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DELINEATION OF FOOD INSECURE AREAS
USING REMOTE SENSING AND GIS
(FOOD AVAILABILITY ANALYSIS)

The case of South Gondar Zone

A Thesis Submitted to the School of Graduate Studies of
Addis Ababa University, for Partial Fulfillment of the
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THE CASE OF SOUTH GONDAR ZONE

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D E C L A R A T I O N

I here by declare that the dissertation entitled “**DELINEATION OF FOOD INSECURE AREA USING REMOTE SENSING AND GIS: (FOOD AVAILABILITY ANALYSIS), THE CASE OF SOUTH GONDAR ZONE**” has been carried out by me under the supervision of Dr. Bekele Abebe, Department of Earth Sciences, Addis Ababa University, during the year 2009 as a part of Master of Science in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

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C E R T I F I C A T E

This is certified that the dissertation entitled “**DELINEATION OF FOOD INSECURE AREA USING REMOTE SENSING AND GIS (FOOD AVAILABILITY ANALYSIS), THE CASE OF SOUTH GONDAR ZONE**” is a bonafied work carried out under my guidance and supervision. This is the actual work done by Birhanu Gedif for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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Dedicated to my beloved wife

Woletesilasio

Abstract

Food insecurity is a matter of both limited food availability and restricted access to food. Food availability is the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports. The main objective of this study is delineation of food insecure areas in south Gondar Administrative Zone using remote sensing and GIS from the food availability perspective. The necessary data were generated from satellite images, meteorological data, and other ancillary data. The data analysis technique evolved generation of major factors determining food security. Because there are numerous factors determining food security, the researcher selected cyclic drought and soil erosion as determinant factors from crop production (food availability) perspective. Deviations of NDVI from the long term mean and the Vegetation Condition Index (VCI) derived from SPOT-4 near real time dekadal NDVI images for eight years were used for drought detection. The results were validated using ground truth data such as crop production, food aid beneficiaries and the amount of food aid distributed including the number of stunted and under weight children and pregnant and lactating mothers. The soil loss spot areas through erosion from the study area were estimated using USLE. These two determinant factors were then weighted and overlaid in the ArcGIS environment to generate a map indicating food insecure areas. Of the total areas of the Zone 16.3% is found to be generally food secure, 42.5% moderately food insecure, 32 % highly food insecure and 9.7% is chronically food insecure. The result of the research indicated that food insecure areas can be mapped by ecological boundary, which could be very important during area targeting for food aid and solve the problem under of area targeting using administrative boundaries. In the research it is recommended that delineation of food insecure areas using Remote Sensing and GIS at local level should be encouraged. This system could be scaled up at regional and federal level after incorporating other factors determining food security. In doing so, (1) resource liquidation will be reduced to its optimum level (2) inclusion and exclusion errors for emergency response and or food for work or cash for work will be minimized.

Key words: Drought, food insecurity, food availability, Drought detection, Dekade, near real time, inclusion, exclusion, and resource liquidation.

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Acronyms

ARTEMIS	Advanced Real Time Environmental Monitoring Information
BOFED	Bureau of Finance and Economic Development
CCD	Cloud Cover Duration
DEM	Digital Elevation Model
DPPC	Disaster Prevention and Preparedness commission
NMSA	National Meteorological Service Agency
FAO	Food and Agricultural Organization
FEWS	Famine Early Warning System
FFSP	Federal Food Security Program
FIVIMS	Food Insecurity and Vulnerability Information and Mapping Systems
FSPCDPO	Food Security Program Coordination and Disaster Preparedness office
GAO	United States Government Accountability Office
GIEWS	Global Information and Early Warning System
GIS	Geographic Information Systems
HICE	House Hold Income Consumption Survey
MOFED	Ministry of Finance and Economic Development
NDVI	Normalized Difference Vegetation Index
NGO	Non Governmental Organizations
PDSI	Palmers Drought Severity Index
SRTM	Shuttle Radar Topographic Mapping
SPI	Standardized Precipitation Index
PSNP PIM	Productive Safety Net Program Implementation Manual
UN	United Nations
VAM	Vulnerability analysis and Mapping
VCi	Vegetation Condition Index
WB	World Bank
WFP	World Food Program
WFS	World Food Summit

CHAPTER ONE

INTRODUCTION

1.1 Background

In 1974, at the world conference in Rome, about 100 countries adopted the universal declaration to eliminate hunger and malnutrition by half in 2015. At this time the analysis of the causes of hunger was abandoned and the modern idea “food insecurity” was adopted (WFS, 1996). More than 800 million people throughout the world, of which the lion share is for developing countries, do not have enough food to meet their basic nutritional needs (WFS, 1996). Food insecurity can be chronic or transitory. A constant failure to access food is distinguished as chronic, while a temporary decline to access food is considered as transitory. It is a matter of both limited food availability and restricted access to food.

In spite of efforts to reduce food shortage, the number of population in need of food aid is increasing through time in the world in general and in Africa in particular. This is highly associated with cyclic drought and climate change. Recently the world leaders at Copenhagen were discussing climate change due to human interferences. Particularly the third world countries are highly affected by the increase in temperature due to atmospheric pollutions. Their crop production is challenged by the situation.

Ethiopia has been dependent on food aid and is one of the largest food aid recipients in Africa. More than 8 million people in rural Ethiopia are estimated to suffer from chronic food insecurity and many more from transitory food insecurity (IFPRI, 2008). Even in normal years people in different part of the country receive food aid. Dependence on rain fed agriculture is the primary determinant of household food insecurity.

At present, it is the concern of many national, regional, and international organizations to ensure proper identification of food insecure areas so that to execute aid and development activities in most effective and efficient manner. As a result there is a growing interest in the use of remote sensing and GIS technology to delineate food insecure areas quickly and effectively.

Taking these into cognizance, the study tries to show the possibility of delineating food insecure areas using remote sensing and GIS for area targeting for assistance and development activities.

1.2 Statement of the Problem

The food security situation of Amhara Region in general and South Gondar Zone in particular is worsening. There has been food aid since 1980s in the zone. For the purpose of food aid and development planning, area targeting needs scientific approach and technical expertise. But in the zone in particular and in the region in general area targeting is not supported by recent technologies.

Governmental and Non Governmental Organizations undertake pre and post harvest crop assessment at Woreda level to determine the area and the number of beneficiaries for food aid. The questionnaire based early warning report is also one of the grounds they are using for targeting. This questionnaire is filled mostly by those who do not have training about the importance and technique of early warning. This is due to higher human resource turnover at Woreda level.

The post harvest assessment compiled at woreda level is not reliable for targeting food insecure areas. It is mostly compiled by Woreda agricultural experts, who collect reports from the Kebele development agents for the compilation. The regional and zonal level experts try to crosscheck the report at field. But there is no statistical method of area selection for cross checking.

Having seen the post harvest assessment and other early warning reports, the relevant body decides the areas with food deficit and the number of beneficiaries at woreda level. This system does not devise a method to delineate kebeles and villages which have to be legible to be beneficiaries from the program and projects. Generally the system is subject to resource liquidation.

Sharp (1997), as cited by Devereux (2004), stated that in Ethiopian poor targeting system for food aid becomes a significant determinant of food insecurity. This indicates that some of the areas where the poor are living are missed during targeting. On the other hand, the areas targeted in which the better are living are benefiting from the programs and projects. This is one of the problems encountered. Having limited resource and an increasing number of food insecured populations, the system is not able to solve these kinds of problems. Limitations of the system persist due to a lack of good baseline information. Disaggregated data at local level and lack of adequate and skilled staffs at all levels result in weak targeting including inclusion and exclusion errors (WFP, 2007)

Identifying and characterizing the food insecure area is necessary for designing and conducting action to improve their situation and reduce their number. One of the most significant challenges in improving the national food security programme is availability of timely, up-to-date, and accurate data for planners and decision makers. There were disagreements over classification of Woredas as

chronically food insecure and transitory food insecure. Using modern technology can solve the conflict.

To minimize the problem, identification of major factors of food insecurity and delineating the food insecure areas is vital and helpful. It ensures reliable resource management and early warning of food insecurity. Moreover, integration of geoinformations, socio-economic data and environmental factors boost solutions for the problem under investigation. The use of GIS to provide a spatial framework for delineating food insecure areas allows the use of new units of analysis, for example, switching from administrative to ecological boundaries. Food security maps are useful tools in focusing on pockets of spatially distributed vulnerable areas.

Determination of food insecure areas using the traditional system is laborious and time consuming. Besides, the data are not available on time and reliable for decision making. Satellite sensor data are consistently available, cost effective and can be used to delineate the food insecure areas with better accuracy than the existing one.

Time series SPOT-4 images are helpful for this purpose. Spatial and non spatial (socio-economic) data can be integrated to delineate food insecure risk areas. The map produced from the research could be vital for the regional and zonal respective planners.

1.3 Objectives

1.3.1 General Objectives

The general objective of this research is to delineate food insecure areas using Remote Sensing and GIS techniques in south Gondar zone from the crop production (food availability) point of view.

1.3.2 Specific Objectives

- Evaluate the effectiveness of drought indices for detecting drought prevalence
- Show historical drought trends using SPOT-4 NDVI images
- Mapping soil erosion spot areas
- Mapping food insecure risk areas of south Gondar zone

CHAPTER TWO

LITERATURE REVIEW

2.1 The Concept of Food Security

Food security as a concept was originated in 1974 at the first World Food Summit and since then it has been a topic of considerable attention at global, regional and country levels. The conceptual framework has progressively developed and expanded along with the growing incidence of hunger, famine and malnutrition. It has become more complex due to a shift in the level of analysis from global and national to household and individual levels. At the beginning, food security was conceived as adequacy of food supply at global and national levels, a view which focused simply on food production variables and overlooked the multiple factors that affect food access. That was why analysts have been advocating production self-sufficiency as a strategy for nations to achieve food security.

The 1974 World Food Conference defined food security as: “availability at all times of adequate world supplies of basic food-stuffs” (WFS 1975). Just after 12 years, however, the World Bank defined food security as access by all people at all times to enough food for an active and healthy life (WB 1986). It consists of food availability (adequate supply of food through domestic production and food aid), food access (through home production, purchase in the market or food transfer) and utilization (the appropriate biophysical condition required to adequately utilize food to meet specific dietary needs).

The World Food Summit definition (1996) "Food security exists when all people at all times, have physical and economic access to sufficient, safe and nutritious food to meet the dietary needs and food preferences for an active and healthy life" is widely accepted now. It reinforces the multidimensional nature of food security. This definition is in keeping with the three classic aspects of food security: **availability** of staple foods, **stability** of supplies and **access** for all to these supplies; but it also contains the idea of adapted food, what is known as the "**biological utilization**" of food.

Food security is a multidimensional subject and can not be captured by a single or specific indicator. Therefore, it is important to understand its essential components. The widely accepted components

are food availability, food access and food utilization (FAO, 2006). Due to the growing incidence of hunger, famine and malnutrition in many parts of the third world, the concept of food security was redefined in such away that the unit of analyses shifted from national and global levels to household and individual levels. The concept was developed and improved through time as a result of increasing development in technology, which has caused significant changes and new paths in the systems of its analysis.

Recently, in the millennium development goals, food insecurity is given a due attention throughout the world. Of the eight millennium development goals, reducing the proportion of people who suffer from hunger by half between 1990 and 2015, took the first place (UN, 2005). In Ethiopia it is planned to halve the proportion of people whose income is less than one dollar a day and suffer from hunger between 1990 and 2015 (FDRE, 2005).

Food insecurity is a situation in which individuals have lower physical and economic access to their dietary need. It could be seasonal or transitory need. The parameter of categorizing transitory and chronic food insecurity differs from country to country. Generally chronically food insecure households are not resilient to shocks and are continuously vulnerable.

Sometimes there exists confusion among the terms *famine*, *hunger*, *food security* and *malnutrition*. Food security in the one hand and the above four terms in the other hand are inversely related concepts. Famine and hunger are results of food insecurity.

- A. ***Famine***: an absolute lack of food affecting a large number of population for a long period of time to such an extent that they can not subsist without external assistance.
- B. ***Hunger***: it is not a famine. It is similar to undernourishment and is related to poverty. In this case people do not have adequate food for days. Usually in poor countries this exists just before the coming harvest. When it persists for a long period of time, covering large number of population and resulting in mass migration and death, it becomes famine.
- C. ***Undernourishment***: the condition of people whose level of food consumption is consistently insufficient in terms of calories consumed in relation to their requirements. Chronic food insecurity is known as undernourishment (FAO, 200).

The recommended daily allowance for nourishment is 2100 kcal. When we consider this amount in Ethiopia it is very low (Devereux, 2000). Famine and hunger are both rooted in food insecurity.

Therefore, in conditions of chronic food insecurity there is always an impending famine. There are three types of food insecurity identified by FAO (2000). These are:

- I. Chronic food insecurity:** it affects individuals or groups of people who consume or have regularly been consuming less than the minimum needed amount over a long period of time.
- II. Cyclic food insecurity:** affects lower number of farmers who have enough to eat in their immediate post harvest period but not enough to carry them through to the next harvest period.
- III. Transitory food insecurity:** Affects urban dwellers dependent on highly unstable markets and agricultural products exposed to high incidence of natural disaster.

2.2 The Role of Remote Sensing and GIS for Food Security

At the global level, remote sensing is being used to monitor crop and weather conditions throughout the growing season at 10-day intervals, as well as to gauge the impact of drought through indices such as the Normalized Difference Vegetation Index (NDVI), the Vegetation Condition Index (VCI), the Cold Cloud Duration (CCD) and the Temperature Conditions Index (TCI). At national and local levels, information from these indices can also be used to monitor growing season and assess the extent of drought to help national authorities take measures to acquire food or to adjust cultivation methods in case of water shortages (UN, 2000).

GIS and Remote Sensing technologies are helpful to identify regions experiencing unfavorable crop growing conditions and food supply shortfalls and to determine food insecure areas and/or populations (Minamiguchi, 2006). Remote sensing data are important to detect environmental situations of an area. Remotely sensed data, especially AVHRR data from NOAA has been used in drought early warning and food security application in several southeast Asian countries. The data provides the extent and severity of recent droughts (Wilhite, 1993). Along with remotely sensed data, post harvest assessment, population number, Soil degradation and number of stunting and underweight can be analyzed and synthesized in the GIS environment for food security map generation.

The need to know where the poor are located is increasing through time. Remote Sensing and GIS plays a paramount role in satisfying the need. The use of Geographical Information System (GIS) as an infrastructure provides spatial analysis capabilities to develop and display different scenarios

through integrating and analysis of geospatial food insecurity data. In other words, determination of the spatial distribution of vulnerable people, reasons behind the food insecurity, trend of the food insecurity problem, and fundamental issues and parameters affecting the food security are helpful for decision making in food security achievement programs.

The mitigation of food insecurity requires information regarding disaster in real time. Recent advances in operational space technology have improved the ability to address many issues of early warning through the data in real time. Advancement in GIS has made possible the use of mapping techniques to analyse and present complex food insecurity and vulnerability information in ways that greatly facilitate understanding and decision making (Minamiguchi, 2006). Maps generated can provide decision makers to easily understand visual information about the location and areal extent of insecure population.

2.3 Previous Important Works

Several studies have been conducted on food security. A number of organizations are devoted towards the analysis and early warning of food insecurity at global, regional and country level from early 1990s. These projects deal primarily with people in Africa being vulnerable to food insecurity due to low agricultural productivity (Nazmul, 2001)

The Food and Agricultural Organization (FAO, 1998) has produced a Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) that can assemble, analyze and disseminate information about the problem of food insecurity and vulnerability. Vulnerability analysis and Mapping (VAM) of World Food Programme (1999) prepared composite map of vulnerability by putting different weights on different indicators.

Organizations concerned with food security of chronically hungry people (i.e. repeatedly over a number of years) are interested in knowing where, when, and who they are as well as the immediate and underlying causes of this unnecessary phenomenon, with a mandate not only to feed the hungry poor, but also to do something about it. The United Nations World Food Programme (WFP), through its Vulnerability Analysis and Mapping Unit (VAM), is initiating an effort to improve the quality of vulnerability analysis and strengthen links with intervention design (Haan and et al., 2001).

In the Middle East, Mexico and other countries small area estimation system of food insecurity and poverty mapping is common. In general, small-area estimation is a statistical technique that

combines survey data and census data to estimate the welfare for disaggregated geographical units such as municipalities or rural communities. A statistical model is estimated to predict a dependent variable related to welfare, e.g., consumption, income, etc. This model is usually based on survey data. Then the estimated parameters are applied to identical variables in a census database to predict the level of welfare that would be expected for the observed levels of the variables in the census associated with disaggregated geographical units (Bellon et al., 2004). This system is applied in Mexico and the models developed appeared to perform quite well, although there was a tendency to overestimate actual poverty rates.

FAO has been utilizing low resolution satellite remote sensing data on an operational basis to monitor vegetation and rainfall development over large areas through ARTEMIS (Advanced Real Time Environmental Monitoring Information) since 1988. The FAO GIEWS (Global Information and Early Warning System) on food and agriculture utilizes ARTEMIS to monitor food supply and demand conditions for all countries in the world. It provides continuous and timely warnings of food shortage, drought and hunger (Minamiguchi, 2006). The organization uses SPOT-4 and 5 with one km resolution NDVI to extract information about drought, crop growing and range land condition and CCD (METEOSAT derived image) which provide proxy for rainfall.

Since information is critical for providing assistance, a number of institutions are engaged in disaster early warning, baseline information and food security surveillance activities. In Ethiopia, in addition to DPPC, government agencies engaged in such activities include the Central Statistical Agency, the Welfare Monitoring Unit of the Ministry of Finance and Economic Development, and various line ministries.

Famine Early Warning System Network (FEWS NET) of the USAID produces a monthly food security report using secondary data generated through the Early Warning Working Group consisting of DPPC, Save the Children–UK, World food Programme, CARE and other government and non-governmental organizations. FEWS NET also makes use of satellite imagery for spatial analysis, which it receives directly from NASA and every ten days. FEWS NET is mainly focused on Africa, where the majority of food security warning systems operate, but it also covers parts of central Asia, Central America, and the Caribbean. FEWS NET is an activity of the U.S. Agency for International Development that provides timely food security information for 17 countries of Sub-Saharan Africa. Analyses identify vulnerable populations and hazards that threaten their livelihoods, leading to early warning of potential food security emergencies.

The main activities that FEWS NET undertakes includes satellite monitoring of vegetation and rainfall, field monitoring of agricultural production and marketing, analysis of vulnerability, consensus planning to respond to food insecurity, food aid targeting, and building capacities of local food security organizations.

The normalized difference vegetation index (NDVI), developed by NASA scientist Compton J. and the rainfall estimate (RFE) algorithm developed by NOAA scientists (Herman *et al.* 1997) constitute the principal remote sensing tools that FEWS NET uses to evaluate environmental conditions. In cases where FEWS NET requires higher-resolution data, it also utilizes data from the LANDSAT-7, Terra, and Tropical Rainfall Measuring Mission (TRMM) satellites.

NOAA and USGS produce the second most important remote sensing product for FEWS NET, a rainfall estimate based on Meteosat-5 cold cloud duration, rain gauges, wind speeds, relative humidity, and elevation. For every ten-day period, FEWS NET provides RFE data and maps for Africa (Gonzalez, 2000).

Together with analyses of trends from past FEWS NET current vulnerability analyses, long-term data facilitate the identification of geographic areas that have experienced a long-term erosion of food security because of climate change.

Table2_1: FEWS NET remote sensing data sources

SATELLITE	SENSOR	PRODUCT
NOAA	14 AVHRR 8 km and 1 km NDVI	NOAA
Meteosat	5 infrared rainfall estimate	Meteosat
Defense Meteorological Satellite Program	SSM/I	rainfall estimate
LANDSAT-7	ETM+	land cover
Terra	MODIS	250 m NDVI
Tropical Rainfall Measuring Mission	Microwave Imager (TMI)	rainfall estimate

WFP Vulnerability Analysis and Mapping (VAM) department uses state of the art mapping technologies to identify areas where people are most vulnerable to hunger and to estimate their needs. The annual FAO/WFP Crop and Food Supply Assessment mission estimates national cereal and pulse production, import requirements and needs for emergency food aid (Lautze, et al, 2003).

The shared concern of Djibouti, Ethiopia, Kenya, Somalia, the Sudan and Uganda on the effects of such disasters led to the establishment in 1986 of the Intergovernmental Authority on Drought and Development (IGADD). This body coordinated sub-regional efforts to combat the effects of drought and other natural disasters. The original IGADD Plan of Action recommended the establishment or strengthening of national early warning systems for food security and the establishment of a sub-regional food security information system to coordinate national, sub-regional, regional and international efforts in this field. The project contributed significantly to developing early warning methodologies throughout the region. The systematic comparison of actual and expected values of key indicators, the use of statistical clustering techniques to classify land units on the basis of these indicators and the merging of classifications for a range of indicators to produce vulnerability and risk maps are valuable diagnostic techniques in early warning methodologies (FAO,1997).

2.4 Determinants of Food Security

There are a number of factors affecting food security. They differ from country to country and from region to region. There have been debates concerning the identification of major factors of food insecurity since 1994 World Food Conference. Food insecurity in general is induced by natural and human factors and political and economic crisis (Minamiguchi, 2006).

Up to 1960s availability of food at the global and national level was considered as the main factor for food insecurity. It was clearly indicated in the definition given to it at the first World Food Summit (1974) “Availability at all times of adequate world food supplies of basic foodstuff to sustain a steady expansion of food consumption and to offset fluctuations in production and prices”. As a result, the national and international food policies were focused on ways of increasing food production rather than on policies that focus on ensuring access to food at the household levels (Tilaye, 2004). But later researchers revealed that availability of food at the global level does not guarantee acquisition of food at national or household levels.

Sen (1981a) is credited for bringing a shift in paradigm directing the emphasis of researchers and practitioners to vulnerability to food insecurity under the context of plenty of food availability at macro level, access/entitlement to income earning employments and resource endowment that can be transformed into food through production and trade. Nowadays the major components of food security are given a due attention in development goals. Clover (2003) explained that no single factor is responsible for food insecurity in Africa. Africa’s food emergencies (for transitory food

insecurity problem) are a result of a combination of problems ranging from drought and adverse weather patterns to civil conflict and HIV/AIDS. GAO (2008) identified the major factors of food insecurity in the sub-Saharan African countries. They consist of limited agricultural productivity and rural development, poor health condition and lack of access to credits.

Mulat et al (2006) identified the major factors of food insecurity in Ethiopia are Erratic weather conditions, Environmental degradation, Rapid population growth and declining farm size, Technological gaps, Infrastructural, institutional and other constraints and limited role of civil societies in policy formulation and implementation.

Therefore, since food insecurity is a multi-dimensional subject that cannot be captured by single/specific indicator, it is important to understand the essential components of food security. The widely accepted components of food security are food availability, food access, food utilization and stability (FAO, 2006).

2.5 Food Security Situation In Ethiopia

In spite of vast agricultural potential, Ethiopia has been under the state of food insecurity since 1970s. It has been chronically dependent on food aid and is one of the largest food aid recipients in Africa. More than 8 million people in rural Ethiopia are estimated to suffer from chronic food insecurity and many more from transitory food insecurity (IFPRI, 2008). Over the last thirty years Ethiopia has been in the news for widespread and persistent food insecurity. Even in normal years people in different part of the country receive food aid. The poor performance of agriculture is a large part of the explanation for the case. Dependence on low production rain fed agriculture is the primary determinant of household food insecurity. This undiversified system of livelihood is susceptible to shocks.

Off farm employment opportunities in the rural area of the country are limited and their income generating potential has been insignificant. Most of the time, the poor are earning money at the cost of the environment. Recently the government is introducing non agricultural (off farm) activities as sources of income in the rural areas to reduce poverty and food insecurity.

Though food insecurity as a problem was felt in the 1960s, it is only started influencing policy in the 1980s, when the food self sufficiency became one of the objectives of the ten years perspective plan. The food poverty in the country is equally important in rural and urban areas. The

consequences of food insecurity are reflected in the high level of malnutrition (stunting and under weight of children under five and pregnant and lactating mothers) (FDRE, 2002).

When we see the last three years, the price of cereals remained above average and despite the government report in a significant increase in production at the national level, price increased further. This situation has had a great impact on the already food insecure people in both rural and urban areas.

2.6 Major Factors of Food Security in Ethiopia

The food insecurity in Ethiopia is derived directly from dependency on undiversified livelihood based on low input and output rain fed agriculture. The low productivity is also supported by low land and fragmented holding due to population growth. Ethiopian farmers do not produce enough food even in good rainfall years to meet their consumption requirements.

As to Devereux (2000) the main triggers of food insecurity in Ethiopia are drought and war. He suggested that the problem of food insecurity in Ethiopia can be conceptualized simply by population pressure (which results in small and fragmented land holding), soil degradation (reducing productivity), recurrent drought and limited off-farm employment opportunities. Devereux concluded that rainfall is the single most important determinant of Ethiopia's economic success or failure from year to year. This is because of the fact that more than 85% of the population is engaged in rainfed agriculture.

In the Ethiopian Sustainable Development and Poverty Reduction Program, a combination of factors which result in series and growing problem of food insecurity are identified. They are: adverse climate change (drought) combined with high human population pressure which has led to a decline in the size of per-capita land holding, environmental degradation, technological and institutional factors (MOFED, 2002). FSPCDPO (2008) of the Amhara National Regional State identified the following determinant factors for food insecurity in the region: cyclic drought, soil degradation, forest degradation, pest infestation and crop disease, poor market integration, undiversified livelihood system, gender biased practice, poor infrastructural development and dependence syndrome.

Devereux (2000) generally sub-divided the food insecurity analysts of Ethiopia in to two. The physical ecology cluster and the political economy cluster. The former focuses on population growth, declining soil fertility and drought as the major factor as determinants of food insecurity

whereas the later are groups blaming the government policies, weak market integration and institutional failures as the major determinants of food insecurity.

In Ethiopia, agriculture plays a more significant role in the development of national food security than just being the source of food. It is a source of income to the farmers in addition to its importance as a source of food. Therefore, agriculture has to be viewed in the context of food production, job creation and income generation. In Ethiopia there are three major types of food supply systems (FSS), mainly dependent up on the performance of rainfall. They are the subsistence crop dependent FSS, the market dependent FSS and the livestock dependent FSS covering 75%, 15%, and 10% respectively (FAO, 2000).

In the developed countries it is only about 5% of the population engaged in agriculture (Devereux, 2000). However, in Ethiopia rainfed agriculture continues to be the major occupation of more than 85% of the population. This major economic source is largely dependent upon precipitation. As a main stay of occupation it could not have been contributing much to the farmers as an income generating source during the disaster periods.

According to the HICE (House Hold Income Consumption Survey) of 1999/2000, the major sources of income from major occupations are displayed in the following table.

Table 2_1: Source of income

R.No	Sources of income	Rural in (%)	Urban in (%)
1	Agriculture	72.5	4.6
2	Off- farm activities	5.4	30.3
3	Wage and salaries	2.9	41.2
4	House and other rent	0.2	0.5
5	Dividends and profit share as well as bank savings	3.9	8.7
6	Gift and remittance	3.5	8.1
7	Other receipts	11.8	6.7

Source: MOFED (2002)

It is clearly indicated that 72.5% of the income is from the agricultural sector. Therefore, it will be very difficult to deal with food security in Ethiopia neglecting the agriculture sector. It is also the major source of food for the population of the nation and hence the prime contributing sector to food security. In addition agriculture is expected to play a key role in generating surplus capital to speed up the overall socio-economic development of the country (NMSA, 2001). As a result, increasing agricultural production in a sustainable manner could address the problem of food

shortages in the country. An increase in agricultural production will benefit agro-processing enterprises by supplying raw materials. This in turn, increases job opportunity and diversifies sources of income which finally improves the resilience of the poor during disasters and escalating food price in the market.

Food insecure farmers (chronic or transitory) as well as non farming community get some food or all their food from the market, the former to supplement their production and the latter as a main source. To purchase from the market they have to have the purchasing power to cover the cost. However, many households in drought prone areas and moisture deficit areas as well as urban areas lack sufficient income to meet their basic needs (MOFED, 2002).

2.6.1 Cyclic Drought as a Determinant of Food Security

Many of the food emergencies in Ethiopia are induced by drought. There is a complex interaction between drought and food insecurity. Drought is the most common form of environmental risk leading to food insecurity (Devereux, 2006). It is only in poor countries that drought turns into famine, often resulting in population displacement, suffering, and loss of life (Shaha, 2008).

The impact of drought on rural livelihoods is not clearly understood in developing countries using modern technologies. Cyclical drought has tremendous impact on long term food security. This is because of the fact that recovery from previous crisis is cut short by the next drought (GAO, 2002). Since the entire agricultural activity of Ethiopia is associated with the behavior of rainfall, drought should be given an important attention and its impact should not be divorced from the societal context (Wilhite, 1993).

The occurrence of drought and famine in Ethiopia is dated back to 253 BC. The records of drought period exist in different literatures including religious books. 1066-70, 1071-72, 1252, 1272-73, 1274-1275, 1435-36, 1454, 1468, 1562, 1800, 1826-29, 1835, 1836-1837, 1872, 1888-90 (the great Ethiopian famine), 1891-1892, 1895-1900, 1913-1914, 1921-22, 1932-34, 1953-58, 1964-66, 1969, 1971-1972, 1975-1976, 1978-1979, 1982, 1983-1984, 1999-2000, 2002-2003 and 2008-2009 are major drought years recorded (Glantz, 1987, Teshome, 2006 and USAID, 2007).

It seems that the frequency of drought and number of affected population increases through time. There have been deaths from drought affected population in the recent past in the country. The table below shows the situation.

Table 2_2: drought affected population

R.No	year	Affected population	Human loss	remark
1	1972/1973	1.9 million	250,000	
2	1983/1984	8 million	1 million	
3	1999/2000	10.6 million	Excess	No data is available
4	2002/2003	>13 million	No major deaths	The advancement in early warning and contingency planning reduces death
5	2007/2008	8.6 million	No major deaths	

Source: USAID (2007)

Since drought as a disaster is a determinant factor for food insecurity (particularly in rain fed agriculture dependent population), there is an immediate operational need to keep in truck of drought conditions for monitoring and prediction. It is a regular feature of Ethiopian weather pattern disrupting cropping operations, which results in reduced amount of income from the sector and food insecurity if it persists for a considerable period of time (Almayehu, 1993). In addition to the reduction of crop yield, drought is associated with insect infestation and plant disease (Chopra, 2006). That is why the Government of Ethiopia focuses on reducing the country's vulnerability to drought and other natural calamities in its poverty reduction strategy (MOFED, 2002).

Sometimes, there would be drought even if the area is green, called green drought. It is a type of drought condition associated with apparent ample rainfall but reduced agricultural productivity because of poor timely rains or ineffective precipitation. The characteristics of drought are distinctly regional reflecting unique meteorological, hydrological, agricultural and socio-economic characteristics (Wilhite, 1993).

Drought definitions vary from region to region and may depend upon the dominating perception, and the task for which it is defined (academic study or a drought-relief plan). Drought always starts with the lack of precipitation, but may or may not (depending on how long and severe it is) affect moisture, streams, groundwater, ecosystems and human beings. This leads to the identification of different types of drought: meteorological, agricultural, hydrological, socio-economic, ecological which reflect the perspectives of different sectors on water shortages.

Therefore, one can say that the magnitude of drought is closely related to the timing of the onset of the precipitation. There are four types of drought, meteorological drought, agricultural drought, socio-economic drought and hydrologic drought (Chopra, 2006).

- **Meteorological drought:** 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 components of the hydrological system such as soil moisture, stream flow, ground water and reservoir levels etc.

- **Agricultural drought:** this links various characteristics of meteorological or hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, , 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. It is generally accepted to be a period of dryness caused by a precipitation shortfall during the crop growing period resulting in a substantial reduction in yield. Agricultural drought impacts depend not only on its duration and intensity but also on the type of crop, its stage of growth and soil characteristics. Therefore, Agricultural drought is a crop specific phenomenon (Wilhite, 1993).

- **Socio-economic drought:** it is associated with the demand and supply aspect of economic goods together with elements of meteorological, hydrological and agricultural drought. This type of drought mainly occurs when the demand for an economic good exceeds its supply due to weather related shortfall in precipitation and is highly variable from region to region.

- **Hydrological drought:** this is associated with the deficiency of water on surface or subsurface due to shortfall in precipitation. Although all droughts have their origination from deficiency in precipitation, hydrological drought is mainly concerned about how this deficiency affects.

The relationship of types of drought can be easily understood from the Sequence of Drought impacts chart below.

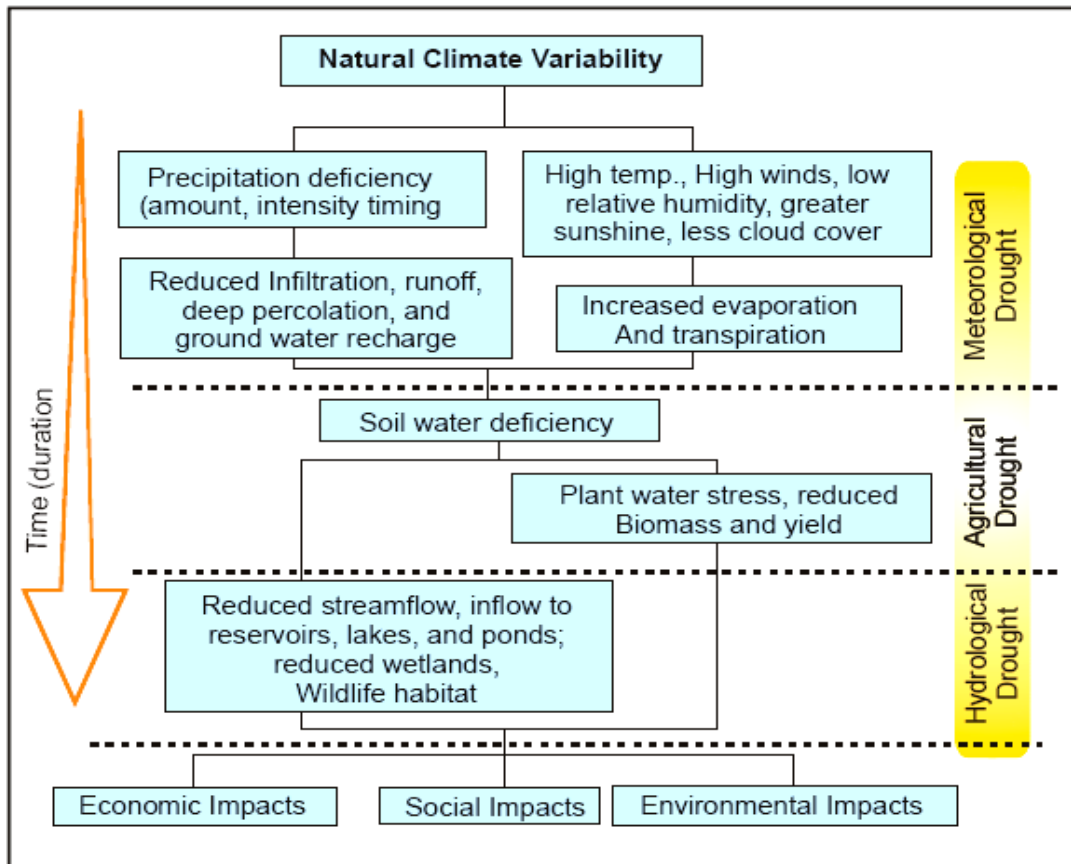


Figure 2_1: relationship of drought types
<http://drought.unl.edu/whatis/concept.htm>

Every year millions of acres of agricultural land in the world are affected by drought. Its prevalence often leads to devastating economic and social impacts. As mankind faces the inevitable onset of drought, the development of drought mitigation measures is an important task. The first step in this endeavor is a drought watch capability. Satellite based drought watch system will serve this goal (Wilhite, 1993). With the help of environmental satellite, drought can be detected 4 to 6 weeks earlier than before and delineated more accurately, and its impact on agriculture can be diagnosed far in advance of harvest, which is the most vital for food security (Kogan, 1990 cited in Chopra, 2006).

Several indices have been developed for the quantification of drought (based on the type of drought). Conventional methods of drought monitoring suffer from limitations with regard to timeliness, objectivity, unreliability, and inadequacy, but satellite sensors provide spatial information on vegetation stress caused by drought conditions. This shows that a comprehensive study on drought can be conducted using satellite sensors.

Different types of drought require different drought indicators. In agricultural drought monitoring, the most suitable indicators needed are the factors that are responsive to soil moisture status as a result of soil water balance process. Soil moisture deficit has critical relation with crop water requirements and it is important in assessing the impact of drought on crops. The choice depends on hydro-climatology of the region, the type of drought, the vulnerability of society, the purpose of the study and the available data (Narendra, 2008).

2.6.2 Soil Erosion as a factor for Food Insecurity

Soil Degradation is the deterioration or total loss of the productive capacity of the soils for present and future use' (FAO, 1988).

The wealth of a country depends on its ability to conserve and manage its land resources. Because of the aridity of a considerable area of Ethiopia, seasonally heavy rainfalls and flooding in the highlands, and loss of vegetation cover, much of the country has for decades been subject to erosion, land degradation, enormous soil loss, and reduced moisture availability. Some of the adverse consequences of land degradation include declining food production, drought, ecological imbalance, and deterioration in the living standard of the population.

Land degradation from overgrazing, to soil erosion and cultivation of steep slope and fragile lands has resulted in loss of biodiversity, productivity, stability and resiliency (USAID, 2000). Natural resources such as soil, water, plants and animals are key factors affecting farm productivity. Massive land degradation undermines the productive capability of agricultural sector. Vegetation cover not only control erosion and conserve water, but also serve to recycle nutrient, reduce evaporative demand on crops and soil and increase soil organic matter.

According to USAID (2000), Ethiopia is considered to have one of the most serious soil degradation problems in the world, in which on over 2 million hectares of land the soil depth is so reduced that the land is no longer able to support cultivation. The overall degradation of the natural resource base, in particular land and vegetation, has led to increasing rainwater losses through runoff (and associated soil erosion), which in turn has exacerbated the impact of drought. This downward spiral of environmental degradation has resulted in further land productivity decline, loss of biodiversity and continuing desertification.

In Ethiopia, identified drought affected areas are moisture deficit areas with erratic rainfall, high deforestation and soil erosion and areas in which steep slope lands are used for cultivation (FRDE, 1994). The population is increasing alarmingly over time. The growth rate is not proportional to the economic growth of the country. That is why the production from agriculture is unable to feed 73,918,505 heads. Rural people lack sufficient land to produce their food. The rapid population growth rate has led to severe land shortage and rapid natural resource degradation. In Amhara National Regional State, 94% of the households have insufficient land to meet their food needs (IFPRI, 2008). The average land holding is insufficient to feed a family of five (average household size) in the country (Devereux, 2000)

High population density in large areas of the country has created negative impact on agricultural production and environmental security. Reports of the highland reclamation study have shown the seriousness of soil erosion on the highlands. Furthermore, deforestation and soil degradation are major causes for food insecurity and poverty in Ethiopia; most of these arise from human and livestock pressures on land, leading to environmental degradation.

The urgent need to meet the demand of the growing population and of industries has led to the degradation of agricultural resource base. Large areas of virgin land in Africa are opened up for export crops (Sinha and et al, 1988). It is true in the Ethiopian case where large areas of virgin lands in the western parts of the country opened up for resettlement. It is observed that a large number of people are now settled and affect the ecology of the area through deforestation. The need for opening new land for cultivation, timber and fuel wood has caused extensive deforestation. This, in the highlands of the country adversely influenced water conservation and led to soil erosion, silting and floods.

Since natural resource and its utilization is a complex cycle, it will be very difficult to precisely calculate the loss due to population pressure. The population growth of 3% a year is leading to a doubling of the human population every 25 years. Population increase has led to a dramatic increase in energy demand and this has been met mainly by wood (from range and forest) and organic matter such as animal manure. It is observed that rural households are compelled to clear and cultivate lands on steep hill side. This condition aggravates the soil loss through water erosion and deforestation.

2.6.3 Wasting, Stunting and Underweight as Indicators of Food Insecurity

A condition of low weight-for-height, or *Wasting*, is a reflection of recent malnutrition, which may be caused by acute food shortage or serious infections. Data from MOFED, (2006), shows that the prevalence of wasting in the country is about 8%. Height-for-age, or *Stunting*, is an indicator of chronic malnutrition. It indicates long- term or accumulated nutritional deficiency resulting from lack of adequate dietary intake over a long period of time, or recurrent illness. The prevalence is much higher among rural children (40%) than urban (30%). Weight-for-age, or *Under Weight*, based on the principle that a child has an expected weight for his/her age, measures the general nutritional status of children. The prevalence of underweight children in the country was 37% in 2004. This considerable proportion of underweight children; which reflects both wasting and stunting, signals the extensive distribution of malnutrition among young children of the country. The prevalence of underweight children across regional states varies from as low as 13% in Addis Ababa to as high as 45% in Amhara region.

2.7 Drought Indices

Drought Indices are continuous functions of rainfall /or temperature, river discharge or other measurable variables. Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better studied than others for certain use (Amare, 2007).

There are a number of indices to track and define drought. They have been around for nearly a century now. No one definition covers all possible forms of drought and no one index can possibly capture all the various definitions. The turning point in the evaluation of drought indices is back to the 1960s, when Palmer devised PDSI. Following new technological innovations we have now many more indices available aiming at monitoring and predicting drought's onset, intensity, duration and spatial extent.

2.7.1 Drought Indices Derived From Meteorological Data

Rainfall is an important meteorological parameter which influences the type of vegetation in a region. Drought indices are normally continuous functions of rainfall and/or temperature, river discharge or other measurable variable. Rainfall data are widely used to calculate drought indices, because long- term rainfall records are often available. Rainfall data alone may not reflect the spectrum of drought-related conditions, but they can serve as a pragmatic solution in data-poor regions. Meteorological data based indices include Palmer Drought Severity Index

(PDSI), Crop Moisture Index (CMI), Standardized Precipitation Index (SPI) are short lists. The simplest drought index is the deviation from a normal precipitation, which is called rainfall anomaly (Dunkel, 2009).

Meteorological stations provide weather information on daily basis or several times a day for environmental monitoring purpose, including drought watch. But they are not sufficient to characterize regional drought. Its weather parameters are physical in nature and are not sufficient to characterize agricultural drought and its impact on vegetation (Wilhite, 1993). This type of data is used to calibrate the drought situation result from satellite image based drought delineation. But observation from satellite image provides more timely information and better spatial coverage.

2.7.2 Drought Indices derived from Remote Sensing data

Utility of remote sensing data in drought assessment has long been proven. It is far superior to conventional methods at an optimal spatial extent. Remote Sensing technology in its current state of art can help in predicting, mitigating and monitoring of drought. Data from various satellites can be utilized for this purpose irrespective of the perspective that a researcher has towards drought, whether it is agricultural, meteorological or hydrological. It enables to understand the manifestations of drought in a larger area more directly than through conventional methods, and of all, in less time consuming manner (Sharma, 2006). The drought prone area or risk zone identification is usually carried out on the basis of historic data analysis of rainfall or rainfall and evaporation and the area of irrigation support. The conventional methods lack identification of spatial variation and does not cover man's influence such as land use changes.

Remote Sensing based method for identification of drought prone areas uses historical vegetation index data derived from satellite images. It provides spatial information on drought prone areas depending on the trend in vegetation development and frequency of low development (Jeyaseelan, 2003). Drought indicators calculated from satellite-derived surface parameters have been widely used to study droughts. Normalized Difference Vegetation Index (NDVI) and Vegetation Condition Index (VCI) are of extensively used vegetation indices.

2.7.2.1 Normalized Difference Vegetation Index (NDVI)

The vegetation condition reflects the overall effect of rainfall, soil moisture, weather and agricultural practices and the satellite based monitoring of vegetation plays an important role in drought monitoring and early warning.

When a drought exists, due to notable reduction of the rainfall, the capacity of vegetation to carry out the chlorophyll function is reduced. This occurrence is demonstrated by the spectral response to the EMR falling up on them. Thus, the response of the green vegetation (in a good physiological and healthy state) is characterized by a substantial absorption in the red region and a large reflection in the infrared region in the electromagnetic spectrum. Unhealthy, aged or stressed vegetation increase its reflection in the red region of the spectrum and decrease in the infrared region of the spectrum.

NDVI was first suggested by Tucker in 1979 as an index of vegetation health and density (Sharma, 2006). The NDVI is currently the only operational, global-based vegetation index utilized. This is in part, due to its 'ratioing' properties, which enable the NDVI to cancel out a large proportion of signal variations attributed to calibration, noise, and changing irradiance conditions that accompany changing sun angles, topography, clouds/shadow and atmospheric conditions (Jeyaseelan, 2003). NDVI for a given season can serve as an indicator of drought severity by inferring deficiencies in photosynthetic capacity in drought years as contrasted with other years (Wilhite, 1993). It is related to the photosynthetically absorbed radiation by examining the ratio of reflected infrared to red wave length and is an excellent measure of vegetation health. Healthy plants have a high NDVI value because of their high reflectance of infrared light, and relatively low reflectance of red light.

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

Where, NIR and RED are the reflectance in the near infrared and red bands of the EMR. NDVI is a nonlinear function that varies between -1 and +1 (Undefined when NIR and VIS are zero). Values of NDVI for vegetated land generally range from about 0.1 to 0.7, with values greater than 0.5 indicating healthy vegetation.

However, NDVI uses only two bands and is not very sensitive to the influences of soil background reflectance at low vegetation cover, and has a lagged response to drought because of a lagged vegetation response to developing rainfall deficits due to residual moisture stored in the soil. Previous studies have shown that NDVI lags behind antecedent precipitation by up to 3 months. The lag time is dependent on whether the region is purely rainfed, fully irrigated, or partially irrigated. The lag time will be shorter in areas which are dependent up on rainfall. NDVI itself does not reflect drought or non-drought conditions. But the severity of a drought (or the extent of wetness, on the other end of the spectrum) may be defined as NDVI deviation from its long-term

mean (DEV_{NDVI}). This deviation is calculated as the difference between the NDVI for the current time step and a long-term mean NDVI for that month for each pixel (Sharma, 2006):

$$DEV_{NDVI} = NDVI_i - NDVI_{mean}$$

Where, $NDVI_i$ is the NDVI value for month i (current NDVI) and $NDVI_{mean}$ is the long-term NDVI for the same month. When DEV_{NDVI} is negative, it indicates below-normal vegetation condition/health and, therefore, suggests a prevailing drought situation. Cited by Sharma(2006) Thenkabail and et al said that in general, the departure from the long-term mean NDVI is effectively more than just a drought indicator, as it would reflect the conditions of healthy vegetation in normal and wet months/years. This indicator is widely used in drought studies. Its limitations are that the deviation from the mean does not take into account the standard deviation, and hence can be misinterpreted when the variability in vegetation conditions in a region is very high in any one given year (Thenkabail et al., 2004). So in low vegetation cover conditions, deviations may be less well correlated to changes in vegetation cover.

2.7.2.2 Vegetation Condition Index (VCI)

VCI is an indicator of the status of the vegetation cover as a function of minimum and maximum NDVI encountered for a given ecosystem over many years. It shows, effectively, how close the current month's NDVI is to the minimum NDVI calculated from the long-term record of Remote Sensing images. VCI enables to separate the short-term signal from the ecological signal (Amare, 2007). VCI is defined as:

$$VCI_j = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{mean})} * 100$$

Where, $NDVI_{max}$ and $NDVI_{min}$ are calculated from long-term record for a particular month and j is the index of the current month. The condition of the ground vegetation presented by VCI is measured in percent. The VCI values around 50% reflect fair vegetation conditions. Sharma, (2006) indicated that the VCI values between 50 and 100% indicate optimal or above normal conditions. At the VCI value of 100%, the NDVI value for this month (or week) is equal to $NDVI_{max}$. The VCI values below 50% indicate Different degrees of a drought severity.

Cited by Sharma, (2006) Kogan, (1995) illustrated that the VCI threshold of 35% may be used to identify extreme drought conditions and suggested that further research is necessary to categorize the VCI by its severity in the range between 0 and 35%. The VCI value close to zero percent reflects an extremely dry month, when the NDVI value is close to its long-term minimum. Low VCI values over several consecutive time intervals point to drought development.

These studies suggest that VCI captures rainfall dynamics better than the NDVI particularly in geographically non-homogeneous areas. Also, VCI values indicate how much the vegetation has advanced or deteriorated in response to weather. It provides better understanding of assessment of drought spatial characteristics, as well as its duration and severity in good agreement with precipitation patterns (Chopra, 2006). Areas with different values of NDVI will have similar VCI values. VCI provides accurate information not only for the cases with well defined, prolonged, widespread, and intensive droughts, but also, for localized, short term and poorly defined droughts (Wilhite, 1993).

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

3.1 Geographical location

South Gondar administrative zone is found in Amhara National Regional State and is 666 kms from Addis Ababa and 113 km from Bahir Dar. It is geographically located between 11⁰22' and 12⁰33' north latitude and 37⁰25' and 38⁰43' East longitude, constituting an area of 14,595 Sq.km. It shares common borders with East Gojjam in the south, West Gojjam in the south west, Lake Tana in the west, north Gondar in the north, Wag Hemra zone in the north east, North Wollo in the east, and south Wollo in the south east. Abbay River separates South Gondar from the two Gojjam zones.

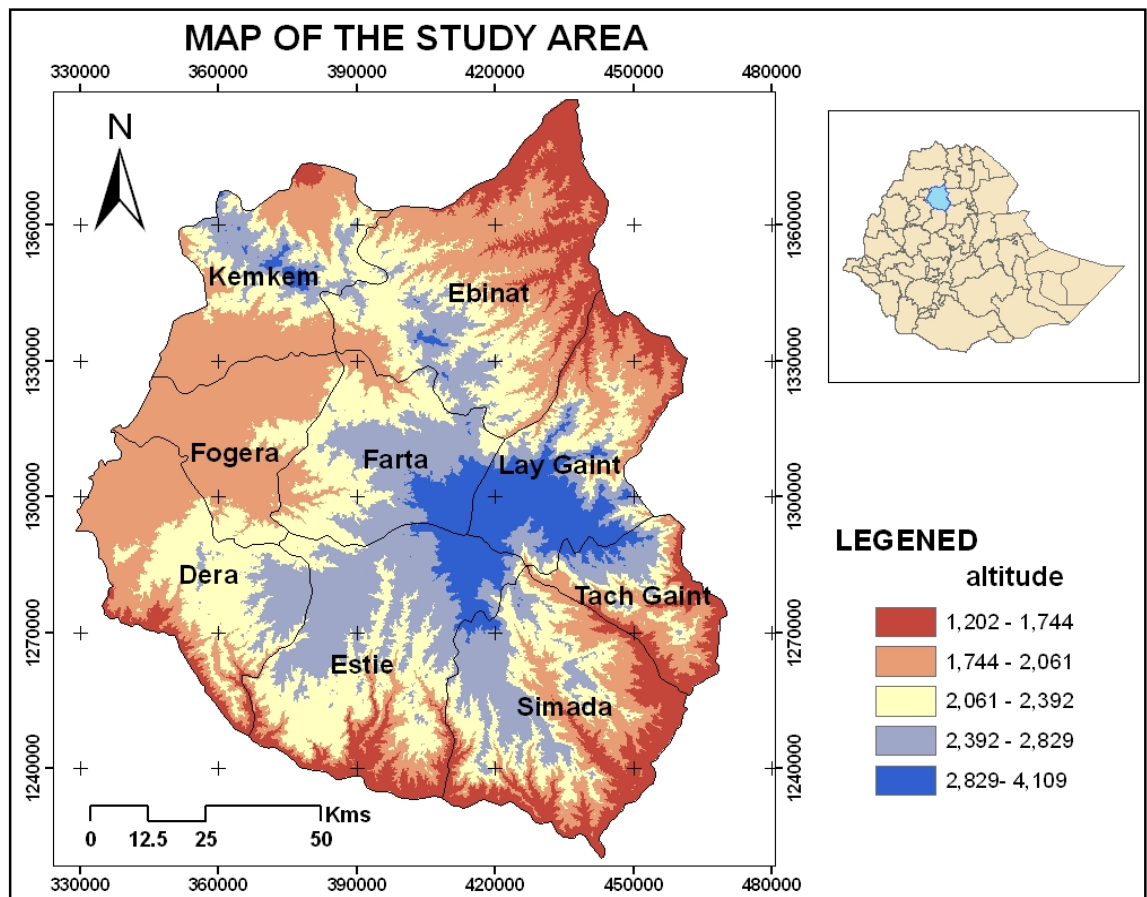


Figure 3_1: study area

3.2 Demography

Based on the 2007 census, the total population of the zone is 2,047,206. From the total population 1,008,293 are men and 1,038,913 are women. Rural inhabitants and urban dwellers constitute 1,852,732 and 194,474 respectively (CSA, 2007). Having an estimated area of 14595 square kilometers, the population density of the zone is estimated as 140.3 people per square kilometer.

3.3 Major Economic Activities

From the total population, 90% are engaged in agricultural activities for their livelihoods. 92% of their income is generated from agriculture, 3% from daily labor, 2% from trade, 2% from handicraft and 1% from others (unpublished baseline data from the zone). The major crop they produce are Teff, Maize, Wheat, Sorghum, and Rice. The major cash crops are “chat”, Potato and Onion. The major productions through irrigation in the zone are Onion, Tomato, and Potato. Even though it is not well organized some of the population is engaged in Fisheries at Lake Tana.

The water resource from river Gumara, Rib, Lake Tana, Mena and other smaller rivers is providing suitable conditions for irrigation agriculture for parts of some Woredas. In addition to this, the summer flood in Fogera plain supplies fertile soil to the area. That is why the Fogera plain becomes always green with its irrigation agriculture. Farmers can produce crop three times a year. This is the major rice producing area in the country where the majority of households are food secure.

3.4 Rivers and Lake

The major rivers found in South Gondar zone are Gumara, Rib and Mena rivers. The western part of the zone is bounded by Lake Tana, in which people benefit from fisheries and irrigation agriculture. All rivers of the zone drain in to Lake Tana and Tekeze River.

3.5 Infrastructural Condition

There is only one hospital in the zone and one health centre at each woreda until recently. Now there exist two health centers in some woredas. At each kebele there is one clinic serving the local people. But they are not well equipped and health extension workers are not well experienced to satisfy the need.

The Asphalt road from Bahir Dar to Gondar crosses three Woredas of the zone (Dera, Fogera and Libo Kemkem), whereas the other five Woredas have all weather gravel road. The road network of

the zone is among the lowest in the country. Except the main roads to Woredas, there exists poor all weather road for four wheel drives. The clean water supply coverage of the zone is 45.5%.

3.6 Tourism

South Gondar is full of cultural heritage. There are a number of monasteries and traditional church education centers. Monasteries in Lake Tana are taken as tourism heritage to attract tourists. Among the traditional church education centers is Betelehem. It is the only education centre for “aquaquam masmeskeria” (people who graduate from the school after completing their education in the style of chanting/hymn in the church after saint Yared of Ethiopia).

3.7 Topography and Climate

The zone is divided in to highland and lowland areas. The altitude ranges from 1202 to 4109 ms above sea level. The highlands are found above 1500 meters above sea level. The lowlands are found between 500 to 1500 meters above sea level. Climatically Dega type is found above 2,300 mts, Woyinadega from 1500 to 2300, and kola/hot below 1500 Mts. The annual temperature of the zone is ranging from 18.2⁰c to 29.9⁰c. It receives 1257.41 mm mean annual rainfall. It is in the main summer season (June, July and August) that the zone receives the maximum rainfall.

The western part of the zone is plain area (the Fogera plain) subject to flooding during the summer season, a cause for major water born diseases to human being and animals.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 Remote Sensing Data collection

4.1.1 Spot NDVI Image

Since 1998, FAO has been acquiring the NDVI data derived from the vegetation instrument aboard the SOPT- 4 and 5 satellites every ten days covering the entire landmass of the globe at 4 km resolution. However, the selected regions of NDVI images are received at a resolution of 1km. It is more suitable for national and regional monitoring of major seasonal variations in vegetation patterns, which in turn provides information concerning different phases of plant and crop growth. In 1km resolution image, details are much more visible at sub national level compared to the NOAA imagery with 10km resolution (Minamiguchi, 2004). NDVI images from SPOT-4 have been proven to be useful for early warning and drought and crop monitoring over large arid and semi-arid areas such as substantiated in Africa. They are used to support the agro-meteorological information normally used for early warning.

The dekadal and monthly composite satellite data have provided a cost effective and efficient resolution for monitoring the current crop season allowing effectively identifying areas suffering from low rainfall and drought.

There are limitations in using NDVI. It provides only a very rough measure of crop growing conditions or vegetation vigor. Low NDVI values between crop germination and maturation could indicate that crops have suffered water stress, where as high NDVI values do not necessarily reflect the condition of food crops. A sudden increase in the vegetation in the rainy season increases NDVI. This does not always indicate that crops have been planted. Similarly a sharp reduction of value is detected towards the end of the crop season/as short as 20 days/ or crop harvesting reduces the overall NDVI signature of the agricultural area. Therefore, to interpret NDVI, it is essential to know actual planting times using crop calendar and the crop harvesting period of an area.

The NDVI provides an indicator of changes in vegetation in response to biophysical conditions, including plant type, weather and soil, whose main use is to compare the current state of vegetation with previous time periods to detect anomalous conditions(for example the same time in an average

year or a reference year). This tool assists decision makers to determine food security and predict the areas in need of food aid.

SPOT-4 and 5 NDVI images are found aggregated in a dekadal basis, 36 dekadal images stacked together for a single year. In order to obtain actual NDVI values each dekadal layer should be rescaled by multiplying raw data with 0.004 and subtract 0.1, i.e., (**Value*0.004**) - **0.1**.

- NDVI time series between April 1998 and December 2005 (3 composites per a month, 36 layers per year, except for 1998, with 1 km resolution) is collected from <http://free.vgt.vito.be> web site

A dekade is one third of a month. These are:

- Dekad-1: The first 1-10 days in the month.
- Dekad-2: 11-20 days
- Dekad-3: 21-days to end of the Months.

The dekadal data were combined into monthly, seasonal and yearly totals.

4.1.2 LandSat Image and SRTM

The Landsat image with path number 169 and row number 52 with an acquisition date of 03/08/2003 is downloaded from the internet. Furthermore, topography is essential for soil loss estimation. It was derived from 30 meter resolution SRTM (Shuttle Radar Topographic Mapping) data. A DEM (Digital Elevation Model) is helpful for topographic factor (LS factor) generation.

4.2 Meteorological Data

Decadal based rainfall data was collected from the EMSA. There are 14 stations which are distributed unevenly in the zone. Their distribution can be seen from the figure 4_1. Rainfall data are essential to support NDVI data for drought risk assessment and meteorological drought map production. It is also essential for rainfall Erosivity ,factor generation for soil loss estimation from the zone.

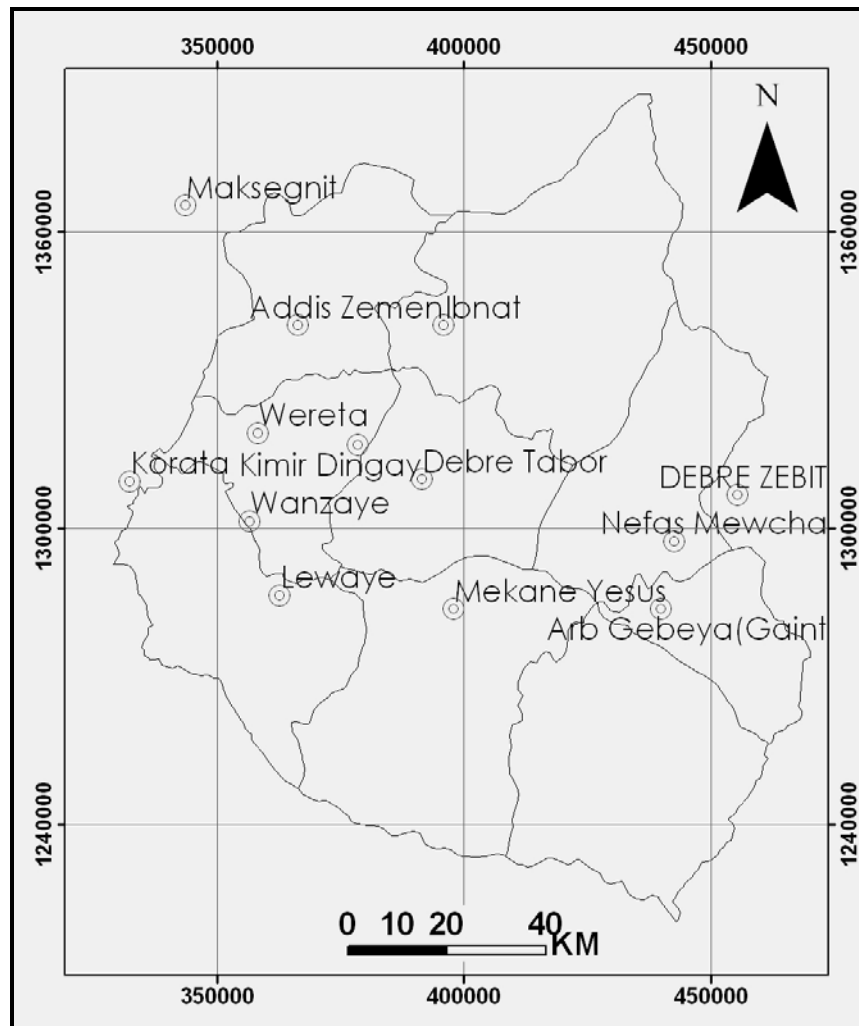


Figure 4_1: meteorological stations

4.3 Food Aid beneficiaries

Among the nine Woredas of the zone five are food aid beneficiaries at least for about six months a year. This could be in a PSNP or other food security programs. For this study the number of beneficiaries from PSNP during 2008 is taken. The program, provide 15 kg of grain or 90 birr per month for about six months a year.

Table 4_1: food aid beneficiaries of the study area

R.NO	WOREDAS	BENEFICIARIES	FOOD AID REQUIRED IN QT.
1	Ebinat	77618	69856.2
2	Libo Kemkem	42686	38417.4
3	Lay Gaynet	88438	79594.2
4	Tach Gaynet	54198	48778.2
5	Simada	84652	76186.8
6	Estie	33552	30196.8

(Source: Zonal food security office report, 2008)

4.4 Soil Data

FAO Soil Classification is used to generate the soil erodibility (K) factor for the soil loss estimation. There exist about seven types of soils in the study area, namely Eutric Cambisol, Vertic Cambisol, Eutric Leptisol, Lithic Leptisol, Humic Nitosol and Eutric Vertisol.

4.5 Methodology

The researcher collected data from different sources to achieve the indicated objectives. All are analyzed and interpreted in the ERDAS 8.9 and ArcGIS 9.1 environment.

SPOT-4 NDVI images are analyzed for drought detection using different Indices for Agricultural drought map preparation. Meteorological data are from 14 stations used to generate meteorological drought to support agricultural drought.

Dekadal SPOT-4 and rainfall dekadal data are aggregated in to monthly basis for seasonal drought map generation. This is to suit the major food security factor, food availability through production. Rainfall data (mean annual), land use land cover from Land Sat image, slope length factor (generated from DEM) and K_ factor (from FAO soil classification) are integrated for soil erosion estimation from the zone using USLE.

Finally the soil loss and drought layers are weighted and overlaid for generating food security map. The following is the methodology applied in the research.

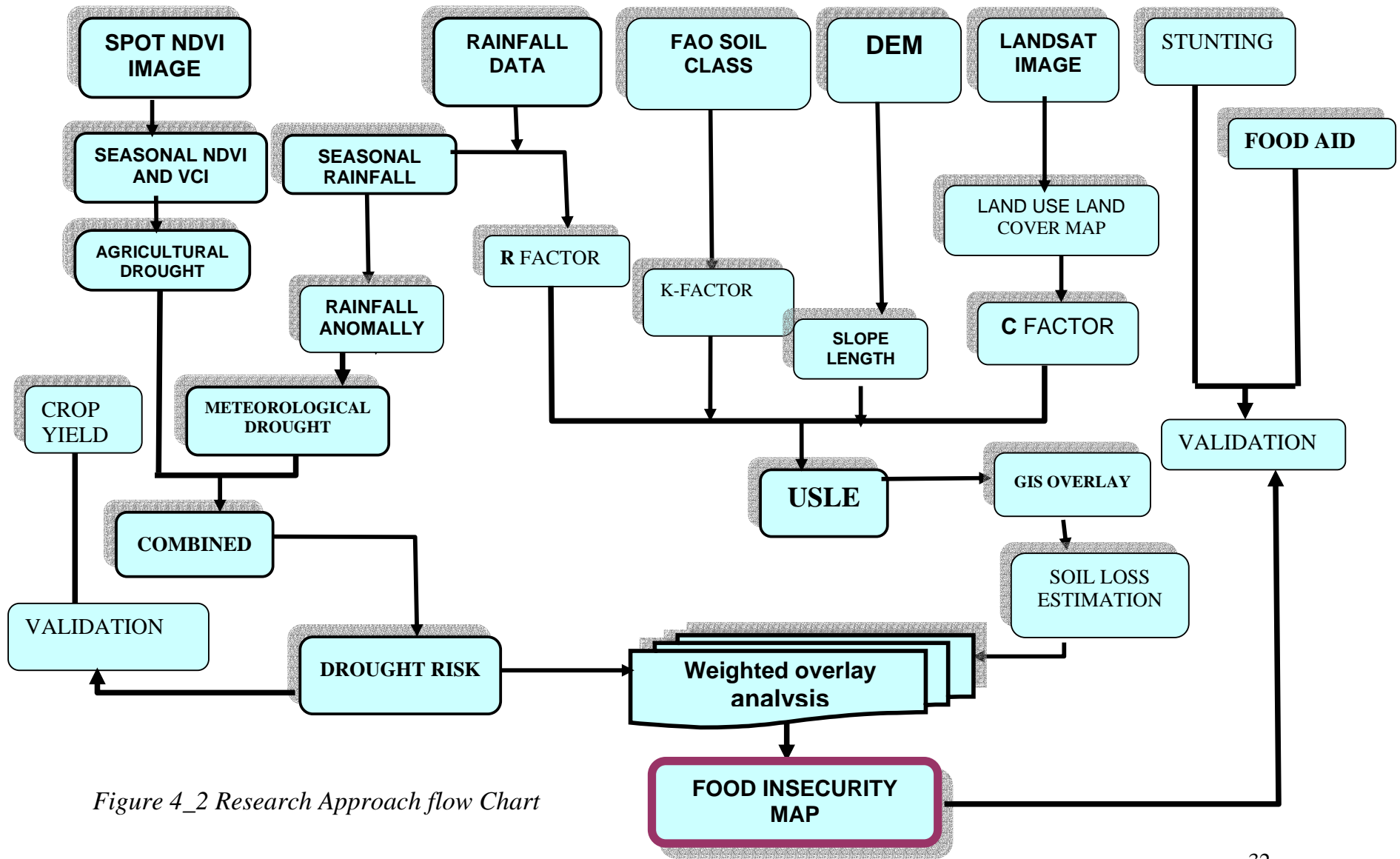


Figure 4_2 Research Approach flow Chart

4.6 Data Analysis

4.6.1. Drought Detection

The development of a near real-time drought monitoring system integrates satellite-based vegetation condition variables (NDVI) and climate-based drought variables and indices. A drought variable can be defined as a prime variable responsible for drought effects; therefore it must be considered as a key element in detecting and monitoring activities. The determinant variable for the meteorological drought is precipitation, whereas for agricultural drought the governing variables are soil moisture and several measures of vegetation conditions and growth. Drought indicators are variables used to describe the beginning, magnitude, duration, severity, and the spatial extent of drought events. Commonly used indicators are based on meteorological, hydrological and agricultural variables. Finally, drought triggers are threshold values of an indicator that allow to detect a drought event and its level. Drought levels are categories of drought, with nomenclature such as "mild, moderate, severe, extreme drought.

The drought detection and monitoring systems allow mainly delivering maps that show the areas where the vegetation is subject to water stress or affected by drought. This gives information about the crop condition of an area. Therefore, in areas where agriculture is the main stay of the population, cyclic drought prevalence determines their food security. The agriculture of South Gondar Zone in particular and the country in general is very important for food self-sufficiency, and food production is highly dependant on drought conditions (Kogan, 1997).

For this study indices for drought monitoring are derived from SPOT NDVI raw data from SPOT 4 VEGETATION system and Rainfall Data. This vegetation system observes the Earth at a resolution of 1 km, with a swath width of nearly 2250 km. This gives almost daily access to any point on the earth surface. These characteristics suit the observation and study of seasonal evolutions in the biosphere and its processes. The indices from SPOT-4 NDVI image are measures of vegetation condition by exploiting the unique spectral signatures of canopy elements in the RED and NIR portions of the spectrum (<http://sirius-ci.cst.cnes.fr:8080/>).

SPOT Vegetation NDVI products are collected for East Africa (1998-2005) and the South Gondar NDVI data are extracted out. The vegetation 10-day synthesis (S10) archive is freely accessible through the website of the vegetation programme directly via the free S10 distribution server (<http://free.vgt.vito.be>), which is not directly compatible with ERDAS and ArcGIS. The

vegetation instrument is dedicated to the daily observation of terrestrial ecosystems and the biosphere, particularly for addressing global change and environmental issues. The instrument is an essential tool for studies on global vegetation. There are three 10-day composite per month in this data set, from the first of the month to the 10th, from the 11th to the 20th, and from the 21st to the end of the month. The last compositing period can vary from 8-11 days, depending upon the number of days in the month.

NDVI is calculated from two bands, the near-infrared (NIR) and RED wavelengths, using the following algorithm:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

Where, **NIR** and **RED** is the reflectance in the near infra-red and red bands, respectively. NDVI is a nonlinear function that ranges between -1 and +1. However, in practice, NDVI measurements generally range between -0.1 and +0.7. Cloud, water, snow, ice and non-vegetated surfaces have negative NDVI values. Bare soils and other background materials produce NDVI values ranging from -0.1 to +0.1. The NDVI values for vegetation are positive and range from 0.1 to 0.7, with low values indicating poor vegetation conditions and possibly unfavorable weather impacts, with values greater than 0.5 indicating healthy vegetation conditions. Lower NDVI values are indicators of prevalence of drought conditions (Prathumchai et al, 2001).

4.6.1.1. Driving Agricultural drought

A. Normalized Difference Vegetation Index (NDVI)

NDVI has been tested by various scientists on its ability to predict drought and serve as a proxy to rainfall data. It has been used to detect drought in various parts of the world in the recent decade (Gurusamy, 2006). There are two characteristics of NDVI that make it ideal for vegetation monitoring.

1. No other surface exhibits higher NDVI values than healthy vegetated surfaces and
2. When vegetation vigor changes due to the nature of vegetation growth and development or environmental induced stress such as drought, the NDVI also changes. Therefore, the NDVI does have paramount potential in drought detection (Beyene, 2007).

Researchers indicated that NDVI has a three months lagged response to drought. However, it has a shorter lag time in areas where there is greater dependence on rain-fed agriculture. Therefore, the complete analysis of NDVI for drought detection requires the identification of length of growing period (LGP) which includes start of apparent growing season, peak of the growing season (where the maximum NDVI value is observed) and harvesting period (where the NDVI value starts to decrease). In the summer season care should be taken whether there is flood during the growing season in the study area or not. The NDVI value in flooded areas is usually lower than the normal. This could not be taken as an indicator of drought prevalence.

The raw data from SPOT VEGITATION system should be rescaled to +1 and -1. the raw data is digital number for a pixel plus certain coefficients and ranges from 0 to 255. The relation between the digital numbers and the real NDVI is expressed as:

$$\begin{aligned}\text{Actual NDVI} &= \text{Coefficient } \mathbf{a} * \text{Digital Number plus coefficient } \mathbf{b}. \\ &= \mathbf{a} * \text{DN} + \mathbf{b}\end{aligned}$$

$$\text{Coefficient } \mathbf{a} = 0.004$$

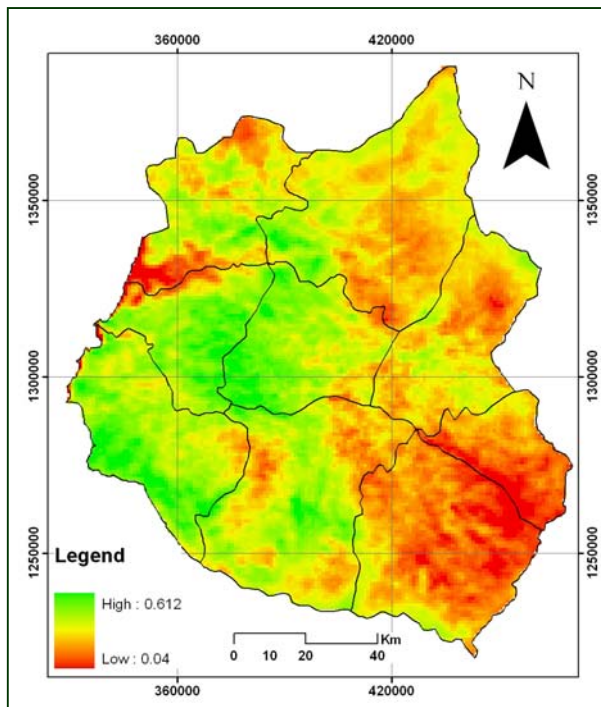
$$\text{Coefficient } \mathbf{b} = -0.1$$

Therefore the actual NDVI can be calculated from the raw data as:

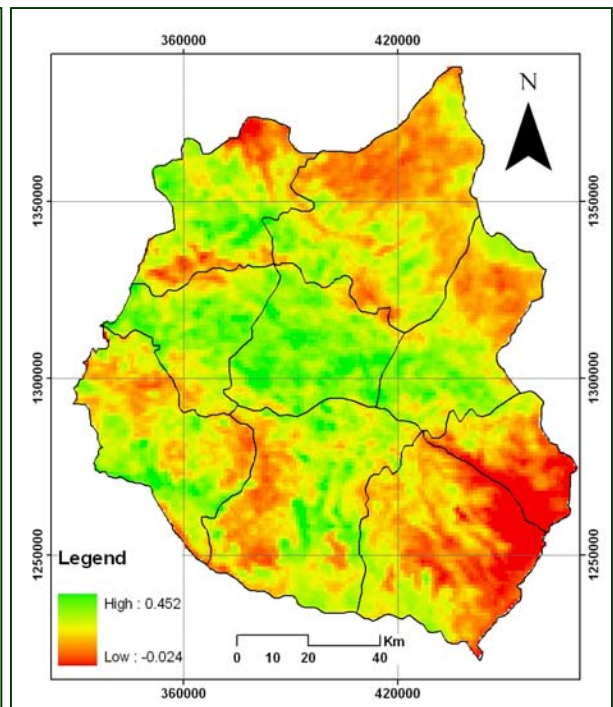
$$\mathbf{(\text{Raw data pixel Value} * 0.004) - 0.1}$$

Since the impact of drought on crop production is important for this study, seasonal NDVI maps for eight years are generated from the raw data. The length of growing season in the study area ranges between June to October. The long term seasonal average is also calculated in a similar manner. To derive seasonal NDVI images the dekadal images were stacked for months of growing period and then their average was taken.

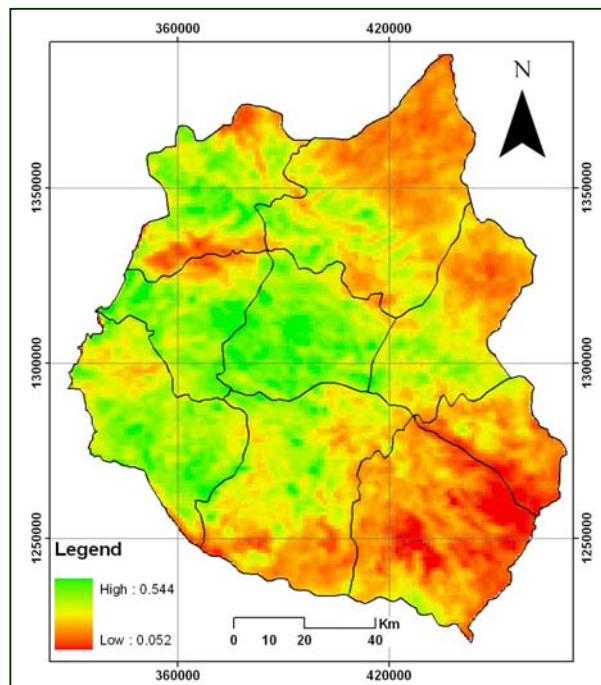
Figure 4_3: Seasonal NDVI maps for the study period



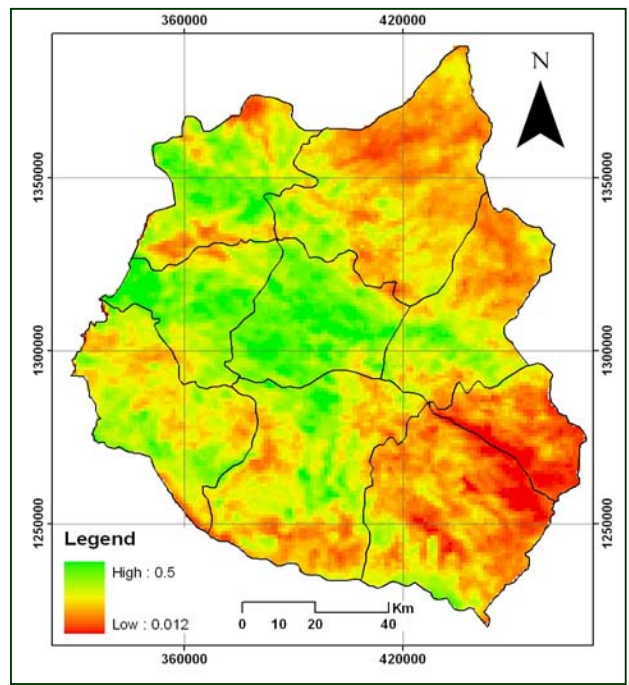
1998 seasonal NDVI map



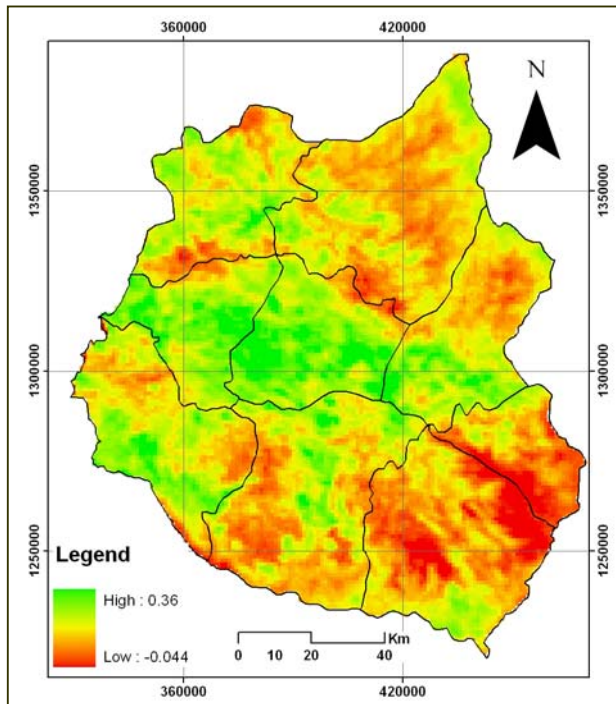
1999 seasonal NDVI map



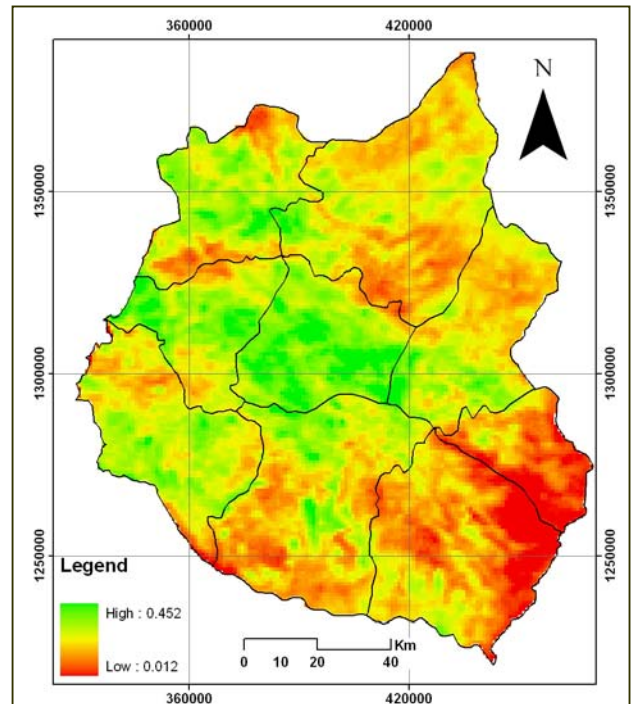
2000 seasonal NDVI map



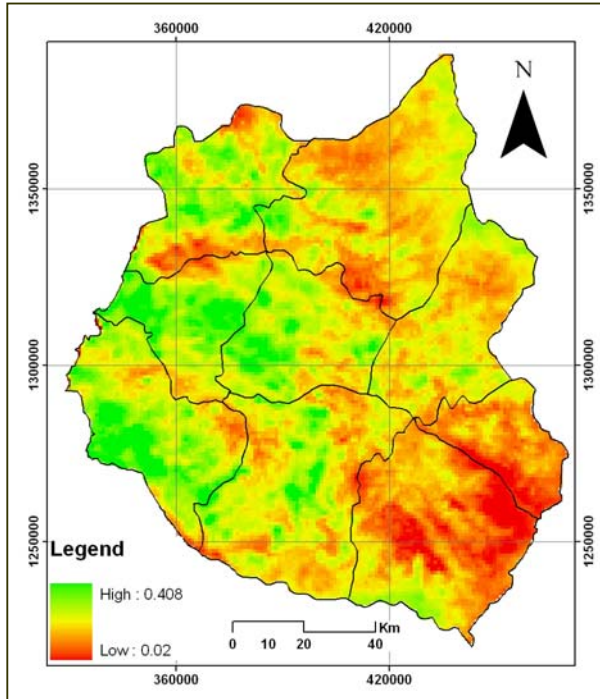
2001 seasonal NDVI map



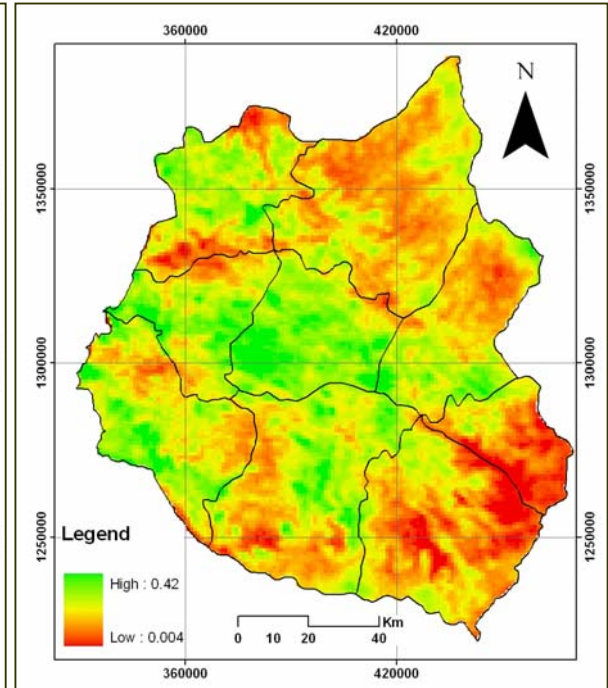
2002 seasonal NDVI map



2003 seasonal NDVI map



2004 seasonal NDVI map



2005 seasonal NDVI map

B. NDVI deviation

NDVI by itself does not reflect the severity and level of drought. The severity of drought can be defined as NDVI deviation from its long-term mean (DEV_{NDVI}). This deviation is calculated as the difference between the NDVI for the current month and a long term mean for this month.

$$DEV_{NDVI} = NDVI_i - NDVI_{mean, i}$$

Where, $NDVI_i$ is the current NDVI for month i and $NDVI_{mean, i}$ is the long term mean NDVI for a calendar month, i . When DEV_{NDVI} is negative, it indicates the below-normal vegetation condition and, therefore, suggests a prevailing drought situation. The greater the negative departure, the greater the magnitude of a drought is. In general, the departure from the long-term mean can be used effectively as one of the drought indicators as it would reflect the conditions of healthy vegetation in normal and wet years (Thenkabail, 2004).

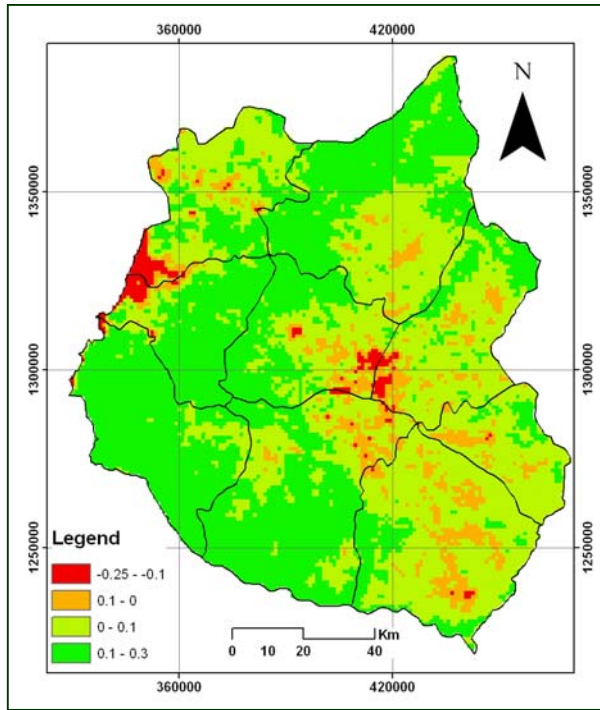
Table 4_2: drought severity class

SEVERITY	DEVIATION
Extreme drought	<-0.25
Sever drought	-0.1 to -0.25
Moderate drought	0.1 to -0.1
Mild drought	0.1 to 0.25
No drought	>0.25

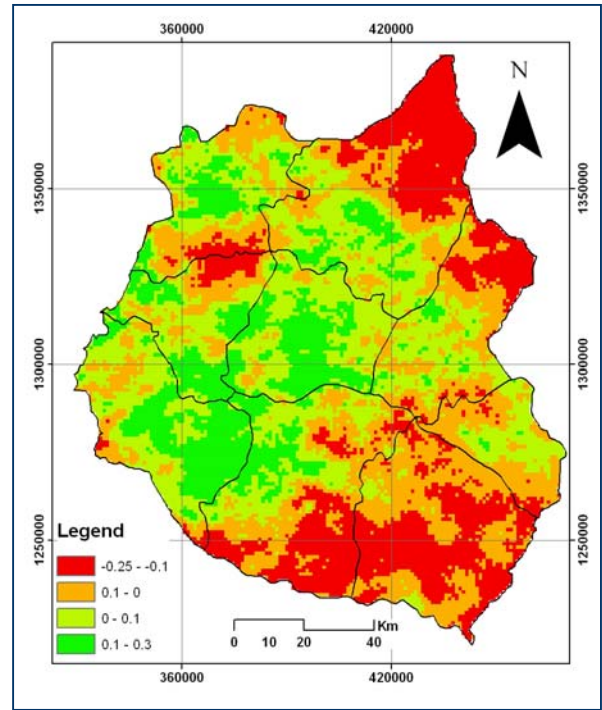
Source: Song et al (2004)

NDVI deviation is produced for each month and months with low NDVI deviation values are taken for the purpose of comparison. See the maps below:

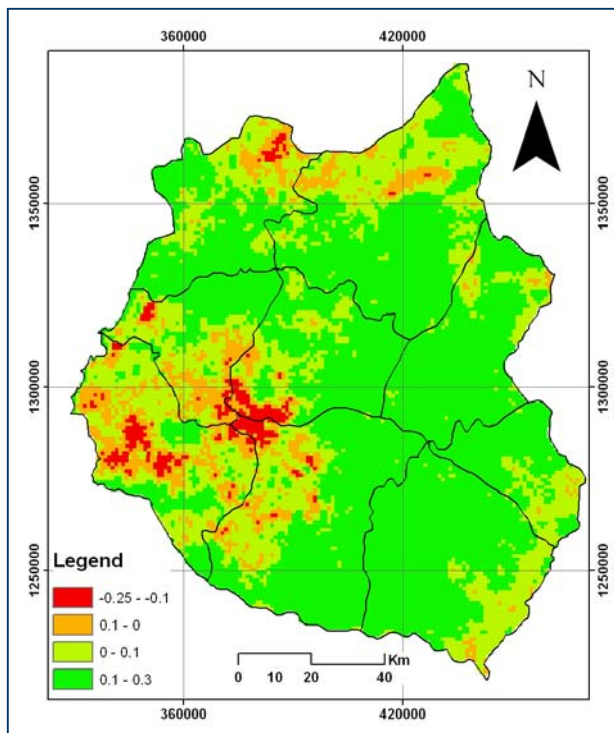
Figure 4_4: Seasonal NDVI deviation maps for the study period



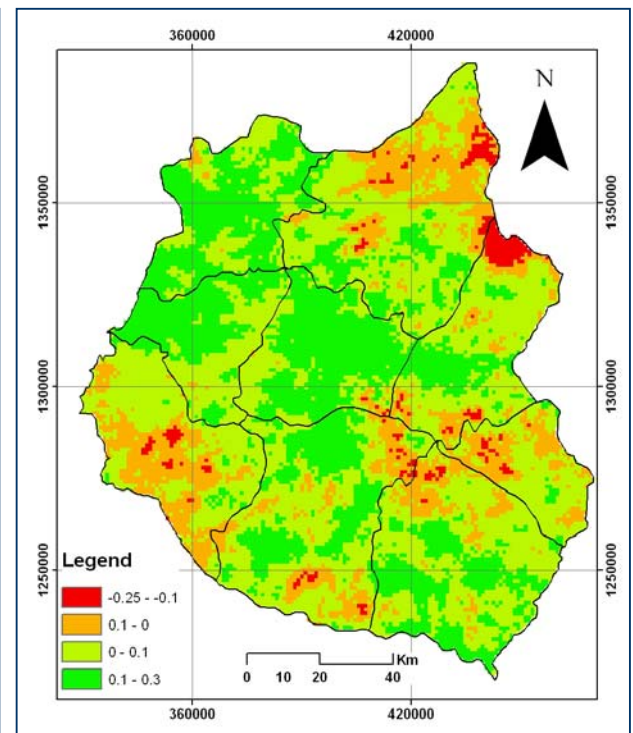
1998 seasonal NDVI deviation



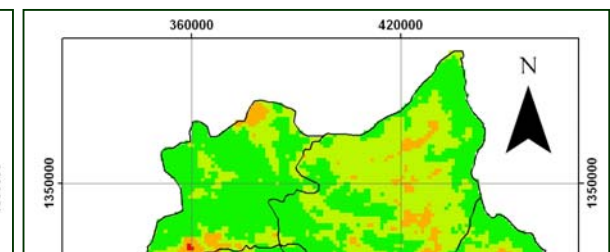
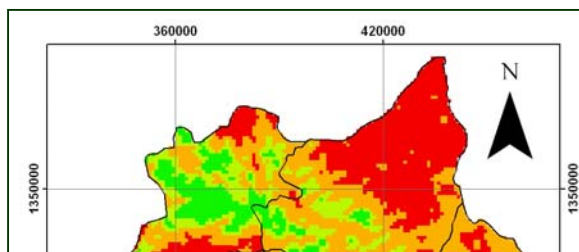
1999 seasonal NDVI deviation



2000 seasonal NDVI deviation



2001 seasonal NDVI deviation



C. Vegetation Condition Index (VCI)

VCI effectively shows how close the NDVI of the current month is to the minimum NDVI

calculated from the long-term record. It indicates how much the vegetation has advanced or deteriorated in response to weather. VCI measured in percent has provided an assessment of spatial characteristics of drought, as well as its duration and severity and were in good agreement with precipitation patterns (Chopra, 2006). It is an indicator of the status of the vegetation cover as a function of the NDVI minima and maxima encountered for a given ecosystem over many years. It normalizes the NDVI (or any other vegetation index) and allows for a comparison of different ecosystems. Therefore, it is a better indicator of water stress conditions than the NDVI (Kogan, 1995).

VCI is dependent up on the number and quality of images available for the calculation of the absolute minimum and maximum.

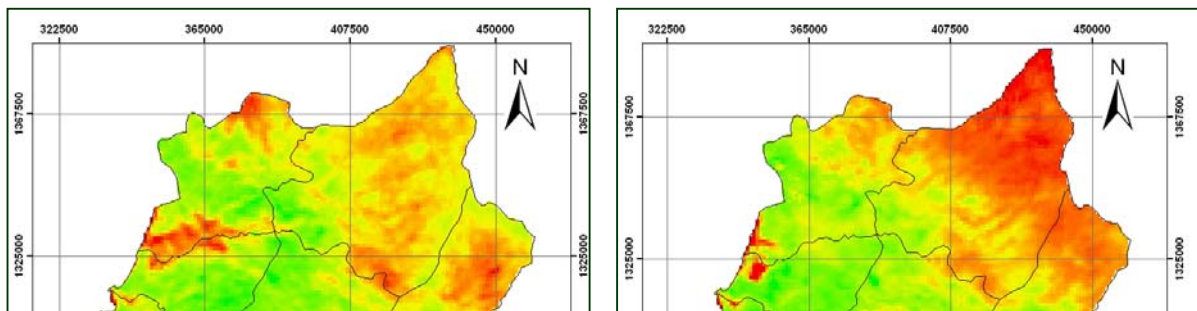
$$VCI_J = \frac{(NDVI_J - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} * 100$$

Where, **NDVI_{max}** and **NDVI_{min}** are calculated from the long-term record for the growing season, and **J** is the index of the current season. The MNDVI is defined as the maximum NDVI for all time intervals of the MVC (maximum value composite) in a year or a month. The seasonal MNDVI was found to be a reliable indicator of variations that can affect the state of vegetation cover and crop condition. The NDVI_{max} can be described by the following expression:

$$MaNDVI_i = \text{Max} \{NDVI_{i16}, NDVI_{i17}, \dots, NDVI_{i30}\}$$

$$MiNDVI_i = \text{Min} \{NDVI_{i16}, NDVI_{i17}, \dots, NDVI_{i30}\}$$

Where, **MNDVI_i** and **MiNDVI_i** is maximum and minimum Normalized Difference Vegetation Index of year *i*, **NDVI_{i16}** represents the first 10-day NDVI composites image of Jun, **NDVI_{i30}** is the third 10-day NDVI composite data of October. Note that; there were only 27 dekadal (10-day) NDVI composites in 1998 unlike other years. This is because of the fact that acquisition of VGT-S10 data started from April 1998.



VCI values around 50% reflect fair vegetation conditions. The VCI values between 50 and 100% indicate optimal or above normal conditions. At the VCI value of 100%, the NDVI value for selected month (dekade) is equal to NDVImax, which indicates optimal condition of vegetation. Different degrees of drought severity are indicated by VCI values below 50%. Kogan (1995) illustrated that a VCI threshold of 35% may be used to identify extreme drought conditions. The VCI value close 0% (zero percent) reflects an extremely dry month, when the NDVI value is close to its long term minimum. Low VCI values over several consecutive time intervals indicate to drought development.

The index captures rainfall dynamics better than the NDVI particularly in geographically non homogeneous areas. It not only permits the description of land cover and spatial and temporal vegetation change, but also allows quantifying the impact of weather on vegetation. It also makes possible for one to compare the weather impact in areas with different ecological and economical resources. VCI values indicate easily how much the vegetation has advanced or deteriorated in response to weather and how far vegetation development is from the potential maximum and minimum defined by ecological limits.

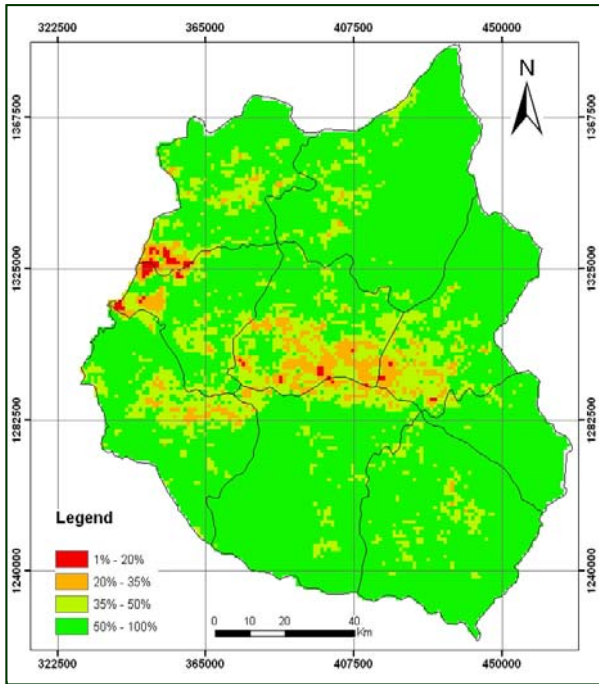
VCI is a pixel-wise normalization of NDVI useful for making relative assessments (e.g. pixel-specific) of changes in the NDVI signal by filtering out the contribution of local geographic resources to the spatial variability of NDVI. The VCI measures how weather conditions have influenced the relative vigor of the vegetation with respect to the ecologically defined limits.

This index is most useful during the growing season because it is a measure of vegetation vigor. When the vegetation is dormant (not in the summer season), the VCI cannot be used to measure moisture stress or drought. Interpretation of the VCI may be more complicated than other drought indices because it provides an indirect measure of moisture (drought) conditions. Anything that stresses the vegetation including insects, disease, and lack of nutrients will result in decreases in plant growth and therefore lower VCI values. Also, areas that have significant irrigation may not respond to precipitation deficiencies (Quiring et al. 2007). It is commonly known that drought is associated with insect infestation and plant disease (Chopra, 2006). Vegetation stress due to these factors is very important. But there is no data concerning this condition at the respective offices.

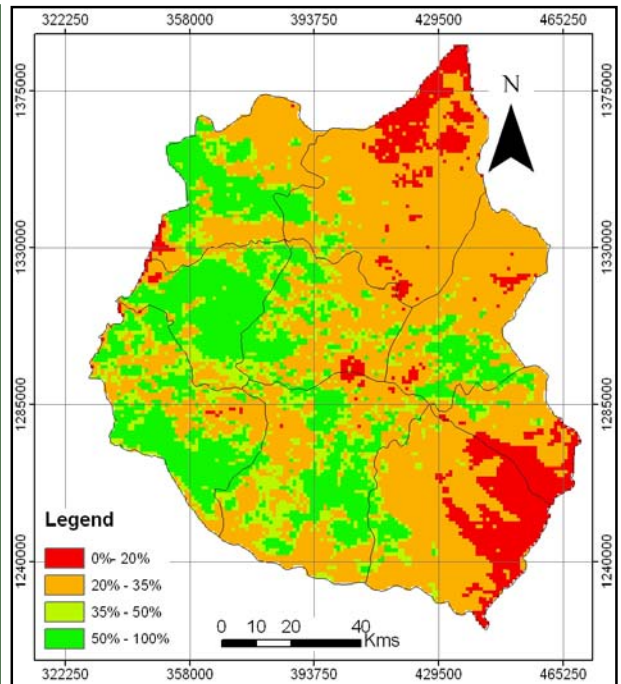
For the purpose of delineating agricultural drought, seasonal VCI values are generated for eight years. According to Kogan (1997), different degrees of drought severity are indicated by VCI below 50% and VCI of 35% is a threshold for extreme drought. Aribo et al (2008) further classified the VCI values below 35% arbitrarily for east Africa as:

1. 50% to 100%, normal to above normal condition (wet);
2. <50% to 35%, moderate drought;
3. <35 to 20% severe drought;
4. <20% to 0% very severe drought

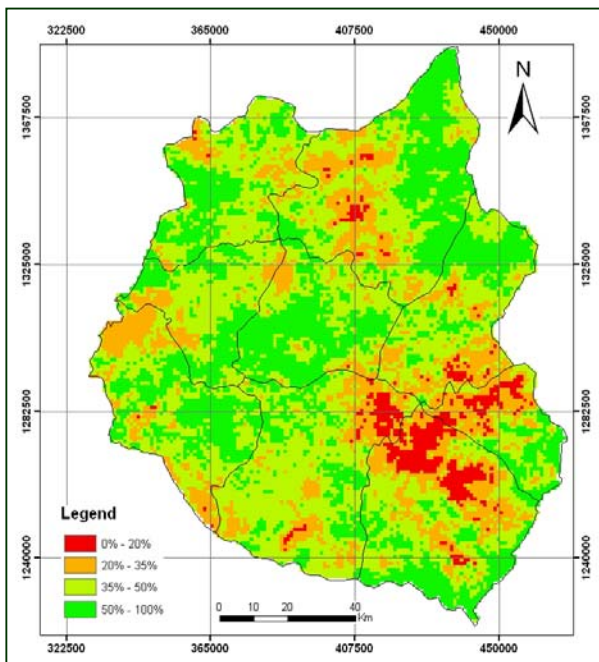
Figure 4_7: Seasonal VCI maps for the study period



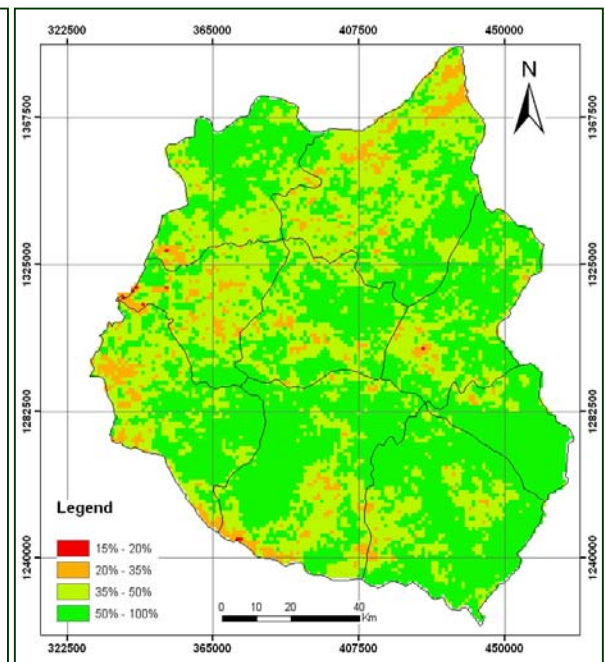
1998 seasonal VCI Map



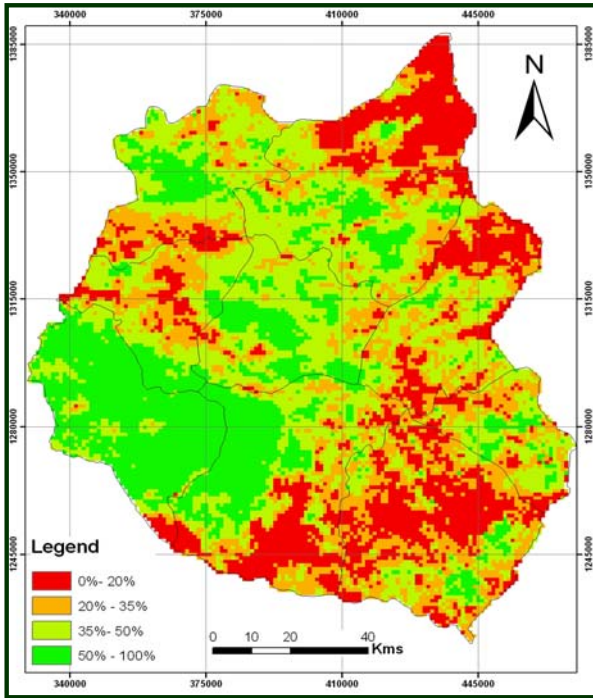
1999 seasonal VCI Map



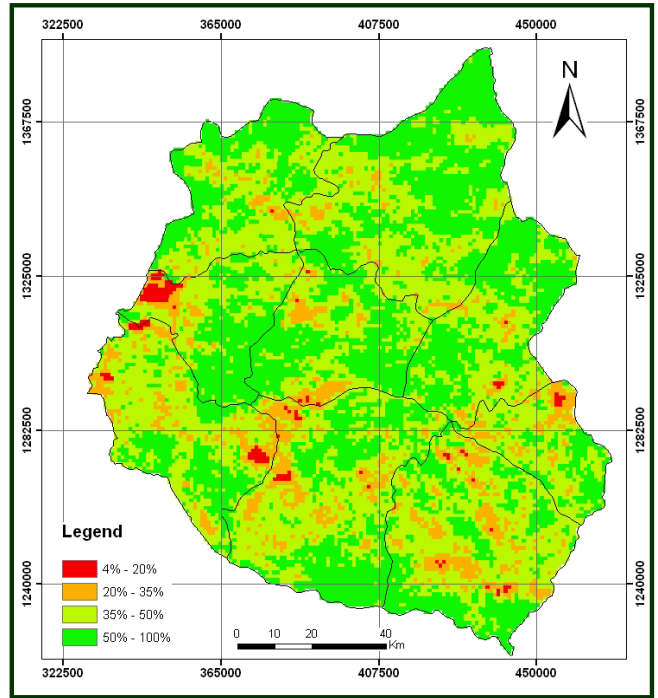
2000 seasonal VCI Map



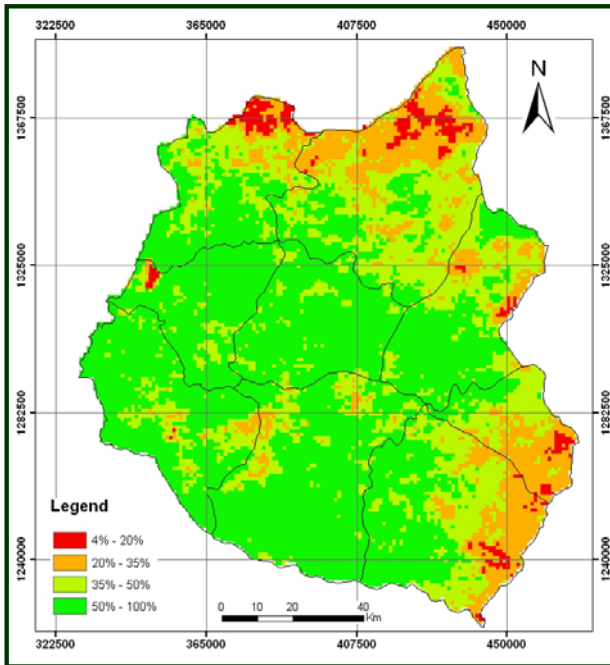
2001 seasonal VCI Map



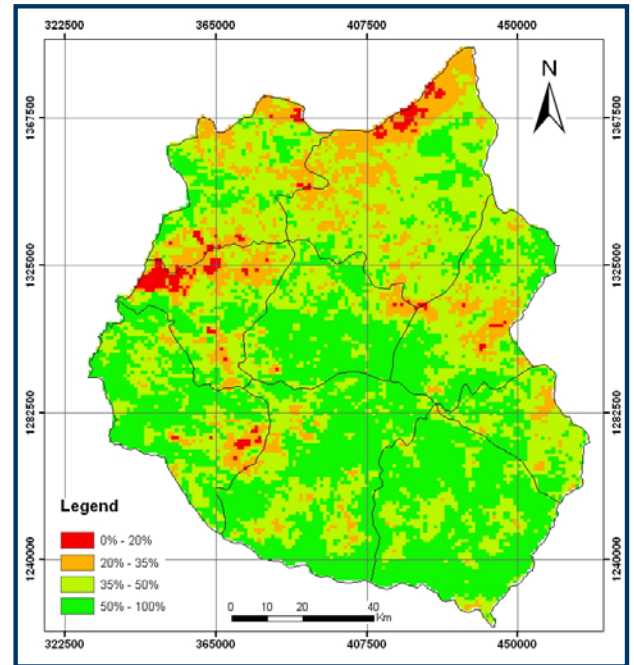
2002 seasonal VCI Map



2003 seasonal VCI Map



2004 seasonal VCI Map



2005 seasonal VCI Map

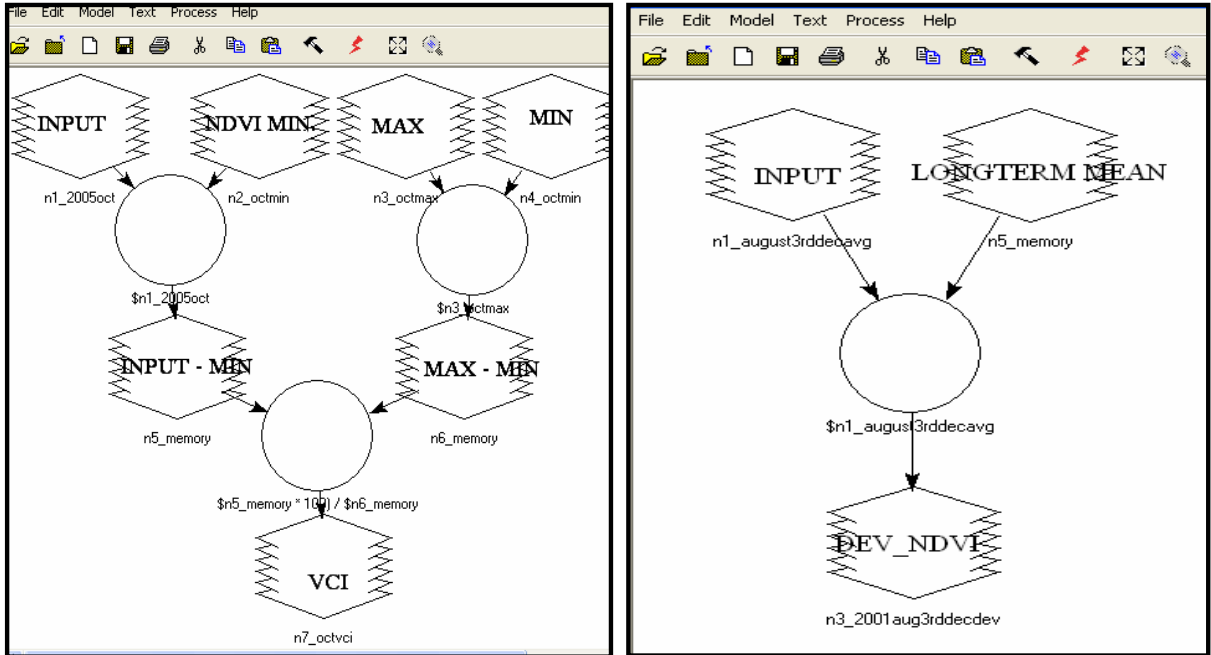


Fig 4_8: VCI and DEV_NDVI models

4.6.1.2. Driving Meteorological drought

Rainfall (Precipitation) Anomaly

Meteorological drought indicates the deficiency of rainfall compared to normal rainfall in a given region. Places where long-term average rainfall is less, year-to-year variability is greater and so the likelihood of drought is greater (Chopra, 2006). Any forms of Meteorological drought occurrences are related to some antecedent and relative precipitation amounts for the previous period. This period could be from 3–4 weeks to years. Therefore, the simplest drought index is the deviation from a normal precipitation value. One can generate some combination of deviation, or can somehow normalize the deviation values for a better comparison of generalization. Finally, the simplest expression of the difference from the normal could be defined as drought index.

Rainfall anomaly, expressed in percentage, has been computed from 1998 - 2005 for the growing season (June-October) to generate meteorological drought maps. Rainfall anomaly has been computed as:

$$RFA_i = [(RF_i - RF_{\mu}) / (RF_{\mu})] * 100$$

Where, RFA_i is rainfall anomaly for ith year, RF_i is seasonal rainfall for ith year and, RF_μ is mean seasonal rainfall. They are multiplied by 100 to normalize the result.

Meteorological drought is defined as a situation when the seasonal rainfall received over an area is less than 75% of its long-term average value. Recently 63% is taken as a threshold for drought severity, (Dunkel, 2009). It is further classified into slight drought when rainfall is 25% less than the normal, moderate drought when rainfall is 50% less than the normal and severe drought when rainfall is 63% less than the normal (WMO, 1975).

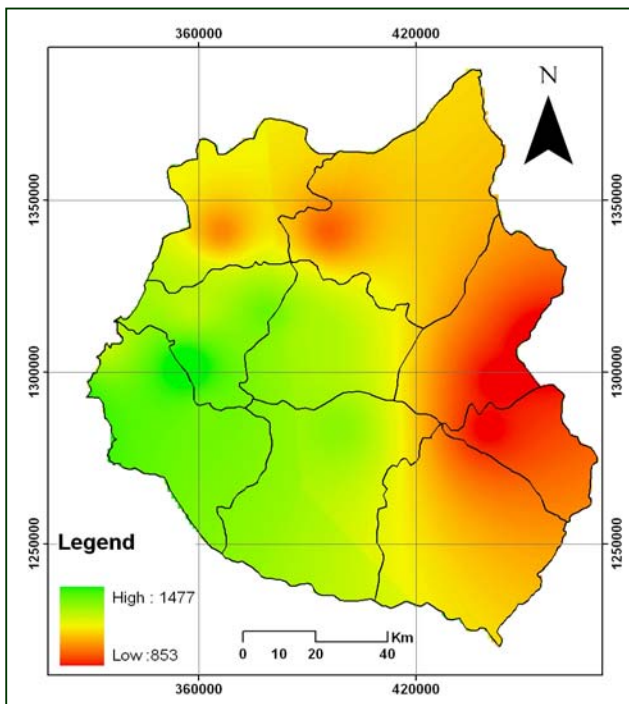


Figure 4_9: Long terms seasonal mean RF

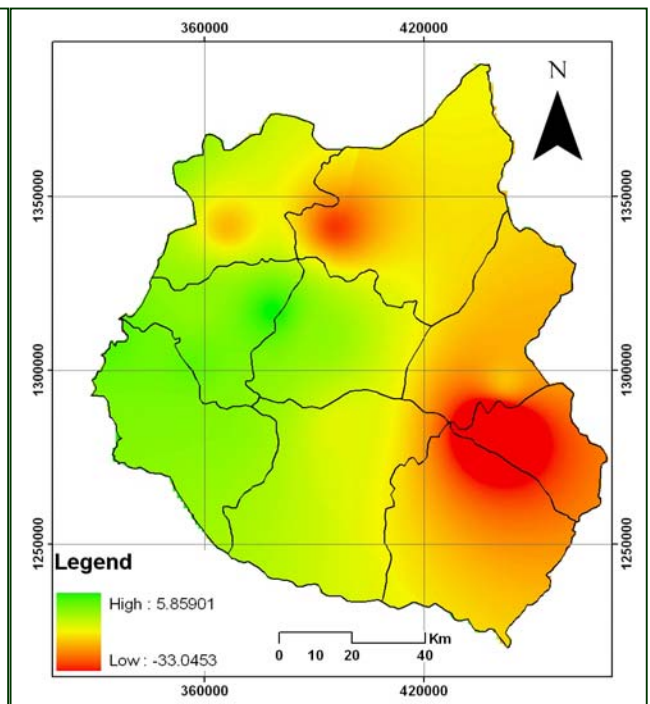


Figure 4_10: seasonal deviation

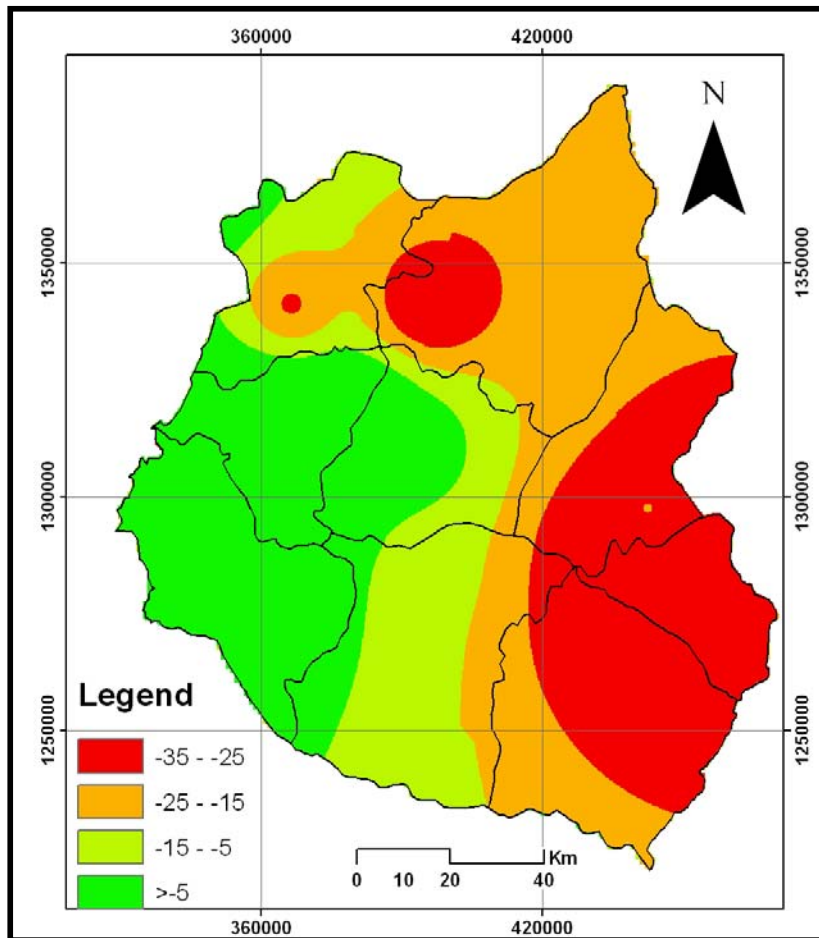


Figure 4 -11: meteorological drought map

The unevenly distributed stations hinder the accuracy of meteorological drought map. The Rainfall anomaly index gave an approximate picture of the meteorological drought prevailing in the study area. For example Farta woreda has enough moisture for crop production, but identified as moisture stressed area. As a result of this the researcher did not use this factor as a layer in the derivation of the final drought map.

4.6.2. Parameter Estimation of USLE

USLE is applied to predict amount of annual rate of soil erosion in South Gondar Administrative Zone. The model encompasses six parameters, which are directly linked to variables (climate, topography, vegetation cover, management practices) that affect soil erosion. Remote Sensing and Geographic Information Systems are vital to generate such physically distributed parameters, integrate the layers and put the outcomes in the form of map and attributes.

Estimation of soil loss using USLE for the study area is undertaken for the identification of spot soil loss areas, in which crop production is decreasing as a result. The downward spiral of soil degradation results in further land productivity decline, loss of biodiversity and continuing desertification.

4.6.2.1. The USLE Model

The USLE is the most widely used model in predicting soil erosion. It is selected to be applied as a model for estimating the soil erosion rate because of its suitability, simplicity and availability of information. The equation is presented as:

$$\mathbf{A} = \mathbf{R} * \mathbf{K} * \mathbf{L} * \mathbf{S} * \mathbf{C} * \mathbf{P}$$

Where, **A** = soil loss ($\text{t ha}^{-1} \text{y}^{-1}$), **R** = erosivity ($\text{J m}^{-1} \text{h}^{-1}$), **K** = erodibility ($\text{t m h ha}^{-1} \text{J}^{-1}$), **L** = slope length (meter), **S** = slope steepness, **C** = cover and management (dimensionless), **P** = support practice (dimensionless). The model was modified and adapted to Ethiopian highland conditions by Hurni (1985).

4.6.2.2. Rainfall Erosivity (R) Factor

The soil loss is closely related to rainfall through the detaching power of raindrop striking the soil surface and through the contribution of rain to runoff. The concept of rainfall erosivity presented by Hudson (1971) and Wischmeier and Smith (1978) describes the erosivity as an interaction between kinetic energy of raindrops and the soil surface. The degree of detachment is dependent up on Erosivity Factor having the same soil type, topographic conditions, soil cover, and management.

The Rainfall erosivity factor R was calculated according to the equation given by Hurni (1985), for Ethiopian conditions based on the easily available mean annual rainfall (P). It is given by a regression equation:

$$\mathbf{R} = - 8. 1 2 + (0. 5 6 2 \times \mathbf{P})$$

Where, P is the mean annual precipitation in mm.

After calculation of erosivity values for each station an erosivity map, was produced by interpolating the surface from points using an inverse distance weighted (IDW) technique in ArcGIS spatial analyst environment. The Rainfall Erosivity map represents an important source of information about the potential rainfall erosivity of the study area.

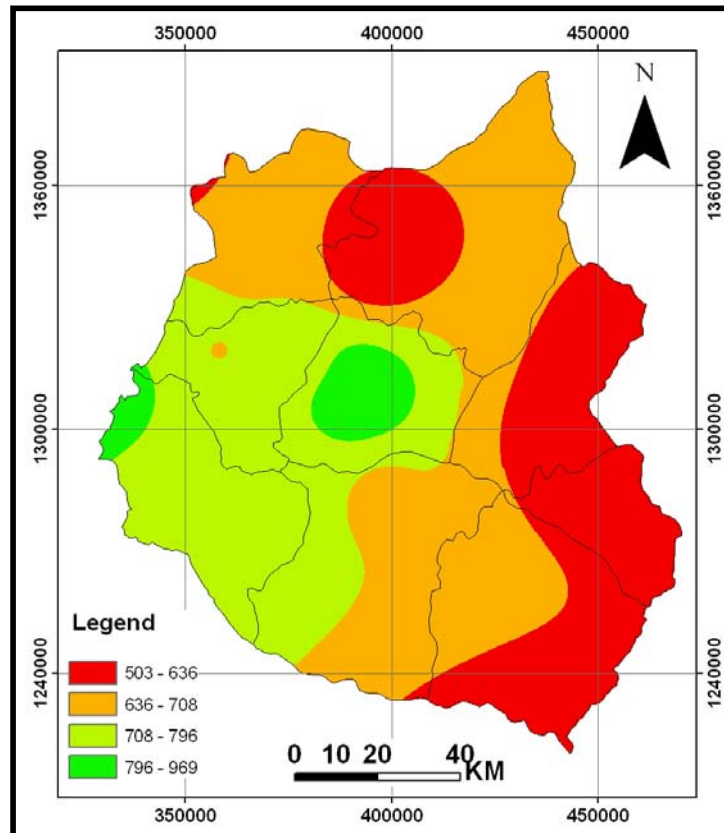


Figure 4_12: Rainfall erosivity

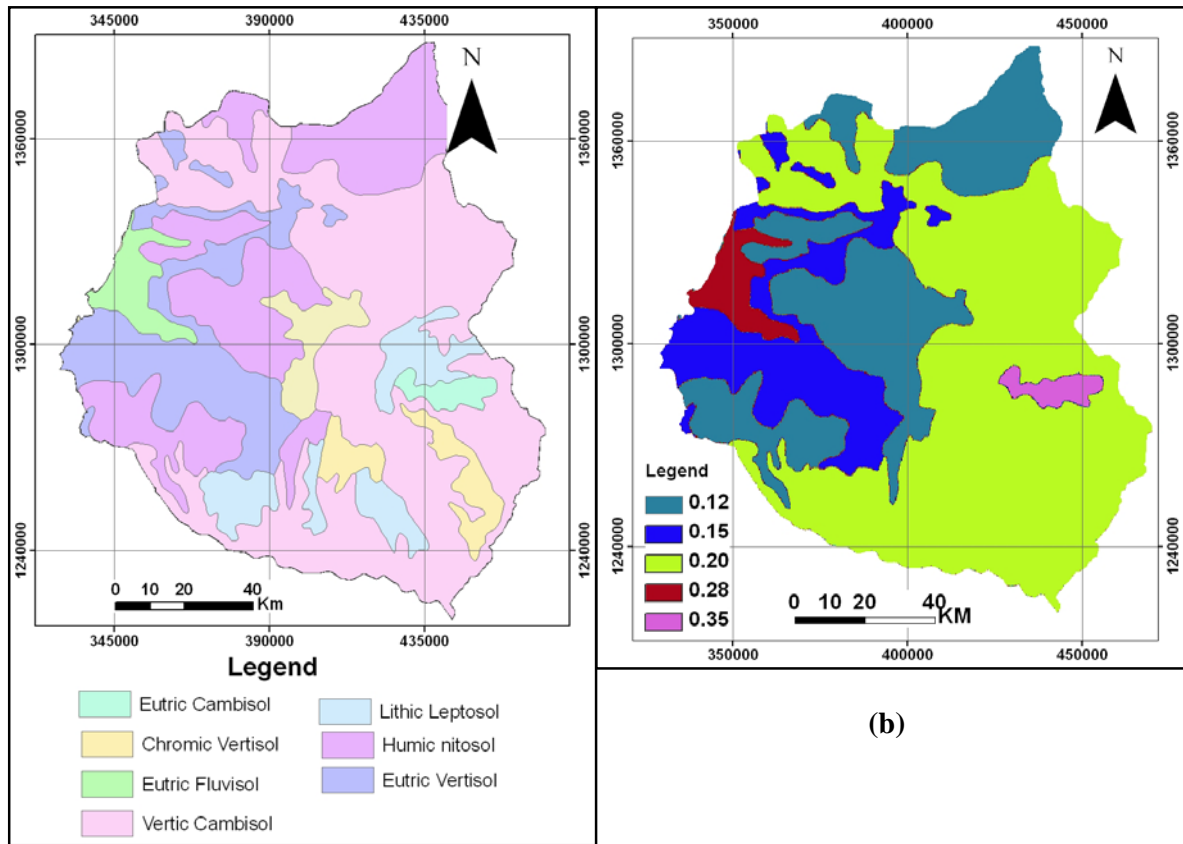
4.6.2.3. Soil Erodibility (K) Factor

The soil erodibility factor K is a quantitative value, which is experimentally determined taking the soil texture and structure, the organic matter content and the permeability into consideration. The USLE K factor reflects the combined effect of the soil properties that significantly influence the soil loss. Some soils erode more easily than others even when all other factors are the same. This difference is termed as soil erodibility and is caused by the properties of the soil itself. Wischmeier and Smith (1978) defined the soil erodibility factor as the soil loss rate per erosion index unit for a specified soil as measured on a unit plot. The value of K ranges from 0 to 1. Hellden (1987) developed a USLE for Ethiopian condition by adapting different sources and proposed the K values of the soil based on their color (see table below).

Table 4_3: soil erodibility factor

R.NO	SOIL TYPE	K_FACTOR
1	Eutric Cambisol	0.35
2	Vertic Cambisol	0.2
3	Eutric fluvisol	0.28
4	Eutric Leptisol	0.2
5	Lithic Leptisol	0.2
6	Humic Nitosol	0.12
7	Eutric Vertisol	0.15

The soil data set was found in vector format. The vector format was changed to grid and the grid data set was reclassified based on K-value for each soil class.



Figuer4_13: (a) Soil Class and (b) K_Factor

4.6.2.3. Topographic factor (LS Factor)

Slope length is the distance from the point of origin of overland flow to the point where the slope decreases enough so that deposition begins. Longer slopes increase erosion. The LS factor

characterizes the effect of topography on erosion in USLE. By using DEM with finer resolution, it is possible to calculate both slope length 'L' and slope gradient 'S' (Moore et al, 2001).

$$LS = \text{Power} \left(\frac{\text{Flow Accumulation} * \text{Resolution}}{22.1, 0.6} \right) * \text{power} \left(\sin(\text{slope}) * 0.01745 \right) / 0.09, 1.3$$

Slope (in %) and flow accumulation was directly derived from the DEM.

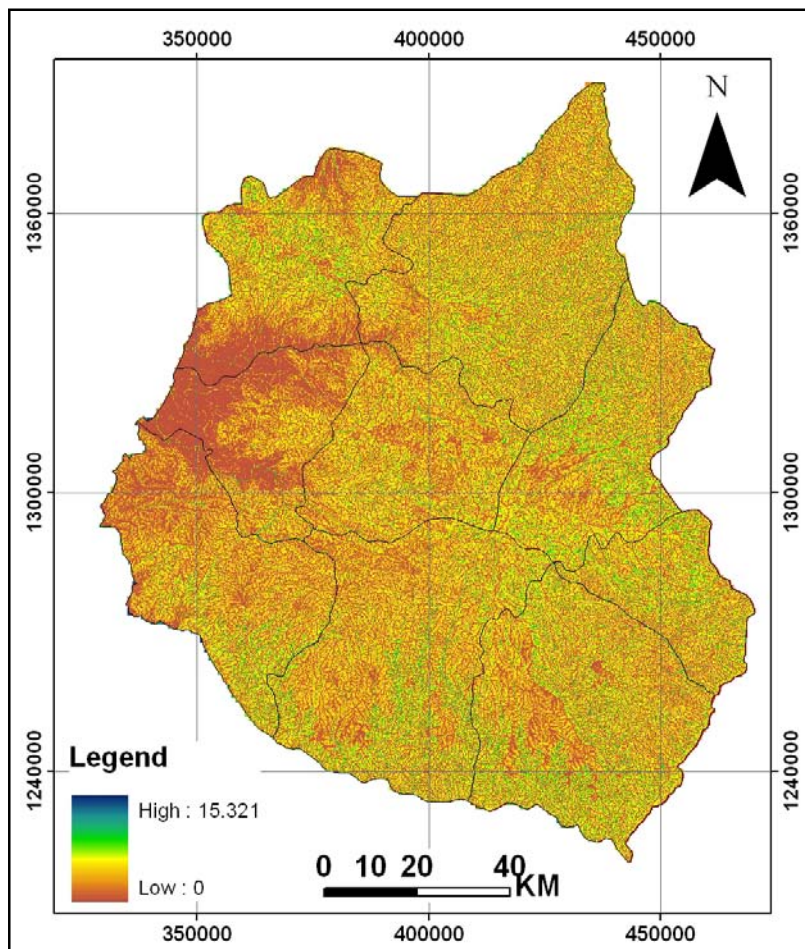


Figure 4_14: LS_factor

4.6.2.4. Land use/Land Cover (C) Factor

Crop management factor represents the ratio of soil loss under a given crop to that of the base soil (Morgan, 1994). Wischmeier and Smith (1978) defined C-factor as the ratio of soil loss from land

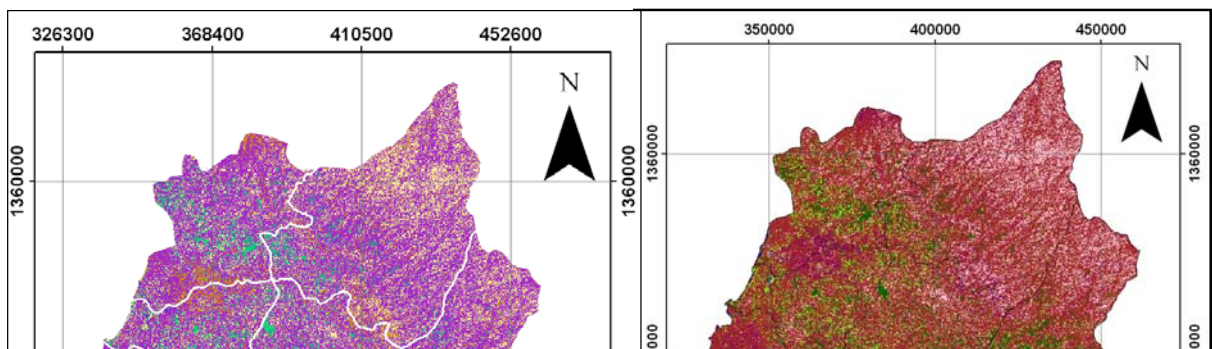
with specific vegetation to the corresponding soil loss from continuous fallow. The **C**-factor represents the effect of cropping and management practices in agricultural management, and the effect of ground, tree and grass covers on reducing soil loss in non-agricultural situation. The higher the ground and vegetation covers, the less the soil loss is and vice versa.

Land use/Land cover map was used for analyzing the **C**-value. **C**-factor measures the combined effect of all the interrelated cover and management variables. Assessment of the type of land use/Land cover was made separately for each land cover unit and the corresponding **C**-factor was obtained from Hurni (1985), which was adapted to Ethiopian condition.

After changing the coverage to grid, a corresponding **C**-value was assigned to each land use classes.

Table 4_4: crop management factor

LAND USE LAND COVER TYPE	C_FACTOR
Bare land	0.6
Forest land	0.01
Grass land	0.01
Intensively cultivated land	0.15
Moderately cultivated land	0.1
Water body	0



(b)

(b)

(b)

(a)

from the classification it is found that 60% is moderately cultivated, 19% intensively cultivated, 6% grass land, 3.2% forest land and 11.7 bare land. The northern, north eastern, eastern and south eastern part of the zone is intensively cultivated and its fertility is reduced as a result. The forest cover of the zone is reducing from time to time. A number of poor are dependent up on charcoal making, a determinant factor for deforestation in rural areas of south Gondar.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1. Drought trend

The trend of drought in south Gondar zone shows that some areas are frequently affected. Since the impact of drought on food security is mostly in the growing season, seasonal NDVI deviation and VCI are computed. The seasonal drought situations for eight years are generated using different drought indices and the following result is found.

5.1.1 Drought delineation by NDVI deviation

The NDVI deviation of the zone varies through time. The seasonal NDVI deviation ranges from 0.61 to -0.044. The maximum NDVI deviation was recorded in 1999 and 2002. The drought condition in the zone during the first (1998 to 2001) and the second (2002 to 2005) four years of the study period shows that there is an increase in the number of very severe drought affected Woredas.

Table 5_1: number of drought affected woredas

Description	1998	1999	2000	2001	2002	2003	2004	2005
Very severe drought affected woreda		5		1	4	4	2	3
Severe drought affected woreda	4	1	4	3	4		2	3
Sum of affected Woredas	4	6	4	4	8	4	4	6

The drought severity is computed by combining all seasonal NDVI deviations. The drought map from NDVI deviation shows that part of Ebinat, Lay Gayient, Tach Gayient, Eastern Estie, and Simada Woredas recorded very extreme drought conditions. Farta, Libo Kemkem, Fogera and Dera Woredas experienced moderate to sever drought.

In order to reduce the impact of Flood area NDVI values on the overall NDVI deviation map generation, some of the dekadal NDVI should be omitted. It is clear from the map below that surplus producing areas of Libo Kemkem, Fogera and Dera Woredas are identified as severely drought affected.

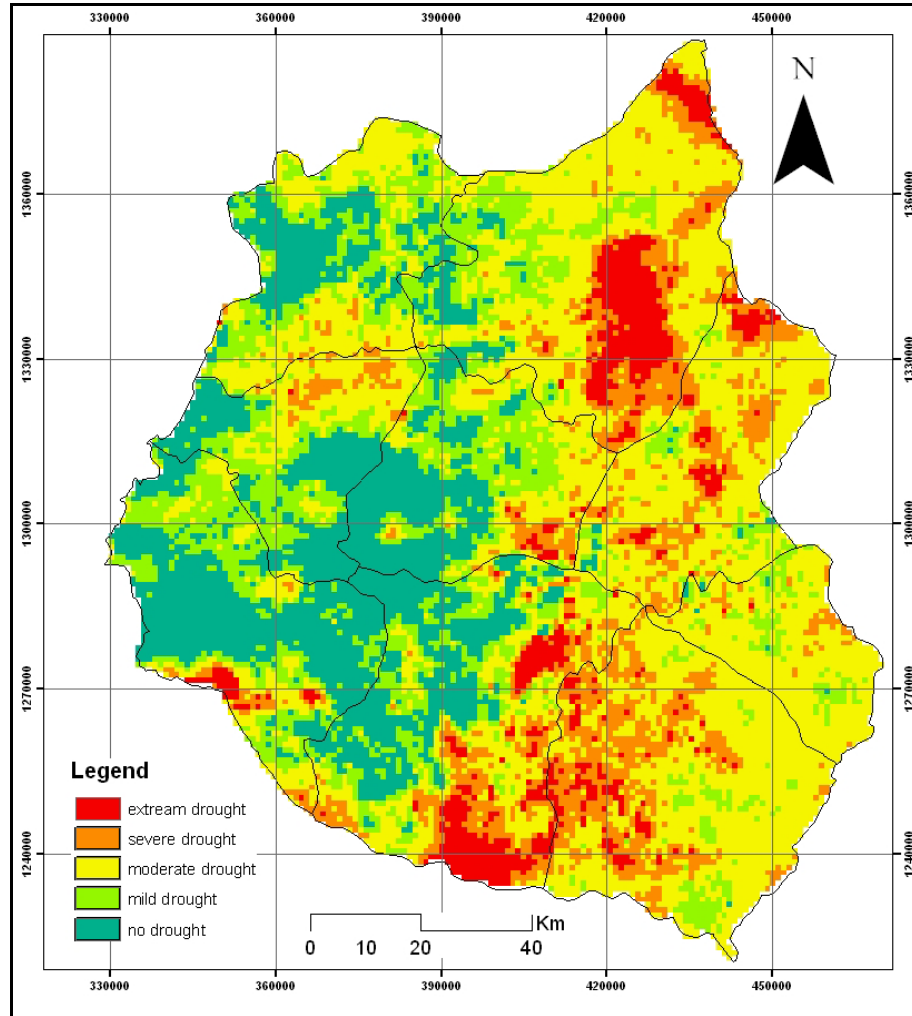


Fig 5_1: drought map generated from seasonal NDVI deviation

The NDVI deviation to some extent contradicts with the ground truth. Farta, Fogera and Dera Woredas are Surplus producing areas. The Fogera plain is now the known in Rice producing site in Ethiopia and farmers are self sufficient throughout the year. They are not under the food security support programs for drought emergence. Some times they are supported for flood emergences during summer season. The stunting and under weight conditions of south Gondar Woredas are also the other aspect contradicting with this result. It is only in Ebinat, Lay Gayient, Tach Gayient,

Libo Kemkem and Simada Woredas under weight and stunting children and lactating mothers are found through the Enhanced Outreach Survey (EOS). On the other hand Libo Kemkem Woreda, one of the seriously affected woreda, is identified as moderately and mild drought affected one. But practically people living in northern part of the woreda were not able to produce enough food

to support their families due to drought, land degradation and other similar factors and as a result they are taken in to voluntary resettlement to Quara woreda resettlement site.

The reason behind this result is lack of normalization in NDVI deviation. It is in the VCI that NDVI values are normalized for drought detection.

Table 5_2: number of stunted and under weights

Woreda	Underweight and stunted
Libo Kemkem	1057
Ebinat	3157
Lay Gayient	986
Tach Gayient	3093
Simada	2747

5.1.2 Drought delineation by Vegetation Condition Index (VCI)

The final drought risk map, which has been obtained by integrating the risk maps, is generated from all seasonal VCI.

Table 5_3: number of drought affected Woredas

Description	1998	1999	2000	2001	2002	2003	2004	2005
Very severe drought affected woreda		3			7		2	
Severe drought affected woreda		5	2		1		2	2
Moderate drought affected Woredas	2		2	3		5	1	2
Sum of affected Woredas	2	8	5	3	8	5	5	4

Even though there is data inconsistency on yearly crop production, this can be validated by the yearly crop production of each woreda in the following selected years in which there exists data.

Table 5_4: Yearly crop production

woreda	Yearly crop production in Quintals			
	2001	2002	2004	2005
Ebinat	379,297	133,875	327,464	316,937
Libo Kemkem	285,675	161,807	537,725	538,123
Fogera	440,328	360,644	790,575	877,895
Farta	702,594	465,897	511,101	545,231
Lay Gayint	409,877	145,370	341,428	341,421
Tach Gayint	117,533	263830	146,196	146,196
Simada	489,127	149817	384,638	384,634
Estie	1,116,387	592,027	124,6602	1,155,164
Dera	695,345	496,977	824,901	788,011
SUM	4,636,133	2,532,817	5,172,680	5,093,612

The total crop production in 2002 was the lowest of all years under study. The production was almost half of the previous year. Other things being constant, this was because of the severe drought condition during the growing season.

Annual food aid distributed in the zone during the study period proves that the finding of the research fit best.

Table6_5: number of food aid beneficiaries and food aid distributed

Description	1998	1999	2000	2001	2002	2003	2004	2005
Number of beneficiaries	212,793	352,246	592,378	324,595	252600	666,400	87,944	381,144
Distributed Food in Qt.	144946	215079	501,879	299,087	197,345	565,461	167,978	No data

The total beneficiaries in 2003 as a result of sever drought conditions in 2002 crop growing season was the highest of all years.

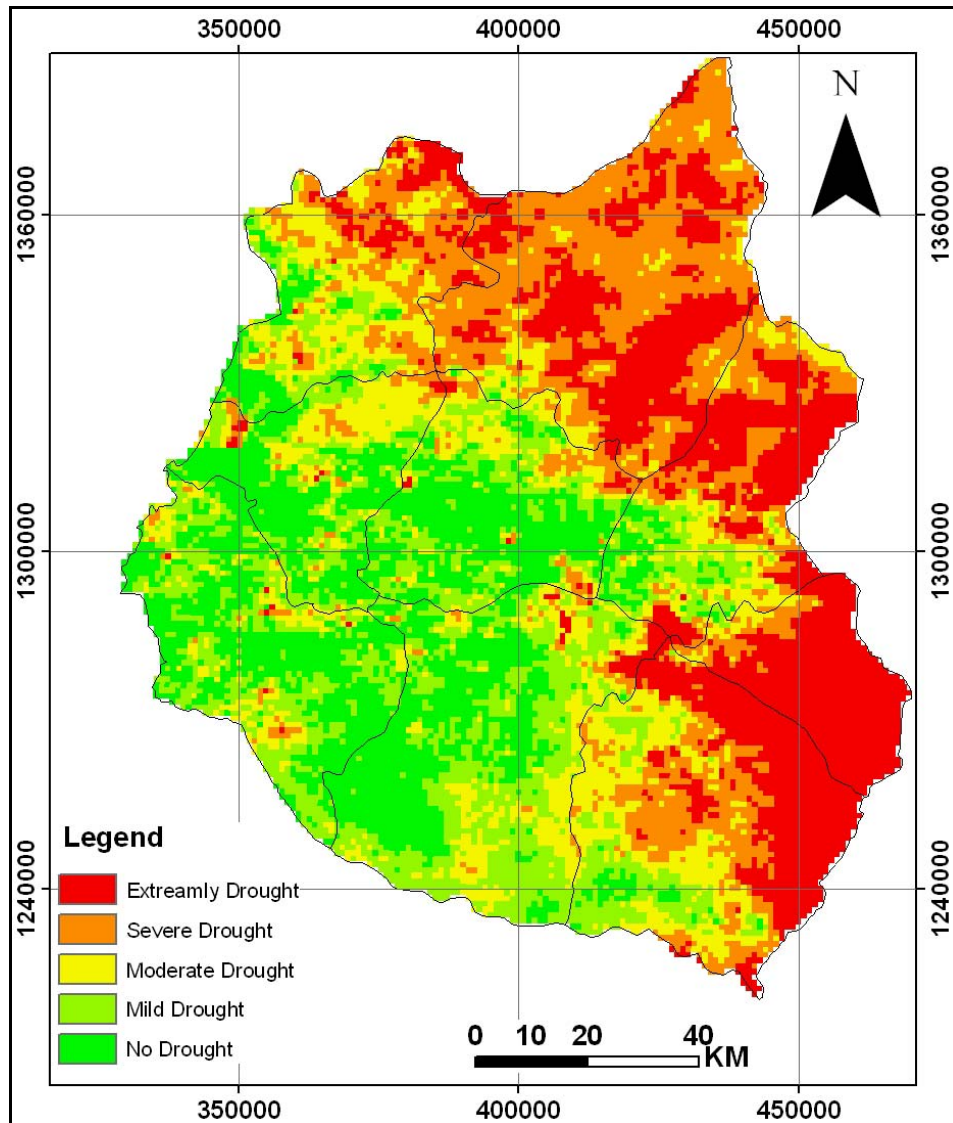


Figure 5_2: Drought map generated from seasonal VCI deviation

The VCI best describes drought condition of the zone. The food aid beneficiaries and the number of stunting and underweight people are the ground truth used to the result.

Libo Kemkem, Ebinat, Lay Gayent, Tach Gayent, Simada and East Estie areas are highly affected by drought conditions in the given eight years. In this study the Vegetation Condition Index (VCI)

was computed for the year 1998 to 2005. As can be seen from the maps the results obtained clearly show that there is an existence of drought situation in both years.

5.1.3 Drought delineation by PPT anomaly

The deviation of rainfall at each station indicated that there was a severe drought prevalence in 2002 in South Gondar Zone. This shows a positive relationship between the NDVI values and rainfall conditions recorded. The crop growing season of 2002 got the lowest rainfall and hence identified as the driest year. The federal government along with European Union was curious about that and designed an Emergence Drought Recovery Project (EDRP) for those Woredas affected by drought conditions.

Northern part of Libo Kemkem woreda and almost all kebeles of Ebinat Woredas are identified as moderately drought affected areas. But they are chronically food insecure areas due to repeated drought occurrence.

Because of the existence of only one meteorological station at each woreda, the data is found not to be reliable for drought area delineation and risk assessment. It is from that single station that the spatial rainfall data was interpolated for the whole area of each woreda, which could be misleading.

5.2. Estimated Annual Soil Loss

The cross product of the LS, R_factor, K_factor and C-factor layers with 30 m by 30 m out put size was generated to estimate the potential annual soil loss in south Gondar Zone. The management factor (P_factor) was given a value of 1. This is because of the fact that soil and water conservation structures in the zone are not sustainable. Since 1980s there were different projects and programs supporting the construction of such structures. But the food aid beneficiaries and cash for work employers used to destruct the structures aiming to construct it again with an other payment by next year. In addition to this the structures are not made in good standard so as to resist the summer season flood. As a result of this, the structures are not that much effective and hence, the P_value was taken as 1.

The amount of soil loss from each parcel ranges from 0 to 206 t/ha/year. The average annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year, and it can be even higher on steep slopes with soil loss rates greater than 300 tons/hectare/year, where vegetation cover is scant (USAID, 2000). Hurni (1985) estimated the soil loss tolerance level for the different agro ecological zones of Ethiopia to be in the range 1– 16 t/ha/yr. Hurni (1985) considered the soil loss between 0 and 2t/ha/year as nil. This amount of soil loss rarely exceeds the natural soil formation rate. By considering these conditions, the soil loss from the study area is classified as low (0 to 10 t/ha/year), moderate (10 t/ha/year to 30 t/ha/year), severe (30 to 100 t/ha/year) and very severe (>100 t/ha/year). In Ethiopia Hurni (1985) categorized average soil formation rates based agro climate zones which are delimited based on altitude (m) and annual rainfall (mm). Accordingly the soil formation in desert altitude called “Bereha” (altitude <500m) as 1 t/ha/year, Kolla 3 t/ha/year, dry to Woynadega 12 t/ha/year 16ton/ha/year and Moist and Woyinadega 12t/ha/year. The research site falls with in dry and moist Woynadega and the rate soil loss from 0 to 10 is taken as low.

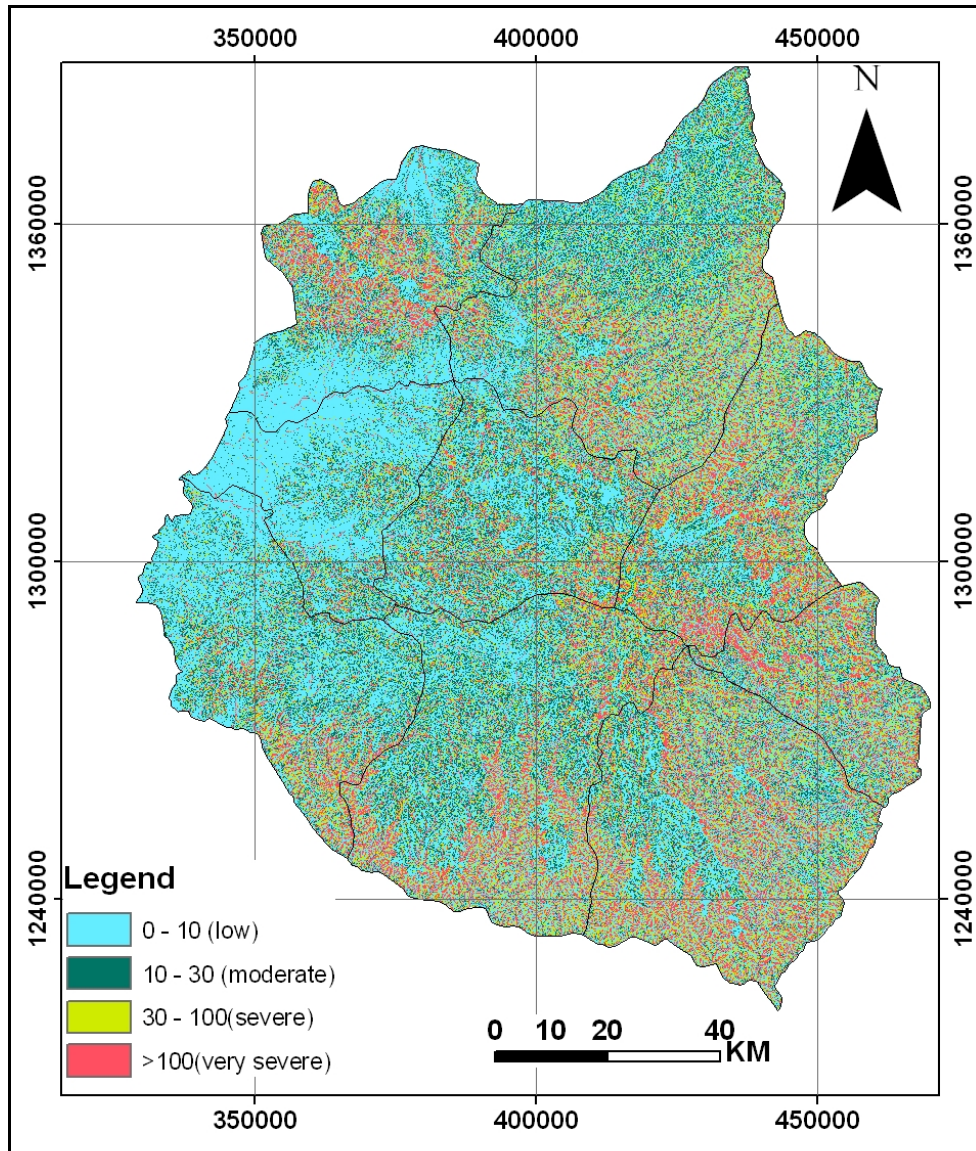


Figure 5_4: Estimated soil erosion map

Libo Kemkem, Ebinat, lay Gayient, Tach Gayient, Simada and Easter Estie experience severe soil loss from the study area. The Fogera low land, which is mostly familiar with summer flood, experiences the lowest soil loss (near 0 t/ha/year). This is because of the fact that summer flood transports large amount of soil from the highland areas and deposit on the plain areas, which supports for the formation fertile soil and land cover.

5.3. Delineation of food insecure areas

Food insecure areas are delineated by taking erosion and drought layer. The Amhara region (in which the study area falls) has identified drought and erratic rainfall as the main reasons for food insecurity (Ramakrishna and Assefa, 2002). Discussion was made with different Regional food security and disaster prevention office experts on the weight of drought and erosion impact on food security and drought was weighted as 70% and Erosion 30%. Drought and soil loss layers are weighted to generate food insecurity map of South Gondar Zone.

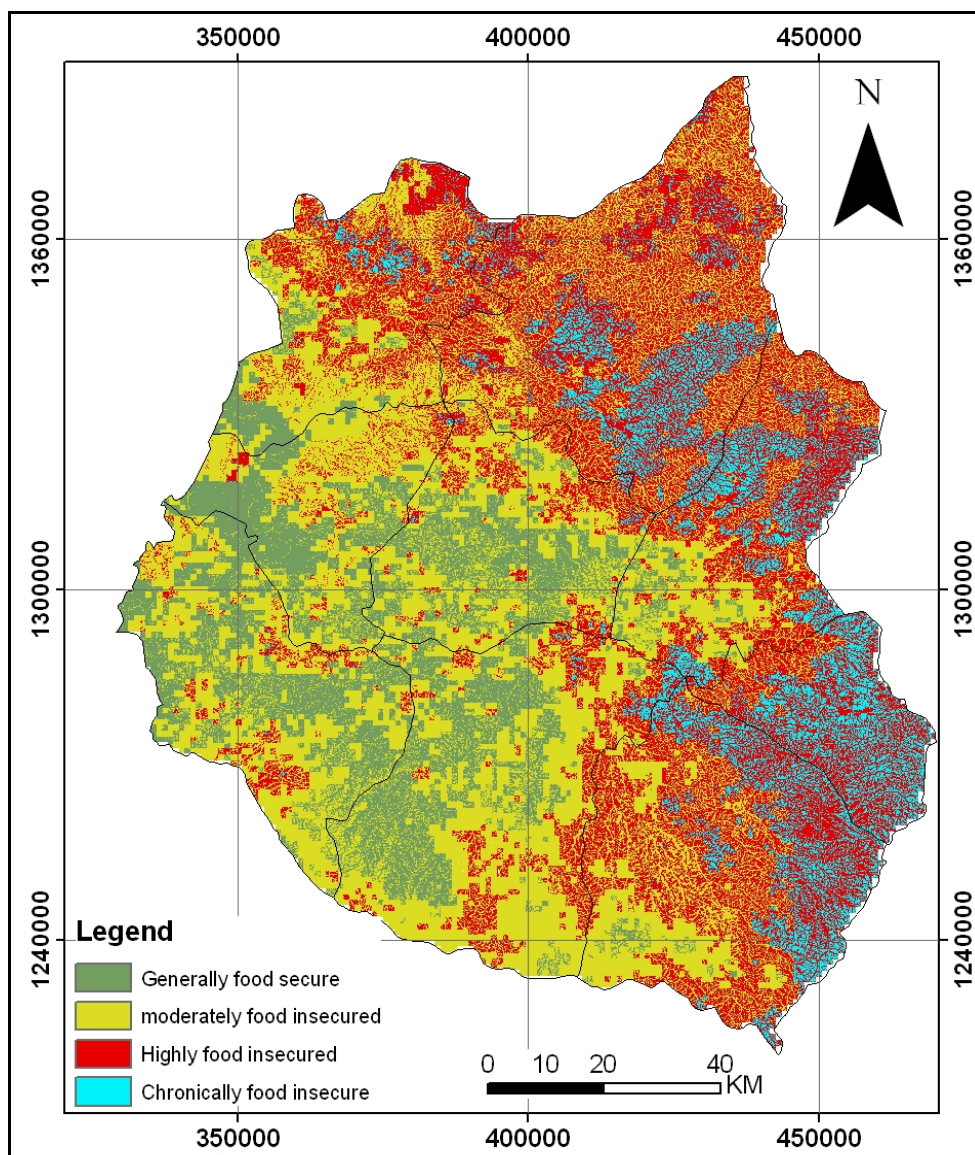


Figure 5_5: food security map

Libo Kemkem, Ebinat, Lay Gayient, Tach Gayient, Simada and the north eastern part of Estie are found to be chronically food insecure areas. The food aid and other food security program intervention do not consider areas which are chronically and moderately food insecure areas. In addition to this the result from this research indicated that food insecurity can be mapped at ecological level than administrative boundary level. The existing system now is attached itself with the delineation of food insecurity at administrative boundary level.

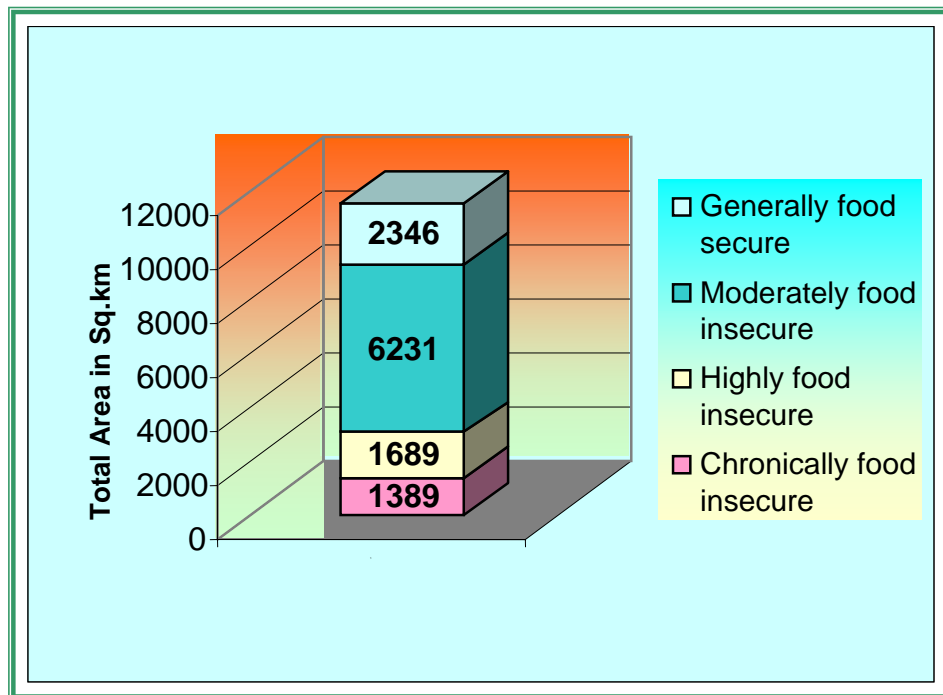


Figure 5_6: contribution of each food security type to the total area

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study attempted to delineate food insecure areas in south Gondar zone from the crop production (Food Availability) perspective. In the process it has been demonstrated that GIS and Remote Sensing is technically feasible to delineate food insecure areas

SPOT_4 images are help for comparative analysis of the trend of derived NDVI of a given year relative to the trend in a normal year for spatially and temporally continuous drought risk assessment and area delineation. Agricultural drought statistics can be improved significantly with the use of time series of greenness indices derived from satellite image data. The deviation from maximum greenness for a spatial unit, during a particular decade, can be a good proxy for optimal rainfall necessary for the ecosystem in that spatial unit for that respective time of the year.

The integration of satellite derived information with other socioeconomic condition of the society enable delineation of food insecure areas. Remote sensing and GIS based methodology has several advantages that include a wide and extensive coverage, regular data availability, timely data availability and dissemination as well as being highly cost-effective.

It has been argued in this paper that the next step might involve a conceptual shift towards the challenges of tackling food insecurity through identifying the right population for targeting through reducing inclusion and exclusion as much as possible.

From the entire work it is found that the north, Eastern and South eastern part of South Gondar Zone are moisture stress areas as is indicated by the greenness indices, which are therefore made the area susceptible to drought. This finally resulted in low agricultural products, the major cause for food insecurity. It is evident that the drought in 2002 caused low crop production, hence food shortage in 2003.

The economic, social, and environmental costs and losses associated with drought in the Zone are significant. A critical component of planning for drought is the provision of timely and

reliable climate information, including seasonal forecasts, that aids decision makers at all levels in making critical management decisions. Remote sensing and GIS can play a paramount role to predict drought before its occurrence. The approach was applied for drought severity monitoring in the main growing season, which generated a series of maps showing spatial distribution of drought severity for eight years period in the study area.

The main objective of the study was to delineate food insecure area from the crop production perspective using SPOT-4 NDVI data and other ancillary data. It was found that people living in cyclic drought affected areas with severe and very severe soil erosion are subject to food insecurity and hence, dependent up on food aid. People living in 16% of the area are generally food secured, 42.5% are moderately food insecure, 32 % are highly food insecure and 9.1% are severely food insecure.

6.2 Recommendations

Based on the findings the researcher would like to suggest the following:

1. A true food security can only be facilitated by an early warning system (EWS). A regional EWS that gives access to similar timely and accurate early warning products would provide a good tool for decision-making. Therefore, it should be apparent from this method that reliable and effective early warning system (EWS) for food security is inevitable for the resilience of the population.
2. The respective Zonal and Regional offices can predict drought before their occurrences. For this activity SPOT-4 NDVI or NOAA images of the respective area should be accessed by those offices from Global Information and Early Warning System (GIEWS) or Advanced Real Time Environmental Monitoring Information System (ARTEMIS) of the FAO Environment and Natural Resources Service.
3. Further researches are needed to improve the findings from this by incorporating other factors determining food security. Having made the system reliable it could be scaled up at regional or national level with a web based GIS as is common in Middle East and Far East Countries.

4. The meteorological drought is a good indicator of drought prevalence to support the Satellite derived VCI and NDVI deviation. But the gauge based rainfall data are not that much reliable being one station at each woreda, as is the case of the study area. Therefore, it is recommended to derive spatial rainfall data from CCD image using WINDISP software prepared by FAO.
5. Food insecurity does not follow the administrative boundary. Therefore it is feasible to apply Remote Sensing and GIS to delineate food insecurity risk maps at ecological boundary level for different interventions.
6. The socio-economic aspects should be studied in detail in order to prepare emergence and development plan in affected area.

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APPENDICES

Appendix A: Population Number of the Study Area by Woreda

Woreda	Urban + Rural			Urban			Rural		
	Both sexes	Male	Female	Both sexes	Male	Female	Both sexes	Male	Female
Ebinat	220,955	112,552	108,403	11,996	5,562	6,434	208,959	106,990	101,969
Libo Kemkem	198,374	100,951	97,423	22,050	10,948	11,102	176,324	90,003	86,321
Fogera	226,595	115,693	110,902	25,184	12,339	12,845	201,411	103,354	98,057
Farta	232,337	118,599	113,738	6,780	3,443	3,337	225,557	115,156	110,401
Lay Gayint	206,458	104,372	102,086	22,818	10,995	11,823	183,640	93,377	90,263
Tach Gayint	101,930	51,024	50,906	7,994	3,788	4,206	93,936	47,236	46,700
Simada	228,207	113,274	114,933	10,278	5,030	5,248	217,929	108,244	109,685
Misrak Este	210,767	107,517	103,250	13,902	7,013	6,889	196,865	100,504	96,361
Dera	246,351	125,898	120,453	16,123	7,644	8,479	230,228	118,254	111,974
Debre Tabor	55,157	27,430	27,727	55,157	27,430	27,727	-	-	-
Merab Este	120,075	61,603	58,472	2,192	1,100	1,092	117,883	60,503	57,380
TOTAL	2,047,206	1,038,913	1,008,293	194,474	95,292	99,182	1,852,732	943,621	909,111

Appendices B: seasonal average and deviation rainfall

