DILLA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

DROUGHT RISK ASSESSMENT USING REMOTE SENSING AND GIS A CASE STUDY IN ABAYA DISTRICT, ETHIOPIA

A thesis submitted to

DillaUniversityCollege of social science and Humanities, College of Postgraduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in GIS and Remote Sensing

BY

Birhane Legesse

Advisor: Dr.Abiyot Legesse

Dilla University, Dilla,Ethiopia

May, 2020

DILLA UNIVERSITY
School of Graduate Studies

Approval Sheet

This is to certify that this thesis work entitled "drought risk assessment using remote sensing and GIS a case study in abaya district, Oromia region" submitted by Mr. BirhaneLegese in partial fulfillment of the requirements for the award of Master of Science in GIS and Remote Sensing by the Dilla University. The research work presented here meets the accepted standards with respect to originality and quality work of candidate and has been carried out in Geography & Environmental Studies Department under the supervision of Dr. AbiyotLegesse.

Signed by the Examining Committee:

Dr. AbiyotLegesse	____________	19/09/2020
Name of Advisor	Signature	Date
Dereje Likissa	____________	_01/09/2020_
Name of Chair Person	Signature	Date
Dr. Vanum Govindu	____________	**01.09.2020**
Name of External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the council of graduate studies (CGS) through the school of graduate studies graduate committee (SGC) of the candidate's major department.

===

Acknowledgments

I am thankful to the almighty GOD for the divine blessings showered upon me to complete this work. I would like to express my deeply felt gratitude to my advisor, Dr. AbiyotLegessedepartment of Geography and Environmental Studies, I am very grateful to the EMSA for giving meteorological data and the Dilla University ICT Maintenance Office Staffs for allowing to use Internet connection to download satellite Images. I am greatly indebted to all my family members for their helpful nature throughout my assignment. My special gratitude goes to all my friends for their cooperation in providing me with morale, technical and valuable material supports while I was doing this research work.

Table of Content

LIST OF TABLES

LISTS OF FIGURES

LIST OF ABBREVIATIONS

AOI Area of interest

Arc GIS Aeronautical Reconnaissance Coverage Geographical Information System

CSA Central Statistics Agency

EIAR Ethiopian Institute of Agricultural Research

ERDAS Earth resource data analysis system

GIS Geographical Information System

IDW Inverse Distance Weight

NDVI Normalized Difference Vegetation Index

ENMSA Ethiopian national meteorological services agency

MODIS Moderate Resolution Imaging Spectra Radio-meter

PDSI Palmer Drought Severity Index

RS Remote Sensing

RF Rain fall

SPI Standard precipitation Index

USGS United States Geological Survey

VCI Vegetation Condition Index

CMI Crop moisture index

BoARDBureau of Agricultural and Rural Development

List of Appendices

Abstract

Drought is the most complex but least understood of all natural hazards. Timely information about the onset of drought, extent, intensity, duration and impacts can limit drought related *losses of life, human suffering and decrease damage to economy and environment. In this study an attempt has been made to assess drought using RS and GIS techniques in West Guji Zone, Abaya district. Standardized Precipitation Index (SPI) was used to determinedrought in the study area.Rainfall data of study area and around the district were used and interpolated to determine the spatial pattern of meteorological drought and threshold (average) value for different classification types of drought through SPI. Agricultural drought risk areas were identified based on Normalized Difference Vegetation Index (NDVI)anomaly by using vegetation index data set with 250m resolution from MODIS satellite image from 2004-2018, because the Landsat image with resolution of 30m was affected by strip line and cloud of some year, so it's not incredible to use for study.NDVI anomalyfrom the mean values was typically classified to determine the agricultural drought risk area.The spatial patterns of agricultural drought events and the levels of its severity ranged from slight in most of the years to severedrought in 2015 and 2010. Generally, the extent of severe drought coverage, registered in this case, stretched areas of central, western and in small pocket of south eastern parts of the study area and* the study area was stricken by sever (11.34 %) moderate (46.8%), slightly (37.5%)and no drought (4.36 %)agricultural drought risk map. *Meteorological drought risk map indicated that the study area has been affected*by extreme sever (58%), sever (27%), moderate(9.36%)and slight(5.64%) meteorological drought. *From the above result the satellite developed indices based on the ground data is vital for successful drought assessment and identification of drought vulnerable areas.*

Key words: Agricultural droughts, Meteorological drought, GIS, RS, MODIS, NDVI, SPI,

CHAPTER ONE

INTRODUCION

1.1. Background of Study

Drought is perhaps the most complex and damaging natural hazard. It can recur frequently and cause considerable damage to agriculture, economy, nature, and property, potentially affecting the lives of a large number of people (Kogan, 1997). Drought is a natural disaster causing adverse impacts on vegetation, animals & people (Edossa et al. 2010). Drought is generally considered as a deficiency of rain fall over a prolonged period of time. Although it is equally prevalent in all parts of the world, their impact is more pronounced in developing countries where rain fed agriculture is the major economic base. In Ethiopia, drought occurs frequently and forms the major natural hazard. In many parts of the country, agricultural production are characterized by significant fluctuation due to variation in moisture availability and this in turn lead to crop failure and wide spread drought (Abraha, 2013).

Drought risk is a product of a region's exposure to the climatic hazard and its vulnerability to extended periods of water shortage (Wilhite, 2000), if nations like Ethiopia improves their understanding of the hazard and the factors that influence vulnerability. The impact of drought can be reduced through mitigation and preparedness.There are number of indicators for drought monitoring and assessments. Every indicator has its strength and limitations in drought detection. The most common Meteorological drought indices are SPI,PDSI, etc. The strength of SPI is easy to calculate based onPrecipitation; the different time scales SPI indicate durationof drought and impacts on hydrology and agriculture.

SPIassimilate information on rain fall, stored soil moisture or water supply but they do not express much localspatialdetail.Thus, a major drawback of climate based drought indicators is based on precipitation (water supply)alone and does not take into accounttemperature or evapotranspiration(water depletion), their lack of spatial detail as well asthey are dependent on data collected at weather stations which sometimes are sparsely distributedaffecting the reliability of drought indices (Brown et al. 2002). On the other hand, satellite derived drought indicators calculated from satellite derived surface parameters have been widely used to study droughts. NDVI, VCI and TCI are some of the extensively used vegetation indices.

Remote sensing and GIS technique is increasingly being regarded as a useful drought detection technique as evidenced by its use across many parts of the World (Chopra, 2006;Park, et al. 2004; Partheepan and Dayawansa, 2008).

Remote sensing and GIS can successfully contribute to monitoring and assessment of process changes in ecosystem (Kienberger et al., 2002). GIS in drought assessment helps to create spatial digital database to hold meteorological information and generate thematic layers that represent spatial distribution of drought for both Standardized Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI). Using GIS, we can delineate areas with high drought risk using SPI and NDVI and compare the results from both models (Nezar et al., 2004).

Drought produces a complex web of impacts that cover many sectors of the economy. The consequence of drought also goes beyond the area experiencing physical drought. Moreover, drought can impose both direct and indirect challenges. Among others, drought reduced crop, rangeland, and forest productivity; increase fire hazard; reduced water levels; increase livestock and wildlife mortality rates; and cause a devastating damage to wildlife and fish habitat. The consequences of these impacts illustrate indirect impacts. In the process of reducing the causalities of drought, remote sensing and GIS technology play a significant role. To this end, this thesis is concerned with drought risk assessment using remote sensing and GIS with particular emphasis in Abaya District/*Woreda, Oromia Regional State.*

1.2. Statement of the problem

In Ethiopia drought is a frequently occurring phenomenon. It is the single most important climate related natural hazard impacting on the country from time to time .The spatial extent and frequency of drought events have both increased and it is now occurring once every five year or even less at different intensities causing significant impacts on agricultural output, economic loses and adverse social consequences (Gebrehiwot et al,2011) .

A Case Study done in Southern Zone Tigray, Entitled Drought Risk Assessment Using remote sensing and GIS by Legese Hadush in 2010.The researcher used only Quantitative research approach by using Spot Vegetation NDVI with 1km resolution ,Satellite rain fall data&Ground station rain fall data & Ancillary data by using the data from 1988-2005. The main finding of the study was eight years seasonal pattern of rainfall and NDVI indicated that Northern, Western and Eastern parts of the study area has low rainfall distribution during the farming season as well as has low NDVI value(Legese Hadish,2010).

Moreover, the research had done in Oromia Regional State West Hararge zone Entitled Agricultural Drought Risk Area Assessment and Mapping Using remote sensing & GIS byWondesen Nagassa in 2017. The researcher has been usedmixed research approach by using Spot vegetation NDVI PROVA Vegetation NDVI with 1km by 1km, Agricultural data &Ground rainfall data by using data from 2005 to 2013. The study revealed that West Hararge zone experiences drought range from slight to severe levels occurring within two to three years gaps. The years 2005 and 2009 have been found to be the years of the worst drought while 2007 and 2012 were the wettest years, showing good yields (Wondesen Nagassa, 2017).

Furthermore, the Project had done Entitled Risk Assessment in Borena Zone by the SWIS Non-Governmental organization in 2015. The focus of the document relates to pastoralist and relates to arid & semi-arid land regions of the country with the specific of the Borena Zone. The project has been found out that overwhelming natural hazard facing the southern lowlands of Ethiopia is that of drought accounting for 98 percent of fatalities. Moreover, a High risk drought area includes the Borena Zone of Oromia Regional State (Swiss NGO, 2015).

According to Abaya Woreda Yearly report of five years from 2013 to 2017 the drought monitoring and drought early warning system have been based on ground data collection through the post - harvest assessment to identify drought affected area. As a result, the activity of drought risk assessment administered only with the purpose of identifying the population needing food and non-food aid due to the drought. Furthermore, the data that wascollected by the *woreda's* agricultural experts in the post - harvest period are not reliable due to the limitations accompanied with instruments, procedures and professional expertise in the area.

The information obtained from different sources demonstrates that the study area is affected by recurrent droughts. However, as far as the researcher reading is concerned, in the district there is no objective research work. Moreover, an assessment undertaken by woreda's agricultural experts not supplemented by remote sensing and GIS technologies. In most case, the expertise also lacks the necessary prerequisite to undertake the assessment objectively..

On another hand most of the researchers have been used temporal data of eight for years & Spot NDVI 1km by 1km resolution, Satellite rain fall data &Ancillary data by using Quantitative research approach. Whereas this research has been used Mixed research approach by using MODIS vegetation NDVI with 250 m resolution & Ground rain fall data& Ancillary data with time series data from 2004-2017 of 15 years. With cognizance of this entire gap, the study has been carried out to detect drought in Abaya district by using GIS and Remote Sensing techniques.

1.3. Objectives

1.3.1. General objective:

- The general objective of this research is to examine drought risk areas using Remote Sensing and GIS techniques in Abaya District.

1.3.2. Specific Objective

The specific objectives of this study are to

- identify Agricultural and Meteorological Drought using different drought indices
- map drought prone area by combining Agricultural and meteorological drought and
- determine the impact of drought in the study area

1.4. Research Questions

1. Is there an identified meteorological and agricultural drought using different index in the study area?
2. How does map of the drought prone area by combining meteorological, agricultural drought?
3. Is there any considerable impact of drought in the study area?

1.5. Significance of the study

There is a firm conviction that the use of Satellite Remote Sensing data and Geographical Information System (GIS) can effectively facilitate the detection, identification and mapping of agricultural drought risk prone areas. Reliable agricultural drought risk area mapping is expected to enhance decision making process for drought monitoring and mitigation actions. Thus, it is hoped that agricultural drought risk zone map produced from this study, can be useful for policy makers to prioritize their action plan based on the indicated risk level. Researchers also can use it to generate agricultural technologies and information including the techniques for the selection of drought tolerant and adaptive crops, as well as for the generation of crop and soil moisture management strategies. Moreover, it may be helpful for development agents and Non-Governmental Organizations (NGO) to facilitate scaling up of the best techniques with success stories to similar risk zones elsewhere. Apparently, this research has significance in providing a better foundation for using Remote Sensing and GIS-based approaches to assess, monitor and manage drought effects. It also offers the opportunity to use different drought monitoring indices, with increased efficiency in spatial and temporal resolutions, to determine the levels of drought and its effects on crop production. Evidently, therefore, it is hoped that the result of the study will provide agricultural experts, water managers and policy makers with better tools for assessing, forecasting and managing agricultural drought risk areas on much more précised scales. Fundamentally, it is firmly believed that the result of the study will also provide the local farming communities with basic knowledge and awareness that can empower and enable them to make competitive and constructive efforts towards resiliently surviving drought hazards through efficient management of the meager water resources available to them.

1.6. Scope of the Study

The study focuses on only on West Guji zone Abaya woreda of Oromia Regional state. Satellite data are MODIS image and ground station rain fall data from six stations with surrounding the study area. The temporal time coverage was from 2004 to 2018. On this study we have not to examine local area temperature since it's approved with different study as there is climate change through time. Even though there is a problem related to delineating the drought affecting area, the study limited only to the problem of drought in Abaya district.

1.7. Limitations of the Study

There are several constraints that the researcher facedthese limitationsduring conducting the study.These problems werelack of time and financial problem, unwilling of the respondents to respond timely. Therefore, the cumulative effect of these and other constraints may have created some influence and affect the quality of the research. But, as soon as possible I tried to manage those issues accordingly.

1.8.Organization of the thesis

The thesis is organized in to five chapters .the first chapter gives back ground information of the study .The second chapter covers , the study related to existing review of literature of research done on drought risk assessment, types of drought, impacts, meteorological and Agricultural indices, application of RS and GIS technology in the monitoring, prediction and assessment of drought. The third chapter represents the general description of the study area, sources of data, methods of data collection and methodology to meet the required objective of the study area. Chapter four represents the result and discussion that covers the analysis of long term NDVI temporal images from MODIS satellite to arrive at the agricultural drought and rain fall data to determine the meteorological drought. The analysis also covers description of the relationship established between rain fall and crop yield, correlation between SPI and NDVI, and discussed what effects does crop yield as a result of variability in rain fall. Finally chapter five presents conclusion and recommendation of the study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Definition of Drought

According toWilhite (2000), Drought is considered by many to be the most complex but least understood of all natural hazard affecting more people than any other hazard.

Drought is defined as “the naturally occurring phenomenon that exists when Precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affects land resource production systems” (UNCCD, 1999).

2.2. Types of Drought

According toWilhite and Glantz(1985), Drought can be categorized as follows;

Meteorological Drought:is defined on the basis of degree of dryness, in comparison to a normal and the duration of the dry period. It simply implies rainfall deficiency where the precipitation is reduced by more than 25%from normal in any given area. These are region specific, since deficiency of precipitation is highly variable from region to region.

Hydrological Drought:refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, lake, reservoir and ground water levels. There is a time lag between lack of rain and less water in streams, rivers, lakes and reservoirs. Hydrological drought often leads to reduction of natural stream flows or ground water levels, and stored water supplies.

Agricultural Drought:defined as deficiency of top soil moisture and susceptible of crop during different stage of development .Agricultural drought links with some characteristics of meteorological and hydrological drought which produce agricultural impacts, focus on rain fall shortage, soil water deficits and reduced reservoir levels. This links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual potential evapotranspiration, soil, soil water deficits, and reduced ground water or reservoir levels. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, and its stage of growth and the physical and biological properties of the soil.

Socio - economic drought: is associated the demand and supply of economic goods with elements of meteorological, hydrological and agricultural drought. This type of drought mainly occurs when the demand of economic goods such as water, forage, food grains, hydroelectric power, exceeds its supply due to weather related deficiency in water supply.

2.3. Impacts of drought

The impact of drought can be economic, social or environmental. Drought produces a complex web of impacts that spans many sectors of the economy .drought impacts are categorized as direct and indirect. Direct impacts include reduced crop production, forest productivity; reduce water level, increased livestock and wild life mortality rates and damage to wild life habitat. The effect of these direct impacts indicates indirect impact. Remote sensing and GIS technology significantly contributes to all the activities of management (Jeyaseelan, 2003)

2.4. Drought in Ethiopia

Drought occurs equally severe in all types of climatic Region of the world (Glantz, 2001). But its severity is higher when it occurs in developing countries especially Africa. This is because of that majority of the population depend on rain fed agriculture Ethiopia is one of the African Countries frequently affected by extreme drought & Famine (Gebrehiwot et al, 2011).

In Ethiopia weather risks are major determinants for occurrence of drought. A historical record indicates that there were about 30 drought events occurring in the country. 13 of these drought events are caused severe economic loses and destroyed crops contributed to death of people &Animals (Glantz, 1987,Teshome, 2006, USAID, 2007) (www.foo.org/drought % 20 report % 2008). Oromia Region, particularly, Abaya District has suffered from a different severe droughts and food insecure. The lack of sufficient precipitation, during the Belg rains season (Feb-may) with delayed summer/june - September) have led to wide spread food in securing in the study area.As the overwhelming majority of the country's population depends on rain fed agriculture and related economic activities for its livelihood, agriculture remains by far the most important sector in Ethiopian economy. Yet, because the country's rainfall is significantly scanty, a slight change in it bears drastic negative effects on the agricultural production, in general, and the seasonal crop yields, in particular. The effect of climate variability is felt, even more severely, among the poorer subsistent farming households. Hence, the subsistence agriculture is characterized by significant fluctuations in yield and production due to risks associated with rainfall variability. Practically, more than 95% of the climate dependent crop production is usually conducted by small holders and subsistent farmers, who have the least capacity to cope up with the variability of climate change by resiliently resisting its severe negative impacts (Wolde Amlak, 2009). Apparently, persistent drought risks, associated with the year-to-year variability of rainfall and scarcity of water, have become determining challenges to the sustainable increments of the national agricultural productivity and the household food security. Climate change extremes have had direct and often persistent severe impacts on farmers' assets and livelihoods in Ethiopia, for the last many years. For instance, the 1998-2000 droughts have claimedover 75%of the average annual income of the households in the northern parts of the country.

2.5. Drought Risk Prone Zones Assessment in Ethiopia

Risk assessment involves speculation and evaluation of the magnitude and severity of the unexpected negative outcomes, either quantitatively or qualitatively. Risk assessment and evaluation, the drought prone area or risk zone identification is usually carried out on the basis of historic data analysis of rainfall and evaporation and the area of irrigation support activities.

In Ethiopia, drought monitoring mechanisms were based on meteorological information obtained from ground stations such as rainfall, weather conditions, crop performance and water availability. In other words, until recent times, ground stations used to be the major sources of national information for agricultural drought risk assessment. However, this reliance on ground data could not lead to successful results, as a poor density of weather stations, for instance, could make it difficult to acquire sufficient spatial and temporal climate data (Brown et al., 2002).

Besides, the conventional approach does not cover man's influences on the wellbeing of the ecosystem, such as land use changes, irrigated area developed and the area affected due to water logging and salinity. The Remote-Sensing and GIS based method for identification of drought prone areas were one of the most well understood and clearly detected climate change phenomena (Jeyaseelan et al. 2002).

2.6. The Role of GIS and RS in Drought Study

Remote sensing techniques make it possible to obtain and distribute information rapidly over large areas by means of sensors operating in several spectral bands, mounted on aircraft or satellites. A satellite, which orbits the Earth, is able to explore the whole surface in a few days and repeat the survey of the same area at regular intervals, whilst an aircraft can give a more detailed analysis of a smaller area, if a specific need occurs. The spectral bands used by these sensors cover the whole range between visible and microwaves. The advancements made in the orbital satellite technology could aid in mapping the disaster area, prediction/forecasting of impending disaster, and disaster relief management. Satellite-based remote sensing has been widely used over the past ~ 30 years for national to global-scale many environmental monitoring activities, including drought monitoring (Tsegaye, T. 2013).

The remote sensing techniques can be used to monitor the current situation- before, during or after disaster. Severity of drought can minimize through the effective methods of using satellite image and rainfall data that plays a great role in mitigating the impact of drought.Satellite image plays a role to detect the onset of drought, its duration and magnitude. Rapid developments in computer technology and the Geographical Information Systems (GIS) help to process Remote Sensing (RS) observations from satellites in a spatial format of maps both individually and along With tabular data and "crunch" them together to provide a new perception - the spatial visualization of information of natural resources. The integration of information derived from RS techniques with other datasets - both in spatial and non-spatial formats provides tremendous potential for identification, monitoring and assessment of droughts and floods (Jeyaseelan, 2002).

GIS in drought assessment helps to create spatial digital database to hold meteorological information and generate thematic layers that represent spatial distribution of drought for both Standardized Precipitation Index (SPI) and Normalized Difference Vegetation Index (NDVI).

Drought index have been developed as a means to measure drought. Assessing and monitoring of drought is based on a given thresholds forecasting precipitation deficit over a specific period time .different meteorological and vegetation indices are available to drought .the turning point in the evaluation of drought indices, when palmer (1965) developed palmer drought severity index (PDSI).at the present day, we have many drought indices aiming at the monitoring and predicting the beginning, intensity, duration and spatial extent of drought.

2.7. Satellite Based Drought Indices

Drought indicators assimilate information on rainfall, stored soil moisture or water supply but do not express much local spatial detail. Also, drought indices calculated at one location is only valid for single location. Thus, a major drawback of climate based drought indicators is their lack of spatial detail as well as they are dependent on data collected at weather stations which sometimes are sparsely distributed affecting the reliability of the drought indices (Brown and Reed et al. 2002). Satellite derived drought indicators calculated from satellite-derived surface parameters have been widely used to study droughts. Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI) are some of the widely used vegetation indices.

2.7.1. Normalized Difference Vegetation Index (NDVI)

Tucker first suggested NDVI in 1979 as an index of vegetation health and density (Thenkabail and Gamage et al. 2004). NIR and RED are the reflectance in the near infrared and red bands. NDVI is a good indicator of green biomass, leaf area index, and patterns of production (Thenkabail and Gamage et al. 2004; Wang and Wang et al. 2004), Mediterranean (Vogt et al., 1998), and Senegal (Li.et al.2004) indicate meaningful direct relationships between NDVI derived satellites, rainfall and vegetation cover and biomass.

2.7.2. NDVI Anomaly:

NDVI Anomalyis a Departure of NDVI from the long-term average, normalized by long-term variability.It is generated by subtracting the long-term mean from the current value for that month of the year for each grid cell. NDVI anomaly is a deviation of vegetation condition from the average and the previous period. The use of anomaly isolates the variability in the vegetation signal and establishes meaningful historical context for the current NDVI to determine relative drought severity (Anyamba and Tucker, 2012).NDVI anomaly is to identify negative anomaly over expanse of large areas covering several tens of square kilometers. Hence, small-scale changes in land cover will not affect the use of NDVI anomaly for drought monitoring.

According to Murali et al. (2008) and Gizachew and Suryabhagavan, (2014), NDVI anomaly was used as index derived from NDVI can be used to assess seasonal crop conditions. The resulting NDVI anomaly assigned to the respective grid cell was reclassified into five drought severity classes based on Table 1 below.

Table 1: Agricultural drought risk classification using NDVI anomalies

Percent of NDVI Anomalies	**Class**
0% to -10%	Slight drought
-10% to -20%	Moderately drought
-20% to -30%	Severe drought
above -30%	Very Severe drought

Source: (Gizachew et al., (2014)

2.8. Meteorological Drought Indices

2.8.1. Palmer Drought severity index (PDSI):

In 1965, W.C. Palmer developed an index to measure the departure of the moisture supply (Palmer, 1965). The objective of the Palmer Drought Severity Index (PDSI) is to provide standardized measurements of moisture conditions so that comparison could be made between locations and between months. The PDSI is a meteorological drought index that is responsive to abnormal weather conditions either on dry or abnormally wet side. The index was specifically designed to treat the drought problem in semiarid and sub humid climates; with palmer himself cautioning that extrapolation beyond these conditions may lead to unrealistic results.

The Palmer Drought Severity Index (PDSI, Palmer, 1965) has a time scale of about 9 months (Guttmann, 1998), which does not allow identification of droughts at shorter time scales.The Palmer Index has typically been calculated on a monthly basis, and a long-term archive of the monthly PDSI values for every Climate Division in the United States exists with the National Climatic Data Center from 1895 through the present. The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The disadvantage is that it is not good for short term forecasts.

2.8.2. Standardized Precipitation Index (SPI)

SPI was developed by McKee et al. (1993), is available tool for the estimation of the intensity and duration of drought events. The SPI was designed to quantify the precipitation deficit for multiple time scales. In SPI calculations, the long-term precipitation record for a desired period is fitted to a probability distribution. If a particular rainfall event gives a low probability on the cumulative probability function, then this is indicative of a likely drought event. Thecumulative probability gamma function is transformed into a standard normal random variable Z with mean of zero and standard deviation of one so that the mean SPI forthe location and desired period is zero (Edwards and McKee 1997). Positive SPI values indicate greater than median precipitation, while negative values indicate less than median precipitation. A drought event occurs any time the SPI is continuously negative and reaches intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude". The SPI is used widely in the United States and in more than 30countries on a research and operational basis.

Table 2: Meteorological drought risk classification using SPI values (McKee et al., 1993)

SPI Values	Class (Description)	Probability
2.0 and more	Extremely wet	0.977–1.000
1.5 to 1.99	Very wet	0.933–0.977
1.0 to 1.49	Moderately we	0.841–0.933
-.99 to .99	Near normal	0.159–0.841
-1.0 to -1.49	Moderately dry	0.067–0.159
-1.5 to -1.99	Severely dry	0.023–0.067
-2 and less	Extremely dry	0.000–0.023

CHAPTER THREE
3. MATERIALS AND METHODS

3.1. Description of Study Area

The study was conducted in Abaya district, west Guji zone, Oromia National regional state of Ethiopia. Geographically it is found between 06°11'56" to 06°25'06"Latitude and between 37^{o}50'00" to 38°20'15"Longitude. It is bordered by Lake Abaya from the West and Gelana district from the South, Sidama zone from the north and Gedeo zone from the East (see fig.1). The study area is 365 km far from Addis Ababa to South direction and is crossed by the Addis Ababa Moyalle international road. It is 7km far from Dilla town. It covers a total area of 187,134 hectare. Out of which 60,728.23hectare is farm land, 45275hectare pasture land,10,716 hectare natural forest,1688.5hectare planting forest, 62,295hectare swampy, and the others (degraded land, shrubs, and water) body. The total populations of the study area are139914 of which 70657 are male and 69257 are female.

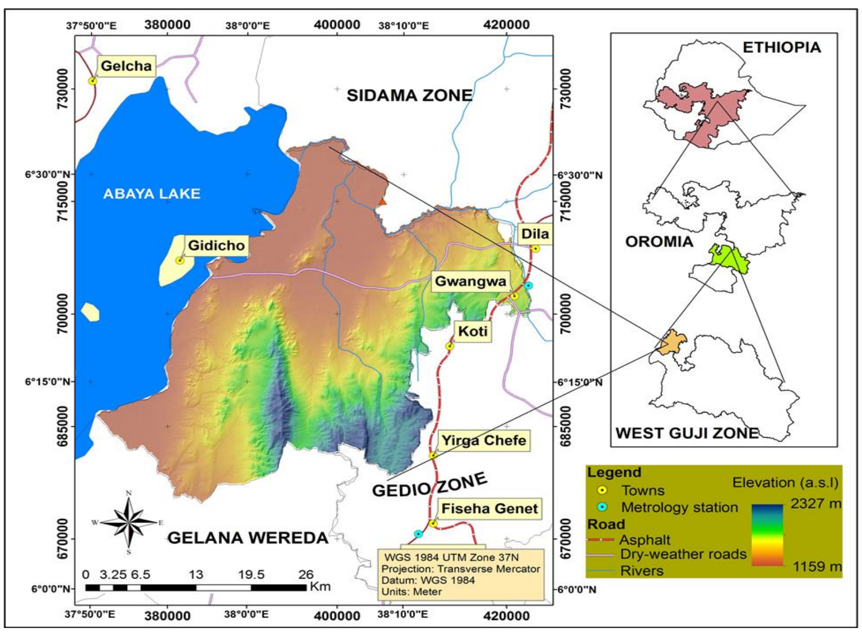

Figure 1: Location map of the study area

3.1.1. Topography

Abaya district lies within altitude of 1200m - 2060m.a.s.lwith an average elevation of 1680m.a.s.l. Generally, the topography of the woreda can be grouped in to plain, mountain, lake, valley, low plateau and marshy area. Among the mountains; Muticha, Shombo, Kara, and Buchisi are the most elevated.

3.1.2. Drainage System

The Abaya district drainage system is characterized by perennial and seasonal rivers. The perennial rivers include Gidabo which flows along the border of Abaya district and Sidama zone to LakeAbaya, SuboRiver that drains from the north eastern part of the district to the Lake Abaya with total length of 80km, Gelana and others likeAmalake and Rabo are those rivers originate from Gedeo high lands draining to Lake Abaya. The only Lake of the Abaya district is Lake Abaya. Lake Abaya is the largest rift valley lake in Ethiopia. It is located to the west direction of the district and has a total area of 1070km^2 with the depth of 13m. LakeAbaya is used by the surrounding community for subsistent fishing activity and serving for navigation between Lado people and west Abaya towns of the SNNPR.

3.1.3. Climate

Abaya district has only two types of agro-climatic zone. These are Woinadega and Kolla. About 30% of the total area of the district falls under Woinadega and the remaining 70%of the area is under Kolla. Even though the district has no Meteorological station, data obtained from the neighboring station reveal that the average annual rain fall is estimated at 1223mm and average annual temperature ranges from 16^0 c -28^{0}c.Abaya district has two major rain seasons, namely Spring(belg) and autumn(tsedey). Spring is the major crop season .It begins from March 15 and ends on May 15.The second rainy season is Autumn in which only a few cereal crops are grown begins from half of September and ends in half of November.

3.1.4. Soils

The soil type of Abaya district is Calcaric and Euricfluvisols,EuricNitosols and Chromic and Orthicluvi sols. Of these, the first two are covering the largest part of the district. According to the recent information, the major soil types in percent are clay loam ,68% ,clay 15.25%,sandy loam11%,sandy soil 5.75%.These are the major soils in the district.(BoARD , 2016).

3.1.5. Major Economic Activities

The population in the study area practiced mixed farming. According to Abaya Agricultural and Rural development office reviewthat the population in the study area are practiced mixed farming and the farming techniques used by most farmers are traditional.The widely grown crops in the area are maize, teff, hair coat, bean, cabbage, coffee, banana and enset. Livestock also constitute important part of the society's economy activity in the study area. Thereare about18, 530 cattle, 29,963 goats, 9041sheep, 775 horses, 542 mule, and 551donkeys as (BoARDreport, 2017).

3.2. Research Methodology

3.2.1. Method of Study

Mixed research approach was used in this study. Sequential explanatory design was used in this study. Analysis of drought risk was made using spatial and non-spatial data obtained from different sources. Most of these data are quantitative. Thus, the dominant method used was quantitative followed by qualitative method which involved collection and analysis data pertaining to perception about the potential impacts of drought in the study area. Using monthly rainfall data, the SPI value were computed and from MODIS satellite image, vegetation healthiness were gained to examine drought status in the woreda. Using image processing Normalized Difference Vegetation Index (NDVI), NDVI Anomaly and Standardized Precipitation Index (SPI), and Crop yield production were done. Thus,spatial analysis was used to verify NDVI, SPI and crop trend.Finally, the drought layers weighted and overlaid to generate drought severity class map.In order to accomplish this study the following primary and secondary data were collected. The primary data sources were satellite imagery, data from questionnaire and interview. The secondary data were Meteorological data and Crop yield data used to carry out this study from 2004 to 2018.

3.2.2. Data sources:

a. Remote sensing data:

Land sat satellite image is atmospherically corrected or free from cloud and most representatives to the land surface conditions, the images that were available for our study area and time series (2004-2018) are affected by strip line and cloud cover. In order to minimize such error it recommends using MODIS satellite image by tolerating spatial resolution issues as best.

The MODIS products of NDVI is available from year 2004 to 2018 (March to May) have been used for processing in the study.The MODIS products are freely distributed by the U.S through Land Processes Distributed Active Archive Center (http://lpdaac.usgs.gov) or USGSGlobal Visualization Viewer (http://glovis.usgs.gov).

For the analysis of drought severity, MODIS satellite images vegetation indices were freely downloaded through *http: //ladsweb.nascom.nasa.gov/data*websitewith the spatial resolution of 250 m and temporal 16 days on a sinusoidal grid level 3 products.

b. meteorological data:

Monthly rainfall was collected for the period of 15 years from 2004 - 2018. Monthly rainfall Data of 6 stations has been collected from Ethiopian national meteorological services agency (ENMSA) to interpolate the rain fall distribution and to compute the SPI value for the study area. It consisted of the monthly precipitation records from 1988 to 2017, total of 29 years with some data gaps in some of the stations in the entire period. Making themeteorological data compatible with other remote sensing data is required due to which monthly rainfall data has been chosen for the research to average them to season. These monthly rainfall records have been used toidentify the Meteorological drought seasons and rainfall deficient seasons. These have been also employed to generate Meteorological drought indicator and identify Meteorological droughtover Abaya district.

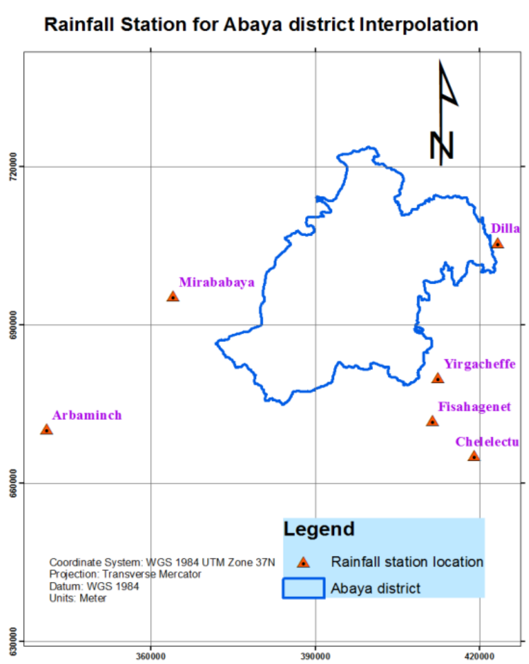

Figure 2: Meteorological Rainfall monthly data of stations around Abaya surrounding.

C.Ancillary Data:

Crop production is very sensitive to agricultural drought. In order to find out the relationship between crop yield and the existing drought condition and thus validate satellite based drought events, average yearly crop yield data of the study area were collected from the agricultural institute. Thus ancillary data includes agricultural seasonal crop production yield amountobtained from Abaya woredaof agricultural office(BoARD, report, 2018) and the administrative boundarymaps from Woreda administrative office. These maps have been used for the separating differentenvironment for analysis how production amount depending on rainfall between study periods of 2004 to 2018.

3.2.3. Software Package

In the research study Google Earth, ERDAS Imagine 2014, and ArcGIS 10.3 was used. ERDAS Imagine 2014 version remote sensing software were used for image preprocessing , graphical display, mosaicking and sub-setting of the image on the basis of Area of Interest (AOI). Similarly, ArcGIS 10.3 software was utilized to interpolate, compute the SPI, statistical analysisand to describe the composite map and extent of drought risk condition in the study area. Finally Microsoft Excel 10 version was used for rainfall data and crop yield production data arrangement and processing.

3.2.4. Sampling Methods:

The target populations of the study were Agricultural Development Agent workers, Manager of Agriculture of the Abaya Woreda, Agronomist & Farmers. The sampling method used by the researcher was Stratified purposive sampling method was used. In the very beginning, the researchers divided the kebeles in to Woinadega &Kola. Then, the samples were selected purposively depending on the knowledge &experience they have in the area under study. Finally, the researcher took as the sample Agricultural Development agent workers two from each kebele i.e. 54 population , woreda Agriculture office manager 1, Agronomist 1, And Farmers from Kola kebeles 4 & From Woinadega 4 totally 64 populations taken as a sample. The researchers distributed Semi structured questionnaires for Agricultural Development agent workers. Moreover, for the triangulation purpose, Interview was made with woreda Agriculture office manager, Agronomist, and farmers.

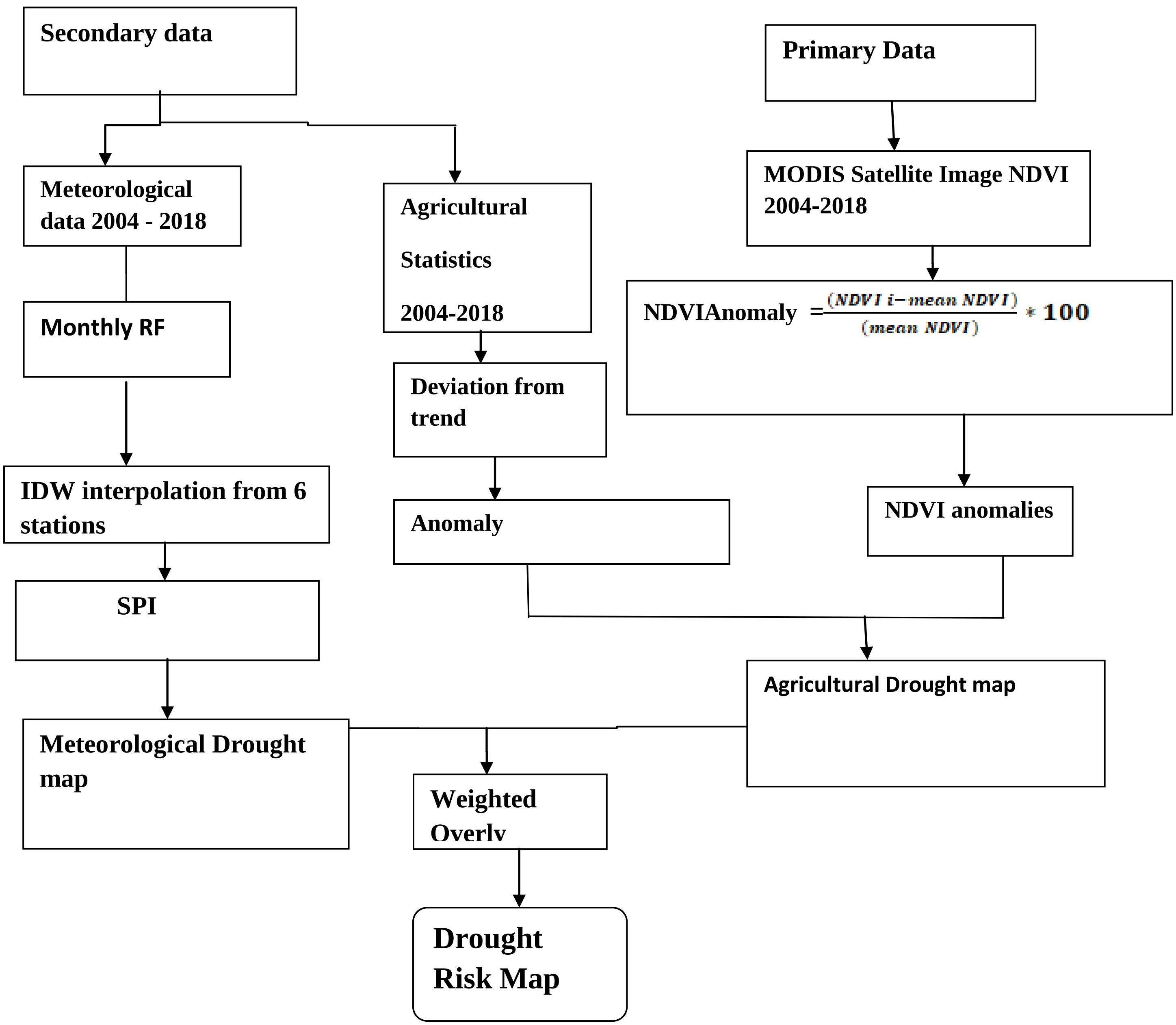

Figure 3: Flow diagram of research methodology

3.3. Data Analysis Methods

3.3.1.Computation of normalized difference vegetation index (NDVI)

The normalized difference vegetation index (NDVI) gives a measure of the vegetative cover as it is sensitive to the chlorophyll content of plants. In other words, dense vegetation shows high value in the NDVI imagery while areas with little or no vegetation show negative value. NDVI of MODIS image have two bands, the near-infrared (NIR) band 2 and RED band 1 wave lengths. The MODIS satellite image without pyramid was rescaled and re-projected to change HDF to tiff format using toolbar of "Project raster". And the raw data of NDVI value range is not on clear color scale or it is not given in standard range of NDVI value. Then, it has been rescaled into normal NDVI range (-1 to +1) by using conversion factor on spatial tool under Raster calculator of Arc map applications.We can find more information about this product and the scaling factor on the product information pageof webinar NASA dataset. That means

$$Actual\ NDVI = OldNDVI * 0.0001 - - - - - - - - - - - (1)$$

After changing raw NDVI MODIS image into actual NDVI scale, the MODIS image subset or clipped with study area boundary shape file data using "Extract by mask" toolbar on ArcGIS.

3.3.2. Computation of normalized difference vegetation index anomaly

According to Murali et al. (2008) and Gizachew etal., (2014) an index derived from NDVI can be used to assess seasonal crop conditions. In order to drive the vegetation drought conditions for the study period seasonal March month of each year, therefore, calculations were done using (eq. 3) by generating value of seasonal March month NDVI of each year, and long-term mean value of all year NDVI. To derive NDVI anomaly for a specific year using theMarch month result, and mean NDVI from 2004-2018 has been computed using the following formula.

$$NDVI\ Anomaly\ = \frac{(NDVI\ i - mean\ NDVI)}{(mean\ NDVI)} * 100 - - - (2)$$

Where, Anomaly NDVI imply NDVI anomaly in **i**thyear, NDVI i were indicate March month NDVI in each year and mean NDVI were the average March month of each year NDVI during the period of study. Here Mean NDVI for 15 years was then computed by using the following expression.

$$meanNDVI = \frac{(NDVIMarch\ 2004 + NDVImarch2005 + \cdots + NDVImarch2018)}{15}$$

Time series of NDVI anomaly was used to detect agricultural drought. The results were then reclassified into five drought severity class. The threshold values used in this study period to classify agricultural drought risk using NDVI anomalies was presented in Table 1.

Table 1: Agricultural drought risk classification using NDVI anomalies

Percent of NDVI Anomalies	**Class**
0% to -10%	Slight drought
-10% to -20%	Moderately drought
-20% to -30%	Severe drought
above -30%	Very Severe drought

Source: (Gizachew et al., (2014)

3.3.3. Computation of Standardized Precipitation index (SPI)

Since any drought condition is the manifestation of reduced precipitations or depleted moisture content in the soil, rainfall based drought indicators offer direct and simple techniques for monitoring the onset, expansion, and intensity of drought situations.Standardized Precipitation Index (SPI), a tool derived by McKee et al., (1993) a measure of meteorological drought has been calculated from the available rainfall data collected by the National Meteorological Department. SPI as has been mentioned earlier is an index that was developed to quantify precipitation deficit at different time scales.1-month SPI reflects short term conditions and its application can be related closely to soil moisture; the 3-month SPI provides a seasonal estimations of precipitation; 6 and 9-month SPI indicates medium term trends in precipitation patterns therefore, three month was selected to calculate SPI from six rainfall stations using monthly rainfall data for the period of 2004-2018 only for the crop growing season (March-May). The threshold for indicating severity of meteorological drought has been adopted from U.S. drought mitigation center. Monthly rainfall data of the 6 stations surrounding the study area that present in other woreda that were used as an input to calculate SPI using ArcGIS toolbox that was IDW interpolation. Inverse distance weight is one of the interpolation methods in which the sample points are weighted during interpolation such that the impact of one point to another with distance declines from the unknownpoint. Inverse Distance Weight is the simplest interpolation method and deterministic models. Deterministic model include IDW, rectangular, natural neighbors and spine. Interpolation uses vector points with known values to estimate unknown locations to create raster surface covering an entire area.

The interpolated maps for March to May months from 2004 to 2018 as study period are reclassified into different meteorological drought severity classes. The resultant maps were added to get meteorological low drought and high drought years between those 15 years. Thereafter, Standardized precipitation Index (SPI) was calculated using map algebra raster calculator tool of the same software in order to prepare the yearly seasonal (March to May) precipitation deficit in the study area (equation. 3).

$$SPI = \frac{(Xi - Xm)}{\sigma} ----------(3)$$

Where, Xi is monthly rainfall record of the station; Xm is rainfall mean; and σ is the standard deviation. Monthly rainfall data of the 6 rainfall stations that surrounding the study area were used as an input to calculate SPI using computer software which can be downloaded from web site at http://drought.unl.edu/monitor/spi/program/spi_program.htm#program.

Xm is rainfall mean that computed with following expression;

$$Xmean = \frac{(x1 + x2 + \cdots + x29)}{29} -------------------(4)$$

Where x1, x2…x29 have been used monthly rainfall records from 1988 to 2017, total of 29 years to identify the rainfall deficient seasons and Meteorological drought. These have been also employed to generate Meteorological drought over Abaya district. Finally the results computed from seasonal rainfall data of March to May SPI value were assigned and reclassified based on the drought severity class of SPI.

Table 2: Meteorological drought risk classification using SPI values (McKee et al., 1993)

SPI Values	Class (Description)
2.0 and more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately we
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

3.3.4. Crop Yield Production

To quantify the impact of drought on production of major cereals crops in Abaya district correlation between SPI and district level crop yield have been analyzed. Since NDVI takes advantage of reflective and absorptive characteristics of plants in the red and near-infrared portions of electromagnetic spectrum and has been used in research of vegetation yield and productivity, crop yield has also correlated to NDVI. Yield trend has been computed to see the trend over last 15 years (2004-2018). Yield trend has been computed in district basis. (Table 1: appendix).

3.3.5. NDVI Anomaly Based Agricultural drought risk map

The final Agricultural drought risk map of the study area was prepared by using Multi Criteria Evaluation (MCE) techniques. In order to compute the frequency of drought occurrence, the threshold value of SPI, NDVI anomaly and crop yield were used and reclassified into compatible classes. These binary images were then calculated in Arc GIS Spatial Analysis tools to obtain the desired seasonal maps showing the frequency of drought occurrence at each year rainfall season.

The seasonal frequency maps derived from each drought index were, then, reclassified into common scale based on the frequency of drought occurrence. According to Lemma Gonfa (1996) the probability of drought occurrence in a given area can be classified into high, moderate and low drought probability zones when drought occurs in more than 50 percent, 30 to 50 percent and less than 30 percent of the years, respectively. Finally, maps from each drought indices were weighted according to the percentage of their influences, using ArcGIS software; and then combined using weighted overly analysis.Based on the level of agricultural drought severity, therefore, two drought and two wet years were identified and mapped for each drought indices. Thus, it was found that mapping agricultural drought risk can be useful to guide decision making process in drought monitoring and reducing the impact of drought on agricultural production and productivity level by identifying definite sites for specific adaptation and mitigation actions.

3.3.6. SPI Based Meteorological Drought

SPI has been mainly computed to derive meteorological drought Three month SPI was chosen for computing the meteorological drought from 2004 to 2018.Based on the SPI value, two drought years and wet years was selected .Drought severity of the SPI has been correctly classified the two drought years in to the sever and moderate meteorological drought.

CHAPTER FOUR

4. DATA PRESENTATION, ANALYSIS AND DISCUSSIONS

4.1. Data Presentation and Analysis

This chapter covers the analysis of long-term NDVI temporal images to arrive at the agricultural drought and standard precipitation index based meteorological drought. It covers also the description of the relationship established between the rainfall and vegetation as well as the between SPI and NDVIanomaly. Also what effects are crop yield have as the results of variability in rainfall is being discussed.

4.1.1. Spatial Pattern of NDVI Anomaly

Analyses of anomaly NDVI were showing how the pattern and/or distribution of vegetation in such 15 year continuous trend from 2004 to 2018 it depicts as follow. I take the minimum amount, mean amount, and maximum amount of NDVI anomaly for each years. And the result placed on the table below.

Table3: Spatial Pattern of NDVI Anomaly

NDVI/Year	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Maximum	5.485	4.034	4.516	3.951	5.387	3.621	2.596	3.818
Mean	2.562	1.794	2.2075	1.816	1.609	1.596	-0.066	0.1805
Minimum	-0.361	-0.446	-0.101	-0.319	-2.169	-0.429	-2.728	-2.457

NDVI/Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Maximum	6.381	5.734	8.692	0.674	2.484	1.775	7.698
Mean	1.2905	0.3435	1.504	-1.4615	-0.4425	-0.203	0.973
Minimum	-3.8	-5.047	-5.684	-3.597	-3.369	-2.181	-5.752

NB: Here NDVI anomaly value exceed standard of [-1, +1], since it expressed in percentage for study time.

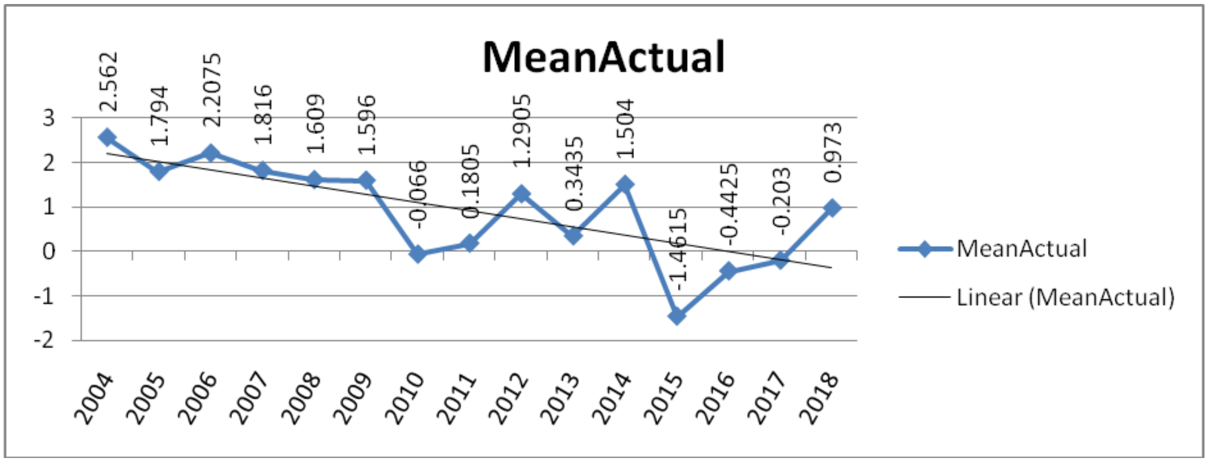

Figure 4: NDVI anomaly value for Abaya district (2004-2018)

This result shown below on the line graph that their value relationship and average healthiness of vegetation regarding the precipitation condition. Here we see Vegetation healthiness high in year 2014 and 2018 based on mean amount value of NDVI. As the (Figure 4)shows that the average amount of greenness of vegetation was higher in year 2014 and 2018, and the lower was in year2015 and 2010.The above graph for NDVI Anomaly and Exponential trend line indicate the decreasing of vegetation healthiness from year to year in average.

4.1.2. Spatial pattern and Relationship between Rainfall and NDVI

During the 15 years (2004-2018), there was considerable year-to-year variation in precipitation and NDVI.

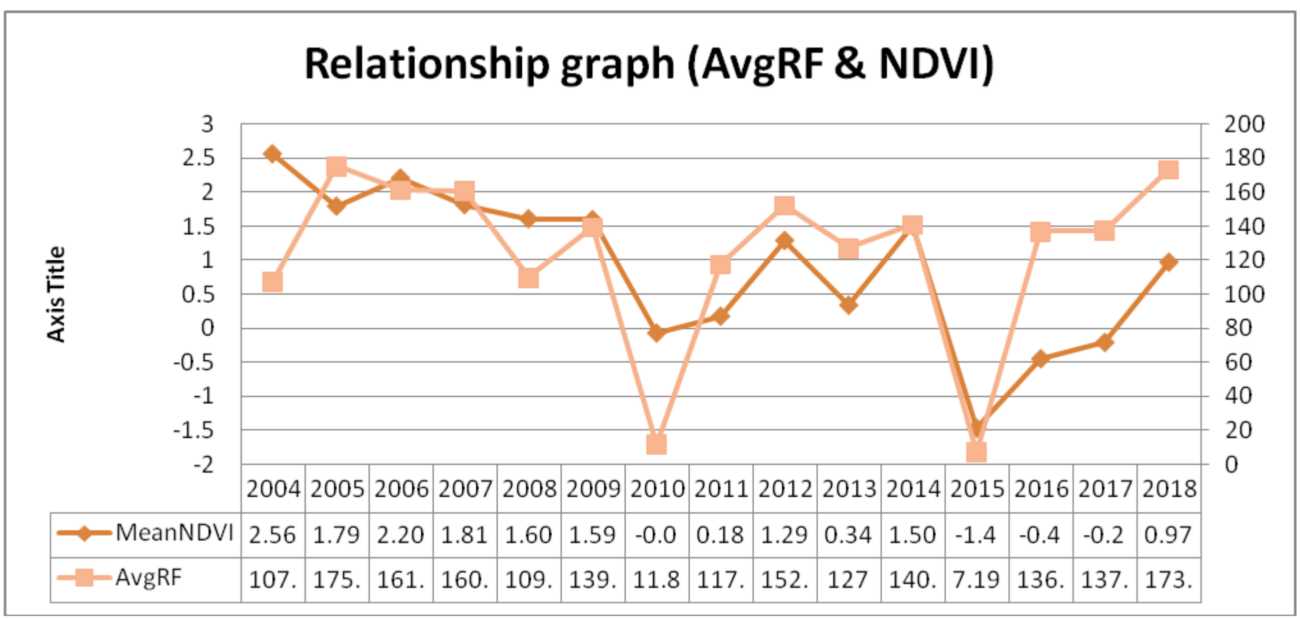

Figure 5: Relationship between Rain fall and NDVI

As indicated in the above (Figure 5) in year 2010 & 2015 the amount of precipitation and NDVI has a proportional value. This is to mean that NDVI and the average rainfall value reduced during drought years particularly in year 2015 and 2010.By contrast the data revealed that NDVI and average rainfall value increased during wet years i.e. 2014 and 2018.

Table 4: Rainfall amount measurement for 2004-2018years

RF/Year	2004	2005	2006	2007	2008	2009	2010	2011
Maximum	138.23	221.27	207.03	233.43	147.19	231.20	23.66	160.23
Mean	107.235	175.33	161.185	184.69	109.85	139.34	11.855	117.72
Minimum	76.24	129.39	115.34	135.95	72.51	47.48	0.05	75.21

RF/Year	2012	2013	2014	2015	2016	2017	2018
Maximum	178.56	212.92	207.95	14.35	164.97	155.96	213.04
Mean	152.235	171.97	161.85	7.19	136.81	137.405	173.445
Minimum	125.91	131.02	115.75	0.03	108.65	118.85	133.85

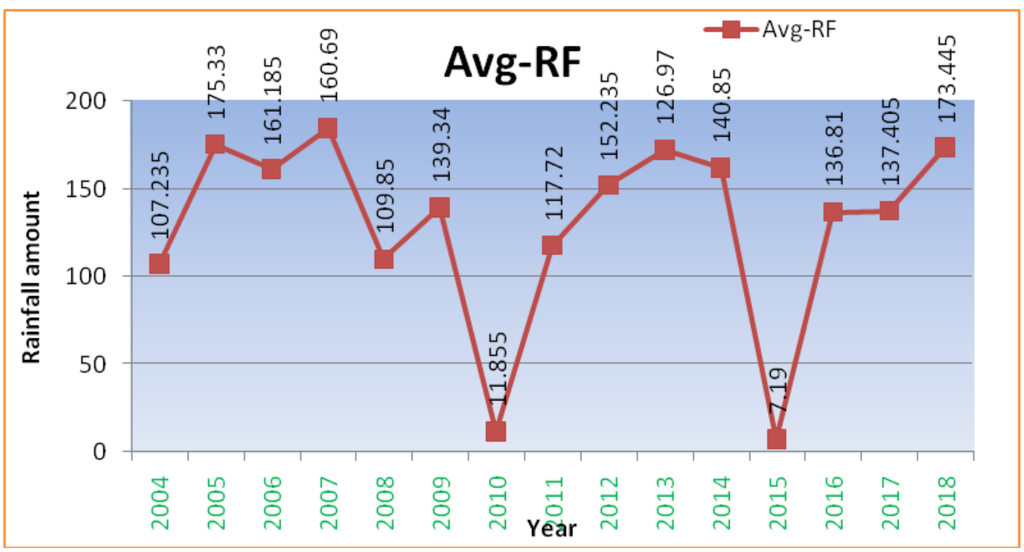

Figure 6:Average rainfall amount on study period (2004-2018)

The above (Figure 6) shows average rainfall amount for year 2010 & 2015 were very limited. The interview made with farmers, agricultural office manager, agronomist and questionnaires made with agricultural development workers results shows that there was a drought in 2010, 2015 and 2017. In the same vein, the key informants revealed that in 2004, 2014 and 2018 the area received a good amount of rainfall. As indicated from (**Appendix 3**) one can easily understand that the qualitative data supports the ground data.

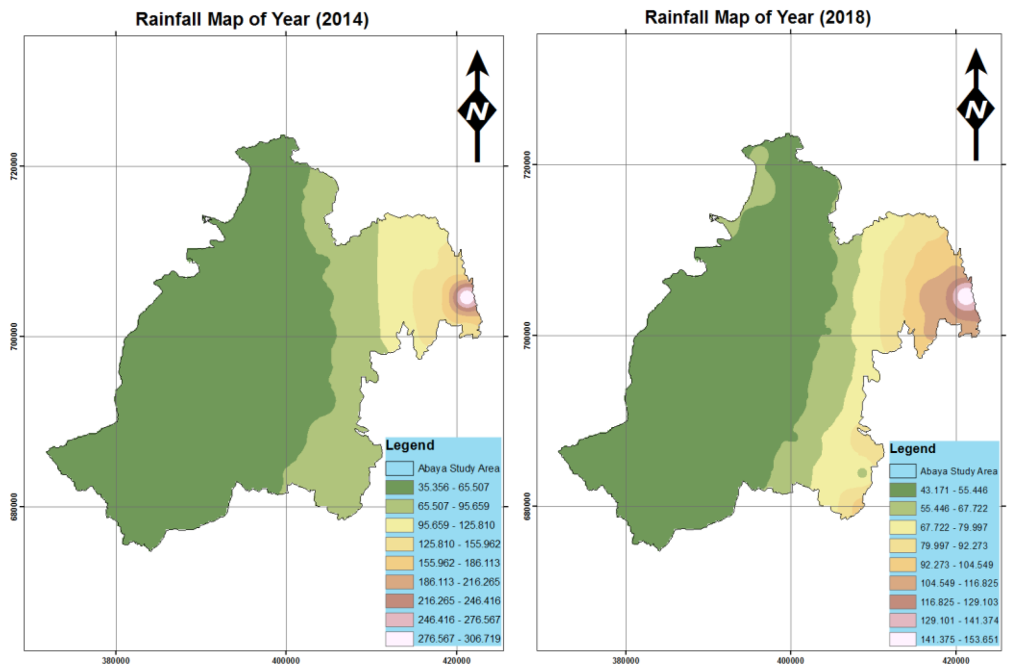

Figure 7: Spatial pattern of Rain fall wet years

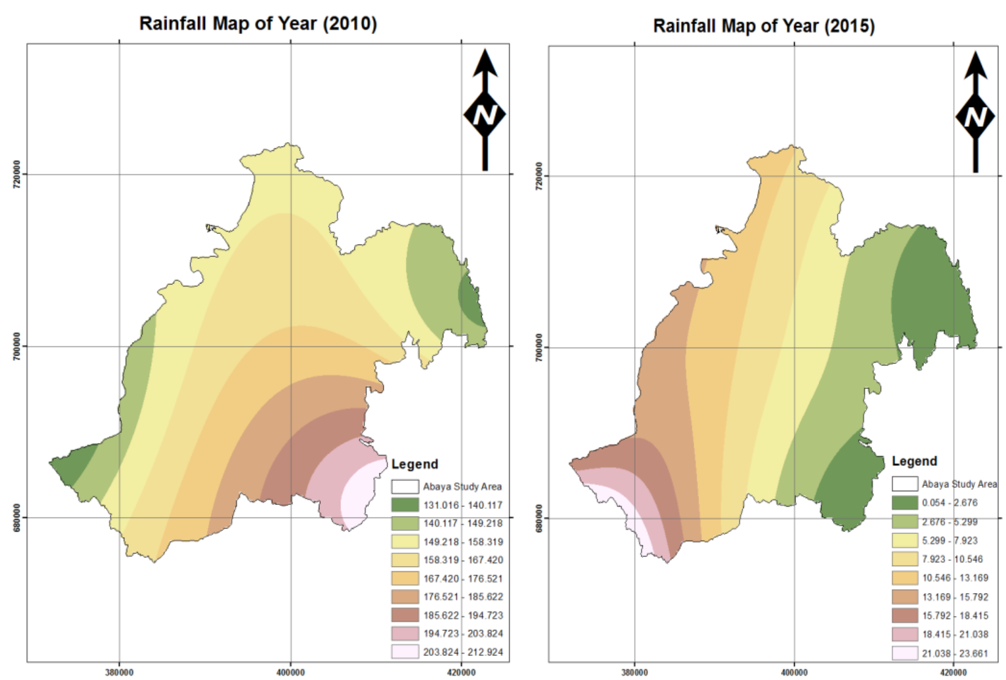

Figure 8: Spatial pattern of Rainfall in drought year

The NDVI anomaly is useful indicator as a measure of agricultural drought when compared to normal plant health. NDVI anomaly is one of agricultural drought index that shows the drought severity level. Based on this drought monitoring index result, 2010 and 2015 years were considered as a drought years during the main cropping season.

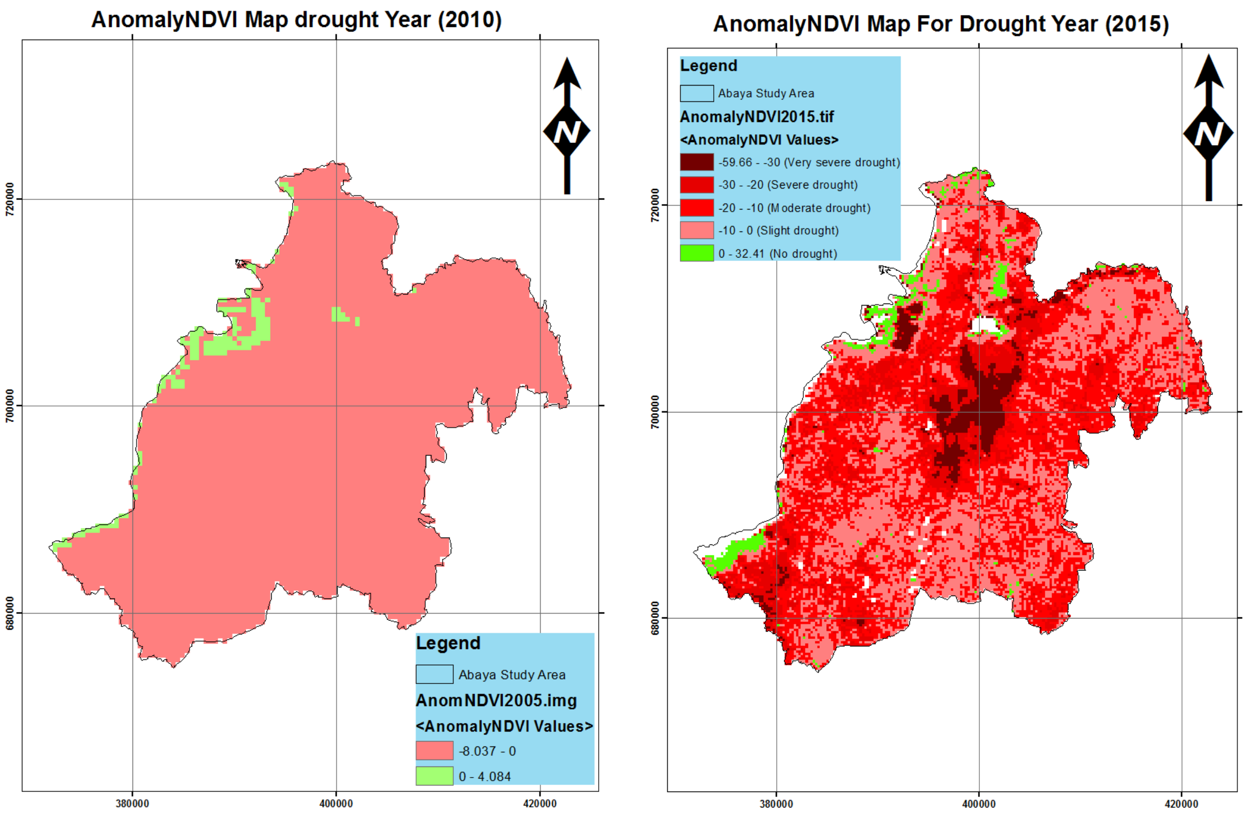

Figure 9: NDVI Anomaly for drought years (2010 and 2015)

Regarding the wet years, it can be observed from the map depicted in (Figure 10) 2014 and 2018 were selected as wet years and their level of drought extends from slight to non-drought.

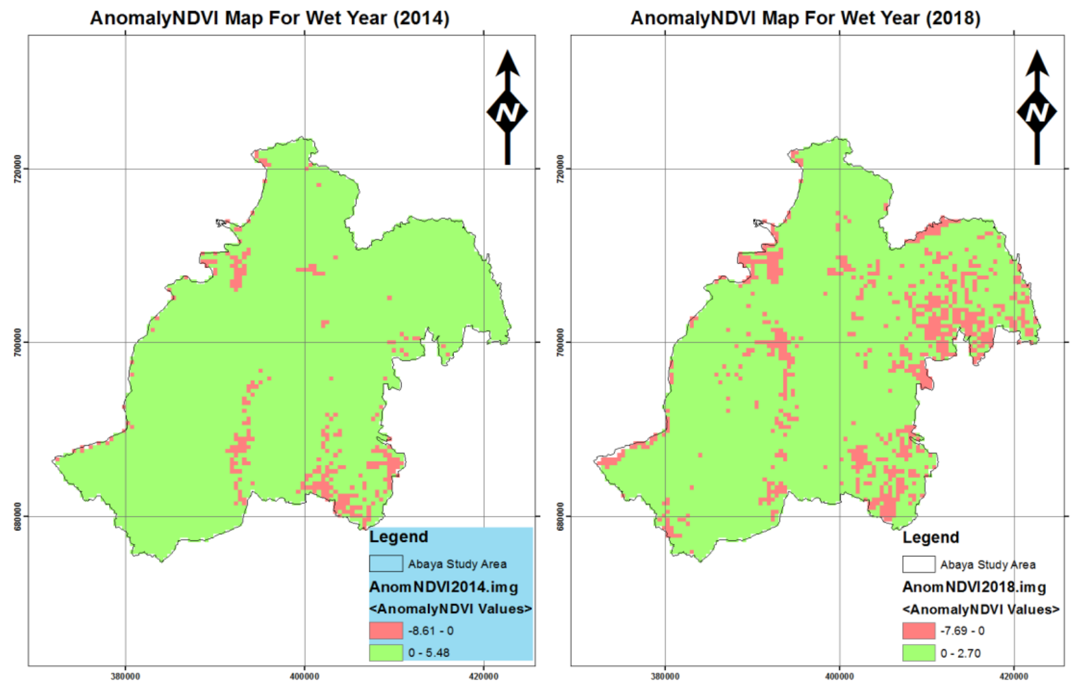

Figure 10: NDVI anomaly of wet years

NDVI anomaly is one of the best agricultural drought indices that demonstrate the severity levels of the impact on crops and vegetation. Based on the information obtained from the processing result of the 15 years NDVIanomaly.The spatial patterns of agricultural drought for the years 2015 and 2010, and wet for the years 2018 and 2014 were computed for crop production areas to determine the severity of agricultural drought.The results of the NDVI anomaly computation confirmed that the spatial patterns of agricultural drought events and the levels of its severity ranged from slight in most of the years to severe in 2015 and 2010. It is important to note here that in the NDVI anomaly analysis, the regular 2009 drought shifts to 2010. Apparently, therefore, in all the discussions, references to drought of the early period will be made to 2010. Generally, however, the extent of severe drought coverage, registered in this case, stretched areas of central, western and in small pocket of south eastern parts of the study area.

4.1.3.NDVI Anomaly Based Agricultural Drought

NDVI Anomalyhad mainly used to computeagricultural drought. Theagriculturaldrought severity map was generated by overlying the NDVI Anomalydrought maps of 2010 and2015 years.The weight was given according to their degree of influence using pair-wise comparison. the NDVI Anomaly value of the two maps were separately reclassified and weights were assigned to each classes of the drought mapbased on the NDVI Anomaly value .To the highest positive value of NDVI Anomaly weight of 1 was assigned for **no drought** while thehighest negative value weight of 4 was assigned for**severe drought**. Drought severity was assigned for agriculturaldrought risk map and drought classes in the study area.

According to theagriculturaldrought risk map (Figure 11) severe drought primarily occurred in central, south east and western parts of the study area while majority of study area experienced moderate and slight droughts. As shown in (Table 5) that the study area was stricken by sever (11.34 %) moderate (46.8%), slightly (37.5%)and no drought(4.36 %)agricultural drought.

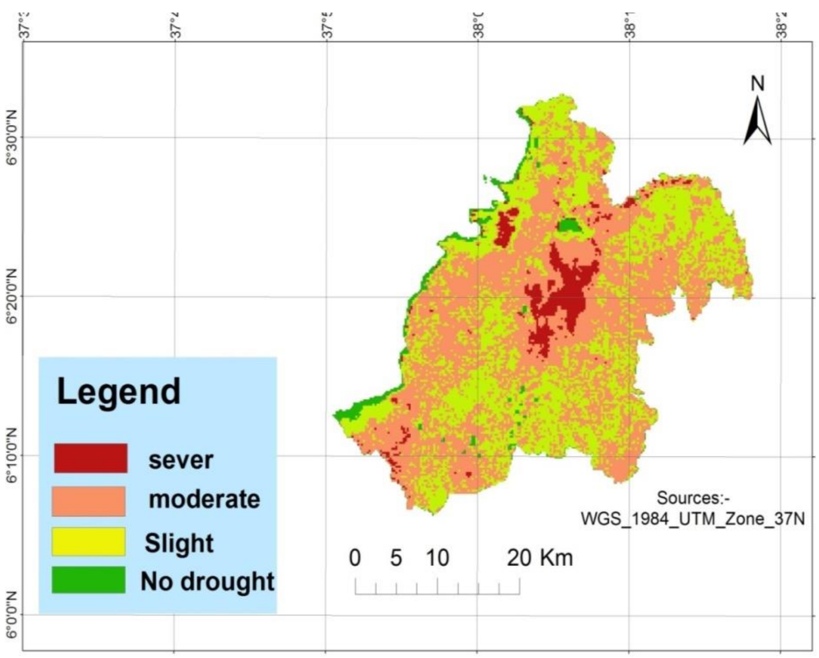

Figure 11: Agricultural Drought risk map

Table 5:percent of area covered by Agricultural drought expressed by NDVI Anomaly index

NO.	Drought classes	Area in KM^2	Percent (%)
	Severe drought	45.78	11.34
1	Moderate drought	188.96	46.8
2	Slight drought	151.41	37.5
3	No drought	17.6	4.36
	Total area	403.764	100

4.1.4. Spatial and Temporal Patterns of SPI

In the process of monitoring the effects of the fifteen years' precipitation pattern variations on Abaya district, the standard precipitation indices (SPI) were computed for thegrowing seasons of the area. The following table shows the mean, maximum, and minimum of SPI from year 2004 to 2018.

Table 6: Spatial and Temporal Patterns of SPI

SPI/Year	2004	2005	2006	2007	2008	2009	2010	2011
Maximum	0.10	1.66	0.79	1.30	0.28	1.16	-1.92	0.47
Mean	-0.35	0.835	0.34	1.005	-0.22	-0.03	-2.135	-0.095
Minimum	-0.80	0.01	-0.11	0.71	-0.72	-1.22	-2.35	-0.66

SPI/Year	2012	2013	2014	2015	2016	2017	2018
Maximum	0.74	0.89	1.18	-1.92	0.51	0.33	1.25
Mean	0.475	0.515	0.42	-2.15	0.305	0.115	0.5
Minimum	0.21	0.14	-0.34	-2.38	0.10	-0.10	-0.25

Based on the above values the graphical distribution of standardized precipitation Indices (SPI) for study period (2004-2018) constructed as follows.

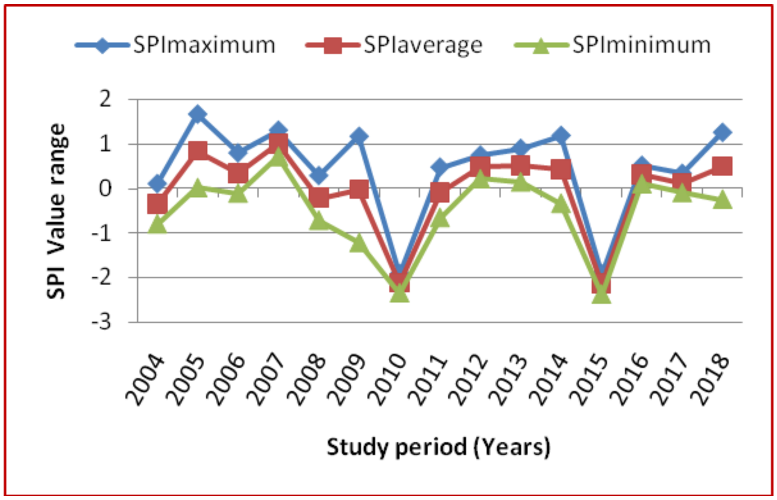

Figure 12: Spatial and Temporal Patterns of SPI

As explained by the SPI values that ranged from -2.34 to -1.92 and – 2.37 to – 0.99in the years 2010 and 2015respectively, the droughts happened were much more severe compared to other years with maximum and minimal value.Based on the SPI value, Meteorological drought level two drought years and wet years was selected. The spatial distribution patterns and severity levels of drought in the study area, the SPI for the two drought years (2010 and 2015) and wet years (2014 and 2018) were analyzed and reclassified. Asseen in (Figure 13) below there was some area coverage differencefrom the NDVI anomaly index output in above (figure 9), meaning the SPI spatial pattern analysis result showed that the whole area was hit by drought, ranging from very severe to severe level of severity, during the year 2010, while in the year 2015, the range of the severity was from very sever to slight drought levels.

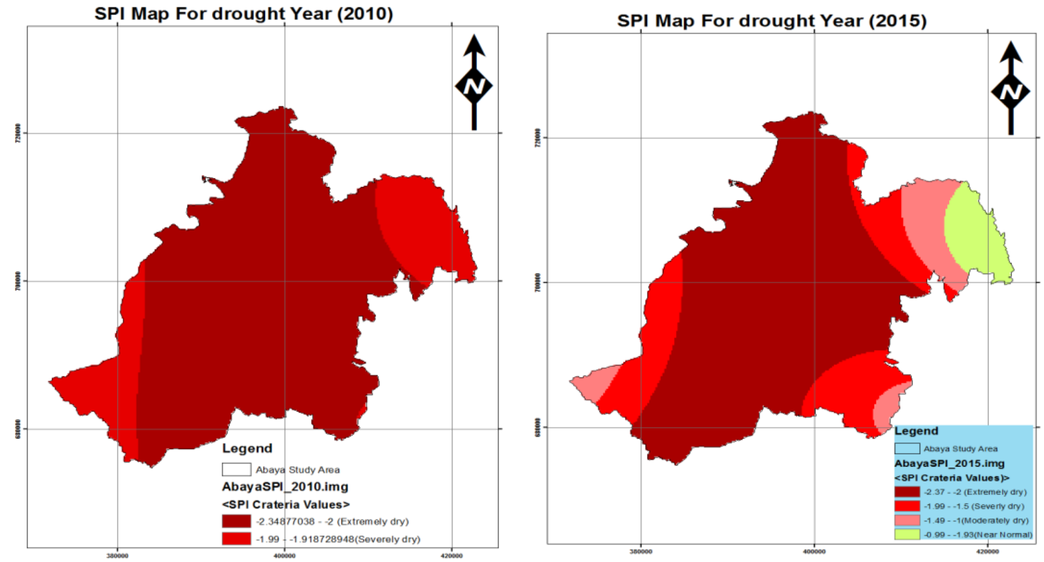

Figure13: Spatial pattern of drought severity for the drought years expressed in SPI

Since SPI can be used to identify both dry and wet years, SPI analysis was applied to the identification of the wet year condition. As clearly shown on (Figure 14) the two years 2014 and 2018 were the wettest years, for the study period. In the years indicated as wettest, the degree of drought severity was bound to slight drought only that do not extend to much more than. This, in effect, means that the good seasonal rainfalls had helped the study area to be slight drought during the two years.

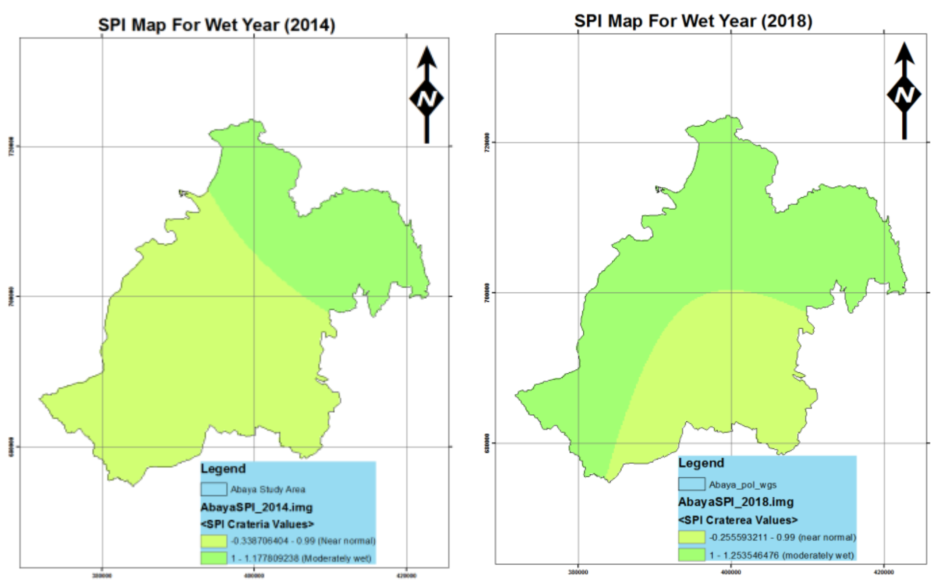

Figure 14:Spatial pattern of drought severity for wet years 2014 and 2018 expressed in SPI Index.

4.1.5.SPI Based Meteorological drought

SPI had been mainly computed to derive meteorological drought .Drought impacts was assigned using spatial analysis tool.The drought years of 2010 and2015 were weighted overlay by linear combination. the SPI value of the two maps were separately reclassified and weights were assigned to the drought each classesbased on the SPIvalue in the range of 1-4.To the highest negative value of SPI weight of 4 was assigned while thehighest positive value weight of 1 was assigned then drought severity was assigned for the then meteorologicaldrought risk map and drought classes in the study area.As themeteorologicaldrought risk map (Figure 15) showed that most of the study area was covered byvery sever and sever meteorological drought area.As indicated in (Table 7) the study area was affected by very sever (58%), sever (27%), moderate(9.36%)and slight(5.64%) meteorological drought.

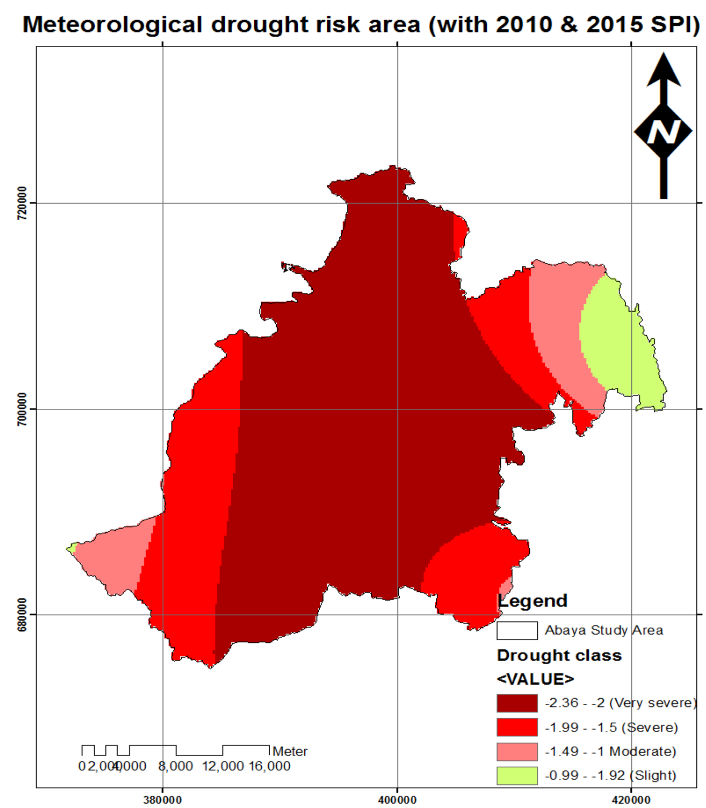

Figure 15: Meteorological drought risk map

Table 7:percent of area covered by Meteorological drought

no	Drought class	Area KM^2	Area in %
1	Extreme drought	6991.47	58
2	Severe drought	3254.665	27
3	Moderate	1128.28	9.36
4	slight	679.86	5.64
	Total area	12054.275	100

4.1.6. Time Series exchange on crop production

Like that of Precipitation Index result the crop production up and down through study period (2004-2018). From figure place below the agricultural product following rainfall amount on seasonal was show less amount in 2015 and 2010, but on year 2014 and 2018 there was high amount of crop yield. It looks like see from linear trend line the production amount increase averagely through study period. This may be rainfall amount increase and crop production incidence become greater.

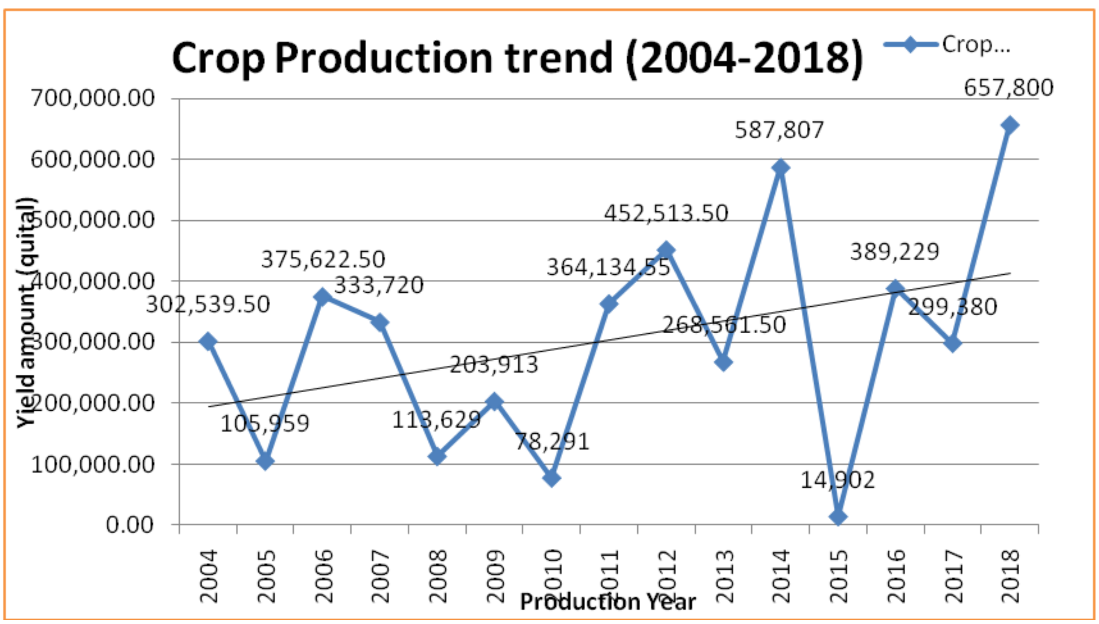

Figure 16: Trends of Crop of production **Source:** (BoARD, report: 2018).

The graph clearly indicates the direct relationship between the amount of rainfall and crop production. As indicated in (Table 4) increase in the amount of rainfall improves crop production. The interview held with key informant and farmers provided the same result. For instance, according to the interview result the community in the study area encountered a prolonged drought in 2010 and 2015. In the same year the study area witnessed a limited crop production that made the people dependent on aid.

4.2. Discussion

4.2.1. Identification ofDrought AreaBased on satellite and Ground data

The remote sensing-based method identification of drought risk areas uses historical vegetation index data derived from NASA satellite series and provides spatial information on drought risk area depending on the trend in vegetation development. Although its characteristics vary significantly from one region to another, the analysis of NDVI anomaly temporal images and ancillary data crop production was used to arrive at the agricultural drought, while the of rainfall was utilized in determining the meteorological drought. The degree of Anomaly NDVI change was different across the different categories of drought risk level, as identified in this study. The highest Anomaly NDVI changes were witnessed in areas classified as being very high drought risk. While low drought risk areas experienced a lower NDVI changes, moderate drought risk areas were observed with moderate Anomaly NDVI change values.

In addition to this, the questionnaires made with woreda agricultural development workers result showed that there was drought on average 3 to 4 years from 2004 -2018. They explained that the fluctuation of rainfall and temperature are no unusual for them that it affect considerably human life, animals, crops as well as other natural resources. In the same manner, the information from the farmers shows the same result. Most of the farmers identified the same drought years with agricultural experts, the in turn corresponds to NDVI anomaly and SPI value. The Farmers also attempted to indicate the causalities of the drought by calculating their personal and societal loss in terms of crop and livestock production. For instance, the personal loss of livestock production of the key informants ranges from 3 cattle to 50 cattle. Among others, cows and sheep are the most affected by drought. In addition to this, the farmers also sold some of the cattle to buy food both for them and the remaining cattle. However, at the end of the drought season only some farmer alone can succeed in managing or reducing the risk.

According to woreda agricultural experts the impact of drought include scarcity of grazing land, different diseases that affect both human and livestock population, and scarcity of water for human and livestock. In the same manner, in addition to the above impact farmers added the following impacts like decrease milk production which is very important source of income for the pastoralist community, the spread of different diseases that facilitate the death of many cattle, loss of grass to feed the cattle. As informed by the agricultural office manager and agronomist, the intervention and mitigation mechanism should include irrigation based agriculture practices development, drought tolerated crop species adaptation and wisely resource conservation and utilization system.

4.2.2. Relationships of SPI and NDVI Anomaly

When we see the relationship between standardized precipitation Index (SPI) and NDVIAnomaly, there was high correlation. That meaningfor drought year when the district faceslow level NDVI on 2015 year, SPI of same district on year 2015 comes to down than others. Similarly, for no drought2014 the Anomaly NDVI and SPI relate to each other. This implies on year of high precipitation, there also high effect on vegetation healthiness and on other way when there was low precipitation the NDVI also become unhealthy.

4.2.3. Characterization of yield reduction due to agricultural drought

Similar to drought indices output, the highest yield reduction occurred in 2015 and 2010 cropping seasons. In 2015 cropping season, nearly all areas were hit by agricultural drought, and agricultural yield reduction reached 0.33 %. In 2010 cropping season, the level of yield reduction was 10 %. Spatial pattern of yield reduction for the wet years (2018 and 2014) is depicted in (Figure 20) the level of yield reduction was very high (>75%).

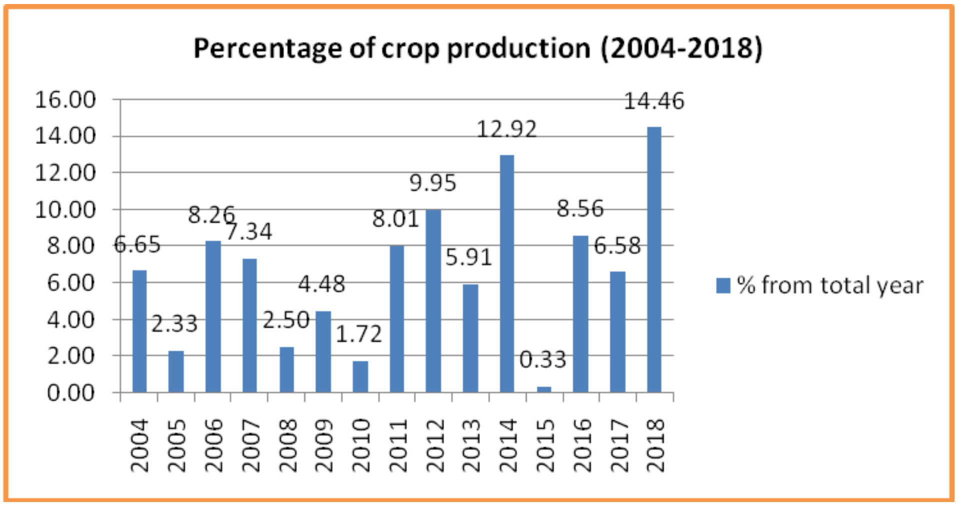

Figure 17: Crop reduction due to Agricultural Drought Source: (BoARD, report: 2018).

4.2.4. Influence of rainfall on the vegetation growth and development

As reflected by the NDVI, precipitation or specifically speaking, rainfall is one of the most important climatic change factors that can influence the growth and development of vegetation. In the study conducted by Henericksen (1986) cited in BeyeneErgogo (2007), for instance, it has been confirmed that NDVI was highly sensitive to an extended rainfall anomaly.

The empirical data from interview with agricultural office manager, agronomist and farmers show that the study area was hit by severe drought in 2010, 2015 and 2017. In those years there was high reduction of rainfall amount. According to the agricultural experts, particularly2010 witnessed that almost no rain in the study area. In the interview the year 2007, 2014 and 2018 identified as wet year or almost the area received good amount of rainfall.

4.2.5. Evaluation *of SPI with NDVI Anomaly and crop yield*

NDVI anomaly and SPI have been computed for the district as whole and it shows that when SPI is positive NDVI anomaly is also positive, which states that NDVI anomaly and SPI shares a linear correlation. Since SPI represents the water deficit or excess, positive SPI represents that water has been available to plants in just the right amount so the NDVI has a positive value.

It can be observed in (figure 9) that NDVI anomaly was nearly -20% when SPI was -2.37. These low values pertain to year 2015, which was extremely drought year. Therefore it can be said that strong relationship exists between SPI and NDVI anomaly, according to which a drought can be declared when SPI values fall the threshold of -1.5. District wise correlation between SPI and NDVI anomaly showed that NDVI anomaly and SPI had a significant correlation in almost of the districts of the Abaya. This implies when the district get rain, the vegetation healthiness increase also. Based on the relationships between NDVI anomaly and three month SPI, SPI threshold of -1.5 corresponds to 75% of negative anomaly in NDVI. In similar way the correlation and regression between SPI and crop production was observed. Thus, those combinations indicate as rain season of this district the relationship between the parameters using GIS and remote sensing technologies examine trend in similar way. That mean agricultural and meteorological meet using ground and satellite data. Between the study period (2004-2018) SPI increase, anomaly NDVI also increase and when SPI amount decrease, the anomaly NDVI also decrease.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1.Summary of major findings and conclusion

Based on the objectives of the study, Remote Sensing and Geographical Information System technology as well as ground based observations mechanisms have been used to collect fifteen years' data on the behaviors of agricultural and meteorological drought in Abaya district.

Agriculture remains by far the most vulnerable and sensitive sector that is seriously affected by the impacts of climate variability and climate change usually manifested through rainfall variability and recurrent droughts. Using satellite images and rainfall data as an input parameter for drought indices, spatiotemporal variation of seasonal agricultural drought patterns and severity can be detected and mapped with the help of advanced techniques of remote sensing and GIS. Hence, agricultural and meteorological drought assessment using RS and GIS technique is importance to assess the past and the present agricultural and meteorological drought conditions, and generate baseline information that helps to monitor real time situation in the future for different adaptation options within relatively large geographical area and repetitive time scale coverage. The comparative performance of the indices explaining the existence of agricultural and meteorological drought indicated that SPI and NDVI anomaly.

The fifteen years seasonal pattern of SPI and NDVI anomaly (2004- 2018) indicate that the northern, western andeastern parts of the study areas have low rainfall distribution during farming season as well as has low NDVI anomaly values. NDVI anomaly and SPI are found to be good indicators of the occurrence of drought and its impacts on the crop performance. Drought can be taken as a major manifestation of crucial mismatch between the rainfall time and the normal cropping seasons of a given geographical area. Mismatch between the quantitative, temporal and spatial distribution of rainfall and the cropping seasons have been found to be inflicting negative effects on the quality and quantity of crop yields. The district has experienced various levels of droughts during the study period, the years 2010 and 2015 have been found to be drought years while 2014 and 2018 were the wettest years, showing good yields. In view of this, agricultural risk zone map produced by integrating the drought year maps indicates that Abaya district can be classified into slight, moderate and severe agricultural drought risk area, respectively. The study area was stricken by sever (11.34 %) moderate (46.8%), slightly (37.5%)and no drought (4.36 %)agricultural drought risk map. The agricultural drought risk map should be useful to guide decision making processes in drought monitoring and to reduce the impact of drought on agricultural production and productivity, while identifying appropriate sites for specific adaptation. Meteorological drought map of the study area indicated that most of the study area affected by extreme sever (58%) and sever (27%)meteorological drought.majority of study area were more affected by meteorological drought than agricultural drought.These validation results of the satellite developed indices based on the ground data is vital for successful application of satellite derived indices for drought assessment and identification of drought vulnerable areas. Thus, the satellite derived drought-indices with support from ground data, can sufficiently identify and characterize the onset and severity of drought condition. Therefore, it is essential to quantify the magnitude of drought severity into various degrees of drought severity classes.

5.2. RECOMMENDATIONS

Though the present work deals with satellite and meteorological parameters as well as crop yield statistics to arrive at a combined risk yet due to unavailability of ancillary data, still some of the portions which could not be handled and can be taken up in further research are listed below.

- Delineating areas under drought risk, relevancy of risk assessment can be made more meaningful when the human population as well as livestock population under risk can be assessed. Therefore it is recommended to include the socio-economic data to better understand the vulnerable factors.
- The woreda should allocate resources with the aim of drought mitigation and adaptation. Adaptation is adjustment in natural response to expected drought effects, which exploits beneficial opportunities whereas mitigation of drought is a human intervention aimed at reducing the climate variability to improve livelihood of the community.
- Some of the results of the study and the analyses methods and principles applied, can be used as bases for interested academic and action researchers to undertake other similar works.

Reference

- Abaya Woreda Office of Rural Development and Agriculture (2017). Annual Report. Unpublished Report.
- Abraha, M. E (2013).Assessment of Drought Early Warning in Ethiopia.
- Agnew, C. T. (2000). Using the SPI to identify drought. *Drought Network News*, 12 (1),
- Alley, W. M., (1984). The Palmer Drought Severity Index: limitations and assumptions. Journal of Climate and Applied Meteorology, 23(7), 1100-1109.
- Beyene, E. (2007). Drought Assessment for Nile Basin Using Meteosat Second Generation Data with Special Emphasis on the Upper Blue Nile Region. M. Sc. Thesis. ITC, Enscheda, Netherlands.
- Brown, J. B. C. Reed et al., (2002).A Prototype Drought Monitoring System Integrating Climate and Satellite Data. Percora 15/Land Satellite Information IV/ ISPRS Commission I/FIEOS (2002).
- Chopra, P. (2006) Drought Risk Assessment Using Remote Sensing & GIS: A Case Study of Gujarat. M.sc, Thesis, ICT, Enschedes crop moisture index, Weather wise, 21(4), 156 – 161.
- D.A. Wilhite (2000). Drought as a Natural Hazard: Concepts and Definitions'. Global Assessment, W. D.A. Routlegde, vol.1, 1-3.
- Edossa, D, Babel, M &Das Gupta, A. (2010). Drought Analysis in the Awash River Basin: Water Resource Management. Ethiopia Vol. 24(7), 1441-1460.
- Edwards, D. C. and T. B. McKee (1997). Characteristics of 20th Century Drought in the United States at multiple time scales: Climatology Report Number 97(2), Colorado State University, Fort Collins: Colorado.
- Gebrehiwot, T van der veen, A & Maathuis, B (2011).Spatial & Temporal Assessment of Drought in the High lands of Ethiopia. International Journal of Applied Earth Observation and Geo information, Vol. 13(3), 309 -321.
- Gizachew and Suryabhagavan, K.V. (2014). Remote Sensing and GIS Based Agricultural Drought Assessment in East Shewa Zone, Ethiopia, Tropical Ecology. Vol. 55(3), 349-363.
- Glantz, M .H. (1987). Drought & Hunger in Africa: Denying Famine a Future. Cambridge University press: Cambridge.
- Guttman, N. B. (1998).Comparing the Palmer Drought Index and the Standardized Precipitation Index. JAWRA Journal of the American Water Resources Association. Vol.34, 113-121.
- Haile, T. (1988) Causes & Characteristics of Drought in Ethiopia. Ethiopian journal of Agricultural Sciences.

- Heim, J. and Richard, R. (2000). Drought Indices: A Review. Drought: A Global Assessment. D. A. Wilhite, Rutledge. 1,159-167.
- Jeyaseelan, A.T. and Venkataratnam, L. (2003).Remote sensing Towards Agricultural Drought Monitoring Retrospective & Perspective. NNRMS Bulletin ,Vol. 28, 24-43
- Jeyaseelan, A.T. (2002).Drought & Flood Assessment & Monitoring Using Remote Sensing & GIS: Crop Inventory & Drought Assessment Division, National Remote Sensing Agency, Department of Space Govt. of India: Hyderabad.
- Kienberger, S. and Zeil, P.(2002).Vulnerability Assessment and Global Change Monitoring: The Role of Remote Sensing –Potential and Constraints for DecisionSupport, Centre for Geo-informatics. Salzburg University, Austria.
- Kininmonth, W.R., Beard, G. S. and Mullen, C.E. (2000). Australian Climate Services for Drought Management : A global Drought assessment D.A. Wilhite (Ed), Rutledge, 210-222
- Kogan, F. N. (1997). Global Drought Watch from space. Bulletin of American Meteorological Society. Vol.78, 621- 636.
- Lemma, G. (1996). Climate Classification of Ethiopia. Meteorological Research Report Series. No.3: Addis Ababa, 1-8.
- Li, J., J. Lewis, et al., (2004).”Evaluation of Land Performance in Senegal Using Multi-temporal NDVI and Rain fall Series.” Journal of Arid Environments.Vol.59, 463-480
- McKee ,T,B. , Doesken ,N.J., Kleist, J.(1993).The Relationship of Drought Frequency& Duration to Time Scale in 8th Conference in Applied Climatology. American meteorological society: Anaheim.CA, 179-186.
- McKee, T. B., Doesken, N. J., & Kleist, J. (1995). Drought Monitoring with Multiple Time Scales. *Proceedings of the Ninth Conference on Applied Climatology*, 233–236.
- Murali, K., G. Ravikumar & M. Krishnaveni. (2008). Remote sensing based agricultural drought assessment in Palar basin of Tamil Nadu State, India. Journal of the Indian Society of Remote Sensing, Vol. 37, 9-20.
- Nezar Hammouri and Ali Ei-Naqa, (2004). Drought Assessment Using GIS and Remote Sensing in Amman-Zarqa Basin, Jordan. The Hashemite University: Faculty of Natural Resources and Environment.
- Park, S., Feddema, J.J., and Egbert, L. S., (2004) Impacts of hydrologic soil properties on drought detection with MODIS thermal data, Remote Sensing of Environment, Vol. 89, 53-62.
- Palmer, W. C. (1968). Keeping Track of Crop Moisture Conditions, Nationwide: The new crop moisture index, Weather wise, 21(4), 156-161

- Palmer, W. C., (1965). Meteorological Drought. Research Paper no. 45, United State. Department of Commerce Weather Bureau: Washington, D.C.
- Partheepan, K., Dayawansa, N. D. K., (2008). A GIS and Remote Sensing Modeling Approach for Drought Risk Assessment in Batticaloa District, Srilanka, Paper-14, Third South Asia Water Research Conference: Innovative Modeling Approaches for IWRM, May 2008, Dhaka, Bangladesh.
- Teshome Erkineh, (2006).Climate Risk Management in Practice: Managing Food Security in Ethiopia. **(***www.ppttube.com/flash/iij_ethiopia.swf)*
- Tsegaye, T. (2013). Integration of Drought Monitoring Tools for Proactive Food Security Management Under Evolving Climate Agricultural food and Fisheries Outlook Forum, April 10-11, Mexico City: Mexico.
- Thenkabail, P. S.,Gamaga, et al,.(2004).The Use of Remote Sensing Data for Drought Assessment and Monitoring in South West Asia .Colombo, Srilanka, International Water Management Institute, 1-23.
- Wang, p. Wang, et al., (2004).”UsingMODISLand surface Temperature and Normalize Difference Vegetation Index Products for monitoring Drought in the southern great plains, USA,”International Journalof Remote Sensing , 25(1), 61-72
- Wilhite, D. A ,&Glantz ,M H.(1985).Understanding the Drought Phenomenon: The Role of Definitions Water International, 10(3) ,111-120.
- Wolde Amlak, B. (2009). Rainfall variability and crop production in Ethiopia Case study in the Amhara region In: Proceedings of the 16th International Conference of Ethiopian Studies, Trondheim, Norway.

Appendix 1: Average Seasonal Rainfall (March to May) of 6 stations from 2004-2018

Year/Station	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Arbaminch	69.0	154.0	127.2	111.8	79.9	62.8	168.0	92.0	122.6	131.9	105.8	122.2	105.5	75.2
Dilla	72.8	120.7	130.8	224.9	133.1	46.0	170.5	165.7	166.0	161.8	175.1	134.8	154.3	128.2
Mirababaya	93.6	138.7	82.7	106.0	50.3	67.8	171.0	59.6	108.5	96.8	95.8	96.3	95.4	86.1
Chelelectu	65.6	148.5	167.7	181.1	134.6	156.9	187.8	83.4	168.7	128.1	96.3	91.0	128.3	38.1
Fisaha genet	125.8	153.15	172.4	192.95	124.4	159.325	221.225	134.9	140.575	166.725	131.1	145.5	163.025	158.8
Yirgacheffe	116.5	194.3	200.6	232.4	125.6	207.3	236.2	145.5	150.4	197.2	153.2	162.8	165.8	116.6

Appendix 2: crop yield of the study area from 2004_2018

No	1	2	3	4	5	6	7	8
Year	2004	2005	2006	2007	2008	2009	2010	2011
Yield (quintal)	14,902	108,959	303,913	333,720	113,629	78,291	375,622.50	364,134.55
No	9	10	11	12	13	14	15	
Year	2012	2013	2014	2015	2016	2017	2018	
Yield (quintal)	587,807	268,561.50	452,531.50	302,539	389,229	299,380	657,800	

Source: (BoARD, report, 2018)

Appendix 3: **Response of the key informants**

Questionnaire	choice	No. of respondents	Percentage (%)
• Is drought happened in Abaya woreda between 2004 _	Yes	39	72.2
	No	15	27.8
• The most devastating drought ye	2010,2015and 2017	9	16.7
	2004,2007and 2017	13	24
	2010 and 2017	18	33.3
	2009 and 2017	6	11.11
	2004,2010 and 2015	8	14.8
• Severity level of drought in the study	Low	5	9.25
	Medium	26	48.1
	High	22	40.74
• Is drought having impact on people and Livest	Yes	46	85.2
	No	8	14.8
• The most affected/died cattle by droug	cow	24	44.44
	calf	21	38.9
	sheep	9	16.7

Appendix _ A Questionnaire to be filled by rural development extension experts

Dilla University College of Social Science and Humanities, Department Of Geography and Environmental Studies The researcher of this study is conducting research for the partial fulfillment of Msc in GIS and remote sensing at Dilla University. The main objective of this questionnaire is to collect data related to drought in Abaya district and its impact on people and livestock to give suggestions to minimize the impact of drought risk in Abaya district. Therefore, you are kindly requested to provide me with your sincere response.

Personal information

Sex………male ☐ female ☐ Age ☐ Woreda……………

Experience………………..1- 5 ☐ 6-10 ☐ 11-15 ☐ >16 ☐

Educational status……….Diploma ☐ degree ☐ master ☐ Other ☐

1. In which year/years did drought happened in your area between 1996- 2010 E.c ?.

………………………………………………………………………………………………

2. Which was/were the most devastating drought?
   ………………………………………………………………………………………………
   ……………………………………………………………………………………

3. What was the severity level of the agricultural droughts that occurred during the 15 years?

   A, low B, Medium, C, high

---

4. Which years were the wettest?...

5.What was the level of yield reduction during the drought year/years?...
....

6.Was the rains later or it rains earlier than the expected rainy time? How do you describe this characteristic of the local rainfall during the past 15 years in terms ofspatial distribution?………………………………………………………………………………
……………………………………………………………………………………………………

7. What were the impact of drought on people and livestock in the district? Would youexplain?...
....

8. What types of mitigation options have been used to minimize the drought risk in the district?
………………………………………………………………………………………………
…………………………………………………………………………

Appendix B: Guiding questions for key informant interviews

This guiding question is prepared to collect data related to Drought in West Guji Zone, Abaya district. The study was conducted to full fill the requirements of a MSc degree in Remote Sensing and GIS at Dilla University. As this research is entirely for academic purposes, you are not be asked for your names or any identifying information. All the information you provide is confidential and the researcher guaranty your full anonymity. Most importantly open and honest answers are the most valuable as there are no wrong or right answers. If you have any queries about this research, please feel free to ask in any ways. I would like to thank you in advance for your voluntary participation in this study.

1. How many years you have been live here?..
2. Do you think that drought would happen between 1996- 2010 E.chere ? yes☐ NO ☐
3. If your answer is yes , In which year/years ? 1996 , 1997, 1998 ,1999, 2000 ,2001, 2002, 2003, 2004 ,2005,2006,2007,2008,2009,2010 ?
4. Which was/were the most devastating drought? ……………………………………………………………………………………………
5. Which year /years was/were the wettest? ……………………………………….
6. Do you think that, drought have impact on people and livestock? yes ☐ NO ☐
7. If your answer is yes , what is the impact of drought related to:
   - Fodder reduction on livestock…………………………………………
   - Livestock production……………………………………………………….
   - Milk production…………………………………………………………
8. How many cattle affected /died in the drought year?

9. Which animal is more suspected for drought?

10. What measures taken to minimize the drought risk?

The referents responsibility _________________ Date of reference________________