landless society lives close to the wetland and for study area in general.
- ❖ Participate every person on nature and natural resource conservation and keeping from degradation as his own property.
- ❖ Create strong relationship between agricultural experts and rural population on wise use of resource and natural resource conservation.

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ANNEXES

ANNEX A. RESEARCH QUESTIONNAIRE

In rural Ethiopia, natural resources are the basis of the livelihoods of local communities. People usually use various services of these natural resources and also change their nature through, e.g., expansion of agriculture. Wetlands are important ecosystem that support various components of natural resources. They are, however, prone to changes due to population growth whereby their size and pristine nature change through time. Generally, the conditions of the natural resources change over time as a function of population growth.

A. Check list for Key informant questionnaire and interviews

1. Name:____
2. Region_____, Zone________, District,_______Kebele(s)_____________
3. Age:--All key informants must be above 50 years____________________
4. Educational level:

   A) None B) Elementary C) high school D) others

   Specify: ____
5. Sex:

   A, Male B, Female
6. Current marital status of respondents

   A, Single B, Married C, Divorced D, Widowed
7. What is your major occupation?

   A) Farmer

   Since when: ____

   B) Farmer and other business C) others

   Specify: ____
8. Do you Know Jarmet wetland area extent and its land cover?

☐ Yes ☐ No

9. Information on boundaries of the wetland at different time.

9.1. Where is the boundary of the wetland in 1972?

9.2. Where is the boundary of the wetland in 1986?

9.3. Where is the boundary of the wetland in 2000 to 2015?

10. Information on the land cover of the wetland

10.1: what was the land cover of the wetland in 1972,1986,2000,2005 and present?

A) Covered entirely with sedges?

B) Partly covered with sedges and partly with patches of forests?

If there were a forest patches inside wetland, where is there locations?

____

C. Was the wetland covered with water year round?
If yes, what is its extent?

____

11. Information on the status of the natural resources of the wetland

11.1. Wildlife resources

A. What type of wildlife were there in 1972?

1972	1986	2000	2005	At present

Note: ____

B. What wildlifes were common in 1972, 1986, 2000, 2005 and 2015?
Can you name them?

1972	1986	2000	2005	2015

C. Did all wildlifes in 1972, 1986, 2000, 2005 and 2015 live in Jarmat wetland all year round?

____

If not all of them, which wildlifes were coming for a short period to Jarmat wetland?

D. Were there wildlife which were common in 1972 but absent in:

1986?
Name them:

2000?
Name them:

Now?
Name them:

12. Did the area of the wetland increase or decrease?
Explain:

____

If decreased,
10.1: Where is the boundary of the wetland in 1972?
10.2. Where is the boundary of the wetland in 1986?
10.3. Where is the boundary of the wetland in 2000?
13. Was the wetland useful for you and the local community? If yes, what are the uses?

____

14. Did the uses of the wetland for the people change over years? If yes,
14.1. What did people get from the wetland in 1972?
14.2. What did people get from the wetland in 1986?
14.3. What did the people get from the wetland in 2000?
14.4. What are people getting from the wetland now?
15. What are the factors for decrease in the size of the wetland?

____

16. Information on livestock resources

A. When you compare the livestock populations in terms of years, can you arrange the years from the highest to smallest number of livestock? [(from 1 (highest) – 4 (smallest)]

Year	Rank
1972	
1986	
2000	
Now	

If there is decrease in livestock population from 1972 to present what are the main reason for this observed decrease? ____________________________________

B) Do peoples living close to the wetland have more livestock than who live far from it?

17. Was there an incident of fire in the wetland? If yes:

A) When did the wetland burn? ____________________
B) What was the cause of the fires? ____________________
C) What was the impacts of the fire on the wetland?

Impacts	Type	Impacts	Type
Some wildlife disappear after fire		Some birds disappear after fire	
No permanent water below vegetation all year round (dried up)		The use of the wetland has changed	

Additional notes: ____

17. Information on the forest resources of areas around Jarmat wetland

18.1. Were there forests around the wetland? A) Yes B) No

If yes, what are the boundaries of the forests around the wetland in:

i. 1972?
ii. 1986?
iii. 2000?

18.2. Were there forests in the surrounding areas of the wetland? A) Yes B) No

If yes, were are these forests located in:

i. 1972? iii. 2000? V, at present?
ii. 1986? iv. 2005?

18. Information on the extent of erosion

Were there erosion problems in?

i. 1972?

Yes	No

If no why? ____;__________________________

If yes, what do you think has caused this erosion? ___________________________________

ii. 1986?

Yes	No

If no, why? ____

If yes, what you think has caused this erosion? _______________________________________

iii. 2000?

Yes	No

If no, why? ____

If yes, what do you think caused this erosion? ____

20. Information on the wildlife resources of the surrounding forest areas of the wetland

20.1. Birdlife resources

What type of birdlife were there in 1972, 1986, 2000, 2005 and 2015?

1972	1986	2000	2005	2015

Notes: ____

A) What birds were common in 1972, 1986, 2000, 2005 and 2015?
Can you name them?

1972	1986	2000	2005	2015

B) Did all birds in 1972 live in forests all year round in 1972? ________________________

If not all of them, which birds were coming for a short period to forests?

C) Were there birds which were common in 1972 but absent in:
1986?
Name them:

2000?
Name them:

Now?
Name them:

21. Information on rivers/streams draining into the wetland

A) Which rivers/stream were draining into the wetland in 1972?

River/stream											
GPS points											
All year round											
Seasonal											

B) Which rivers/stream were draining into the wetland between 1972 and 1986?

River/stream											
GPS points											
All year round											
Seasonal											

C) Which rivers/stream were draining into the wetland between 1986 and 2000?

River/stream											
GPS points											
All year round											
Seasonal											

D) Which rivers/stream were draining into the wetland between 2000 and present?

River/stream											
GPS points											
All year round											
Seasonal											

22. Information on common trees in the surrounding areas of the wetland

A) What trees were common in 1972?

B) What trees were common between 1972 and 1986?

If some trees have disappeared between 1972 and 1986, what were the reasons?

____

C) What trees were common between 1986 and 2000?

If some trees are disappeared between 1986 and 2000, what were the reason? ___________________

D) What trees were common between 2000 and present?

If some trees are disappeared between 2000 and present what were the reason?

____

B. Checklist for Focus Group Discussion (FGD) on wetland and its surrounding environmental change

1. What policy actions are/were taken to conserve wetlands and other natural resources in this woreda?

2. When we look the socioeconomic of society; which society are independent in food security and which is not in relation to their close location to the wetland?

It is assumed that people close to the wetland have more livestock and perhaps use less fertilizer

3 When you compare the changes in the wetland and surrounding forest areas over years, do you think that the wetland has more changed than the surrounding areas? Specify:

---

4. Are the wetlands being converted for agricultural purposes within the study area?
5. If yes, at what rate are wetlands being change for agricultural purposes?

6. What problems farmers face in wetland use?

7. What is the uses of the wetland and its resources for the surrounding population and Jardega town?
8. What is the impact of population growth over years in wetland and other natural resources?
9. The farm sizes per households are how many hectares?

10. How many populations per square kilometers/population density per square kilometers?
11. Size of land owned by the household/Communal and its use (ha)

Sr.No	Type of use	Before 1972	Before 1986	Before 2000	At present 2013	Reasons for change between those years
1.	Total land owned					
2.	Crop land including gardens					
3.	Grazing area (common)					
4.	Forests and shrubs					
4.	Plantation area					
6.	Land prepared for other purpose					
7.	Marsh and wetland area					
8	Hills and mountains					

14. How do you perceive the trends in annual crop yield on the cultivated wetland at before and currently?

☐ Increase ☐ Decrease ☐ Show no change

15. If your answer for question no, 14, is decrease, please reason out why?

16. How can these wetlands and its surrounding resources be conserved?

a. When protected by Government

b. When protected by Community

c. When distributed to the local community

d. If every person participates in natural resources conservation

16. What is the major cause that drives the surrounding community to encroach into the wetland Proper?

☐ Farm land Scarcity ☐ illegal land taking

☐ Lack of grazing land ☐ if others, specify

☐ Deforestation ☐ Lack of wetland awareness

17. Do you think the local community is beneficiary from the Jarmet wetlands? If yes, in what aspects?

- Please explain

18. What are the factors had contributed to the degradation of the Wetland?

☐ Household size: how?

☐ Settlement expansion: how?

☐ Environmental policy constraints: how?

19. If there is change in the major resources of these wetland and its surrounding environments, please make list of specific change you have perceived on forest, rivers or shrubs, wetlands and grasslands?

20. Do you think that eucalyptus tree farming affect wetland ecosystem? A .Yes B. No

C. Required Secondary Data

1. Population census over years – from CSA on a yearly basis – historical data
   a. Population size
   b. Livestock size
   c. Crop production
2. Present situations – Woreda and recent CSA data
   a. Population size
   b. Livestock size
   c. Crop production
3. Topographic map of the study area or woreda in general from EMA

A. Latitude; 9^{O} 48' 27".00 and 9^{O} 48' 35".00 N

B. longitude; 37^{O} 02' 16".00 and 37^{O} 1' 8" .00 E

To identify roads, hydrology, lakes, rivers, infrastructures, settlements, towns and etc.

4. Metrological data of the study area – 25 years rainfall and temperature data

5. Geological data of the study area

6. Satellite images from Ethiopian Mapping Agency and own downloads from the Internet.

D. CHANGE DETECTION MATRICS

Table 1. Change Detection Matrics of 1972 to 1986

	Initial State 1972															
	LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
Final State 1986	SHL	1.85	9.5	1.52	9.3	3.05	19.1	0.26	16.2	4.79	21.5	1.98	36.8	13.45	13.61
	GL	2.14	11	5.65	34.7	0.75	4.7	0.10	6.2	5.58	25.1	0.33	6.1	14.55	14.97
	FR	2.96	15.2	1.50	9.2	9.00	56.4	0.14	8.7	2.68	12	1.50	27.9	17.77	18.22
	PL	1.94	10	0.29	1.8	0.86	5.4	0.15	9.4	0.28	1.3	0.07	1.3	3.58	3.64
	WL	2.53	13	1.42	8.7	1.08	6.8	0.04	2.5	4.48	20.1	0.26	4.8	9.80	9.90
	FL	8.00	41.1	5.78	35.5	0.73	4.6	0.91	56.9	4.02	18.1	1.21	22.5	20.66	20.77
	CT	19.46	100	16.29	100	15.96	100	1.60	100	22.25	100	5.38	100	79.81	81.11
	CC	17.61	90.5	10.64	65.3	6.96	43.6	1.46	91.2	17.77	77.2	4.17	77.5		
	ID	-5.85	30.1	-1.32	-8.1	2.26	14.2	2.04	127.5	-12.35	-55.5	15.39	286.0		

Table 2. Change Detection Matrics of 1986 to 2000

	Initial State 1986															
	LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
Final State 2000	SHL	2.13	15.8	1.74	11.6	2.94	16.2	1.21	33.5	1.62	16.4	5.46	26.3	15.10	15.18
	GL	0.37	2.7	0.95	6.3	0.97	5.3	0.15	4.2	0.46	4.6	0.96	4.6	3.86	3.88
	FR	3.70	27.4	3.08	20.5	7.04	38.7	0.74	20.5	1.21	1.2	3.16	15.2	18.93	19.22
	PL	0.66	4.9	0.53	3.5	0.65	3.6	0.08	2.2	0.23	2.3	1.32	6.4	3.48	3.49
	WL	1.90	14	4.19	27.9	2.07	11.4	0.39	10.8	3.54	35.8	2.13	10.3	14.22	14.43
	FL	4.64	34.3	4.47	29.5	4.21	23.2	1.01	28	2.65	26.8	7.66	37	24.63	24.91
	CT	13.52	100	15.00	100	18.17	98.4	3.61	100	9.90	87.1	20.73	100	80.22	81.11
	CC	11.39	84.2	14.05	93.7	11.13	61.2	3.53	97.8	6.35	64.1	13.07	63		
	ID	1.66	12.3	-11.12	74.1	1.04	5.7	-0.13	-3.6	4.54	45.9	4.18	20.2		

Table 3. Change Detection Matrics of 2005 to 2015

Final State 2015	Initial State 2005														
	LULC types	SHL		GL		FR		PL		WL		FL		RT	CT
		Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%		
	SHL	0.01	0.4	0.73	5.2	1.10	7.3	0.05	1.4	0.19	3.7	0.35	0.8	2.43	2.43
	GL	0.01	0.4	4.73	33.9	1.29	8.6	0.67	18.7	0.51	10	2.59	6.3	9.79	9.82
	FR	1.68	63.4	0.66	4.7	6.60	44.1	0.37	10.3	0.22	4.3	3.19	7.8	12.71	12.95
	PL	0.12	4.5	0.44	3.2	0.81	5.4	0.63	17.5	0.13	2.6	3.83	9.4	5.96	5.97
	WL	0.60	22.6	0.21	1.5	0.26	1.7	0.07	1.9	2.59	50.9	1.28	3.1	5.02	5.07
	FL	0.21	7.9	7.14	51.2	4.76	31.8	1.81	50.4	1.42	27.9	29.54	72.2	44.88	44.96
	CCT	2.65	99.2	13.93	100	14.97	100	3.59	100	5.09	100	40.90	100	80.79	81.11
	CC	2.64	99.6	9.20	66	8.37	55.9	2.96	82.4	2.50	49.1	11.35	27.7		
	ID	-0.21	-7.9	-4.11	-29.5	-2.02	-13.5	2.38	66.3	-0.01	-0.2	4.07	10		

E. ANNEX 1. ALIBO MAXIMUM TEMPERATURE

TMPMAX	Year	Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total annually
TMPMAX	1990	23.09167	22.7	24.8	25.4	25.8	24.9	22	20.2	20.9	21.1	21.5	23.5	24.3	277.1
TMPMAX	1991	24.325	33.4	32.1	25.8	24.8	24.2	21.4	19.8	20.4	21.6	22	23.4	23	291.9
TMPMAX	1992	23.31667	23.6	29.5	26.5	25.9	23.6	22.3	21.2	20.8	21.3	21.1	21.6	22.4	279.8
TMPMAX	1993	22.325	23.1	23.6	25.4	23.1	23.2	21.4	19.9	20.2	20.5	21.2	22.4	23.9	267.9
TMPMAX	1994	23.95	24.3	25.9	26.5	26.1	34.5	21.4	20.1	19.2	20.6	22	22.8	24	287.4
TMPMAX	1995	22.18333	18.6	26	26.1	25.8	23.2	22.6	19.8	20.4	20.7	21.1	27	14.9	266.2
TMPMAX	1996	24.125	27.3	43.1	23.8	24.2	22.4	20.4	22	16.7	25.4	25.8	21.6	16.8	289.5
TMPMAX	1997	24.25	23.7	24.6	35.2	37	23.2	22	20.8	20.4	22	22	25.6	14.5	291
TMPMAX	1998	21.19167	11	21.4	24.4	22.4	25	22.5	20.5	20.4	21.3	21.3	21.7	22.4	254.3
TMPMAX	1999	23.525	23.2	25.7	26.6	25.8	23.8	31.2	19	19.7	20.6	19.7	21.7	25.3	282.3
TMPMAX	2000	22.58333	24.4	25.6	26.8	23.1	23.7	21.5	19.8	20	21	20.7	22.6	21.8	271
TMPMAX	2001	22.54167	24	25.4	24.4	25.4	23.8	20.5	19.8	19.8	20.8	21.9	22.3	22.4	270.5
TMPMAX	2002	23.25	24	25.8	25.1	25.8	26	21.5	21.1	20.1	21.1	22.1	23.2	23.2	279
TMPMAX	2003	23.23333	24.5	25.7	33.7	26.2	27.4	14.8	19.3	19.8	20.3	21.7	22.2	23.2	278.8
TMPMAX	2004	22.875	24.7	25.4	25.8	25.3	25	20.8	19.9	19.7	20.4	20.9	23.4	23.2	274.5

TMPMAX	2005	25.19167	24.1	25.4	24.2	25.8	24.2	29	16.7	23.8	26.1	26.4	27.4	29.2	302.3
TMPMAX	2006	22.83333	24.8	26.4	25.9	21.3	23.9	21.4	23.3	19	20.8	21.9	31	14.3	274
TMPMAX	2007	24.33333	24.5	32	26.4	25.3	24.1	26.1	28	19.5	18.9	21.1	22.6	23.5	292
TMPMAX	2008	24.08333	24.1	12.8	43.2	32	23.1	22.7	21.5	20.6	22	21.8	22.1	23.1	289
TMPMAX	2009	23.26667	24.1	25.2	25.8	25.3	24.8	23.4	20.1	20.5	22.2	21.4	22.8	23.6	279.2
TMPMAX	2010	23.48333	31.2	25.4	26.4	27.5	24.1	21.4	20	19.1	20.6	21.9	22.1	22.1	281.8
TMPMAX	2011	24.50833	23.3	24.8	41.2	25.4	23.5	32.2	19.7	19.6	16.7	21.8	22.7	23.2	294.1
TMPMAX	2012	24.73333	25.1	26.4	25.9	25.8	24.9	24.6	21.5	19.5	24.1	26.2	22.7	30.1	296.8
TMPMAX	2013	22.86667	23.3	24.5	26	26.3	24.4	20.9	20.2	20.3	21.3	22	22.2	23	274.4
TMPMAX	2014	27.85	24.6	24.8	25.2	25.3	31.5	25.1	31	32.4	28	31.2	26.4	28.7	334.2
		Total monthly	601.6	652.3	691.7	646.7	622.4	573.1	525.2	512.8	539.4	560.7	587	566.1	7079

ANNEX 2. ALIBO MINIMUM TEMPERATURE

MIN.Temp.	**Year**	**Average**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total Annually**
TMPMIN	1990	11.02	10.3	10.7	11.2	12.3	12.7	10.9	10.7	10.4	10.0	10.7	11.4	11.0	132.3
TMPMIN	1991	10.76	11.6	9.5	12.0	12.0	11.6	11.0	10.3	10.0	10.2	10.4	10.6	10.0	129.2
TMPMIN	1992	11.30	10.6	18.6	11.2	11.0	10.3	10.4	10.5	10.5	10.9	11.0	10.5	10.2	135.7
TMPMIN	1993	10.5	9.7	10.5	11.7	11.3	10.9	11.0	10.2	9.8	9.6	10.3	10.5	10.5	126.0
TMPMIN	1994	15.61	10.3	15.8	16.4	17.8	18.9	15.5	15.4	15.5	15.5	16.2	15.1	15.0	187.4
TMPMIN	1995	16.45	14.4	15.6	16.1	17.0	16.4	17.0	16.9	17.0	17.0	16.7	16.9	16.4	197.4
TMPMIN	1996	15.14	16.5	16.0	16.0	15.4	16.5	13.2	11.0	14.3	13.6	17.8	15.2	16.2	181.7
TMPMIN	1997	13.3	12.0	13.5	12.8	10.0	15.1	9.8	16.5	13.2	17.0	16.2	12.5	11.0	159.6
TMPMIN	1998	12.65	11.6	10.3	14.1	12.6	13.2	14.2	11.9	11.6	14.5	12.3	11.3	14.2	151.8
TMPMIN	1999	14.61	9.3	19.0	18.2	13.9	19.2	18.1	11.4	13.3	14.2	13.8	12.7	12.3	175.4
TMPMIN	2000	14.08	13.5	13.4	13.0	12.2	12.3	12.7	13.8	14.2	15.6	15.9	16.6	15.8	169.0
TMPMIN	2001	11.85	15.5	11.6	12.2	13.3	12.0	11.0	10.8	11.7	11.0	11.3	10.9	10.9	142.2
TMPMIN	2002	12.03	15.5	12.1	12.0	13.1	13.1	11.7	11.1	11.2	10.8	11.3	11.5	11.0	144.4
TMPMIN	2003	11.98	11.2	12.1	15.2	12.7	14.1	11.3	11.1	11.1	11.0	11.4	11.6	11.0	143.8
TMPMIN	2004	11.49	11.5	11.4	12.9	12.9	12.7	11.2	10.5	10.6	10.9	10.7	11.2	11.4	137.9

TMPMIN	2005	11.97	11.1	12.8	12.8	13.5	12.8	12.4	12.5	12.5	10.8	11.7	10.3	10.5	143.7
TMPMIN	2006	12.48	12.2	12.7	12.9	16.0	11.9	11.1	14.1	11.0	10.6	11.5	14.2	11.6	149.8
TMPMIN	2007	11.89	10.6	15.2	12.0	12.5	12.0	10.9	16.1	11.0	9.5	10.7	11.3	10.9	142.7
TMPMIN	2008	12.51	10.9	21.1	18.5	11.4	11.3	11.1	10.5	10.6	11.6	11.3	11.0	10.9	150.2
TMPMIN	2009	11.49	11.2	12.0	13.0	12.9	12.9	11.4	11.0	11.1	11.2	11.0	9.9	10.3	137.9
TMPMIN	2010	12.06	17.6	12.8	13.1	8.7	12.9	11.9	10.9	11.4	11.4	11.5	11.6	11.0	144.8
TMPMIN	2011	12.73	11.0	12.4	19.0	13.1	12.6	15.2	11.1	11.0	14.3	11.6	10.7	10.8	152.8
TMPMIN	2012	13.32	11.7	12.8	13.1	13.7	13.0	13.8	11.6	11.2	21.0	10.0	12.8	15.2	159.9
TMPMIN	2013	11.58	11.8	12.6	13.5	13.4	11.5	11.4	10.9	10.8	10.5	11.2	11.0	10.4	139.0
TMPMIN	2014	11.68	10.9	10.5	11.3	11.4	10.0	9.6	13.8	11.7	11.9	13.9	16.3	8.9	140.2
	Total monthly	314.48	302.5	335.0	344.2	324.1	329.9	307.8	304.6	296.7	314.6	310.4	307.6	297.4	3774.8

ANNEX 3. ALIBO PERCIPTATION

PRECIPT.	**Year**	**Average**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total Annually**
PRECIP	1990	116.95	10.6	2.9	49.5	22.5	68.0	212.2	411.9	298.0	249.8	62.9	15.1	0.0	1403.4
PRECIP	1991	101.40	12.5	8.3	13.3	104.8	225.6	249.0	224.4	176.7	162.3	0.0	39.0	1.0	1216.9
PRECIP	1992	150.72	14.0	27.0	50.6	122.1	202.8	88.3	377.0	393.1	225.0	191.6	53.8	63.4	1808.7
PRECIP	1993	288.05	11.4	10.7	52.2	150.4	201.1	186.0	288.9	318.1	269.2	139.0	20.9	0.0	3456.6
PRECIP	1994	91.95	0.0	3.8	11.5	62.5	198.0	156.5	199.9	258.9	179.6	1.0	22.2	9.6	1103.5
PRECIP	1995	97.94	31.0	1.6	35.4	80.9	179.4	159.2	236.4	249.3	145.8	12.3	1.6	42.4	1175.3
PRECIP	1996	132.77	12.9	2.4	104.0	68.7	243.3	214.0	329.5	280.8	223.9	56.2	18.9	38.7	1593.3
PRECIP	1997	127.44	0.0	0.0	59.8	102.0	214.2	230.8	221.5	307.0	179.9	139.9	43.2	31.0	1529.3
PRECIP	1998	117.38	21.2	11.6	99.4	86.4	122.1	171.3	206.3	312.8	218.6	141.0	17.9	0.0	1408.6
PRECIP	1999	219.4	27.8	0.0	0.3	78.7	80.7	201.0	254.4	221.5	142.6	185.8	15.2	16.2	2632.8
PRECIP	2000	120.27	0.0	0.0	1.9	151.0	130.0	169.6	266.7	255.8	246.8	168.7	37.7	15.1	1443.3
PRECIP	2001	101.49	0.0	2.1	24.7	50.2	194.5	245.8	255.2	206.0	107.8	92.3	13.2	26.1	1217.9
PRECIP	2002	116.43	0.0	24.5	82.7	26.2	63.9	268.4	406.3	186.6	242.4	42.7	11.6	41.9	1397.2
PRECIP	2003	125.70	0.4	68.7	72.0	0.0	10.4	288.5	275.0	253.0	425.7	29.6	37.7	47.5	1508.5
PRECIP	2004	118.09	37.9	3.4	10.8	80.4	115.6	301.4	324.9	216.7	186.9	112.3	26.8	0.0	1417.1
PRECIP	2005	105.79	3.2	0.0	150.1	9.4	88.1	198.4	298.0	245.8	178.0	37.5	45.0	16.0	1269.5
PRECIP	2006	114.87	0.0	1.2	34.9	67.0	173.4	232.5	312.2	251.2	242.0	21.5	23.4	19.2	1378.5
PRECIP	2007	125.5	33.6	13.0	26.0	87.6	234.6	292.0	287.5	270.5	198.4	53.5	9.3	0.0	1506.0

PRECIP	2008	144.04	37.0	24.0	47.9	143.0	319.4	122.0	321.9	351.0	284.0	60.8	17.1	0.4	1728.5
PRECIP	2009	106.9	1.1	19.9	55.0	125.5	39.4	208.7	288.8	265.0	148.3	116.6	3.2	11.3	1282.8
PRECIP	2010	95.38	14.1	5.8	24.0	22.6	263.5	149.2	199.1	270.4	178.6	15.2	0.0	2.1	1144.6
PRECIP	2011	105.23	19.1	0.0	27.4	46.3	211.5	302.9	257.7	225.7	124.6	46.7	0.9	0.0	1262.8
PRECIP	2012	91.60	0.0	2.6	31.1	0.6	24.1	204.6	302.8	242.5	189.0	55.3	22.9	23.8	1099.3
PRECIP	2013	123.42	29.7	0.0	34.4	3.2	315.9	217.2	293.8	262.9	164.9	106.4	52.7	0.0	1481.1
PRECIP	2014	134.73	0.0	11.7	52.6	133.5	235.0	264.7	295.3	334.6	190.4	62.0	0.8	36.2	1616.8

ANNEX 4. JARMET PRECIPTATION

PRECIP.	Year	Average	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec	Annual total
PRECIP	1990	134.38	6.4	4.6	37.3	32.1	119.1	280.3	416.1	409.3	239.7	51.3	16.4	0.0	1612.6
PRECIP	1991	104.97	0.0	19.7	40.6	127.8	33.2	259.8	235.7	313.5	168.6	24.5	8.0	28.3	1259.7
PRECIP	1992	109.50	2.8	25.3	47.9	128.6	167.5	209.6	240.9	296.1	98.8	30.0	35.2	31.4	1314.1
PRECIP	1993	155.13	0.0	21.5	28.2	130.7	320.6	227.5	257.7	367.7	285.6	209.4	11.9	0.8	1861.6
PRECIP	1994	117.60	2.2	0.0	9.2	65.6	238.1	163.4	319.0	383.9	163.6	12.2	36.7	17.4	1411.3
PRECIP	1995	126.86	0.0	10.7	74.9	73.6	216.2	150.3	358.3	332.1	208.2	36.7	9.9	51.5	1522.4
PRECIP	1996	134.8	33.9	2.1	74.7	64.0	234.1	241.8	386.1	291.5	154.1	51.1	46.8	37.4	1617.6
PRECIP	1997	122.35	3.9	3.3	48.6	98.0	227.0	219.5	221.9	276.8	147.3	164.3	57.3	0.4	1468.3
PRECIP	1998	144.14	11.9	0.5	16.5	15.2	221.9	289.3	336.6	369.1	226.0	219.9	22.8	0.0	1729.7
PRECIP	1999	127.57	14.0	0.0	0.1	83.1	136.7	266.2	229.6	253.9	260.9	213.3	29.3	43.8	1530.9
PRECIP	2000	113.02	0.0	0.0	3.5	163.9	107.8	141.5	240.4	252.2	238.0	148.1	51.7	9.2	1356.3
PRECIP	2001	103.01	0.2	5.0	66.9	34.0	157.2	135.0	320.1	256.4	111.3	106.6	12.5	31.0	1236.2
PRECIP	2002	112.45	25.3	1.5	43.5	20.6	56.9	256.8	296.4	276.8	278.0	39.2	8.8	45.6	1349.4
PRECIP	2003	107.34	0.4	102.5	78.9	0.4	1.2	245.3	231.0	414.7	195.9	1.4	14.6	1.8	1288.1
PRECIP	2004	117.62	2.2	28.1	18.1	67.5	111.4	245.1	298.6	326.7	170.9	101.9	30.6	10.4	1411.5
PRECIP	2005	110.93	3.5	0.0	151.2	26.5	105.0	198.3	290.4	217.9	205.2	114.4	18.8	0.0	1331.2
PRECIP	2006	138.47	0.4	3.0	21.7	17.0	221.5	212.9	396.6	395.8	225.3	87.6	42.5	37.4	1661.7
PRECIP	2007	147.7	25.8	39.1	40.9	72.2	264.0	246.3	410.3	248.0	193.1	193.1	16.1	23.5	1772.4
PRECIP	2008	119.65	5.2	48.7	47.0	103.1	37.1	171.4	401.0	325.8	211.3	32.1	35.8	17.3	1435.8

PRECIP	2009	101.9	3.2	28.7	47.1	103.1	37.1	161.1	322.5	237.4	135.8	118.2	11.2	17.4	1222.8
PRECIP	2010	118.75	22.3	0.8	1.0	72.1	299.6	107.6	409.6	279.8	183.3	18.7	27.8	2.5	1425.1
PRECIP	2011	151.99	36.0	8.3	68.0	88.3	198.0	213.3	376.5	298.2	156.3	189.4	167.0	24.6	1823.9
PRECIP	2012	113.90	5.3	0.0	92.0	3.2	56.6	221.4	399.0	281.5	197.4	78.9	22.0	9.6	1366.9
PRECIP	2013	130.05	22.1	3.8	27.6	7.6	261.7	231.5	347.1	288.0	201.0	110.3	59.9	0.0	1560.6
PRECIP	2014	170.16	1.9	8.5	83.5	202.3	336.5	321.0	411.0	341.6	178.2	122.3	31.2	4.0	2042.0

ANNEX F. GPS SAMPLE POINTS FOR LULC ANALYSIS

Training area data collections are used for LULC analysis of remotely sensed data acquired in 1972-2015.

S.N	Sample points	**Land cover type in 1972-2015**							
		Present	2008	2000	1986	1972	Easting	Northing	Elevation
1	001	Farmland	Farmland	Farmland	Grassland	Grassland	0286759	1091554	2448
2	002	Shrub land	Forest	Forest	Forest	Forest	0286255	1091255	2331
3	006	Grassland	Grassland	Grassland	Grassland	Grassland	0285855	1091481	2303
4	008	Farmland	Farmland	Farmland	Farmland	Farmland	0286068	1092063	2325
5	011	Grassland	Grassland	Grassland	Grassland	Grassland	0286767	1091777	2425
6	012	Farmland	Farmland	Farmland	Shrubland	Forest	0287087	1091809	2423
7	015	Wetland	Wetland	Wetland	Wetland	Wetland	0287205	1091563	2366
8	017	Farmland	Farmland	Farmland	Farmland	Forest	0287209	1091376	2383
9	019	Farmland	Farmland	Farmland	Grassland	Grassland	0287165	1091324	2390
10	021	Grassland	Grassland	Grassland	Grassland	Grassland	0287373	1091152	2372
11	024	Farmland	Farmland	Grassland	Grassland	Grassland	0287545	1090991	2392
12	026	Farmland	Farmland	Shrubland	Shrubland	Forest	0287543	1090780	2388

13	028	Farmland	Farmland	Grassland	Grassland	Grassland	0287637	1090600	2372
14	029	Farmland	Farmland	Grassland	Grassland	Grassland	0287721	1090442	2393
15	031	Grassland	Grassland	Grassland	Grassland	Grassland	0288006	1090398	2403
16	033	Farmland	Farmland	Grassland	Grassland	Grassland	0288041	1090205	2401
17	034	Grassland	Grassland	Grassland	Grassland	Grassland	0288084	1090176	2400
18	035	Farmland	Farmland	Farmland	Farmland	Farmland	0287905	1090253	2410
19	039	Farmland	Farmland	Grassland	Grassland	Grassland	0288031	1089777	2361
20	040	Grassland	Grassland	Grassland	Grassland	Grassland	0288137	1089777	2365
21	041	Farmland	Farmland	Farmland	Grassland	Grassland	0288366	1089700	2398
22	043	Farmland	Farmland	Farmland	Grassland	Grassland	0288571	1089692	2371
23	045	Plantation	Plantation	Plantation	Farmland	Grassland	0288448	1089414	2392
24	047	Farmland	Farmland	Shrub land	Shrubland	Forest	0288703	1089433	2345
25	048	Plantation	Plantation	Grassland	Grassland	Grassland	0288849	1089413	2378
26	050	Grassland	Grassland	Grassland	Grassland	Grassland	0289217	1089186	2391
27	053	Shrubland	Shrubland	Shrubland	Forest	Forest	0289253	1088062	2324
28	057	Farmland	Farmland	Farmland	Grassland	Grassland	0289418	1087791	2271
29	058	Farmland	Farmland	Shrubland	Forest	Forest	0289181	1087875	2304
30	061	Forest	Forest	Forest	Forest	Forest	0288903	1088099	2322
31	062	Farmland	Farmland	Grassland	Grassland	Grassland	0288694	1088262	2296
32	066	Shrubland	Shrubland	Shrubland	Shrubland	Shrubland	0288361	1088746	2353

33	067	Farmland	Farmland	Farmland	Grassland	Grassland	0288202	1088995	2388
34	070	Grassland	Grassland	Shrubland	Shrubland	Shrubland	0287751	1088947	2381
35	071	Grassland	Grassland	Grassland	Grassland	Grassland	0287457	1089110	2389
36	072	Shrubland	Shrubland	Shrubland	Shrubland	Shrubland	0287323	1089054	2336
37	073	Grassland	Grassland	Grassland	Grassland	Grassland	0287175	1089217	2376
38	076	Plantation	Plantation	Grassland	Grassland	Grassland	0287087	1089750	2440
39	077	Farmland	Farmland	Grassland	Grassland	Grassland	0287192	1090282	2440
40	079	Farmland	Farmland	Farmland	Grassland	Grassland	0287367	1090412	2447
41	081	Farmland	Farmland	Farmland	Grassland	Grassland	0286809	1091411	2440
42	084	Plantation	Plantation	Plantation	Grassland	Grassland	0286524	1091054	2433
43	085	Grassland	Grassland	Grassland	Shrubland	Shrubland	0286249	1090860	2419
44	086	Farmland	Farmland	Farmland	Forest	Forest	0286039	1090908	2407
45	087	Forest	Forest	Forest	Forest	Forest	0286075	1090767	2419
46	088	Farmland	Farmland	Farmland	Farmland	Grassland	0285654	1090892	2348
47	089	Forest	Forest	Forest	Forest	Forest	0285518	1090748	2315
48	090	Farmland	Shrubland	Shrubland	Shrubland	Shrubland	0285409	1090841	2294
49	091	Farmland	Wetland	Wetland	Wetland	Wetland	0285302	1090818	2275
50	093	Farmland	Farmland	Grassland	Grassland	Grassland	0285166	1090688	2299
51	095	Wetland	Wetland	Wetland	Wetland	Wetland	0284898	1090557	2282
52	096	Farmland	Farmland	Farmland	Forest	Forest	0284937	1090300	2310
53	098	Farmland	Farmland	Farmland	Shrubland	Shrubland	0284445	1089229	2405
54	100	Farmland	Farmland	Farmland	Grassland	Grassland	0284273	1089033	2374
55	101	Farmland	Farmland	Grassland	Grassland	Grassland	0284566	1088553	2349

56	104	Plantation	Plantation	Grassland	Grassland	Grassland	0284763	1088920	2388
57	106	Wetland	Wetland	Wetland	Wetland	Wetland	0285053	1089156	2351
58	107	Farmland	Farmland	Grassland	Grassland	Grassland	0285253	1089301	2379
59	108	Farmland	Farmland	Farmland	Farmland	Farmland	0285510	1089232	2422
60	109	Forest	Forest	Forest	Forest	Forest	0286564	1090453	2422
61	111	Farmland	Farmland	Grassland	Grassland	Grassland	0286715	1090306	2386
62	113	Forest	Forest	Forest	Forest	Forest	0286633	1090007	2391
63	114	Grassland	Grassland	Grassland	Grassland	Grassland	0286505	1089848	2401
64	115	Plantation	Plantation	Plantation	Grassland	Grassland	0286477	1089821	2400
65	116	Forest	Forest	Forest	Forest	Forest	0286618	1089650	2347
66	117	Farmland	Farmland	Farmland	Grassland	Grassland	0286647	1088923	2319
67	118	Farmland	Farmland	Farmland	Farmland	Farmland	0286529	1088632	2333
68	120	Farmland	Shrubland	Shrubland	Shrubland	Shrubland	0286049	1088598	2360
69	121	Farmland	Farmland	Farmland	Farmland	Farmland	0284291	1083930	2434
70	122	Farm land	Farmland	Shrubland	Shrubland	Forest	0284056	1083624	2415
71	125	Farmland	Farmland	Farmland	Farmland	Wetland	0283971	1084418	2398
72	126	Farmland	Farmland	Farmland	Wetland	Wetland	0283898	1084483	2399
73	127	Plantation	Plantation	Wetland	Wetland	Wetland	0283847	1084508	2400
74	128	Farmland	Wetland	Wetland	Wetland	Wetland	0283764	1084530	2397
75	131	Wetland	Wetland	Wetland	Wetland	Wetland	0283883	1084714	2401
76	133	Wetland	Wetland	Wetland	Wetland	Wetland	0284016	108403	2391
77	134	Farmland	Wetland	Wetland	Wetland	Wetland	0284044	1084780	2393
78	135	Farmland	Farmland	Farmland	Wetland	Wetland	0284089	1084751	2396

79	136	Farmland	Farmland	Farmland	Farmland	Wetland	0284139	1084734	2395
80	139	Plantation	Plantation	Wetland	Wetland	Wetland	0284158	1084983	2390
81	140	Farmland	Wetland	Wetland	Wetland	Wetland	0284332	1085003	2388
82	143	Wetland	Wetland	Wetland	Wetland	Wetland	0284445	1084855	2383
83	144	Farmland	Wetland	Wetland	Wetland	Wetland	0284459	1084808	2388
84	145	Plantation	Plantation	Wetland	Wetland	Wetland	0284457	1084778	2390
85	146	Farmland	Farmland	Farmland	Wetland	Wetland	0284461	1084741	2395
86	147	Farmland	Farmland	Farmland	Wetland	Wetland	0284557	1084689	2394
87	148	Wetland	Wetland	Wetland	Wetland	Wetland	0284690	1084763	2384
88	151	Farmland	Wetland	Wetland	Wetland	Wetland	0284805	1084549	2394
89	152	Plantation	Plantation	Wetland	Wetland	Wetland	0284841	1084529	2395
90	153	Farmland	Farmland	Farmland	Wetland	Wetland	0284936	1084524	2396
91	154	Wetland	Wetland	Wetland	Wetland	Wetland	0285014	1084523	2400
92	155	Wetland	Wetland	Wetland	wetland	Wetland	0285051	1084703	2394
93	158	Wetland	Wetland	Wetland	Wetland	Wetland	0285178	1085020	2385
94	160	Wetland	Wetland	Wetland	Wetland	Wetland	0285220	1085087	2384
95	161	Farmland	Wetland	Wetland	Wetland	Wetland	0285268	1085056	2385
96	162	Farmland	Farmland	Wetland	Wetland	Wetland	0285314	1085011	2388
97	163	Plantation	Plantation	Plantation	Wetland	Wetland	0285328	1084950	2392
98	164	Farmland	Farmland	Farmland	Wetland	Wetland	0285384	1084899	2395
99	166	Wetland	Wetland	Wetland	Wetland	Wetland	0285578	1084871	2384
100	167	Wetland	Wetland	Wetland	Wetland	Wetland	0285637	1084901	2383
101	170	Farmland	Wetland	Wetland	Wetland	Wetland	0285518	1085130	2384

102	171	Farmland	Farmland	Wetland	Wetland	Wetland	0285538	1085188	2385
103	173	Wetland	Wetland	Wetland	Wetland	Wetland	0285314	1085247	2384
104	174	Plantation	Plantation	Wetland	Wetland	Wetland	0285394	1085334	2384
105	175	Farmland	Farmland	Farmland	Wetland	Wetland	0285465	1085405	2389
106	177	Wetland	Wetland	Wetland	Wetland	Wetland	0285181	1085438	2384
107	178	Plantation	Wetland	Wetland	Wetland	Wetland	0285199	1085480	2387
108	179	Farmland	Farmland	Wetland	Wetland	Wetland	0285203	1085510	2392
109	180	Farmland	Farmland	Farmland	Wetland	Wetland	0285209	1085540	2394
110	181	Farmland	Farmland	Farmland	Wetland	Wetland	0285200	1085575	2398
111	182	Wetland	Wetland	Wetland	Wetland	Wetland	0284951	1085632	2390
112	184	Wetland	Wetland	Wetland	Wetland	Wetland	0284809	1085737	2386
113	185	Plantation	Wetland	Wetland	Wetland	Wetland	0284795	1085794	2394
114	186	Farmland	Farmland	Wetland	Wetland	Wetland	0284814	1085831	2392
115	187	Wetland	Wetland	Wetland	Wetland	Wetland	0284631	1085955	2391
116	188	Farmland	Wetland	Wetland	Wetland	Wetland	0284652	1085975	2393
117	189	Farmland	Farmland	Wetland	Wetland	Wetland	0284665	1085988	2394
118	190	Farmland	Farmland	Wetland	Wetland	Wetland	0284671	1086008	2393
119	191	Farmland	Farmland	Farmland	Wetland	Wetland	0284674	1086021	2394
120	193	Wetland	Wetland	Wetland	Wetland	Wetland	0284444	1086019	2393
121	195	Wetland	Wetland	Wetland	Wetland	Wetland	0284278	1085993	2392
122	196	Plantation	Wetland	Wetland	Wetland	Wetland	0284265	1086023	2394
123	197	Farmland	Farmland	Wetland	Wetland	Wetland	0284257	1086043	2393
124	198	Farmland	Farmland	Farmland	Wetland	Wetland	0284237	1086056	2393

125	199	Farmland	Farmland	Wetland	Wetland	Wetland	0284213	1086078	2396
126	200	Plantation	Plantation	Wetland	Wetland	Wetland	0284163	1086100	2402
127	201	Wetland	Wetland	Wetland	Wetland	Wetland	0284054	1085978	2400
128	207	Wetland	Wetland	Wetland	Wetland	Wetland	0283910	1085998	2397
129	208	Farmland	Wetland	Wetland	Wetland	Wetland	0283827	1086058	2394
130	209	Plantation	Wetland	Wetland	Wetland	Wetland	0283792	1086057	2397
131	210	Farmland	Farmland	Wetland	Wetland	Wetland	0283760	1086053	2397
132	211	Farmland	Farmland	Farmland	Wetland	Wetland	0283706	1086026	2399
133	213	Wetland	Wetland	Wetland	Wetland	Wetland	0283695	1085891	2392
134	215	Wetland	Wetland	Wetland	Wetland	Wetland	0283618	1085684	2388
135	218	Wetland	Wetland	Wetland	Wetland	Wetland	0283664	1085475	2380
136	219	Plantation	Wetland	Wetland	Wetland	Wetland	0283626	1085460	2378
137	220	Farmland	Farmland	Wetland	Wetland	Wetland	0283592	1085448	2380
138	221	Farmland	Farmland	Farmland	Wetland	Wetland	0283551	1085432	2383
139	222	Farmland	Farmland	Farmland	Wetland	Wetland	0283514	1085428	2386
140	223	Farmland	Farmland	Shrub land	Forest	Forest	0283413	1085387	2396
141	224	Farmland	Farmland	Farmland	Wetland	Wetland	0283438	1085338	2395
142	225	Plantation	Plantation	Wetland	Wetland	Wetland	0283460	1085281	2394
143	226	Plantation	Plantation	Wetland	Wetland	Wetland	0283501	1085257	2390
144	227	Farmland	Wetland	Wetland	Wetland	Wetland	0283524	1085230	2388
145	228	Wetland	Wetland	Wetland	Wetland	Wetland	0283561	1085187	2389
146	231	Wetland	Wetland	Wetland	Wetland	Wetland	0283166	1085163	2395
147	235	Forest	Forest	Forest	Forest	Forest	0283238	1084963	2392

148	236	Wetland	Wetland	Wetland	Wetland	Wetland	0283311	1084951	2391
149	237	Farmland	Forest	Forest	Forest	Forest	0283318	1084899	2395
150	239	Farmland	Farmland	Forest	Forest	Forest	0283367	1084779	2401
151	240	Farmland	Farmland	Farmland	Forest	Forest	0283388	1084703	2398
152	241	Wetland	Wetland	Wetland	Wetland	Wetland	0283474	1084622	2389
153	243	Wetland	Wetland	Wetland	Wetland	Wetland	0283554	1084535	2385
154	244	Wetland	Wetland	Wetland	Wetland	Wetland	0283462	1084361	2391
155	246	Plantation	Wetland	Wetland	Wetland	Wetland	0283369	1084273	2391
156	247	Farmland	Farmland	Wetland	Wetland	Wetland	0283297	1084245	2393
157	249	Farmland	Farmland	Farmland	Farmland	Grassland	0285213	1087991	2408
158	251	Shrubland	Shrubland	Shrubland	Shrubland	Grassland	0285439	1087625	2385
159	253	Farmland	Farmland	Shrubland	Forest	Forest	0285337	1087476	2383
160	254	Forest	Forest	Forest	Forest	Forest	0285183	1087193	2362
161	256	Forest	Forest	Forest	Forest	Farmland	0285250	1087158	2352

ANNEX G. GPS SAMPLE POINTS FOR ACCURACY ASSESSMENT ANALYSIS

Test areas data collections are used for assessing the accuracy of remotely sensed data acquired in 2015

Serial number	Sample points	Geographic Coordinates			Land cover type at present
		Easting	Northing	Elevation	Category
1	004	0286182	1091358	2332	Farmland
2	005	0285922	1091531	2320	Farmland
3	007	0286021	1091850	2309	Farmland

4	010	0286764	1091868	2413	Plantation
5	013	0287119	1091682	2395	Farmland
6	016	0287132	1091527	2375	Farmland
7	018	0287133	1091329	2398	Grassland
8	020	0287323	1091225	2380	Farmland
9	022	0287368	1091068	2363	Grassland
10	023	0287510	1091028	2388	Grassland
11	025	0287584	1090926	2387	Farmland
12	027	0287621	1090719	2382	Farmland
13	030	0287840	1090428	2388	Grassland
14	032	0288109	1090283	2396	Grassland
15	036	0287741	1090052	2373	Shrub land
16	037	0287924	1089817	2358	Farmland
17	038	0287876	1089841	2362	Grassland
18	042	0288514	1089658	2389	Farmland
19	044	0288570	1089480	2371	Plantation
20	046	0288565	1089300	2379	Grassland
21	049	0288994	1089381	2397	Farmland
22	051	0289074	1088897	2397	Forest
23	052	0289149	1088157	2355	Grassland
24	054	0289324	1087933	2297	Farmland

25	059	0289133	1087917	2311	Farmland
26	060	0289000	1088120	2342	Farmland
27	065	0288446	1088497	2310	Shrub land
28	068	0288064	1088963	2396	Farmland
29	069	0287857	1088938	2389	Plantation
30	074	0286939	1089364	2413	Farmland
31	075	0286983	1089559	2432	Grassland
32	078	0287317	1090410	2448	Farmland
33	082	0286672	1091268	2444	Farmland
34	083	0286538	1090985	2449	Grassland
35	092	0285215	1090702	2297	Farmland
36	094	0284904	1090556	2282	Wetland
37	097	0284840	1089899	2356	Farmland
38	102	0284680	1088583	2358	Farmland
39	103	0284764	1088895	2392	Plantation
40	105	0284916	1089158	2378	Farmland
41	110	0286743	1090386	2394	Farmland
42	112	0286657	1090122	2388	Forest
43	119	0286105	1088587	2342	Farmland
44	123	0284198	1083846	2428	Farmland
45	124	0284040	1084341	2424	Farmland

46	129	0283761	1084549	2398	Wetland
47	130	0283808	1084644	2398	Wetland
48	132	0283958	1084809	2395	Wetland
49	137	0284115	1984877	2389	Wetland
50	138	0284092	1084952	2385	Wetland
51	141	0284375	1084996	2386	Wetland
52	142	0284471	1084877	2384	Wetland
53	149	0284730	1084718	2388	Wetland
54	150	0284773	1084596	2392	Wetland
55	156	0285133	1084751	2391	Wetland
56	157	0285259	1084947	2389	Wetland
57	159	0285149	1085090	2385	Wetland
58	165	0285557	1084904	2385	Wetland
59	168	0285557	1084989	2380	Wetland
60	169	0285513	1085090	2383	Wetland
61	172	0285365	1085235	2381	Wetland
62	176	0285215	1085420	2382	Wetland
63	183	0284885	1085684	2390	Wetland
64	192	0284551	1086028	2395	Wetland
65	194	0284330	1086007	2393	Wetland
66	202	0284030	1085981	2397	Wetland

67	205	0283936	1085963	2395	Wetland
68	212	0283752	1085952	2395	Wetland
69	214	0283678	1085812	2392	Wetland
70	216	0283594	1085598	2384	Wetland
71	217	0283651	1085520	2384	Wetland
72	229	0283522	1085181	2389	Wetland
73	230	0283340	1085151	2391	Wetland
74	232	0283124	1085128	2396	Wetland
75	233	0283129	1085037	2381	Forest
76	234	0283223	1084990	2389	Wetland
77	238	0283344	1084831	2399	Farmland
78	242	0283552	1084569	2388	Wetland
79	245	0283447	1084300	2391	Wetland
80	250	0285431	1087874	2406	Farmland
81	252	0285389	1087601	2389	Shrubland
82	255	0285111	1087180	2363	Shrubland
83	259	0285720	1088012	2345	Farmland
84	261	0285704	1088111	2336	Farmland
85	264	0285128	1088201	2352	Forest
86	267	0284504	1088266	2334	Wetland
87	269	0284471	1088464	2332	Wetland

88	271	0284282	1088521	2331	Wetland
89	273	0284104	1088601	2329	Wetland
90	275	0283974	1088749	2328	Wetland
91	277	0283946	1088963	2328	Wetland
92	279	0283748	1088935	2326	Wetland
93	281	0283496	1088839	2322	Wetland
94	283	0283443	1088599	2323	Wetland
95	286	0283343	1088213	2324	Wetland
96	288	0283420	1088056	2330	Wetland
97	290	0283629	1088023	2328	Wetland
98	292	0283885	1087861	2330	Wetland
99	294	0284019	1087774	2323	Wetland
100	296	0284188	1087667	2330	Wetland
101	297	0284203	1087664	2330	Forest
102	300	0284238	1087883	2322	Wetland
103	301	0284316	1088091	2326	Wetland
104	304	0283969	1087358	2429	Shrubland
105	306	0283869	1087285	2451	Shrubland
106	307	0283840	1087142	2480	Farmland
107	311	0284259	1086974	2409	Shrubland
108	312	0284266	1087143	2417	Shrubland

109	316	0288458	1088053	2279	Farmland
110	317	0288418	1087984	2295	Grassland
111	320	0288470	1087731	2290	Forest
112	326	0288756	1087571	2317	Farmland
113	329	0289209	1087548	2281	Shrub land
114	330	0289354	1087554	2255	Farmland
115	335	0289622	1087261	2268	Shrubland
116	336	0289575	1087150	2280	Grassland
117	338	0289418	1087026	2290	Forest
118	341	0289378	1086805	2284	Shrubland
119	343	0289244	1086470	2264	Shrubland
120	347	0289209	1086079	2262	Forest
121	349	0289191	1085807	2267	Forest
122	353	0288844	1085129	2285	Shrubland
123	357	0288060	1085176	2422	Farmland
124	360	0287080	1085272	2476	Farmland
125	361	0287139	1085399	2486	Grassland
126	362	0287532	1085728	2454	Forest
127	367	0287754	1086251	2470	Shrubland
128	370	0287982	1086658	2492	Plantation

129	371	0288144	1086848	2466	Forest
130	374	0288337	1087358	2358	Shrub land
131	378	0287711	1087293	2345	Farmland
132	403	0286707	1085843	2420	Plantation
133	382	0286927	1087348	2395	Farmland
134	384	0286499	1088104	2341	Farmland
135	387	0286859	1088450	2328	Farmland
136	389	0287162	1088477	2330	Plantation
137	390	0287446	1088458	2343	Farmland
138	393	0287523	1087780	2358	Farmland
139	395	0287146	1086813	2396	Farmland
140	396	0287178	1086711	2379	Shrub land
141	400	0286794	1086648	2361	Farmland
142	405	0286581	1085452	2410	Shrub land
143	408	0285793	1085440	2396	Farmland
144	411	0285075	1086393	2420	Farmland
145	412	0285525	1086745	2392	Farmland
146	416	0285983	1087561	2375	Farmland
147	419	0286431	1087058	2360	Farmland
148	423	0283790	1083968	2397	Farmland

149	424	0283986	1084066	2405	Farmland
150	426	0285521	1084516	2412	Farmland
151	428	0286137	1084232	2342	Shrubland
152	429	0286271	1084231	2367	Farmland
153	432	0286604	1083976	2398	Farmland
154	434	0287042	1084268	2350	Farmland
155	437	0287542	1084561	2338	Farmland
156	438	0287775	1084577	2360	Farmland
157	441	0288241	1084446	2338	Grassland
158	444	0288768	1084369	2324	Farmland
159	445	0288624	1084197	2347	Farmland
160	448	0288587	1083758	2439	Grassland
161	450	0288518	1083028	2412	Farmland
162	451	0288809	1082889	2439	Farmland
163	454	0289462	1082207	2517	Grassland
164	456	0288917	1082267	2577	Grassland
165	459	0288195	1082301	2551	Plantation
166	461	0287586	1082284	2559	Grassland
167	464	0287176	1082433	2537	Grassland
168	466	0287078	1081969	2461	Farmland
169	469	0286355	1081623	2394	Grassland

170	473	0286690	1082587	2394	Farmland
171	476	0286383	1082831	2398	Grassland
172	478	0285870	1082862	2348	Farmland
173	480	0285604	1082700	2382	Farmland
174	482	0285420	1083168	2407	Plantation
175	486	0282985	1083542	2426	Plantation
176	487	0283064	1083336	2416	Plantation
177	490	0283360	1082897	2421	Plantation
178	493	0284078	1082796	2397	Farmland
179	494	0284224	1082799	2358	Plantation
180	496	0284544	1082648	2382	Farmland
181	499	0284880	1082198	2390	Grassland
182	502	0284945	1081630	2408	Farmland
183	505	0285533	1081883	2337	Farmland
184	508	0285866	1081232	2331	Farmland
185	509	0285706	1081117	2349	Farmland
186	512	0284837	1081194	2359	Shrubland
187	513	0284537	1081243	2360	Forest
188	515	0284326	1081616	2384	Grassland
189	518	0284275	1082310	2404	Grassland
190	520	0283807	1082263	2355	Plantation

191	523	0283890	1081413	2376	Shrub land
192	526	0283095	1081791	2335	Farmland
193	529	0282551	1081439	2350	Farmland
194	531	0282345	1081767	2395	Grassland
195	532	0282329	1082560	2438	Plantation
196	534	0282658	1082602	2471	Plantation
197	540	0282904	1084857	2485	plantation
198	543	0282942	1085716	2457	Shrub land
199	545	0283060	1085840	2494	Plantation
200	547	0282988	1086132	2499	Plantation
201	548	0283244	1086466	2426	Farmland
202	551	0283726	1086564	2462	Farmland
203	553	0283583	1087246	2438	Plantation
204	557	0282460	1086695	2413	Shrubland
205	556	0282514	1086813	2415	Forest
206	560	0282391	1086159	2377	Shrubland
207	566	0282324	1083845	2447	Plantation