

# Using Multi-Criteria Evaluation and GIS for Chronic Food and Nutrition Insecurity Indicators Analysis in Ethiopia

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## **Abstract**

The actual concept of food security focuses on four food security dimensions: food availability, food access, food utilization and food stability. This study aims to evaluate chronic food and nutrition insecurity, one of the food stability types, in Ethiopia in relation to the four dimensions of food security when affected by long-term shocks characterizing the spatial dimensions of vulnerability defined by contributing and outcome indicators. The results are transformed into geographical information to guide decision making to find where the vulnerable to food and nutrition insecure areas are located. In addition, the study evaluates if there are inclusion and exclusion errors in the number of districts and population receiving assistance under the Productive Safety Net Program (PSNP) and identifies a food security dimension related to child undernourishment.

Basic data on eight indicators were collected from different sources and analyzed using the Multi-Criteria Evaluation (MCE) Method to identify areas of concern for monitoring, assessment, resource allocation and intervention that would help in utilizing limited resources for the most affected districts in the country. A composite index combined the indicators into a single numeric proxy indicator for vulnerability to food and nutrition insecurity. The composite index was considered as a more suitable tool to identify food and nutrition insecure areas for program formulation and targeting humanitarian and development interventions. The study findings indicated that northern, north eastern, southern and south eastern, and pocket areas in remaining parts of the country have relatively persistent chronic food and nutrition insecurity. These areas have limited number of clusters of stunted and non-stunted children and as a result there is weak correlation between food security dimension indicators and stunting; however there are strong correlations among food security dimensions. Based on the results, the study provides recommendations to policy makers on the areas in Ethiopia that would need a better assistance under the Productive Safety Net Program and relief food assistance, and address food security dimensions that undernourished children are the most affected.

Key words: Dimensions of Food Security, GIS Multi-Criteria Evaluation, Districts, Food and Nutrition Insecurity, Ethiopia

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## List of Acronyms

Agro-pastoral:	Areas where people are engaged in herding and livestock rearing as well as agricultural activities.
Belg areas)	Short rainy season from March to May (in highland and mid-land areas)
CSA	Central Statistical Authority
CV	Coefficient of Variation
CVI	Chronic Vulnerability Index
DEM	Digital Elevation Model
DFID	Department of Foreign and International Development (UK)
DHS	Demographic and Health Survey
DPPC	Disaster Preparedness and Prevention Commission
DRMFSS	Disaster Risk Management and Food Security Sector
EAs	Enumeration Areas
El Niño	Warm Ocean Current

EPA	Environmental Protection Agency
ESRI	Environmental System Research Institute
EWRD	Early Warning and Response Directorate
FAO	Food and Agriculture Organization (UN)
FEZ	Food Economy Zone
FDRE	Federal Democratic Republic of Ethiopia
FEPA	Federal Environmental Protection Authority
FSNU	Food Security and Nutrition Analysis Unit
GDP	Gross Domestic Product
GIS	Geographic Information System
GTP	Growth and Transformation Plan
IDW	Inverse Distance Weighting
IFAD	International Fund for Agricultural Development
IPC	Integrated Food Security Phase Classification
LEAP	Livelihood, Early Assessment and Protection
LST	Linear Scale Transformation
MCE	Multi Criteria Evaluation
Meher	Long & heavy rain season usually from June to September (in highland and mid-land areas)
msl	mean sea level
MoA	Ministry of Agriculture
MoW	Ministry of Water
NLAP	National Literacy Action Plan
NMSA	National Meteorological Services Agency
Pastoral	Areas where people are engaged in herding or livestock rearing.
PCA	Principal Component Analysis
PRSP	Poverty Reduction Strategy Paper
PSNP	Productive Safety Net Programme
PPP	Purchasing Power Parity
Region	The higher administrative structure
RMSE	Root Mean Square Error
SCUK	Save the Children United Kingdom
SDPRP	Sustainable Development and Poverty Reduction Program
SERA	Strengthening Emergency Response Ability
SSA	Sub-Saharan Africa
SNNPR	Southern Nations Nationalities and Peoples' Region
TFP	Therapeutic feeding Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UN SCN	United Nations Standing Committee on Nutrition
UNU-EHS	United Nations University Institute for Environment and Human Security
USAID	United States Agency for International Development
USGS	United States Geological Survey
WASH	Water, Sanitation and Hygiene
WLC	Weighted Linear Combination
UTM	Universal Transverse Mercator
VAG	Vulnerability Assessment Group
VAM	Vulnerability Analysis and Mapping Unit
WGS 84	World Geodetic System 1984

WHO World Health Organization

## 1. Introduction

It is certainly a fact that food and nutrition security is most basic of all human needs among others for survival of human beings. Even though, an adequate amount of food is produced in the world to meet the needs of all people, food and nutrition security remains a major problem in many parts of Sub-Saharan Africa (SSA).

Socio-economic situations and the adverse impacts of erratic weather on rain-fed agricultural production in SSA have long been documented as a major cause of vulnerability to food and nutrition insecurity in the region. Climate change, with its potential to disrupt weather patterns, change rainfall distribution, and increase temperature beyond what crops can tolerate, has recently emerged as a critical threat to the long term food security of SSA region (UN SCN 2010). The vast majority of the poor in SSA are dependent on agriculture, with 85% of the population obtaining at least a part of their livelihood from the sector. Food and nutrition insecurity is also largely a rural phenomenon, with 83% of the poor living in rural areas (Gautam 2006).

Like many SSA countries on the eastern horn of Africa, Ethiopia shares many similar socio-economic and climatic conditions that influence the character and changing aspects of food and nutrition insecurity. Rural Ethiopians who are subjected to both chronic and transitory food and nutrition insecurity cannot meet their food needs even under ideal conditions because chronic food and nutrition insecurity as a long term and transitory food and nutrition insecurity as a short term are common in Ethiopia (Gross et al. 2000). Usually repeated transitory food and nutrition insecurity leads to the chronic that declines the ability of people to cope with these disasters. The underlying causes behind chronic food and nutrition insecurity are related with structural problems namely, poverty, high population pressure, lack of physical infrastructure, health problems and low levels of human productivity while that of transitory food insecurity are droughts, floods, rapid population growth, low levels of technology employed in agriculture and the resulting low productivity of the sector and other natural hazards such as landslides and frosts (Devereux 2000).

Climate variability in the form of drought and flooding has been reported as a major cause of food and nutrition insecurity in Ethiopia disrupting weather patterns, causing erratic and unpredictable rainfall and high temperature beyond tolerance of crops and livestock as its agriculture is mainly rain-fed. In terms of population size, Ethiopia is

the second largest country in SSA (Zekaria 2008) and this has a direct impact on the growth in increased food demand. As population grows, cultivated land per capita declines forcing smallholder farming to be dominant activity leading to high level of both chronic and transitory food and nutrition insecurity (USAID 2014).

In addition to droughts, floods, rapid population growth, limited access to rural market places due to poorly developed road networks and inaccessibility to food deficit communities also constraints the supply of food causing food and nutrition insecurity (Deichmann 1997). Moreover, the substance rain fed agricultural activities of the people are frequently affected by rainfall variability in amount and pattern and as a result famine is a frequent feature and this likely aggravates poverty limiting economic development activities (FEPA 2008).

Addressing food and nutrition insecurity in Ethiopia also requires addressing socio-economic status using indicators for education and sanitation namely, female adult illiteracy, and unsafe drinking water and toilet facilities. Studies indicated that female's adult illiteracy has impacts on child's proper growth, management of nutrition and diseases, income generating activities and to be productive more effectively while lack of sanitation has impacts on contracting not only diseases and illness that generate health costs but also under nutrition and mortality of children (Haddad 1999; Ejaz et al. 2009; Ajao et al. 2010).

Two food insecurity types, namely chronic and transitory (acute), are generally identified under food stability. In this study, a national scale chronic food and nutrition insecurity analysis was undertaken and acute food insecurity was included as one of the outcome indicators. The four food security dimensions: food availability, access to food, food utilization and stability of food supplies and associated indicators with the four dimensions were dealt in detail in the literature review that guided analysis of chronic food and nutrition insecurity. The review of the literature provides the foundation for understanding previous research activities on the conceptual framework and indicators related with food security dimensions.

## **1.1 Objectives**

The objectives of this study were:

- To evaluate vulnerability to chronic food and nutrition insecurity in Ethiopia with a focus of spatial dimensions of food and nutrition insecurity caused by contributing and outcome indicators.
- To evaluate if there are inclusion and exclusion errors in the number of districts receiving assistance under the Productive Safety Net Programme (PSNP), this provides cash or food to support chronic food and nutrition insecure so that they evolve from dependency over a number of years.
- To examine the relationship between the four food security dimensions (food availability, food access, food utilization and acute food insecurity), and stunting of children under age five using a correlation matrix.

## 1.2 Research questions

The following key questions have been investigated in the study:

- Where are geographical districts with chronic food and nutrition insecure populations located?
- Are there relationships between food security dimensions and stunting of children under age five?
- Are there exclusion and inclusion errors across districts receiving assistance under the PSNP?

The analysis of the above questions and targeting the affected population is a key mechanism for reaching vulnerable populations and ensuring efficient and effective use of limited resources.

The study is structured into several chapters. After the introduction and the description of objective and research questions, the following chapter reviews the literature on the food and nutrition insecurity analytical framework and indicators. Description of materials and methods and justifications for selecting the methodology is given in the third chapter. The fourth chapter focused on data analysis results. Discussions on results, data, methods and limitations are made in the fifth chapter and conclusions are made in chapter six.



## 2. Literature Review

Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996). This definition implies that people who do not satisfy the above conditions are considered food insecure. Ethiopia is mainly agricultural but the production for the last three decades has never been adequate to enable the population to be food secure, which led to reliance on food aid to complement inadequate national outputs. This is not the normal food channel to achieve food and nutrition security and hence food and nutrition insecurity is characterized by incapability of the affected households to attain and retain sustainable livelihoods. Despite being rich in natural resources, Ethiopia is most frequently affected by climate change, population growth and environmental degradation (ReliefWeb 2003); and institutional factors, deterioration in soil fertility and soil loss by erosion (Lacey, 2001) that reduce its agricultural productivity and leads to food and nutrition insecurity in the country.

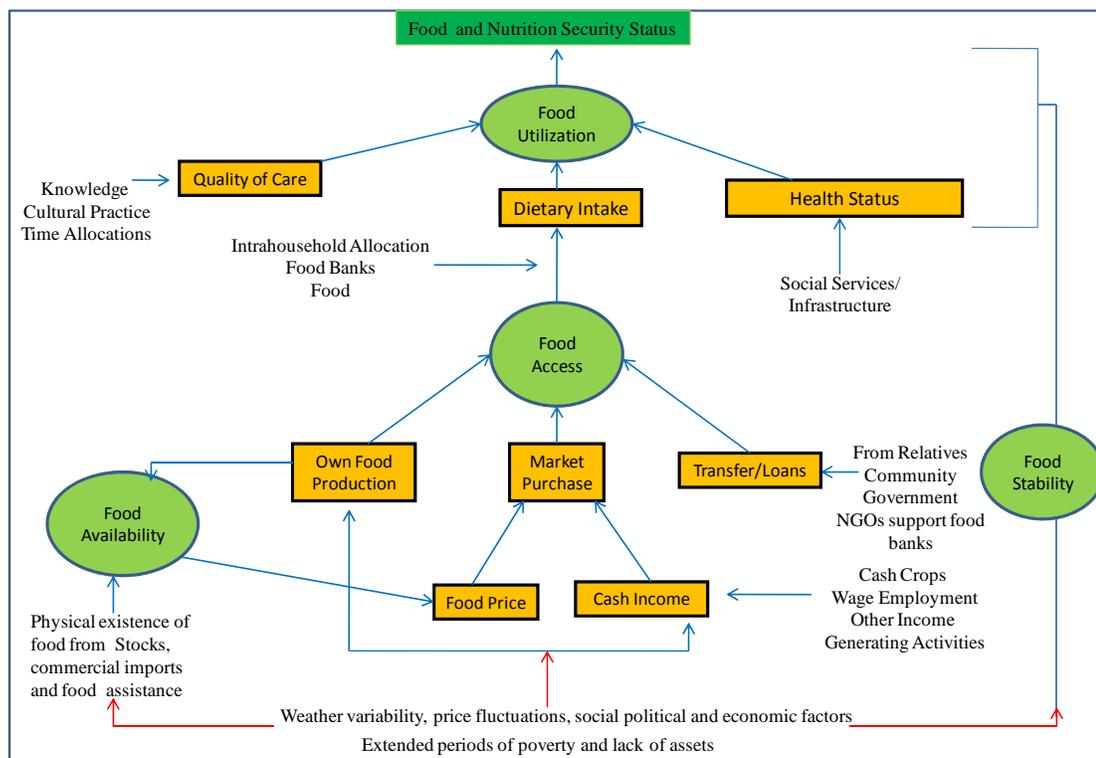
The Federal Democratic Republic of Ethiopia (FDRE) has formulated policies and strategies to guide and manage the overall development of the country with focus on rural and agricultural development. FDRE had designed and implemented a Sustainable Development and Poverty Reduction Program (SDPRP) in the years 2002/03 – 2004/05, with the core objective of reducing poverty. The program established key sector development policies and strategies such as agriculture, food security and safety net programs, education, health services, roads, water resource development (SDPRP 2002). Afterwards, a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) was implemented from 2005/06 to 2009/10. On the basis of the experiences gained and the national vision, the Growth and Transformation Plan (GTP) has been prepared and adopted as the national planning document of the country for the period 2010/11 – 2014/15 Poverty Reduction Strategy Paper (PRSP 2011). However, a large amount of data and proper data analysis are required to monitor the impacts of implementing and adopting these policies and plans and interventions.

To understand food and nutrition insecurity in depth, a literature review was conducted on the existing conceptual framework that integrates the four food security

dimensions and the indicators that contribute, directly or indirectly, in defining and analyzing the status of chronic food and nutrition insecurity.

## 2.1 Conceptual framework

FAO's 1996 food security definition has four main dimensions of food security, namely food availability, food access, food utilization and stability of other three dimensions over time. The conceptual framework used in this study (Figure 1) was adapted from Riely et al. (1999). It integrates the four dimensions, which are used to identify food and nutrition security. It also illustrates the nature of relationship between the four dimensions incorporating relevant indicators that contribute, directly or indirectly, in defining and analyzing the status of chronic food and nutrition insecurity. When shocks of high frequency, extended periods of poverty and lack of assets are introduced, the framework explains one of the food stability types, i.e. chronic food and nutrition insecurity in the country.



Adapted from Riely et al, 1999; Green circles are dimensions of food and nutrition security; orange rectangles are fundamental factors of food and nutrition security while red lines show extreme shocks.

Figure 1. Food and Nutrition Security Conceptual Framework

Based on the food security framework, *food availability* depends mainly on physical existence of food from domestic food production, commercial food imports, food aid and food stocks at household, regional or national levels.

*Food access* is both economic and physical. Economic if a country is able to generate foreign exchange to pay for food imports and physical if it is mainly connected for example to the state of infrastructure, market and storage facility. Food access depends on the availability of food through supplies in the market as well as food prices. It further depends on cash income, which in turn is determined by income from cash crops, wage employment and other income generating activities such as beekeeping and poultry raising. It is also a function of weather variability, price fluctuations, political instability and economic factors (unemployment and rising food price) that cause food and nutrition insecurity. Extreme shocks in these factors may critically disrupt food production making threat to the food access of households leading to loss of productive assets, which can eventually weaken their long term food and nutrition security.

*Food utilization* is usually reflected in the nutritional status of an individual, which depends on quality and quantity of dietary intake that provide enough energy and essential nutrients, quality of child care and feeding practices, knowledge within the households and health status.

*Food stability* refers to the ability of obtaining food over time and is considered as a fourth dimension by some analysts and agencies (e.g., FAO). It describes the temporal aspect of food and nutrition insecurity that is chronic or transitory and affects all three physical elements; food availability, accessibility and utilization.

When a household is unable to meet the food requirements over a long period of time; it is known as chronic food insecurity. A short term problem of crop failure due to low and erratic rainfall, domestic food price volatility, conflict, short term illness or unemployment of a productive member of a household may lead to the transitory food and nutrition insecurity affecting both short and long term chronic food and nutrition insecure households. During transitory food and nutrition insecurity, households are forced to adjust their consumption patterns in diversifying their sources of income from non farming activities, reducing their dietary intake, relying on loans or transfers from relatives, NGOs or government.

Household food security is necessary but not sufficient to guarantee an adequate individual nutrition status, therefore, aspects of health status and its determinants such as clean water supply, sanitation facilities, and knowledge within the household and adequate care or equitable food allocation are essential. For instance, a household may be food secure according to physical and economic factors, but it may still contain under nourished children due to low female adult literacy rates to manage nutrition, sanitation, disease, child welfare and to women’s time constraint caused by domestic work but also by productive activities.

## 2.2 Food security dimensions and indicators

The study of different food security dimensions have been done using different indicators as briefly described in Table 1 below. For a more detailed table, see Appendix B, Table B3. Eight indicators are considered namely, rainfall variability, population density, access to towns, female adult education, access to safe drinking water, toilet facility, acute food insecurity and under-five stunting. To further facilitate their interpretation they are classified as contributing and outcomes indicators of food and nutrition insecurity of which under-five stunting and acute food insecurity are outcome indicators. Outcome indicators are indicators of change capturing results in terms of inadequate food consumption or anthropometric failures in this study while contributing factors are situations that influence by increasing their possibility.

Dimensions	Indicators	Contributing or Outcome	Reference
Food Availability	Rainfall variability	Contributing	NMSA (1983 - 2012)
	Population density	Contributing	CSA (2007). Valid until another census takes place in 2017
Food Access	Access to towns	Contributing	GTOPO30 DEM (2006).
			CSA (2007). Map layers (regions, districts, lakes, roads and towns). Valid until another census takes place in 2017
Food Utilization	Adult female illiteracy	Contributing	CSA (2007). Valid until another census takes place in 2017
	Safe drinking water	Contributing	CSA (2007). Valid until another census takes place in 2017
	Toilet facility	Contributing	CSA (2007). Valid until another census takes place in 2017
Food Stability	Reference of Acute Emerencies (Frequency of hotspot district classification)	Outcome	Hotspot districts classification (2008 - 2013)
Stunting of children under five		Outcome	DHS (2000, 2005, 2011)

Table 1. Food Security Dimensions and Indicators

### 2.2.1 Food Availability

FAO (2006) describes food availability as the extent to which food is available at household level obtained from local shops and markets in terms of sufficient quantity and quality. Similarly, as indicated in the conceptual framework, among others, food availability depends on physical existence of food from domestic food production. However, food production depends on various factors for example climate conditions (rainfall and average temperature), fertility of soil, population pressure, pests and diseases, agricultural inputs and technologies. Among many indicators of food availability, two major indicators namely rainfall variability and population density are identified in this study. Tropical livestock unit per capita is also contributing indicator, however, due to data limitation it is dropped.

#### Rainfall variability

Rainfall variability expressed in terms of droughts or floods affects all aspects of food and nutrition security; food availability, food access, food utilization and stability. According to UNU-EHS (2012) it also affects households' incomes, crop yields, livestock rearing, belongings, and the number of people living together forcing them to migrate affecting them negatively food consumption especially in districts where livelihoods are highly dependent on rain-fed agriculture.

Droughts or floods are deviation from the long-term meteorological average over a certain period of time and are characterized by their severe effects on people's livelihoods, especially on agricultural production and associated food security (Tamer et al. 2014). Ministry of Water and National Meteorological Services Agency (MoW and NMSA, 2007) has were identified years in which major floods occurred in different parts of the country that caused loss of life and property in 1988, 1993, 1994, 1995, 1996 and 2006. Those floods had potential to cause deaths, injuries, diseases, displacement, and destruction of property and crops, changing productivity and livelihood patterns, and inundating farmlands and other infrastructure, leading to food shortage especially in developing countries because of insufficient disaster management structures and lack of economic resources leading to an acute reduction of food availability and limiting access to food and food shortages (Weingärtner 2000; Nyirenda 2013; Samson et al. 2009). In addition to flooding, drought affected

areas will likely become more widely distributed, leading to increased risk of water and, therefore, under nutrition for under five children (FAO 2013). Geographically, vulnerability to droughts caused by the rainfall variability is greatest in the pastoral areas of the lowlands and the densely populated, food-insecure districts of the highlands in Ethiopia (Chanyalew et al. 2010). Most pastoral and agro-pastoral areas of the country are affected by drought; however, the pastoral livelihood is the most affected. Pastoralists in Ethiopia mainly found in the Eastern, Southern and South-eastern parts of the country. The south-eastern or Somali region is the largest among them, which is mostly desert with high temperatures and low precipitation that is frequently hit by drought. Pantuliano and Wekesa (2008) indicated that pastoralism is exceptionally used to dry land environment because as an economic and social system, it operates effectively in low and highly variable rainfall conditions. However pastoralist livelihood in Ethiopia is becoming increasingly vulnerably for example due to climate change, low levels of education, literacy rates and poor infrastructure.

The frequency of drought in south eastern of the country, especially in Somali region has been increasing particularly over the past two decades, and has thus been widely recognized as a key development and environmental challenge according to the Somali regional state report, 2011. This report further suggested that drought hazards have increased in frequency, intensity and magnitude over the recent decades and have adversely impacted on food, feed and water security and the sustainable livelihoods. Department of Foreign and International Development (DFID) and United Nations Educational, Scientific and Cultural Organization (UNESCO) (2012) have also indicated that Recurrent drought has a major impact on livelihoods and been a frequent cause of asset loss and human and livestock mortality in Somali region.

A coefficient of variation (CV) is a statistical measure of the dispersion of rain gauge data points in a rainfall data series around the mean. If  $CV > 30\%$  then it is an indicator of large rainfall variability that may be attributed to El Niño effects (Araya and Stroosnijder 2011). As indicated by Anyah and Semazzi (2007); An El Niño episode is linked to persistent warmer than average sea surface temperatures and consistent changes in rainfall patterns were listed out (FAO 2014) that four out of the nine El Niño events occurred between the years 1985-2013, i.e., 1985, 1991, 2002 and 2009, and coincided with intense and/or extended drought conditions during April to November period, which encompasses the main Meher cropping season in which unfavorable crop-growing conditions prevailed. By contrast, five out of the nine El

Niño events that occurred between the years 1985-2013, i.e., 1986, 1994, 1997, 2004 and 2006 coincided with overall satisfactory crop growing conditions. In measuring rainfall for drought events the level of rainfall accuracy is one of the main factors in achieving forecast accuracy in a certain region. Rainfall accuracy is highly dependent on the density and distribution of rain gauge stations over a region. (Looper and Vieux 2011).

### Population density

Population density is another contributing indicator to food and nutrition insecurity status of districts identified under food availability. Research findings from a number of case studies indicate that high population density may possibly lead to agricultural growth through intensification or results in agricultural stagnation, involution and environmental degradation (Kates and White 1993). However, input intensity rises with population density to around 600 persons per km<sup>2</sup>; beyond this population density threshold, farm productivity, incomes, household assets, and input intensification declines. Higher population density is also found to be associated with smaller farm sizes and decreased fallow land, other factors being constant (Jayne and Milu 2012). Binswanger and McIntire (1987) also indicated that increased rural population density induce a number of changes on tropical agricultural farming systems, including declining labor productivity, decreased fallows, increased landlessness, and declining livestock tenancy.

Data from 37 countries in SSA confirmed a significant relationship between population pressure, reduced fallow periods and soil nutrient depletion, indicating a generally unsustainable dynamism between population, agriculture and environment. The results also indicated that increased land degradation through nutrient depletion related to population pressure and land-use intensity (Pay et al. 2001). In addition to this, population pressure can lead to ecological problems such as: inappropriate land cultivation, over grazing, deforestation, and subsequent erosion (Balcha 2001).

### 2.2.2 Food Access

Food access is one of the four dimensions of food security referring to physical and economic access to food. It is not only domestic food availability that has to be taken into consideration but households must also have access to the necessary resources to acquire food. According to the FAO (2011) economic access

of food security is evaluated using the domestic food price level index, which is calculated dividing the Purchasing Power Parity (PPP) conversion factor by the market exchange rate, thus providing an index of the price of food in the country relative to the price of the generic consumption basket. Other studies also indicated the importance of food price and purchasing power indicators. Food access is to a large extent determined by economic access of food prices and household resources (Pieters et al. 2013), however, as indicated by (Kumar 1989) food prices alone are not very informative unless when data are combined with information on the purchasing power of the target population.

Due to limited data availability on purchasing power of rural population, it is not possible to assess purchasing power data, which is one of the contributing indicator to food and nutrition insecurity instead the study focused on the physical access of food security, i.e., accessibility to market places or towns.

#### Accessibility to towns

For accessibility analysis, markets were represented by towns, that is urban centers with 2000 population or more inhabitants, administrative capitals (regional, zonal, districts, urban dwellers association) regardless of the number of habitants and localities which are not included under administrative capitals with population of 1000 or more persons are considered as towns in Ethiopia (CSA 2011). Each town point has geographical coordinates and associated tabular information on its population for about 934 towns across the country.

The reason behind the use of town accessibility is based on the assumption that areas that have low market integration or poor access provide fewer economic or social opportunities which enable people to escape the affliction of poverty (Deichmann 1997). Local towns and cities are very important to the economic activities of rural population. The closer a village is to a town, for instance, the more likely rural households are to purchase seeds and fertilizers or sell a variety of products and hence improved access to market towns and cities has a positive effect on welfare (Dercon and Hoddinott 2005). Better access to towns is also important because it leads to diversification of rural economies by opening up markets to villagers who wish to sell their labor, agricultural produce or artisanal products (Pozzi and Robinson 2008).

To define towns accessibility time measurement is used because households use different modes of transport indicating that time is more appropriate than the geographic distance measurement with different units, like simple distance measurement. Hau and M.Von 2002 have also stated about the advantages of using travel time as a measure of household level data, i.e., in household studies, accessibility is often measured as the travel time to different destined ends in the same units as spatial travel time measures.

### **2.2.3 Food Utilization**

The third dimension of food security is food utilization. Food utilization refers to preparation and good use of food in which households access and the ability of a body to absorb nutrients. Food storage places, processing, knowledge and practices in relation to food preparation, feeding of young children and other dependent individuals; how food is shared within the households are important factors for food utilization by households (WFP 2009). . Hence, food utilization is related not only to the quantity of food that is eaten, but also to the quality of the diet (Pieters et al. 2013). Three contributing indicators to food and nutrition insecurity namely adult female illiteracy, safe drinking water and toilet facility that present proxy to socio economic status were identified in food utilization category.

#### Female Adult Illiteracy

Female adult illiteracy is one of contributing indicator to food and nutrition insecurity and is a general proxy for education status. Different studies from different countries found that female's adult literacy rates are crucial for the management of food utilization, nutrition, sanitation, disease, and child welfare. Ejaz et al. (2009) have indicated that when females are literate, the dietaries of household members are improved as they have better knowledge about nutritional values derived from foods, increased knowledge of appropriate sanitary behavior that helps to manage disease more effectively and determine the number of children the women have and similarly for income generation and behavioral change (Haddad 1999). Holms et al. (2010) also suggested that female literacy is an important determinant of food utilization. Another study conducted by Ajao et al. (2010), also suggested that households with food insecurity and less educated mothers were more likely to have under nourished children confirming that mother's education is an asset for the child's proper growth,

i.e., low maternal education was significantly associated with stunted children because educated women are likely to be more aware of nutrition, hygiene and health care. In addition to this, the National Literacy Action Plan (NLAP 2012 – 2015) stated that widespread female illiteracy is affecting the health, wellbeing, productivity and overall societal prosperity.

In one of the studies conducted in Zimbabwe, women play an active role in food production but their potential is limited by inadequate levels of literacy that affect the way they access and utilize resources for sustainable agriculture and household security among other factors (Gundu 2009). It also hinders women's freedom to decide on various choices asserting greater mobility in social interactions resulting in hidden women's contribution to agriculture and other sectors in the economy and unaccounted for in monitoring economic performance measurement (Prakash 2003).

Hence, to manage nutrition, disease, and children's proper growth and to be productive more effectively, female literacy is an important determinant and it is worthwhile to include female literacy data in food and nutrition insecurity analysis.

#### Unsafe drinking water and sanitation facilities (no toilet facility)

Access to safe drinking water and improved toilet facilities are proxy for socio economic status and reduce risks of contracting diseases, under nutrition and mortality in children, and health costs. When access to safe drinking water is reliable and accessible, food and nutrition can be improved, increases girls' attendance at school and women's involvement in income generating activities and is an essential input for agricultural production, food processing, preparation and cooking of food (HLPE 2014). Similarly, access to safe drinking water and improved toilet facilities reduces the risk of contracting disease from contaminated water sources (Shittu et al. 2013). When safe water and sanitation are reliable and accessible, it leads to improved food security and nutrition. Mainly in poor rural areas, improving access to safe water, reduces the time women and girls spend on collection of wood and water leading to increased girls' attendance at school and women's involvement in income generating and leisure activities (USAID 2011). In addition to this, it is an important input for agricultural production, food processing, preparation and cooking of food.

Lack of safe drinking water and improved sanitation causes illness as indicated by Keene et al. (2012) that it is a single largest cause of poor health in the

world, contributing to the death of 2 million people a year; a large amount of those preventable deaths are children; in addition to this, illness caused by unsafe drinking water that causes health costs, claim a large share of poor households' income, and reduce productivity that leads to the households' food insecurity (Nexus 2011). However, poor access is not only related with contracting diseases and illness but also with under nutrition and mortality in children. Wamani et al. (2006) reported that children without hygienic toilet facilities were considerably associated with under-two stunting. In addition to this, the findings indicated that poor people have low levels of access to clean water and toilets because of lack of awareness, education and their lack of influence in local governance.

These days, global health experts are acknowledging that food and nutrition security challenges can be met if safe drinking water, sanitation, and hygiene are available in the world's poorest communities. Without access to safe drinking water, proper sanitation and hygiene, food is easily contaminated through exposure to unsafe drinking water, pathogens agents of disease on hands and from flies, and unclean surfaces. This can cause diarrhea, and other intestinal diseases and eventually under nutrition (WASH 2013).

Providing children and adults with access to clean and safe water, the chance to live in a healthy environment, and adequate nutrition are fundamental issues and it is worthwhile to include these indicators in food and nutrition security analysis and identify districts affected by lack of safe drinking water and sanitation to recommend proper interventions.

#### **2.2.4 Food Stability**

To be food secure the whole system must be stable, i.e., food must be available and accessible at household level and then a household must utilize it properly over time. It is considered a fourth dimension by some analysts and agencies (e.g., FAO). It refers to the temporal dimension i.e., time frame over which food and nutrition insecurity impacts at household level are considered that affects the entire three food security dimensions. It has two components namely chronic and acute food and nutrition insecurity (Gross et al. 2000). IPC (2012) defined chronic food and nutrition insecurity as the prevalence of persistent food insecurity, which continues even in the absence of shocks or high frequency of years with acute food insecurity in which people were not able to recover quickly. However, there is a strong linkage

between chronic and acute food and nutrition insecurity and they can happen simultaneously. A district can be at different phases of acute food and nutrition insecurity and simultaneously be at different levels of chronic food and nutrition insecurity.

Devereux (2006) defined food insecurity into three categories namely chronic food insecurity as long term or persistent inability to meet minimum food consumption requirements while acute food insecurity as a short term or temporary food deficit and an intermediate category as cyclical food insecurity such as seasonality. Cyclical food insecurity is similar to chronic food insecurity because it is usually predictable and follows a sequence of known events. However, due to limited duration it can also be seen as transitory food insecurity. To describe severity of food insecurity, he recommends moderate and severe while chronic and transitory to describe the temporal aspect of food insecurity. He further suggested that all chronic, acute and intermediate are endemic in Ethiopia (Devereux 2000) indicating drought and war as the main triggers of transitory food insecurity and structural factors such as poverty, fragile natural resource base, weak institutions and inconsistent government policies contributing to this. He concluded that Rural Ethiopians who are subjected to all forms of food insecurity cannot meet their food needs even under ideal weather conditions, suffering seasonal hunger and under nutrition, and are acutely exposed to famine in years of low or erratic rainfall.

The temporal parts; transitory and chronic, were dealt at district level however, there are better-off, middle and poor households in food and nutrition insecure districts based on land ownership, farm inputs, employment in off farm sector and livestock holdings (USAID 2008). This indicates that there are deep internal food and nutrition security variations among households showing that households don't have similar socio economic conditions at kebele or district levels. The smallest level of administrative unit is kebele with more than 5000 subjects. Unlike the better-off and middle wealth groups, the poor lack livestock products and achieve less or none income from livestock sales and are always prone to food and nutrition insecurity. Ethiopia's Productive Safety Net Programme (PSNP) is a social safety nets program financed by the Government of Ethiopia and by aid that targets the poor through humanitarian response mechanisms to lift households out of food and nutrition insecurity (Wheeler et al. 2012). However, there were still food and nutrition insecure households as indicated in the temporal part of analysis results.

The underlying causes behind chronic food and nutrition insecurities are mostly structural problems of availability, accessibility and utilization and hence include structural deficiencies, which are mostly explained in terms of poverty, inadequate access to productive or financial resources, and inadequate access to resources.

#### Reference of Acute Emergencies

Stability can refer to acute emergencies that lead to chronic food and nutrition insecurity. Chronic food and nutrition insecurity sometimes defined as acute crises; IPC (2012) defined it as high frequency of transitory crises years in the past ten years and is considered as an outcome indicator that is used to classify the severity of area level chronic food insecurity. To address acute food insecurity, DRMFSS deploys an emergency relief food assistance and then conducts a hotspot districts classification on quarterly base to identify the severity levels of each district using indicators related with climate, health, nutrition, agriculture, market, water, education sectors and others that briefly describe the analytical approaches to classify districts into three categories (priority one, two and three), to identify areas of concern for monitoring, assessment, resource allocation and intervention. This helps to utilize the limited resources for the most affected districts in the country. Hotspot frequencies of districts of acute crises from June 2008 – September 2013 conducted 14 times were used in this study as reference of acute emergencies outcome indicator. Because, repeated acute food insecurity in a district leads to chronic food and nutrition insecurity.

#### **2.2.5 Nutrition status: Stunting of U5 children**

Stunting is an indicator of height for age compared to a reference population caused by inadequate food intake caring practices and health over an extended period of time. It is an outcome indicator as indicated by the FAO 2005 that reflects the food security status of households in terms of how available food is translated into consumed food and nutritional levels and problems with poor health, sanitation or child care. A study conducted by Raja 2010 identified the predictors of stunting among children in the developing world and has indicated the importance of addressing all food security dimensions of food security: food availability, food accessibility and food utilization to understand and tackle the stunting among children.

If stunting continues to long term then it may lead to poor cognitive and intellectual development, reduced adult size and decreased work capacities (Hasan et al. 2013). Under nutrition is the underlying cause of 57% of child deaths in Ethiopia, with some of the highest rates of stunting and underweight in the world (SCUK 2009). It is not only an indicator of poor nutritional status but also of unsatisfactory basic need coverage and therefore of complete poverty (Gross et al. 2000).

The three most recent Ethiopian Central Statistical Authority (CSA) Demographic and Health Survey (DHS) reports (DHS 2000, 2005 and 2011), designed to provide data for monitoring the population and health situation in Ethiopia, indicated that stunting rates at national level for 2000, 2005 & 2011 are 57.8 percent, 51.5 percent and 44 percent respectively (DHS 2011). According to the 2011 survey, 44 percent of children under five are stunted and 21 percent are severely stunted at national level or too short for their age that indicates chronic under nutrition posing major impediment to achieving better child health outcomes. Among the stunted children in 2011 survey, more than eighty five percent of them (85.6 percent) reside in rural areas while a relatively smaller proportion of the stunted children (14.4 percent) reside in urban centers. The chronic under nutrition nature and higher percentage of stunting in rural areas gives us a good clue among others to study food and nutrition insecurity in rural districts of Ethiopia.

### **2.3 Previous food and nutrition insecurity analysis in Ethiopia**

Many efforts have been made to construct models to measure levels of vulnerability to food and nutrition insecurity at district and household levels in Ethiopia. One of them is Destitution Study in Ethiopia's North Eastern Highlands implemented by the Development Studies and Save the Children UK (Sharp et al. 2003). Using Principal Component Analysis (PCA), the findings indicated that the percentages of destitute households have increased dramatically in recent years with the indication of continue to rise in the coming years. In addition to this, ill-health was indicated as a cause and a consequence of destitution. Geographic boundary of the study was marked by Food Economy Zones defined by the SCUK, which implies that district level information is not available as one Food Economy Zone (FEZ) but extends to sections of several different districts.

Unlike the Destitution Study conducted at food economy zones, Strengthening Emergency Response Ability (SERA project 2000) conducted at district level in few

districts selected from four major regions in the country. The project findings indicated that the causes of susceptibility fell into five areas namely, population pressure, land and environmental stress; lack of physical and natural resources; structural poverty and chronic food insecurity; lack of access to infrastructure and essential services; and destructive coping strategies and lack of capacity to deal with drought emergency at the household level (Morris 2003). However, according to Jericho (2008), the profiles were difficult to use because they differed in structure among the four regions, organized either according to topic or data source, or in a more synthetic analysis of observed trends in vulnerability, and thus were hard to contrast in order to decide priorities. As a result, there were little support for the expansion of the project, and the project was discontinued in 2004.

Another big effort made in the country was creation of Chronic Vulnerability Index (CVI). It was initiated in 1999 by the World Food Program (WFP) of the Vulnerability Analysis and Mapping Unit (VAM). A Disaster Preparedness and Prevention Commission (DPPC) led Vulnerability Assessment Group (VAG) undertook development of district level CVI for making decisions regarding disaster prevention and preparedness activities. As a methodology, a group used one or more of the traditional statistical measures such as quintile analysis, PCA and linear regression analysis on nine, mostly agriculture related, coping and risk indicators. The quintile analysis was used to re-class each indicator value at district level for 418 districts excluding largely pastoral regions of Afar, Somali and urban areas. Districts were ranked for each indicator from lowest to highest and then divided the total number of cases into five equal groups scaling 1 to 5 quintile system, where 5 represents very high vulnerability while 1 slightly vulnerable situation to arrive at a final Chronic Vulnerability Rating for each district (VAG 2003). The findings indicated that northeastern, eastern highlands and some pocket areas in the west are found to be chronically vulnerable ranging from moderate to high degree of vulnerability. The study was revised in 2004 updating information and including Afar and Somali regions using the same methodology. The study has some strength that it drew together data previously held in different organizations creating strong working relationships among different stakeholders who collected data for their own purposes but shared for this study. In addition to this, the number of indicators, though tilted too much to agriculture sector, were used and data analysis unit (district) that are fairly small administrative units to address and explore aspects of vulnerability. It also

attempted national coverage, while the previous studies were more limited in the number of districts or livelihoods covered.

However, it was not exempt from some of the major weaknesses such as: the methodology used embodies a comprehensive statistical analysis being both time consuming and complex; especially so for the quintile system.

The selected indicators of 1999 were heavily biased towards agricultural areas leaving white spaces on the map for pastoral areas of Afar and Somali regions.

During the 2004 revision of the CVI, the working group attempted to reinsert largely pastoral regions of Afar and Somali into the analysis by using any available data and projecting data from bordering, largely agricultural regions, but the results were not consistent with what the group believed to be the reality on the ground; most of the time, the pastoral areas showed up as uniformly highly vulnerable, even in the case of livestock assets per capita, while the working group generally felt that pastoralists should be relatively well-off (Jericho 2008).

Another attempt made to classify vulnerability to food insecurity is Integrated Food Security Phase Classification (IPC) of FAO that was developed in 2004 by the Food Security and Nutrition Analysis Unit (FSNU) to guide short term objectives linked to medium and long term that address underlying causes and chronic food insecurity. It classifies areas with acute food insecurity into five phases with two units of classifications; area based and household group based using contributing factors and outcomes of food security to make the final call on the classification; for chronic food insecurity classify areas into four classification phases: low to very high chronically food insecure, which are still in prototype forms. Once data is collected, methodologically, IPC uses 'convergence of evidence' approach, obtaining expertise input from individuals for a given district to classify into the above categories (IPC 2012).

In 2010, IPC pilot exercise on acute food insecurity was conducted in one of the regions in Ethiopia, after repetitive workshops externally in Nairobi and internally at regional level in Ethiopia. During the analysis, it represented the views of the technical staff members from different organizations. It has the strengths that it drew together different organizations creating strong working relationships among different stakeholders and expertise. In addition to this, the number of contributing factors and outcome indicators used and data analysis unit (district) that are fairly small administrative units to address and explore aspects of vulnerability. However, major

constraints observed in the process were for example: data availability, quality and timeliness of data, which affected IPC pilot exercise. When government owns and implements the exercise, it will probably be more affected due to staff turnover in government that creates the need for continuous training; requires more money and time to address acute food crises; limited technical and financial capacity of the government at federal and regional levels; high cost in general to get views from a large group of participants. The pilot exercise was conducted at district level in only one of the regions and this creates a problem to determine food and nutrition insecure districts across the country and compare the results with other study findings.

In addition to this, due to slow implementation process of the IPC, Ethiopia currently developed hotspot area classification guideline (Hotspot Areas Classification Guideline, 2014) to identify the most acutely affected food and nutrition insecure districts using for example health, nutrition, agriculture, water, education indicators extracted from DRMFS led Multi-Agency assessment reports occurred in November and June of each year, field observations, ad hoc standard nutrition survey and Therapeutic feeding Program (TFP) admission reports. The main criteria for classifying hotspot districts is selected in order to measure the level of severity of problems and classify districts in to three major priority categories as 1st priority, 2nd priority and 3rd priority. This means that highest concern is for the 1st priority districts and the least for the 3rd, which is categorized as close monitoring. In each sector, at least three indicators should fulfill the criteria to be categorized as 1st priority, 2nd priority and 3rd priority based on the cut off points indicated for each category. The classification approach is similar to that of IPC in that it isn't based on any quantitative models but technical staffs at regional and federal levels from different organizations come together and classify each district based on the available information on quarterly bases. Once a hotspot classification is completed at regional level, it is shared to the federal DRMFS for the review and verification using different sources of information by the hotspot area classification team. After verification and approval by the federal DRMFS, the classification results are shared to government and non-government partners for monitoring, assessment, resource allocation and intervention. Since its inception in 2008, the hotspot classification exercise helped to utilize the limited resources for the most affected districts in the country.

## 2.4 Multi-Criteria Evaluation (MCE) and Standardization of Indicators

MCE is a method commonly used for spatially defined data using a GIS that facilitates setting up an analysis framework that could be regularly re-run with updated data.

It is based on the idea that humans use multiple decision criteria to determine the best solution (Rinner and Martin 2004), which is most commonly achieved by Boolean evaluation and Weighted Linear Combination (WLC). The first involves Boolean overlay whereby all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (AND) and union (OR). The second is known as WLC wherein continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average.

The result is a continuous mapping of suitability that may then be masked by one or more Boolean constraints to accommodate qualitative criteria, and finally threshold to yield a final decision (Eastman J.Ronald 2009).

As a method of data analysis, most of the studies in Ethiopia used a methodology that embodies a sequence of traditional statistical algorithms, namely principal component analysis, quintile analysis, regression analysis and convergence of evidence, which were not exempt from some of the weakness, namely the methodology used embodies traditional statistical algorithms and methods that required frequent mathematical operations (addition and division) to describe the data in abstract numerical space. However, GIS MCE approach is not only built on mathematical and absolute facts but also expertise inputs on deciding on standardization method of variables; deciding on combination method for the variables, and deciding on weights in the additive MCE approach.

Weighted linear combination (WLC) is the most used Multi Criteria Evaluation (MCE) method, also known as simple additive weighting, is based on the concepts of a weighted average in which continuous indicators are standardized to a common numeric range; in this study the range is (0, 1). Once the indicators are standardized, a decision maker combines them by means of weighted average assigning weights of relative importance to each indicator. However, there are different techniques in WLC to develop quantified values for the weights. Among

these techniques, four possible techniques, namely trade-off analysis, ranking, rating and pairwise comparison and are the most used ones in WLC for MCE (Chou 2013; Malczewski 1999; Drobine and Lisec 2009). All these techniques are based on expert knowledge about the criteria and their importance for the problem to be evaluated. The processes of developing weights are therefore preferably done in groups of experts from different fields.

Trade – off analysis: It is less conventional than a Boolean overlay operation, such as union (OR) and intersection (AND) and allows for trade-off in the data and makes use of direct trade-off assessments between pairs of options. With WLC, indicators are permitted to trade off their qualities unlike the Boolean evaluation, which is absolute in nature. This operator doesn't represent either an "AND" or an "OR" and lies somewhere in between these extremes. In this case, indicators with high suitability can be compensated for other indicators with low suitability in a given location unlike Boolean overlay operations. It is neither risk averse nor risk taking. It is one of the most used decision models in GIS for deriving composite maps (Eastman J.Ronald 2009).

Ranking: in a weighted linear combination of ranking technique for MCE every indicator in the study is ranked in the order of preferences. For example, if we have three indicators: we rank them 1, 2, and 3 where 1 is the least important while 3 is the most important. Then the ranking is converted into numerical weights on a scale from 0 to 1, so that they sum up to 1.

Rating usually requires the estimation of weights on the basis of predetermined scale. For example, if there are three indicators, we rate the indicators using percentile – indicator 1 with the lowest percentage as the least important and indicator 3 – with the highest percentage as the most important.

Analytical Hierarchy Process (AHP) is one of the WLC approaches that require data that are easy to obtain derived by using a set of pair wise comparisons, which are used to obtain relative weights of importance of the decision criteria. A matrix is created, where each indicator is compared with the other indicator, relative to its importance, on scale from 1 to 9 where 1 is equal preference between two factors while 9 is where a particular indicator is extremely favored over the other. Then a weight estimate is calculated and used to derive a consistency ration (CR) of the pairwise comparisons. If CR is greater than 0.10, then some pairwise values need to be reconsidered and the process is repeated until the desired value of CR is less

than 0.10 is reached. Like in ranking and rating, AHP weights are also expressed in numerical weights that sum up to 1. However, it has some problems such as when the levels of hierarchy increases, the time it takes increases to produce weights. Another problem with AHP is that whenever indicator is added or deleted from the initial set of indicators, it requires changes in the ratings (Saaty 1980; Bodin and Gass 2004; Coyle 2004).

One of its advantages of WLC method is the ability to give different relative weights to each of the indicators by aggregation because one indicator is more important than another. This relative importance among indicators is usually expressed in terms of numbers, often called weights, which are assigned to different indicators. These weights deeply influence the final choice and may lead to a non-applicable decision mainly when the interpretations of such weights are misunderstood by the decision maker (Chakhar and Mousseau 2010). This procedure is not unfamiliar in GIS and has a form very similar to the nature of regression equation (Eastman J.Ronald 1999).

Once data on indicators is collected standardizing to the same scale is the most important activity before data analysis. Linear Scale Transformation (LST) is the most frequently used deterministic method to transform input data into commensurate factor layers (Derya 2011). Different procedures for standardization were discussed by Vooged (1983) using the minimum and maximum values as scaling points. Standardized scores used in this study range from 0 to 1 (Malczewski 1999). However, it has limitations in the use of WLC method as indicated by Jiang and Eastman (2000) in a decision making process. That is a decision risk due to different aggregation methods in decision making, which may be considered to be the likelihood that the decision may be wrong. They have suggested that this limitation would be solved through the application of fuzzy measures and considering decision making as a set problem in MCE.

### 3. Materials and Methods

This chapter includes summary points of the study area, data sets utilized, statistical analysis of indicators using correlation matrix and application of MCE method & GIS in chronic food and nutrition insecurity analysis.

#### 3.1 Study Area

Ethiopia is an ancient country located in the east Africa, or as it is generally known, the Horn of Africa and is bounded by Sudan in the west and north-west, Kenya in the south, Somalia in the south-east, Djibouti in the east and Eritrea in the north and north-east. It is located between 3° and 15°N latitude and 33° and 48°E longitude that covers a land surface area about 1130000 km<sup>2</sup> (Zewde 1991). South Sudan officially declared its independence from Sudan in 2011 (Dagne 2011) and is now bordering Ethiopia in the southeast.

In terms of population size and total area, Ethiopia is the second largest country in Africa with diversified culture, linguistic and large ethnic compositions, with an estimated population of nearly 77.1 million (Zekaria 2008). It is a predominantly rural and young society, with 84 percent living mainly in densely populated highlands settlements. While the urban population is growing at around 4 percent per year, the rural population is still growing at around 2.3 percent. The proportion of the population under age 15 is 45 percent, with only 3.2 percent above age 65 (Ringheim et al. 2009).

The country's economy is highly dependent on the Agricultural sector. Agriculture in Ethiopia accounts for 42% of Gross Domestic Product (GDP), employing 84% of the population and generating more than 90% of export revenues. However, it is also the most volatile sector, relying heavily on rainfall, archaic farming techniques, and proving sensitive to seasonal shocks. Due to these factors, agriculture remains largely subsistence farming, which coupled with recurrent droughts, low levels of soil fertility, rapid population growth and limited off farm employment activities, have contributed to decreasing rates of per capita agricultural productivity (Mussa 2010). Moreover, rapid population growth resulted in widespread forest clearing for cultivation, over grazing, and misuse of forests for fuel wood and construction materials without replanting has reduced the forest area of the country to 16% in the 1950s and to 3.1% by 1982 (Bishaw 2001). Further estimates of the

distribution of forest and woodland areas, made on the basis of information from LANDSAT imagery (1979) revealed that only 2.8% of the land surface is under forest and woodland. However, at present, accessible high forest areas are threatened by development projects, including coffee and tea cash cropping, human resettlement, grazing and logging operations (MoA 1991).

To create food security stability in the country, implementation of a more comprehensive approach to these critical issues began in 2005 under its food security program and since 2007; Ethiopia has achieved significant economic growth, however, with this significant economic growth, about 29 percent of the population lives below the national poverty line. In addition to this, Ethiopia ranks 174th out of 187 countries on the United Nations Development Programme's human development index, and average per capita incomes are less than half the current sub-Saharan average (IFAD 2012). Moreover, "despite a fast-growing economy, Ethiopia remains one of the poorest countries in the world. It experiences high levels of both chronic and acute food insecurity, particularly among rural populations and smallholder farmers" (USAID 2014).

The poorest sub-sector of rural households are chronically reliant on social safety net programs and food aid and most rural households live on a per capita income of less than USD 0.50 per day. They are finding it difficult to survive without resource to seasonal or permanent urban migration in search of wage employment, food aid and support from social safety net programs (Chanyalew et al. 2010); besides, 84 percent of the population lives in rural areas (Ringheim et al. 2009).

For this study, 665 rural districts from 10 regions across the country (Figure 2) were selected. Because poor food and nutrition insecure are mostly concentrated in rural areas. Only regions and international labels are depicted on the map but district labels are removed due to overcrowded labels on the map. In addition to the regional and district level map; a detailed study area map depicting the Digital Elevation Model (DEM), roads, lakes and rain gage stations was shown in Figure 3.

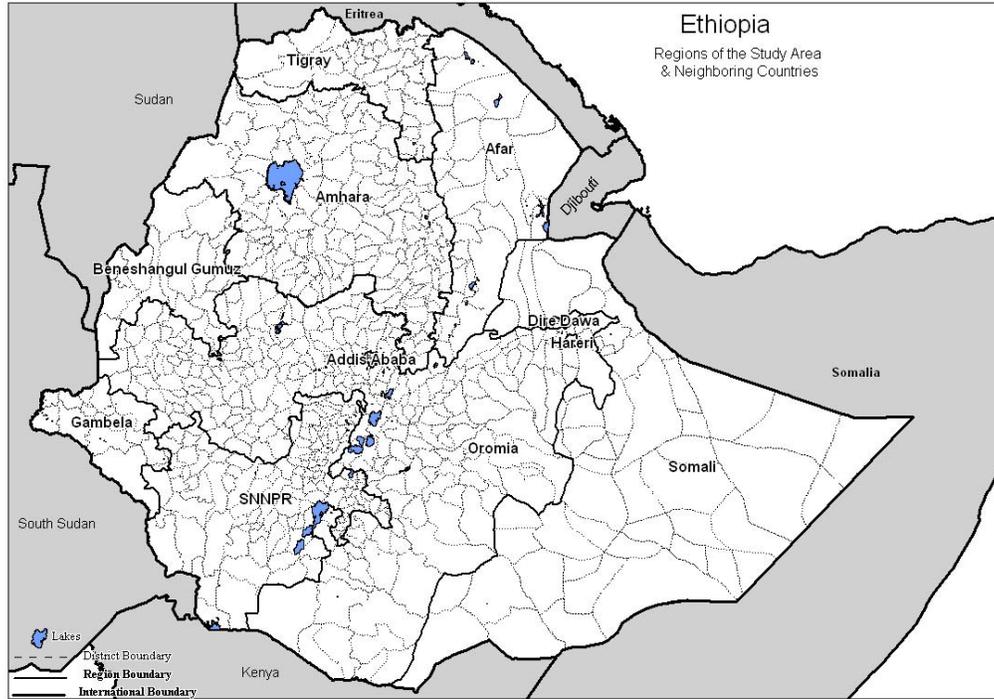


Figure 2. Map of Ethiopia showing regional and district boundaries of Ethiopia.

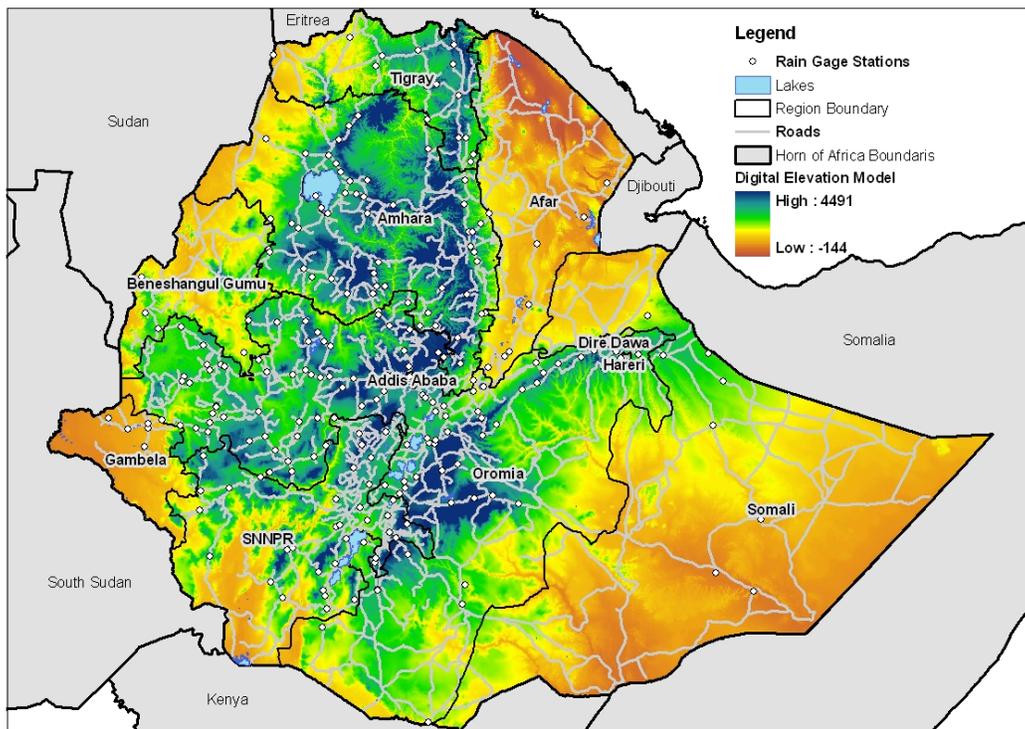


Figure 3. Map of Ethiopia showing the DEM, roads and rain gage stations

## 3.2 Data sets

This section illustrates the data sources used for each indicator in this study: rainfall variability, population density, accessibility to towns, safe drinking water, toilet facilities, female literacy, reference of acute emergencies, stunting of under-five children illustrating the methodologies used to create maps for each indicator. In addition to the indicators, map layers such as regions, districts, lakes, towns and international boundaries were used as indicated in Appendix B, Table B3.

**Rainfall Variability:** is one of the contributing indicators of food insecurity identified under food availability. To look at districts affected by the rainfall variability, 30 years rainfall data during 1983 – 2012, sourced from the Ethiopian National Meteorological Services Agency (NMSA) were used. The data were collected from 250 weather stations across the country. Station-based datasets are direct measures of rainfall at a given location and are accurate to be used in this analysis; however, as new stations are added from time to time, data coverage periods varied from 5 - 30 years.

The Variability of 30 years rainfall was assessed using the Coefficient of Variation (CV):

$$CV = \left( \frac{\text{Standard Deviation of Rainfall}}{\text{Average Annual Rainfall}} \right) * 100$$

First CV values were calculated at each rain gauge stations based on the 30 years (1983 – 2012) of rainfall data and after that rainfall variability map on all years of rainfall was prepared using the Kriging interpolation method “that is an advanced geo-statistical procedure that generates an estimated surface from a scattered set of points with z-values” (Schmidt et al. 2011).

NOAA satellite data estimates (2000 – 2014) from LEAP 3.0.2 software is used to validate and support the rain gauge station data. Data were extracted at district level and exported to Microsoft Excel. In Excel CV was calculated at district level and imported to the ArcGIS for thematic mapping and to validate the rain gauge station map. LEAP (Livelihood, Early Assessment and Protection) is the Government of Ethiopia owned food security and early warning tool, which is embedded in the national risk management framework (for information see <http://www.dppc.gov.et/Pages/leap.html>).

Kriging is geo-statistical interpolation technique used to study the spatial autocorrelation through a semivariogram. Like other spatial interpolations, it assumes both the distance and the degree of variation between known points when estimating values in unknown areas. As indicated by Schmidt et al. (2011), Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogram modeling, creating the surface, and exploring a variance surface. It has been said that kriging uses the data twice: the first time to estimate the spatial autocorrelation of the data and the second to make the predictions.

Kriging Ordinary method is theoretically sound as well as widely applied technique for the rainfall data analysis over any other method followed by Inverse Distance Weighting (IDW) and Kriging Universal (Mahalingam et al. 2015). Similarly, Ly et al. (2011) have indicated that Kriging Ordinary method was considered to be the best and most robust method since it provided lowest Root Mean Squared Error (RMSE) value for nearly all geo-statistical methods. Based on these findings, semivariogram spherical model in ordinary kriging was used in this study.

Topography may have influence on rainfall variability; however, this study has not taken into consideration the influence by the topography.

The CV values were converted to raster and standardized to range (0, 1) using linear scales transformation.

**Population Density:** Another food and nutrition insecurity contributing indicator identified under food availability is population density.

$$\text{Population Density} = \frac{\text{Population}}{\text{District Area in Sq Kms}}$$

The population projection figures in this study are based on the results of CSA 2007. CSA has done projections for each of the regions based on the component method that assumes reliable data of demographic changes, fertility, mortality, deaths and migration as main inputs of the projection adjusting the inputs to the base year. Even though data reliability problems exist, this is the most widely used tool by planners since it provides information on the potential growth or decline of population.

The component estimation method used by the CSA as indicated by Adugna (2014) is expressed by:

$$P_t = P_0 + B - D + I - E$$

Where  $P_t$  = current population

$P_0$  = Base population  
 B = Births  
 D = Deaths  
 I = in-migration  
 E = emigration (or out-migration)

CSA used computer software for the projections to obtain regional and city administrative population projection values. Finally CSA used ratio method that is applied to project the population of small areas; zonal and districts by urban and rural residence and by sex, too were produced.

The projected population figures for 665 rural districts in 10 regions (Tigray, Afar, Amhara, Oromia, Somali, Beneshangul-Gumuz, SNNP, Gambella, Harari and Dire Dawa) were used in this study to identify the most food and nutrition insecure districts. This data together with district polygons received from the CSA were used to create a map of population density at district level.

The population density values were converted to raster and standardized to range (0, 1) using LST.

To achieve a composite food availability map using the following formula,

$$\text{Food Availability} = (0.5 * \text{PopDens}(LST)) + (0.5 * CV(LST))$$

Used as indicated in data analysis flow model in Appendix A, Figure A1.

**Accessibility to Towns:** accessibility to towns is an indicator to food and nutrition insecurity identified under food accessibility. In this regard, the town accessibility model takes different indicators into account to determine the travel time, namely the road network, the slope, the towns, and the lakes.

Slope was extracted from DEM GTOPO30 with a spatial resolution of 1 km, which was downloaded from United States Geological Survey (USGS); primary, secondary, tracks roads and water bodies received from CSA were converted from feature to raster and reclassified into their new values while no data values to 0. The raster which were combined are water bodies, slopes classified into 4 classes and reclassified track roads using estimation of speed depending on slope for different road classes used by Ahlström (2008) (see Appendix B, Table B1). Reclassified primary and secondary roads were used the speed limits in km/h from Pozzi and Robinson (2008). Their study covers east African countries including Ethiopia.

The raster is reclassified into cost (time) values using Appendix B, Table B1. First, time was allocated to each cell depending on slope, road class, water, etc. and then extracted the MAX value to produce the maximum cost to traverse each cell. Speed is distance travelled by a car divided by the time it took the car to travel that distance expressed as;

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

As indicated in Appendix B, Table B1, the cost values assigned to each cell are per unit of distance measured for the cell. That is, if the cell size is expressed in meters, the cost assigned to the cell is the cost necessary to travel one meter within the cell.

A cost distance function calculates the least costly path, in this case the quickest, to reach a destination traveling across a raster friction surface. A cost path consists of sequentially connected links that provide the route connecting each cell location to a destination or target. The cost-distance from any cell to a target is the cumulative cost of all links along the cost path. While there are many possible paths to reach each target cell, there is only one least cost path. The least cost path is calculated for each cell in the analysis window to the target that will be the least costly to reach, based on an iterative allocation (ESRI 2004).

The town accessibility vector layers were converted to raster and standardized to range (0, 1) using LST. To achieve a final result, detailed data analysis flow model is indicated in Appendix A, Figure A2.

**Adult Female Literacy:** is a contributing indicator to food and nutrition insecurity identified under food utilization.

$$\text{Adult Female Literacy} = \left( \frac{\text{Rural Adult Female Literacy}}{\text{All Females Above 15 Years Age Group}} \right) \times 100$$

Data source for adult female literacy is CSA (2007). Later this data was converted to adult female illiteracy, i.e., 100 – percentage literacy to match the data sequence with other indicators included in the study; data represented in the increasing order and the highest values indicating critical situation. The percentage of adult female illiteracy values were converted to raster and standardized to range (0, 1) using LST.

**Unsafe Drinking Water:** is another contributing indicator to food and nutrition insecurity identified under food utilization. Data source for unsafe drinking water is CSA (2007).

$$\text{Unsafe Drinking Water} = \left( \frac{\text{Housing Units with Unsafe Drinking Water}}{\text{All Rural Housing Units}} \right) \times 100$$

Access to improved water data received from those reported their main source of household drinking water to be either a “tap” or a “protected well”. A tap water includes: tap inside the house; tap in compound, private; tap in compound, shared; tap outside compound and protected well or spring. Unsafe drinking water includes unprotected well or spring and river/lake/pond. Parentage of unsafe drinking water represented in the increasing order and the highest values indicating critical situation. The percentage of unsafe drinking water were converted to raster and standardized to range (0, 1) using LST.

**Toilet Facilities:** is one of a contributing indicator of food and nutrition insecurity identified under food utilization. Data source for unsafe drinking water is CSA (2007).

$$\text{Housing Units with Toilet Facility} = \left( \frac{\text{Housing Units with Toilet Facility}}{\text{All Rural Housing Units}} \right) \times 100$$

To match the data sequence with other indicators access to no toilet facilities was calculated using 100 – parentage of toilet facilities while data represented in the increasing order and the highest values indicating critical situation. The percentage of no toilet facilities were converted to raster and standardized to range (0, 1) using LST. Finally, the three contributing indicators of food utilization, i.e., female illiteracy, unsafe drinking water and no toilet facilities, were analyzed using MCE method with almost equal weights, 0.34, 0.33 and 0.33 respectively to produce a composite food utilization map. To achieve a final result, detailed data analysis flow model is indicated in Appendix A, Figure A3.

**Food Stability: Reference of Acute Emergency** is a short term or transitory food deficit due to drought, flooding, conflict, etc. To identify temporary food deficit,

multi-agency national needs assessment team led by DRMFS conducts assessments twice a year following the major production seasons (Meher and Belg). The needs assessment team visits different regions, based on the early warning information, and uses a significant amount of data at district level and well-practiced methods that allows detailed comparisons among affected districts that help estimating relief food needy population.

Once relief food assisted districts and population were identified, using multi-agency team report and other relevant indicators from health and nutrition, agriculture, market, WASH, education, sectors, Ethiopia conducts hotspot district classification analysis quarterly every year as indicted in the Hotspot Woredas Classification Guideline (2014).

The hotspot districts classification conducted 14 times from June 2008 – September 2013 and each district was classified into three classes; 1- first priority, 2- second priority and 3 - third priority. Frequency values of priority one, two and three were added in separate columns. In each column, frequency of priority one was multiplied by 3, priority two by two and priority three by one where three, two and one are weights. The frequency values were added up and ranked to get very severe, severe and moderate acute food insecure districts using 14 as a class interval and three as a number of classes. The feature values were converted to raster and standardized to range (0, 1) using LST. To achieve a final result, detailed data analysis flow model is indicated in Appendix A, Figure A4.

**Chronic food and nutrition insecurity:** The chronic food and nutrition insecurity represents a weighted aggregation of indicators in this study: rainfall CV, population density, access to towns, unsafe drinking water, female adult illiteracy rate, toilet facilities and acute food insecurity that contribute to food and nutrition insecurity. In order to identify the chronic food insecurity areas, a GIS MCE with WLC was used. The indicators were scaled to (0, 1) using LST before weighted aggregation. Finally the four dimensions of food security were assigned equal weights (0.25 respectively), making the sum of the weights equal to one. To achieve a final result, detailed data analysis flow model is indicated in Appendix A, Figure A5.

**Under-five Children Stunting:** As indicated in the literature review, under-five children stunting is an outcome indicator. Percentage of stunting (height-for-age less

than -2 standard deviations of the World Health Organization (WHO) Child Growth Standards median) among children aged 0-5 years, indicator for long-term nutritional deprivation. Stunting is an outcome indicator taken from CSA's DHS (2011) and summarized at cluster level across the country. 2011 DHS sample was selected from census enumeration areas (EAs) from 2007 census in which each kebele, smallest administrative unit, was subdivided. Each kebele was subdivided into census EAs, which were convenient for the implementation of the census. The 2011 DHS sample was selected using a stratified, two-stage cluster design and EAs were the sampling units for the first stage. The sample included 624 and 437 EAs in urban and rural areas respectively of which a representative sample was selected for the 2011 DHS (EDRM 2011; CSA and ICF 2012).

Afar and Somali regions have very few clusters to make relevant conclusion on stunting of children. 650 clusters were used to validate chronic food and nutrition insecurity at districts level. The clusters of stunted and non-stunted children were overlaid on food availability, access, utilization and chronic food nutrition insecurity maps to look at the relationship among stunted clusters and food and nutrition insecure districts.

### **3.3 Correlation Matrix:**

A correlation matrix is used to examine the relationship between the four food security dimensions (food availability, food access, food utilization and food stability (acute food insecurity), and stunting of children under age five. The initial data analysis indicated that stunting and food utilization data were negatively skewed while food access and food availability data were positively skewed. Log transformation in SPSS was used to transform both negatively and positively skewed data. After data transformation, both graphical and statistical methods were used to evaluate normality while scatter plots to evaluate linearity. The graphical methods used to evaluate normality were histograms and Q-Q plots observation while the statistical method includes skewness & kurtosis test (Gaskin 2011); if the absolute value of the statistic value is less than  $3 * \text{Std. Error}$  then there are no skewness or kurtosis problems in the data. If  $(p > 0.05)$  in Shapiro-Wilk test (Shapiro and Wilk 1965) then data are normally distributed. To get an idea about the measure of the direction of the relationship between stunting and food security dimensions indicators, scatter plots were created. In the correlation matrix, the direction and correlation

coefficients between the indicators, the "p" values that tell us whether the correlation right above it is statistically significant or not, and the sample value are indicated.

### 3.4 MCE method and GIS in chronic food and nutrition insecurity analysis

As a method of data analysis, most of the studies in Ethiopia used a methodology that embodies a sequence of traditional statistical algorithms, namely principal component analysis, quintile analysis, regression analysis and convergence of evidence, which were not exempt from some of the weakness, namely the methodology used embodies traditional statistical algorithms and methods that required frequent mathematical operations (addition and division) to describe the data in abstract numerical space. However, GIS MCE method is not only built on mathematical and absolute facts but also expertise inputs on deciding on standardization method of variables; deciding on combination method for the variables, and deciding on weights in the additive MCE approach.

In this analysis, GIS Multi-Criteria Evaluation (MCE) and WLC technique used to combine contributing and outcome indicators to produce chronic food and nutrition insecurity map in Spatial Analyst of ArcGIS.

MCE is based on the concept of a weighted average in which continuous indicators are standardized or rescaled to new ranges of data using simple linear function on quantitative information. With a chosen method of standardization, the quantitative scale can be used in the weighted summation of indicators.

Even though there are some subjectivity in the indicators weighting, it is one of the most used decision making models in GIS and hence, in this study, weighted linear combination of multi-criteria evaluation is used to combine standardized indicators applying equal weights to each followed by a summation of the results to produce food and nutrition insecurity map at district level across the country. That is

$$S = \sum W_i X_i, i = 1 \dots n$$

Where S = the food and nutrition insecurity score.

$W_i$  = weight factor  $i$

$X_i$  = criterion score of factor  $i$

### 3.4.1 Standardization of Indicator Values

Indicators were measured in different scales (percent, hours, numbers, etc...), so it is necessary to standardize them before combination. Once standardized, the indicator maps are positively correlated with suitability. As indicated by Vooged (1983), most often used procedure is score range equation as shown below.

$$X_i = \frac{R_i - R_{\min}}{(R_{\max} - R_{\min}) * SR}$$

Where  $R_i$  is the raw score of factor  $i$ ,  $R_{\min}$  is the minimum score,  $R_{\max}$  is the maximum score, and  $SR$  is the standardized range. Standardized scores range from 0 to 1 (Malczewski 1999).

In order to create chronic food and nutrition insecurity surface, a two stage MCE will be used. In the first stage, contributing factors from food availability and food utilization will be analyzed separately using equal weight on contributing indicators in each category. In the second stage food availability, food access, food utilization and stability indicators weighted equally with 0.25 weights each to create a final chronic food insecurity map making the sum of weights equals to one. Equal weights were used because of lack of standardized weights in previous studies that indicate varied weighting approach. Nutrition status – stunting data have been undertaken to validate the evidence of chronic food insecure districts in relation to food availability, food access, food utilization and stability maps as well as a chronic food insecurity map using both stunting and PSNP data.

The data were entered using Microsoft Excel and Microsoft Access and rechecked for accuracy to minimize errors. Data were exported to GIS software, MapInfo and ArcGIS, used for database design, reading attribute information, metadata, visualization and GIS analysis. Smart Draw CI Trial version was used to show flow of data analysis. Vector and raster layers such as admin boundary polygons, roads, slope, and location data were set in projected coordinate system World Geodetic System 1984 (WGS 84) and Universal Transverse Mercator (UTM) zone 37N.prj.

### 3.4.2 Flow of Data Analysis

Details of techniques and tools used to analyze different food insecurity factors were shown in Appendix A, Figure A1 – A5 using Smart Draw CI. Figure A1 shows model used to create composite food availability dimension map; Figure A2 model for food

accessibility dimension; Figure A3 model for composite food utilization dimension, Figure A4 model for food stability dimension and A5 shows model for chronic food and nutrition insecurity.



## 4. Results

Data and GIS analysis results are presented in this chapter. The results are presented in the order of food availability, food access, food utilization, acute food insecurity and chronic food and nutrition insecurity. Due to lack of standardized weights in previous studies that indicate varied weighting approach, instead equal weights were used on individual indicators of food security dimensions as well as on four food security dimensions. Indicators identified in each food security dimensions are scaled to (0, 1) ranges to create dimension level maps and the final composite chronic food and nutrition insecurity map. Under nutrition at cluster level was overlaid on each of the food security dimensions to look at in which food security dimensions children are the most affected. Similarly, PSNP benefiting districts were overlaid on chronic food and nutrition insecurity map to identify districts, which are excluded or included from the program. The spatial analysis results of four food security dimensions (food availability, food access, food utilization and acute food insecurity) and stunting using GIS MCE and correlation analysis results are presented acknowledging limitation of data and lack of standardized thresholds.

In addition to this, the results are presented as map based information and from the statistical correlation evaluation that can guide decision making to find where the vulnerable to food and nutrition insecure are located, the level of severity of food and nutrition insecurity and food security dimensions that are related with stunting.

### 4.1 Composite Food Availability Dimension and Stunting

The two factors considered under food availability are rainfall Coefficient of Variation (CV) and population density. Variability of 30 years rainfall from NMSA (1983 – 2012) was assessed using CV. The initial analysis results indicated that CV ranges from 21 percent – 62 percent across the country, which later converted to standardized scores ranging from 0 to 1 using LST to create composite food availability map.

As indicated in Appendix D, Figure D1, the mean annual rainfall decreased rapidly in the years 1985, 1991, 2002, 2009 and 2011. This helps to look at graphic representation of annual rainfall variability and indicates that it has big similarity compared to the four El Niño events that occurred in 1985, 1991, 2002 and 2009,

which were related with the intense and/or extended drought conditions during the main Meher cropping season in which unfavorable crop-growing conditions occurred. In the rainfall variability map (Figure 4), the lowest values depict relatively lowest rainfall coefficient of variation districts while the highest values depict highest rainfall coefficient of variation districts.

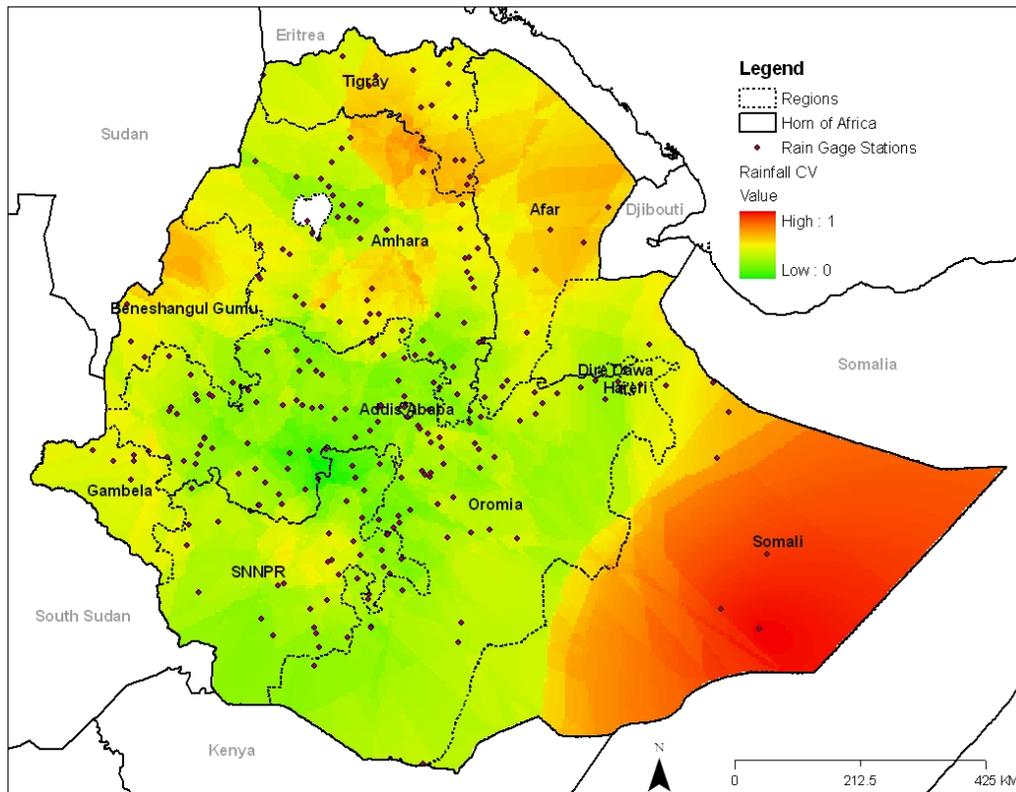


Figure 4. Map of Ethiopia Showing the CV of Rainfall

Population density is another contributing indicator to food availability status of districts. The data source is CSA (2007) and it's valid until another census takes place in 2017, i.e., in 10 years time. The analysis results indicated that population density varies from 0 to 1022 persons per km<sup>2</sup>. Northern and north eastern SNNPR scored beyond 600 persons per km<sup>2</sup> indicating highest demand for food. The population figures later converted to standardized scores that range from 0 to 1 using LST.

Population density map (Figure 5) stretched from the lowest to the highest values using ArcGIS Spatial Analyst. The lowest values depict relatively sparsely populated districts while the highest values depict densely populated districts.

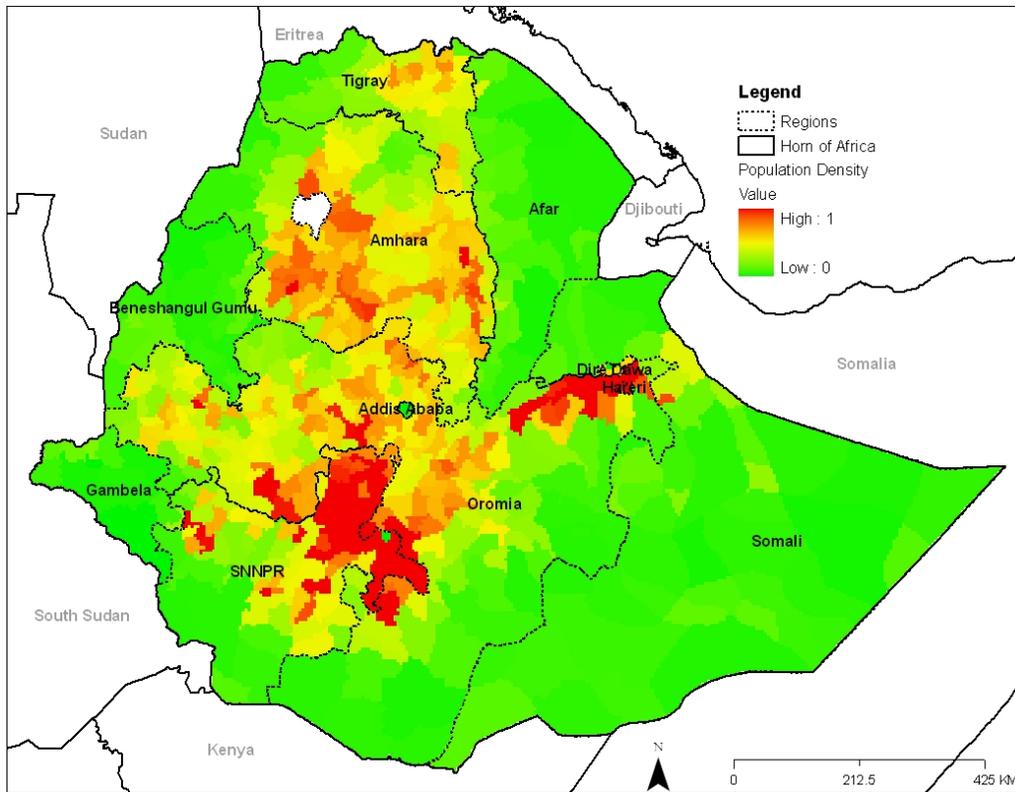


Figure 5. Map of Ethiopia Showing Population Density

The two contributing factors: CV and population density indicators were measured in different scales (percent and population per sq km<sup>2</sup>). So, it is necessary to standardize them before creating combined food availability map. Standardized score or a Z-score allows calculating the probability of a score occurring within a normal distribution and enables to compare and combine the CV and population density scores.

Rainfall variability and population density, were weighted 0.5 respectively making the sum of weights equals to one. The two factors were considered equally important because there were no prior studies which indicated varied weighting approach. In the composite food availability map (Figure 6), the lowest values depict better off food available districts while the highest values depict food in available districts.

Stunting data was overlaid to look at the relationship between composite food availability and clusters with under nutrition.

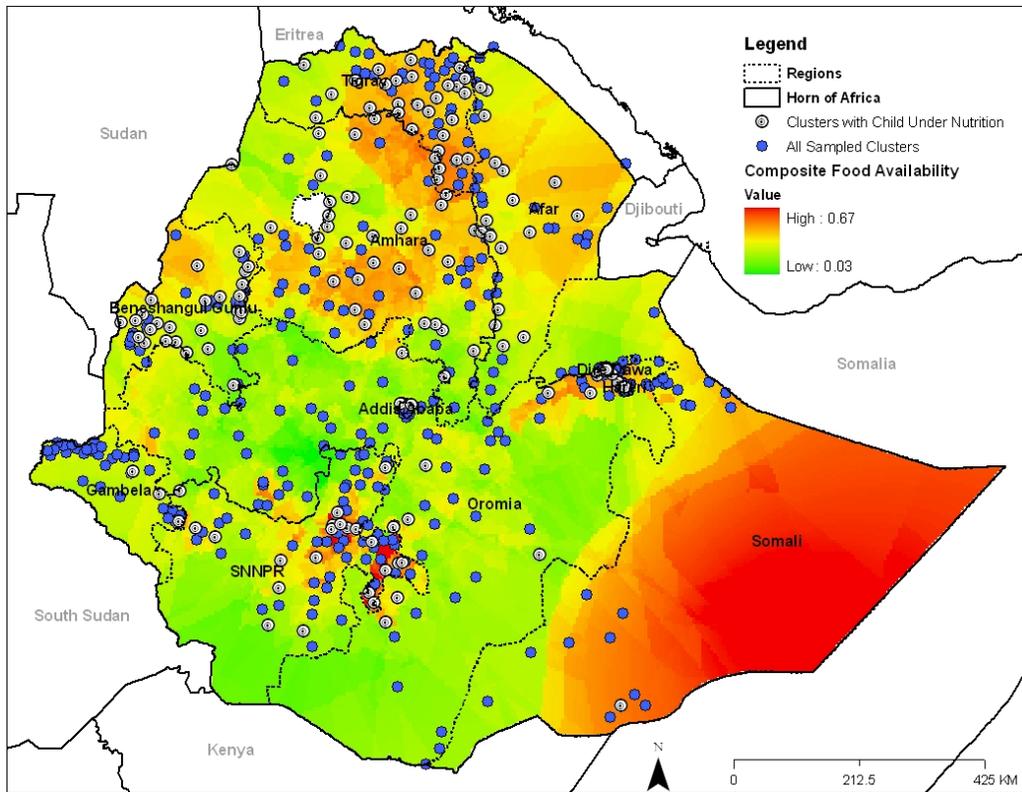


Figure 6. Map of Ethiopia Showing Composite Food Availability and Stunting

## 4.2 Food Accessibility Dimension and Stunting

Another contributing indicator to food insecurity is accessibility to towns. The two data sources for accessibility map were GTOPO30 DEM (2006) and map layers; regions, districts, lakes, roads and towns, which were from CSA (2007) and are valid until another census takes place in 2017.

The analysis results indicated that accessibility to towns varies from 0 to 63.3 hours, which later converted to standardized scores ranging from 0 to 1 using LST. The food accessibility standardized values used later to create chronic food and nutrition insecurity map combining with other standardized indicators scores. In food accessibility map (Figure 7), the lowest values in green depict better off accessible districts while the highest values in red depict inaccessible districts.

Stunting data was overlaid to look at the relationship between food accessibility and clusters with under nutrition.

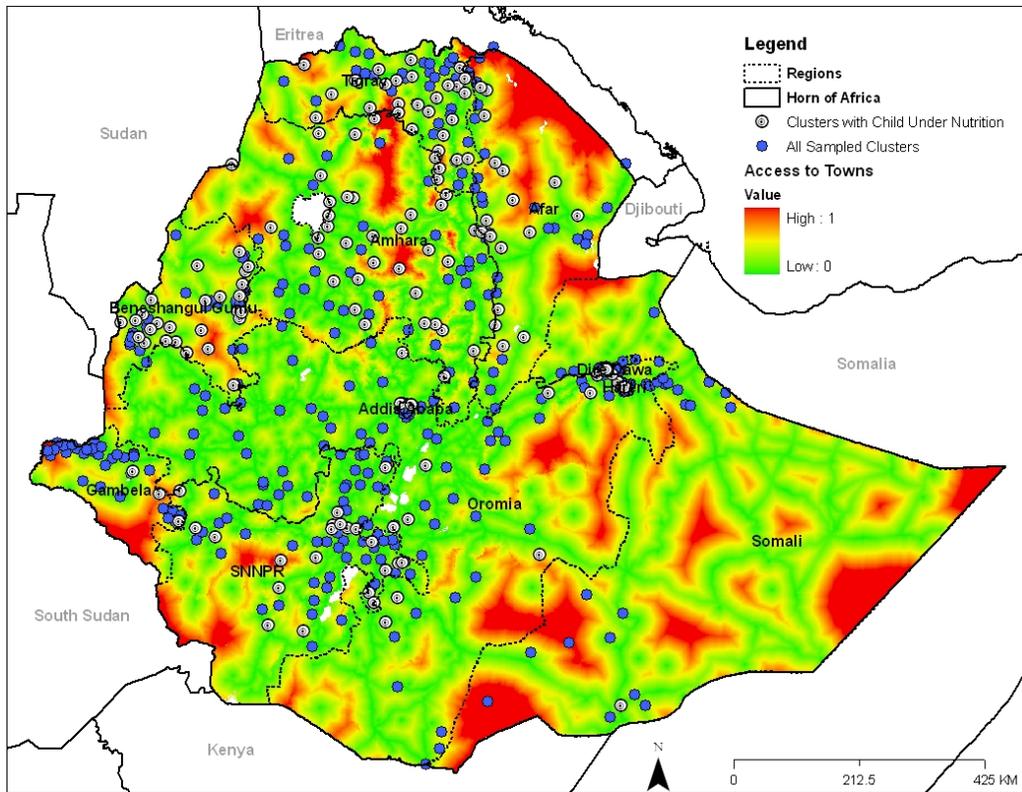


Figure 7. Map of Ethiopia Showing Accessibility to Towns and Stunting

### 4.3 Composite Food Utilization Dimension and Stunting

The three indicators used to explain composite food utilization were female adult illiteracy rate, unsafe drinking water and no-toilet facility. CSA (2011) analytical report at country level indicated that adult illiteracy rate for the population of 15 years and above is 61 percent. The illiteracy rate is far higher for women (71.1%), which is twenty percentages higher than that of men (50.9%). Based on data from CSA (2007), which is valid until 2017, the initial analysis results indicated that female illiteracy rate varies from 46.8 percent to 100 percent, which later converted to standardized scores ranging from 0 to 1 using LST. In female adult illiteracy map (Figure 8), the lowest values depict better off female adult literacy rate districts while the highest values in red depict worst female adult literacy rate districts.

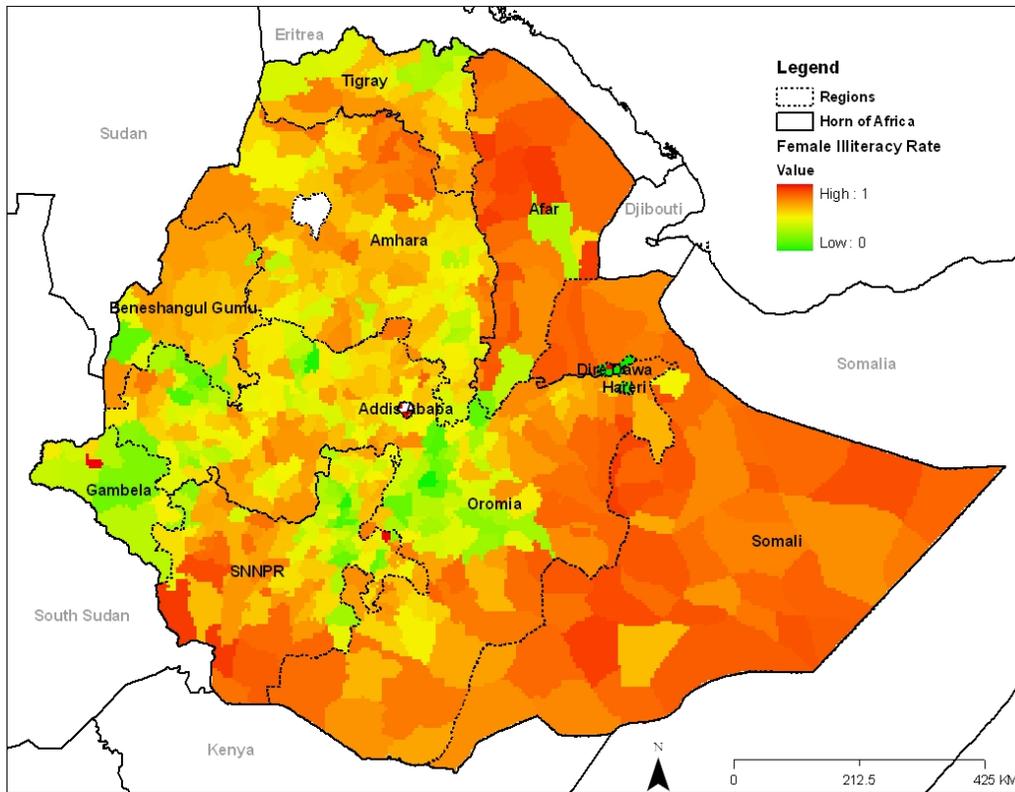


Figure 8. Map of Ethiopia Showing Adult Female Illiteracy Rates

Another indicator of food utilization to food and nutrition insecurity is unsafe drinking water.

CSA (2011) analytical report at country level indicated that about 54.5 percent of the housing units were using unsafe drinking water supply as the main source of drinking water of which 65.5 percent are rural housing units. This implies that 65.5 percent of housing units in the rural Ethiopia were using unprotected source of drinking water supply, which may expose many people for series health problems. Somali region occupies the highest position (73.7 percent) followed by Afar region (about 68.3 percent) in terms of housing units access to unsafe drinking water supply. The analysis results from CSA (2007) data, which is valid until 2017, indicated that unsafe drinking water district vary from 14.8 percent to 100 percent. This later converted to standardized scores ranging from 0 to 1 using LST. In female adult illiteracy map (Figure 9), the lowest values depict districts that were better off unsafe drinking water while the highest values in red depict worst unsafe drinking water districts.

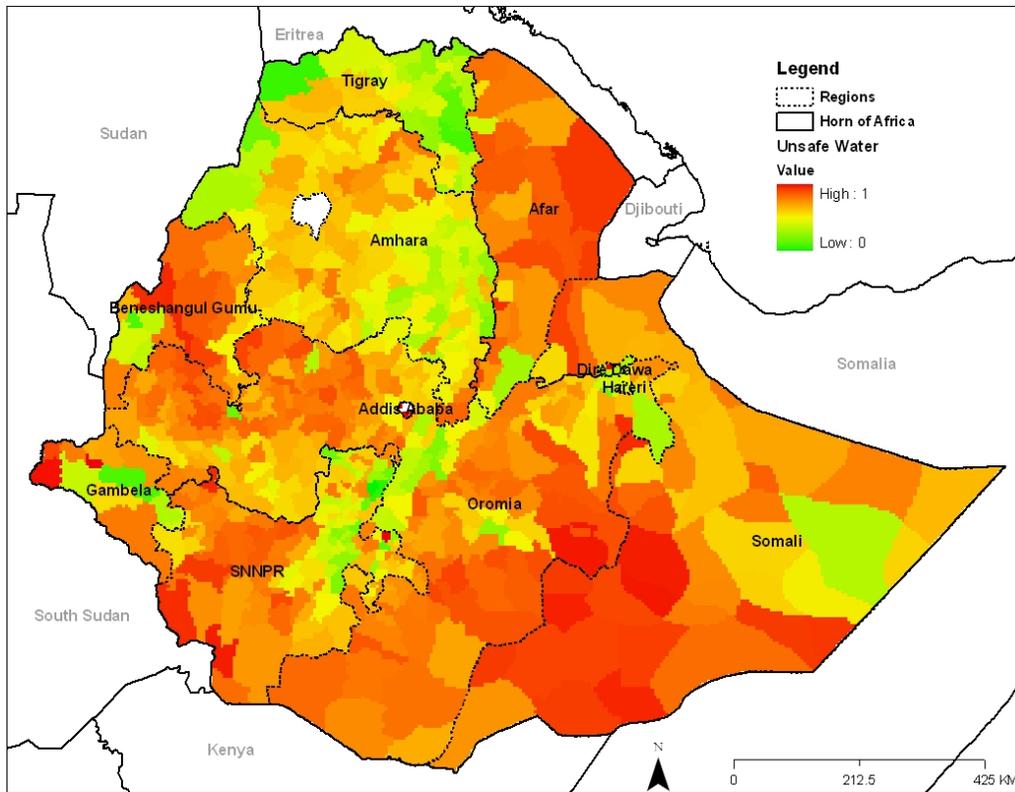


Figure 9. Map of Ethiopia Showing Unsafe Drinking Water Supply

Along with the provision of safe drinking water supply, efficient management of human waste is one of the measurements of environmental sanitation. CSA (2011) report indicated that the majority of the housing units (about 66.7 percent) in Ethiopia had no toilet facility of which 75.8 percent are rural housing units. Afar region occupies the highest position (90.7 percent) followed by Somali region (about 88.8 percent) in terms of access to no toilet facilities. The results of CSA (2007) data, which is valid until 2017 indicated that no toilet facilities district varies from 17.4 percent to 100 percent. The values later converted to standardize scores ranging from 0 to 1 using LST. The lowest values (Figure 10) depict better off toilet facility districts while the highest values in red depict worst toilet facility districts.

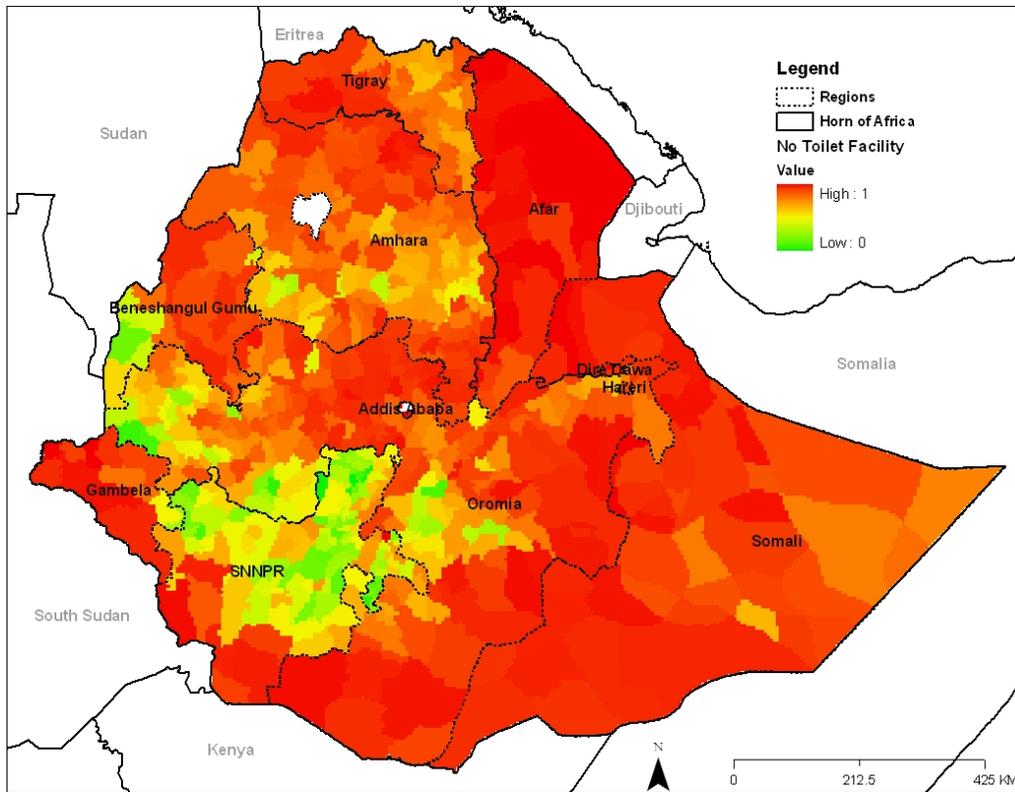


Figure 10. Map of Ethiopia Showing Housing Units with no Toilet Facilities

The three contributing indicators in composite food utilization were female adult illiteracy, unsafe drinking water and no toilet facilities measured in percentage scale and standardized before creating combined composite food utilization map (Figure 11). Standardized score (0, 1) allows calculating the probability of a score occurring within a normal distribution and enables to compare and combine the three indicators. Finally, the three contributing indicators were analyzed using MCE method with almost equal weights, 0.34, 0.33 and 0.33 respectively making the sum of weights equals to one to produce a composite food utilization map (Figure 11). In the map, the lowest values depict better off food utilization districts while the highest values in red depict the worst food utilization districts.

Stunting data was overlaid to look at the relationship between composite food utilization and clusters with under nutrition.

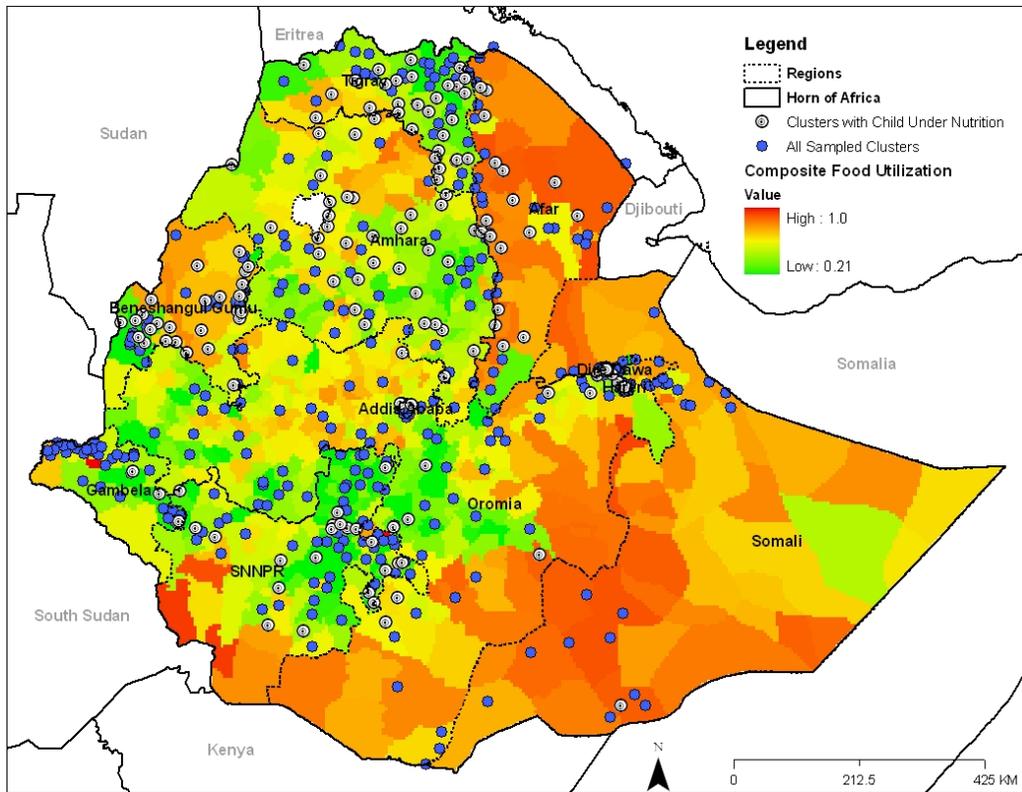


Figure 11. Map of Ethiopia Showing Composite Food Utilization and Stunting

#### 4.4 Food Stability Dimension and Stunting

Acute food insecurity is an indicator in the fourth dimension (food stability) of food and nutrition insecurity. To evaluate acute food insecurity, DRM-FSS hotspot districts classification data (2008 – 2013) data evaluated, which later converted to standardize scores ranging from 0 to 1 using LST. The lowest values (Figure 12) depict better off food secure districts while the highest values in red depict worst food insecure districts.

Stunting data was overlaid to look at the relationship between acute food insecurity and under nutrition.

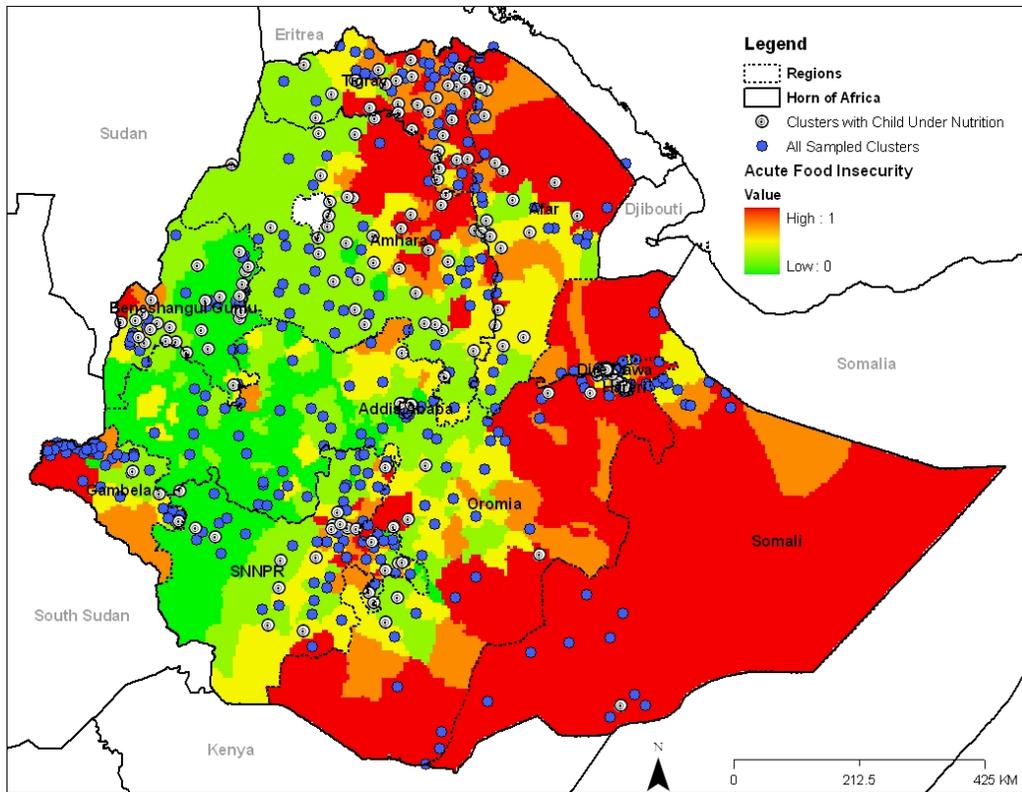


Figure 12. Map of Ethiopia Showing Acute Food Insecurity and Stunting

#### 4.5 The Chronic Food and Nutrition Insecurity, Stunting and PSNP

The four food security dimensions: food availability, food access, food utilization and acute food insecurity indicators were combined to create chronic food and nutrition insecurity map (Figure 13) while overlaying stunting and PSNP. The lowest values depict chronic food and nutrition secure while the highest in red depict food and nutrition insecure districts.

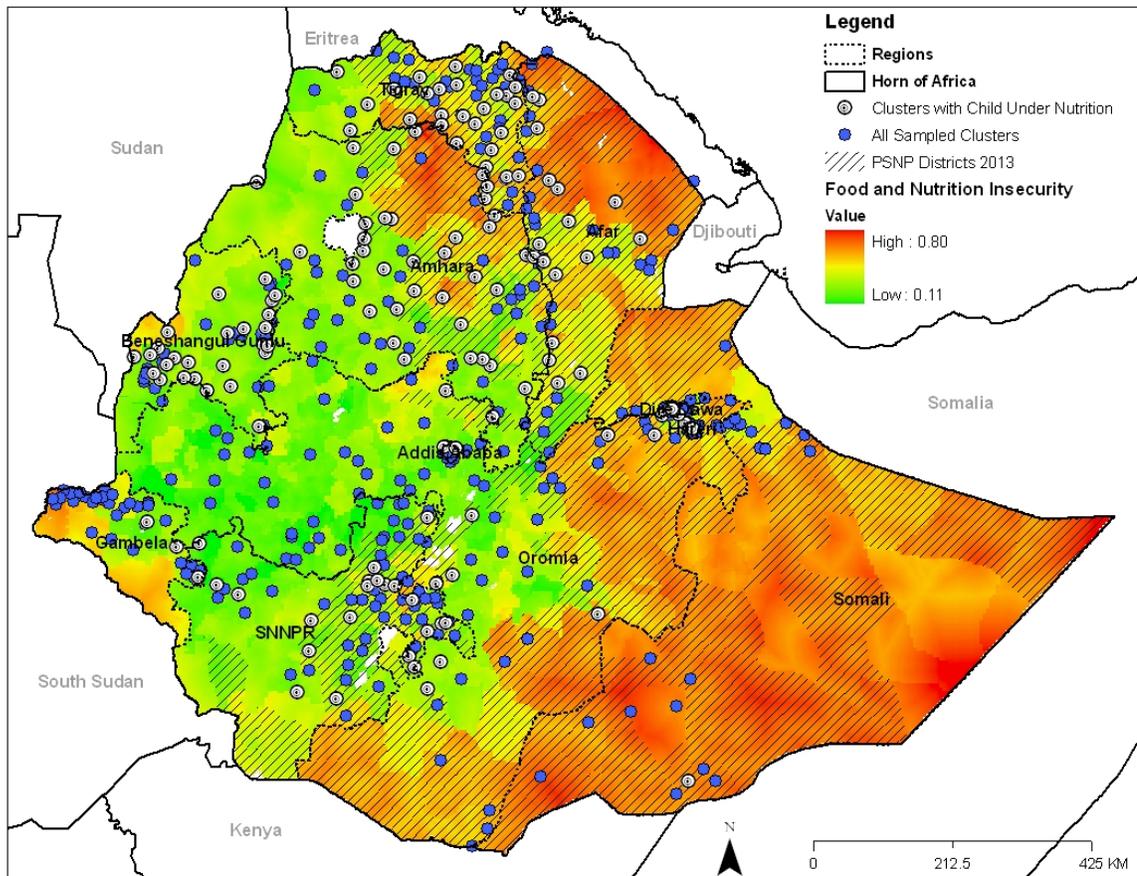


Figure 13. Map of Ethiopia Showing Chronic Food Insecurity, Stunting and PSNP



## 5. Discussion

### 5.1 Discussion of Data, Methods and limitations

In this study eight indicators from four food security dimensions were identified that presented important aspects of the rural Ethiopian life on food and nutrition insecurity. However, some indicators could not be included in this study because of limitation of data availability namely economic access to food security and tropical livestock unit per capita. Economic access of food security comes from purchasing power, which indicates the level of food and nutrition insecurity at household and when aggregated at district. Its limitation may have impact on the level of severity of food and nutrition insecurity in the country. Livestock density in tropical unit would also help to estimate livestock products (raw or processed) that can be consumed at local or when exported to international markets boost purchasing power of households. Limitation of this indicator also may have impact on the overall food and nutrition insecurity data analysis results.

In addition to these, rain gauge density over south eastern parts of the country is sparse and almost nonexistent and is very difficult to quantify the rainfall on the basis of rain gauge observations. To validate the rain gauge station data in that part of the country, NOAA satellite data estimates from year 2000 to 2014 were used extracted from LEAP.

A cost distance function estimates the time required to reach the nearest market place traveling across a raster friction surface that takes into account the road network, water bodies and slopes using the time to travel from Ahlstrom, 2008 to assess districts, which are not easily accessible.

Regions in the southeastern and northeastern part of the country that are highly affected by chronic food and nutrition insecurity had a limited number of clusters of stunting.

Food utilization indicators; adult female illiteracy, unsafe drinking water and toilet facilities are limited essentially to a single point in time (CSA 2007) and that there may be some improvements by now in the country even though these indicators cannot be updated until another census takes place.

Districts are unit of analysis, which are the second smallest administrative units that suggest relatively detailed food and nutrition insecurity in terms of data availability. However, there are better off, middle and poor households in food and nutrition insecure districts based on land ownership, farm inputs, and employment in off farm sector and livestock holdings. This indicates that there are deep internal food and nutrition security variations among households showing that households don't have similar socio economic conditions at kebele or district levels. Kebele level data analysis informs better compared to district about food and nutrition insecurity, however, data aren't available at this level.

The temporal parts; transitory and chronic were dealt at district level, however, a temporal data for emergency relief food aid beneficiary population in millions is from 1995 to 2013 and PSNP from 2005 to 2013, which are summarized at national level as indicated in Appendix B, Table B4 .

As a method of data analysis, most of the studies in Ethiopia used a methodology that embodies a sequence of traditional statistical algorithms, namely percentages, principal component analysis, quintile analysis, regression analysis and convergence of evidence methods, which were not exempt from some of the weakness, namely the methodology used embodies traditional statistical algorithms and methods that required frequent mathematical operations to describe data in abstract numerical space. Some of them attempted to analyze data at food economy zone (destitution study) but not at district levels. This creates administrative decision making concerns because administrative decision making in Ethiopia is taking place at district level but not at food economy zone. Another study (SERA project 2000) used limited coverage, i.e., operational in only 16 districts among more than 800 districts in the country. IPC used convergence of evidence approach at district level that required technical experts from different organizations that classify districts based on the available data. IPC pilot study conducted in one of the regions in Ethiopia but not at national level.

GIS MCE Weighted Linear Combination (WLC) approach is not only built on mathematical and absolute facts but also expertise inputs on deciding on standardization method of variables; deciding on combination method for the variables, and deciding on weights in the additive MCE approach. However, in WLC, equal weight approach was used because of limitations of standardized weights for each indicator from previous studies.

In spite of data limitations, namely valuable indicators that couldn't be included, limited number of clusters for stunting in food and nutrition insecure areas, limited to a single point food utilization indicators and data limitations at smallest level of administrative unit, this study aimed to evaluate food and nutrition insecurity, one of the food stability types, in Ethiopia in relation to the four dimensions of food security. The indicators were converted to standardized scores ranging from 0 to 1. After standardization, WLC of MCE applied to combine indicators in each food security dimension as well as four dimensions of food security namely, food availability, food access, food utilization and acute food insecurity within a GIS for the purpose of determining relatively the most food and nutrition insecure districts in Ethiopia.

Using ArcGIS, 'stretch', chronic food and nutrition insecurity values were stretched from the lowest to the highest. Due to lack of standardized threshold values between 0 and 1 in other similar studies, the resulting values in this study will be valid only for the range of values used in the scaling, i.e. the relatively high and low values within Ethiopia. If absolute threshold values for each indicator were available, these could be used instead of high and low values in a LST and then results from different areas could be compared that give a physical meaning for food and nutrition insecurity in Ethiopia. Despite its limitations (which in many cases are the same for the traditional statistical estimates on different administrative and regional levels), the GIS approach has resulted in a spatially distributed estimate of food insecurity covering the whole country.

Most of high chronic food and nutrition insecure districts from this study overlapped with PSNP implemented districts. Especially in northern part of the country (Tigray and Amhara regions), proper interventions were conducted in food and nutrition insecure districts. However, eighteen districts from Somali, seven districts from Gambella, seven districts from Oromia, two districts from Beneshangul-Gumuz, two districts from SNNP and one district from Afar regions, according to this study are food and nutrition insecure were excluded from the PSNP. At the same time, six districts from SNNP, two districts from Oromia and two districts from Afar regions, in this study are found to be less vulnerable to food and nutrition insecurity were included in PSNP as indicated in Appendix B, Table B2.

Based on the study findings, in total 37 districts, which were shown up to be food and nutrition insecure were excluded, while 10 districts, which do not result as food insecure were included as a beneficiary of PSNP.

As indicated in Appendix B, Table B4, population estimated as needing relief food assistance in the past 19 years alone has risen from 2.7 million in 1996, where a bumper harvest observed (Devereux 2000) to 12.6 million in 2003 (a drought year). In 2005, PSNP designed and implemented to address chronic food insecurity, which provides cash or food supporting the chronically food insecure to evolve from dependency over a number of years. For example there were about 2.5 million relief food beneficiaries in need of relief food assistance from January to June 2013, identified through the multi-agency assessment team and subsequent monitoring results (DRMFSS 2013) while there were 6.9 million PSNP beneficiary populations making a total of 9.4 million beneficiaries. After PSNP implemented, total population estimated as relief food assistance and PSNP varied in between 9.4 in 2013 to 14.3 million in 2008. This indicated that the number of beneficiary population varied from year to year as some of the districts graduate and new ones added into PSNP while emergency relief food assistance improves or deteriorates based on drought occurrence that contributed much to food security situation in the country.

Most of the previous studies attempted to analyze data at a limited coverage but not at national level except CVI. CVI indicated that north eastern, eastern highlands and some pocket areas in the west were found to be chronically vulnerable ranging from moderate to high degree of vulnerability. The finding has some similarities with the findings of this study, however, used different methodologies and data sets.

IPC has conducted a pilot study in one of the regions (SNNPR); however, it lacks national level food and nutrition insecurity analysis to compare with the study findings.

In conclusion, the combined indicators has helped to highlight the dynamics of the resource base vulnerability to food and nutrition insecurity and provided insights on the potential long term vulnerability of the population to food and nutrition insecurity in Ethiopia.

## 5.2 Discussion of Results

### 5.2.1 Discussion of Spatial Analysis Results

The two contributing food availability indicators to food and nutrition insecurity were rainfall variability and population density. In the south eastern parts of the country where sparse rain gauges were observed, NOAA satellite rainfall variability estimates as indicated in Appendix D, Figure D2 were high, which conforms the extrapolated map results from the rain gauge station data. A person product-moment correlation coefficient in SPSS was conducted to evaluate the correlation between rainfall coefficient of variation and the elevation values. As indicated in Appendix D, Figure D4 there is significant linear negative correlation between rainfall coefficient of variation and elevation. This implies that for higher altitudes or mountainous areas the variability of rainfall is lower compared to that of lower altitudes. In the lower altitudes the variability is higher, which indicates that lowland areas in the country, which are drought prone, suffer from variable or erratic rainfalls.

The variability is also indicated using semi-variogram spherical model in ordinary kriging, which is indicated in Appendix D, Figure D4. For rainfall coefficient of variation, the best fit was obtained by using a lag size of 1.1 km and a total of 10 lag intervals. The three elements of the semi-variogram are nugget, sill and range. As indicated in Appendix D, Figure D4, the nugget effect of  $2.5 \text{ (mm)}^2$  at a lag distance of  $(h) = 0$ , which is assumed to be produced by various sources of unexplained error. A sill a value of  $3.91 \text{ (mm)}^2$  indicated where the variogram levels out indicating the distance at which data are no longer correlated. Range (0.84 km) is the distance where the variogram model first flattens out or reaches the sill. Higher rainfall coefficient of variation in lowland areas increased the variability, whereas low rainfall coefficient of variation in highlands reduced the variability and affected the sill values of the variograms.

The analysis results of both indicators (Figure 6) indicated that northern, north eastern, south eastern and pocket areas in other parts of the country are relatively affected by lack of food availability. In addition to this, cluster level variations among stunted children were observed in districts affected by lack of food availability. However, there are some clusters with non-stunted children in this category indicating that stunting is not only food availability problem. The high incidence of child

malnutrition in the districts affected by lack of food availability is indicative of the level of potential vulnerability of those communities' in terms of food availability.

Based on the accessibility surface (Figure 7), districts in north east, south, south east and south west parts of the country are the most affected in terms of accessibility to towns while the remaining parts of the country considered very accessible with a wide variety with opportunities to travel to towns and engage in activities that enable the population to gain some income. In poorly accessible districts, stunting clusters are nonexistent or poorly distributed. In addition to this, most of the stunted children are located in food accessible areas. This may be due to that families are selling crop and livestock products to buy other household materials instead of feeding their children. The areas of poor accessibility represent those places where access to infrastructure is very poor and have less number of roads. Farmers in those areas are compelled to sell off their perishable products at cheaper prices, which mean that they are constantly susceptible to unstable market prices for their produce. Such a trend has the potential to undermine agriculture or livestock productivity and heighten food insecurity issues.

The three indicators combined to create composite food utilization map (Figure 11) were female adult illiteracy, unsafe water and toilet facility. The analysis results indicated that north eastern, southern, south eastern and pocket areas in other parts of the country have relatively food utilization problems. Most districts in northern, central and southern parts of the country, which are relatively affected by food unavailability aren't affected by food utilization indicating that stunting is not only food utilization problem. Some districts in western part of the country were also relatively affected by food utilization problems where stunting were observed.

The acute food insecurity analysis results (Figure 12) indicated that north, north east, south, south east and pocket areas in central and western parts of the country are the most affected in-terms of acute food insecurity. In most food insecure north east and south east, the number of clusters are limited to justify that stunting is related with acute food insecurity. There are some clusters with non-stunted children in this category, which may indicate that stunting is not only acute food insecurity problem.

The four food security dimensions were combined to create composite food and nutrition insecurity map (Figure 13) indicated that northern, north eastern, southern and south eastern parts of the country were relatively highly affected by food

and nutrition insecurity. This is also true for individual dimensions, namely, food availability, food access, food utilization and stability or acute food insecurity before creating composite food and nutrition insecurity map. In areas where all indicators show high level of prevalence, it is apparent that the level of risk in those districts is very high. The districts in the food and nutrition insecurity surface that have high values could be described as food and nutrition insecurity hotspots in the country. They experienced the effects of poor economic and social difficulties imposed by all these indicators, which constitute a threat to well-being of the population in those areas.

### **5.2.2 Discussion of Correlation Analysis Results**

A person product-moment correlation coefficient in SPSS was conducted to evaluate the relationship between under nutrition and food security dimensions. After the data transformation, the analysis results for normality, using skewness and kurtosis (Appendix B: Table B5) visual inspection of their histogram and normal Q-Q plots (Appendix D: Figure D3) showed that the food availability, the food access and the acute food insecurity indicators were approximately normally distributed with a skewness of 0.385 (Std. Error = 0.199) and kurtosis of 0.440 (Std. Error = 0.396); with skewness of 0.228 (Std. Error = 0.199) and kurtosis -0.835 (Std. Error = 0.396); with a skewness of -0.288 (Std. Error = 0.199) and kurtosis -0.890 (Std. Error = 0.396) respectively. But food utilization and stunting data were skewed but not kurtotic. Hence, the skewness and kurtoses analysis results as well as histograms and Q-Q plots (Appendix D: Figure D3) observations indicated that food availability, food access and acute food insecurity data came from a normal distribution while food utilization and stunting data were not qualify to be normally distributed.

However, Shapiro-Wilk test (Appendix B: Table B6) indicated that all "p" values were below 0.05 indicating significance values (sig) were very small and implying that these data were not normally distributed.

The data points of scatter plots (Figure 14) were scattered around for stunting and food security dimensions violating linearity assumptions, while scatter plots holding linearity assumptions among food security dimensions such as food availability and food utilization; food availability and food access; and food availability and acute food insecurity.

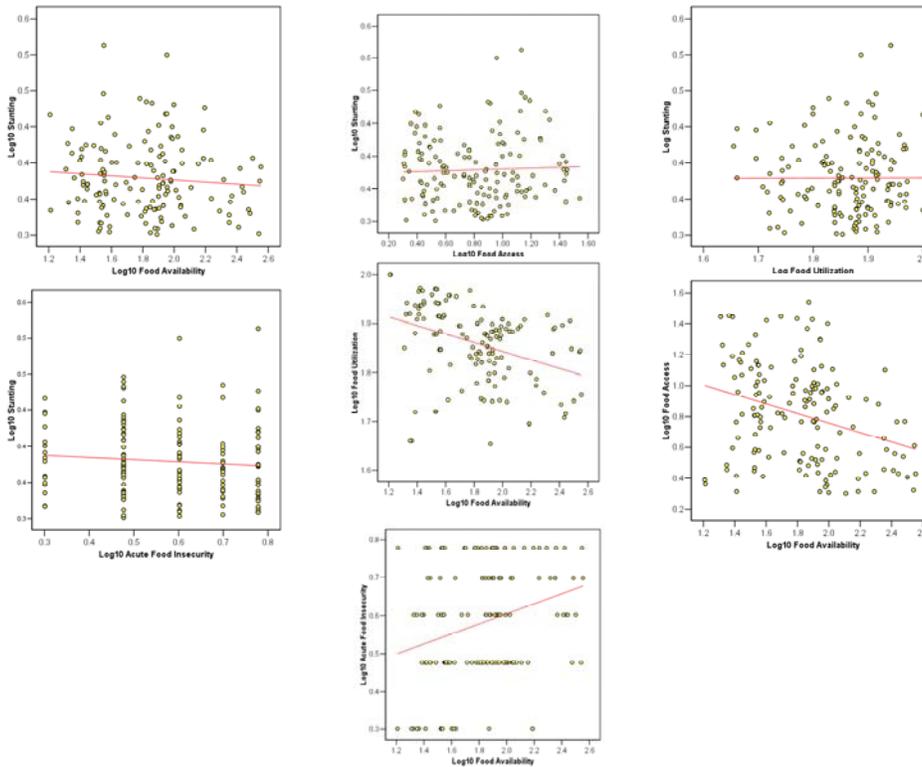


Figure 14. Scatter-Plots among Food Security Dimensions and Stunting

The analysis results of the correlation matrix (Figure 15) indicated that few of the observed relationships were strong, however, there were quite close to zero relationship among food security dimensions and stunting i.e., close to zero positive relationship between stunting and food access ( $r = 0.04$ ); and stunting and food utilization ( $r = 0.003$ ) while there were close to zero negative relationship between stunting and food availability and stunting and acute food insecurity ( $r = -0.09$ ) respectively. Hence, we don't have enough evidence to say that there is a statistically significant linear relationship between stunting and food security dimensions.

The negative strong significant relationship was among food security dimension indicators such as food availability and food utilization ( $r = -0.40$ ); food availability and food access ( $r = -0.31$ ) while positive strong significant relationships observed between food availability and acute food insecurity ( $r = 0.28$ ). Strong positive relationship between food availability and acute food insecurity indicates that the availability of relief food assistance and PSNP from government and donors and small amount of green harvest from agricultural production were helping the poor during acute food insecure times. But higher levels of food availability associated with lower levels of food access and food utilization.

**Correlations**

		Logarithm of Stunting Log10{(Stunting)}	Logarithm of Food Availability Log10{(Food Availability)}	Logarithm of Food Access Log10 [(Food Access)]	Logarithm of Food Utilization Log10 [(Food Utilization)]	Logarithm of Acute Food Ins log10[ (Acute Food Insecurity)]
Logarithm of Stunting Log10{(Stunting)}	Pearson Correlation Sig. (2-tailed) N	1 .282 148	-.089 .282 148	.042 .616 148	.003 .973 148	-.088 .289 148
Logarithm of Food Availability Log10{(Food Availability)}	Pearson Correlation Sig. (2-tailed) N	-.089 .282 148	1 .282 148	-.308* .000 148	-.367* .000 148	.277* .001 148
Logarithm of Food Access Log10 [(Food Access)]	Pearson Correlation Sig. (2-tailed) N	.042 .616 148	-.308* .000 148	1 .000 148	.161 .050 148	.002 .983 148
Logarithm of Food Utilization Log10 [(Food Utilization)]	Pearson Correlation Sig. (2-tailed) N	.003 .973 148	-.367* .000 148	.161 .050 148	1 .000 148	.033 .686 148
Logarithm of Acute Food Ins log10[ (Acute Food Insecurity)]	Pearson Correlation Sig. (2-tailed) N	-.088 .289 148	.277* .001 148	.002 .983 148	.033 .686 148	1 .000 148

\*\* . Correlation is significant at the 0.01 level (2-tailed).

Figure 15. Correlation Matrix among Food Security Dimensions and Stunting

As depicted in Figure 6, low food available areas, namely northern Tigray, central Amhara and central SNNPR were related with high food access (Figure 7).

In addition to this, low food available areas (Figure 6), namely eastern, central and southern Tigray; eastern and central Amhara and central SNNPR were related with high food utilization (Figure 11). This implies that even when food is available in markets and accessible, poor households and its members at communities cannot access or utilize the available food that meet their nutritional needs and lead to productive lives due to lack of enough income.

The major problem for weak relationships among food security dimensions and stunting was lack of stunting cluster data in most of food and nutrition insecure north, north eastern, south and south eastern parts of the country. In addition to this, stunting may also be related with other indicators, which were not included in this study such as poor care or feeding practice, disease burdens, inadequate caloric intake, and insufficient diversification of food production and consumption.



## 6. Conclusions

The findings of this study have indicated that north, north eastern, south eastern and pocket areas in remaining parts of the country have persistent chronic food and nutrition insecurity.

To target emergency and development interventions in those chronic food and nutrition insecure districts, indicator specific intervention would improve the effects of food and nutrition insecurity; for example, rainfall variability map would help in planning where water shortage and other drought alleviation projects are immediately needed; maps depicting road or clean drinking water accessibility are important for an organization planning infrastructure development; map depicting adult female illiteracy rates would help an organization to take responsibility to improve adult female illiteracy rates. Population density map helps for planning resettlement areas or to take other measures. Once the individual maps are addressed, it is useful to humanitarian emergency and development agencies to highlight districts that require close monitoring and also to support emergency and development resource allocation and intervention and by doing so food and nutrition insecurity will be addressed fairly in the country.

Lack of rain-gauge sites in southeastern part of the country affected measuring rainfall variability, which is an indicator of food availability, and requires expansion of rain-gauge sites in those areas.

Similarly, regions in the south eastern, north and north eastern part of the country that are highly affected by chronic food and nutrition insecurity have a limited number of clusters of stunted and non-stunted children to justify that stunting is related with food security dimensions. This suggests that it would be essential to expand the collection of data on stunted children to these areas to better understand the relationships between stunting and food security dimensions to recommend appropriate interventions. In addition to this, stunting may also be related with other indicators, which were not included in this study due to lack of data availability, namely poor care or feeding practice, disease burdens, inadequate caloric intake, and insufficient diversification of food production and consumption. Future studies should attempt to include these indicators to look at the relationship between stunting and food security dimensions. Districts with stunted clusters vary from one food security dimension to another confirming that tackling children under nutrition requires

addressing all food security dimensions: food availability, food access; food utilization and acute food insecurity.

North East and south East parts of the country (Figure 8), which is food and nutrition insecure suffers from low adult female literacy rates. To solve this problem, districts with low female literacy rates require government's follow up to make them empowered learners by setting ceiling for participation that helps them change theirs and their households lives.

The strategy that deals with both chronic food insecurity using PSNP and transitory food insecurity using relief food assistance should continue; it prevented famine or hunger related deaths in the country as drought is a historical phenomenon.

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## 8. Appendices

### 8.1 Appendix A – Data Flow

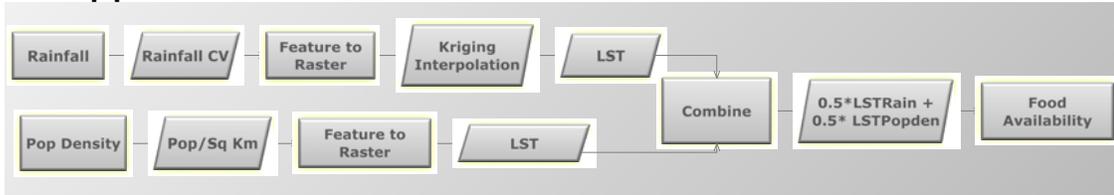


Figure A1: Flow of Data Analysis - Food Availability Dimension

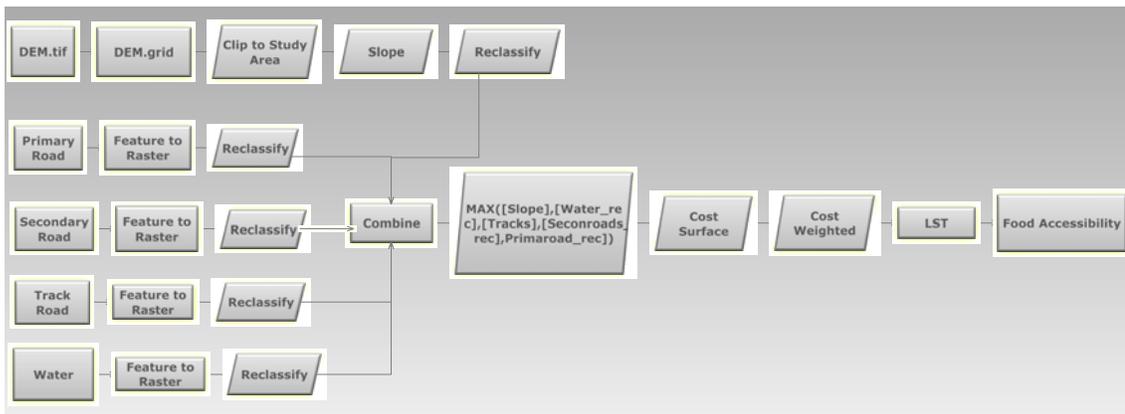


Figure A2: Flow of Data Analysis – Food Accessibility Dimension

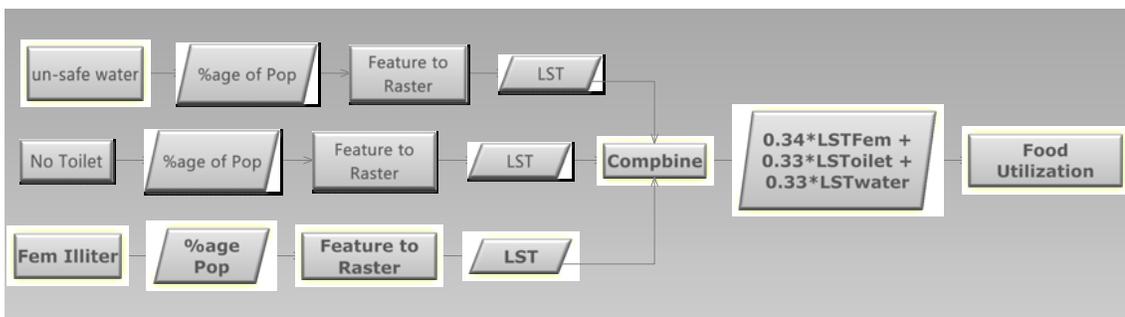


Figure A3: Flow of Data Analysis - Food Utilization Dimension

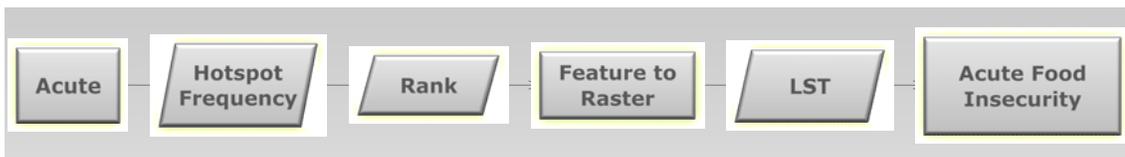


Figure A4: Flow of Data Analysis - Food Stability Dimension



Figure A5: Flow of Data Analysis - Chronic Food and Nutrition Insecurity

## 8.2 Appendix B - Tables

Type of friction	Bus (Speed)	The time it takes to travel 1 metre	Crossing time in sec * 1000
	(Km/h)	(seconds)	(seconds * 1000)
Primary	60.0	0.06	60
Secondary	30	0.12	120
Track	3.5	1.03	1029
0-5% Slope	2.0	1.8	1800
5-10% Slope	1.5	2.4	2400
10-20% Slope	1.0	3.6	3600
> 20% Slope	0.25	14.4	14400
Water	0.0	No Data	No Data

Table B1: The Travel Speed and Crossing Time in Seconds

Region	Districts Included	Districts Excluded
Tigray		
Afar	Amibara	Kuri
	Awash Fantale	
Amhara		
Oromia	Fantale	Malka Balo
	Boset	Dera
		Wara Jarso
		Shashemane Zuria
		Robe
		Adaba
Somali		Hidabu Abote
		Degehamedo
		Gerbo
		Hamero
		Segeg
		Dihun
		Legahida
		Meyumuluke
		Selahad
		Dehun
		Shekosh
		Gode
		Shilabo
		Warder
		Geladin
Beneshangul-Gumuz		Ferfer
		Chereti Weyib
		Guradamole
	Dembel	
	Serkole	
	Kurmuk	
SNNP	Limu	Abaya
	Misha	Bena Tsemay
	Wilbareg	
	Arbaminch Zuria	
	Maji	
	Wondo Genet	
Gambella		Lare
		Jikawo
		Wantawa
		Akobo
		Jor
		Dima
	Itang	

Table B2: Districts Excluded and Included from the PSNP Based on this Study

	Dimension	Indicator	Definition	Rationale	Data Source
Contributing Factors	Availability	Rainfall Variability	Last 30 years' (1983 - 2012) annual average rainfall at each station level to be first computed. Then to compute standard deviation and coefficient of variation that to be used in the spatial interpolation analysis	Rainfall variability impacts include changing productivity and livelihood patterns, economic losses, and impacts on infrastructure, markets and food security. Previously used by Ketahanan (2009).	NMSA (1983 - 2012)
		Population Density	CSA 2007 rural population figures projected to 2012 using growth rates received from CSA and the associated district polygons used to display the population density	Higher population density is associated with smaller farm sizes and decreased fallow land; in addition to this, household assets, incomes, and farm productivity decline sharply. Previously used by Bird et al. (2002)	CSA (2007). Valid until another census takes place in 2017
	Physical Access	Travel Time to the Nearest Town	Conduct spatial accessibility analysis using slope, roads and towns across the country	The closer a village is to a town market, for instance, the more likely rural households are to purchase inputs (e.g., seeds and fertilizers) or sell a variety of products and hence improved access to market towns and cities has a positive effect on welfare. Previously used by Ericksen P et al. (2011).	GTOPO30 DEM (2006). Map layers (regions, districts, lakes, roads and towns). Valid until another census takes place in 2017
	Utilization	Safe Drinking Water	Access to an improved water source refers housing units within a district expressed as a percent of rural housing units, which reported their main source of household drinking water to be either a "tap" or a "Protected well".	Illness caused by unsafe drinking water generates health costs that can claim a large share of poor households' income and reduce productivity that leads to the households' food insecurity. It corresponds to the MDG 7 target 7.C: "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation". Previously used by Ketahanan (2009).	CSA (2007). Valid until another census takes place in 2017
		Toilet facilities	Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection.	Without access to safe drinking water, proper sanitation, and proper hygiene, food is easily contaminated through exposure to unsafe drinking water, pathogens on hands and from flies, and unclean surfaces. This indicator corresponds to the MDG 7 target 7.C: "halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation". Previously used by Ketahanan (2009).	CSA (2007). Valid until another census takes place in 2017
		Adult Female literacy	Adult female literacy refers rural adult female literate / All females above 15 years age group * 100.	Female adult literacy rates are associated with improved nutrition outcomes for the house-hold and for children. Previously used by Ketahanan (2009).	CSA (2007). Valid until another census takes place in 2017
Outcomes	Stability	Reference of Acute Emerencies	Districts with high frequency of acute crises years in the past six years	During normal or typical years conditions of persistent inability to meet minimum quality and quantity of food consumption requirements as is evident even in the absence of a shock/hazard. Previously used by IPC (2012).	Hotspot districts classification (2008 - 2013)
		Nutritional status - Stunting	Percentage of stunting (height-for-age less than -2 standard deviations of the WHO Child Growth Standards median) among children aged 0-5 years, indicator for long-term nutritional deprivation	It reflects the dissatisfaction of basic needs (inadequate feeding and poor health) during the first years of life amongst children < 5 years of age and is one of an appropriate indicator of chronic food insecurity. Previously used by IPC (2012).	DHS (2000, 2005, 2011)

Table B3: Definition and Rationale for Selected Indicators of Chronic Food and Nutrition Insecurity in Ethiopia

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
RFAB	4.0	2.7	3.4	5.3	6.6	7.7	5.2	5.2	12.6	7.2	4.8	2.6	1.8	6.4	4.9	5.2	2.8	3.3	2.5
PSNP											5.1	7.2	7.9	7.9	6.9	7.8	7.7	7.6	6.9
Total	4.0	2.7	3.4	5.3	6.6	7.7	5.2	5.2	12.6	7.2	9.9	9.8	9.7	14.3	11.8	13.0	10.5	10.9	9.4

Table B4: ERFAB (1995 – 2013): Emergency Relief Food Aid Beneficiary and PSNP Population (2005 – 2013) in Millions

	Statistic	Std. Error
Logarithm of Food Availability Log10[(Food Availability)]	Skewness .385	.199
	Kurtosis -.440	.396
Logarithm of Food Access Log10 [(Food Access)]	Skewness .228	.199
	Kurtosis -.835	.396
Logarithm of Food Utilization Log10 [(Food Utilization)]	Skewness -.666	.199
	Kurtosis -.077	.396
Logarithm of Acute Food Ins log10[ (Acute Food Insecurity)]	Skewness -.288	.199
	Kurtosis -.890	.396
Logarithm of Stunting Log10[(Stunting)]	Skewness .854	.199
	Kurtosis .813	.396

Table B5: Skewness and Kurtosis of Food Security Dimensions and Stunting

	Tests of Normality					
	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Logarithm of Stunting Log10[(Stunting)]	.079	148	.024	.951	148	.000
Logarithm of Food Availability Log10[(Food Availability)]	.100	148	.001	.964	148	.001
Logarithm of Food Access Log10 [(Food Access)]	.094	148	.003	.965	148	.001
Logarithm of Food Utilization Log10 [(Food Utilization)]	.118	148	.000	.956	148	.000
Logarithm of Acute Food Ins log10[ (Acute Food Insecurity)]	.179	148	.000	.890	148	.000

a. Lilliefors Significance Correction

Table B6: Shapiro-Wilk test of Food Security Dimensions and Stunting

### 8.3 Appendix D – Figures

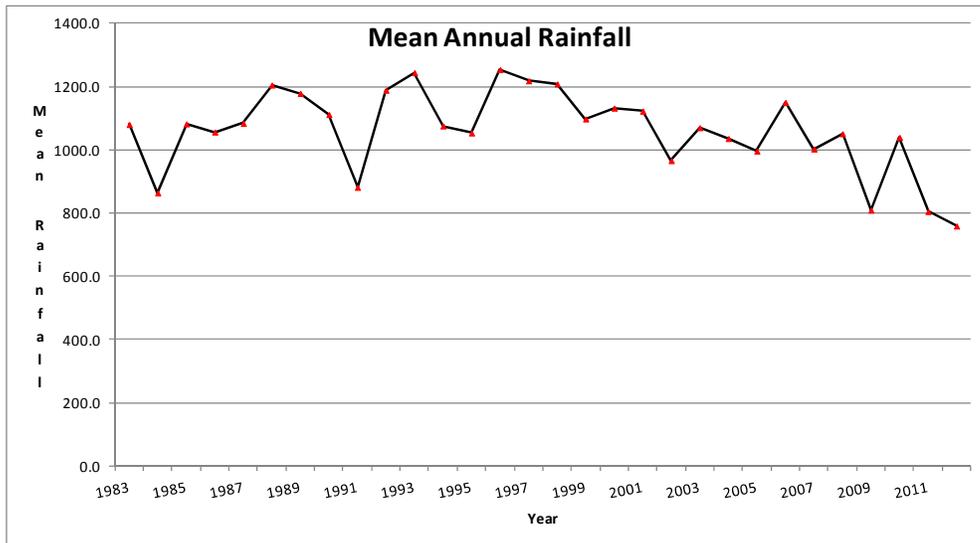


Figure D1: Mean Annual Rainfall (mm) Trend during 1983 – 2012

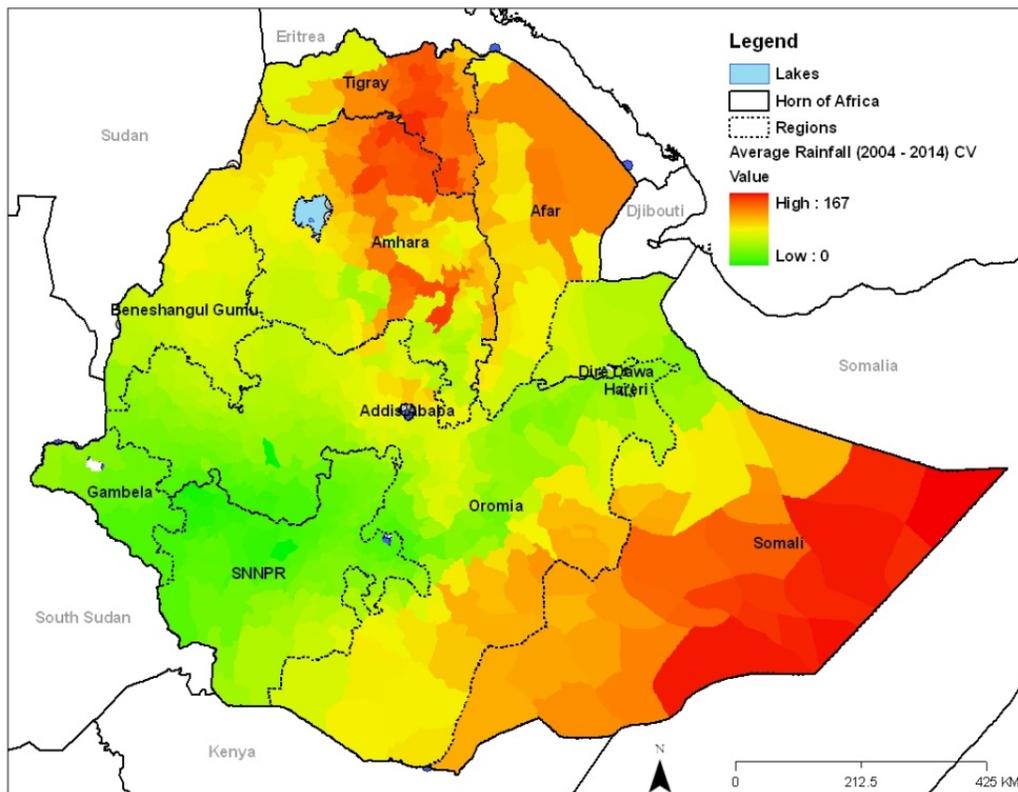


Figure D2: Average Rainfall (2004 – 2014) CV

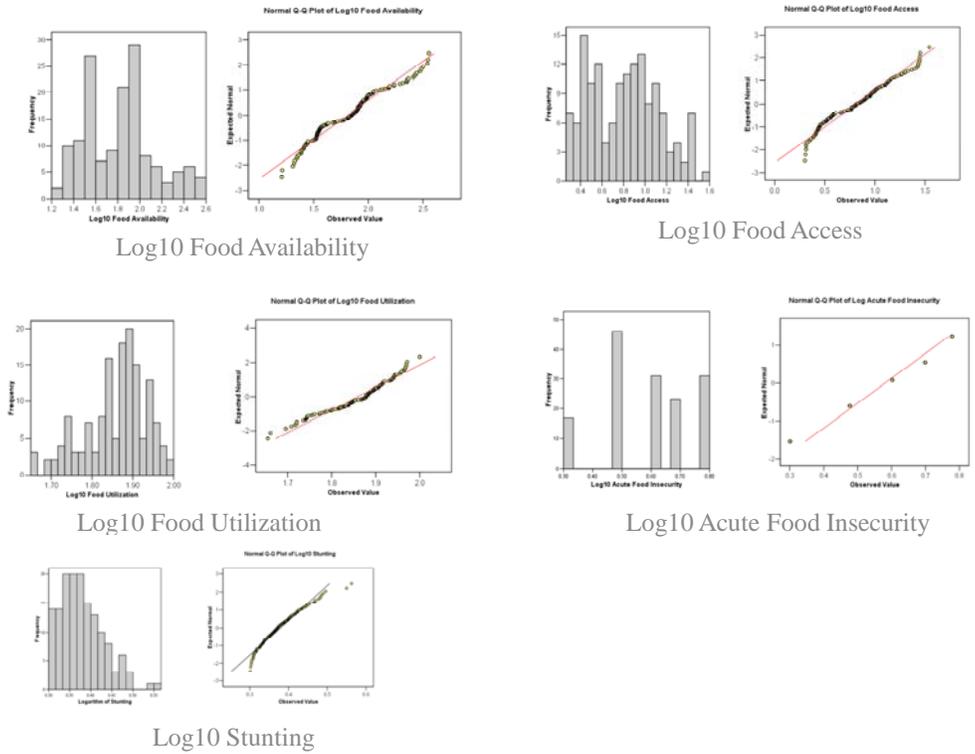


Figure D3: Histograms and Q-Q Plots of Food Security dimensions and Stunting

**Correlations**

		CV	DEM
CV	Pearson Correlation	1	-.233**
	Sig. (2-tailed)	.	.000
	N	248	248
DEM	Pearson Correlation	-.233**	1
	Sig. (2-tailed)	.000	.
	N	248	248

\*\* . Correlation is significant at the 0.01 level

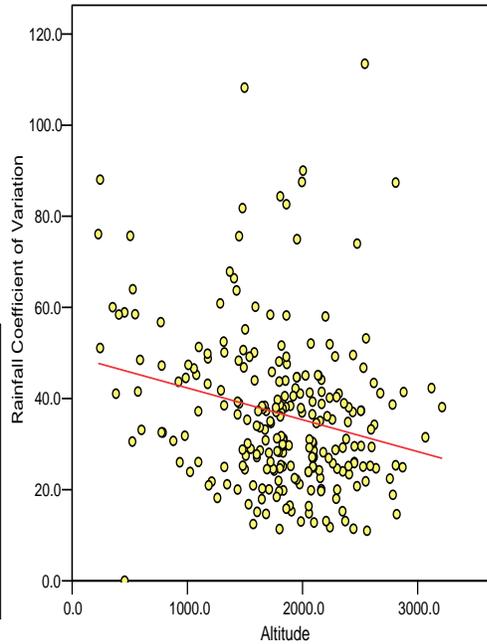
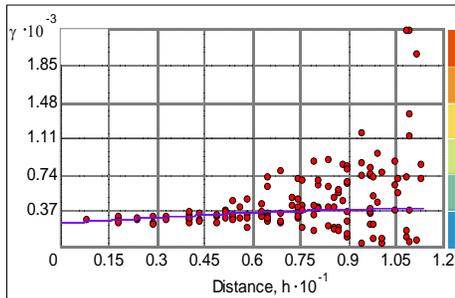


Figure D4: Semi-variogram of CV and Correlation Coefficient between CV and Elevation



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