# Food Security in Ethiopia

## -Analysis of cereal demand and supply: past trend and future prospect-

エチオピアの食糧安全保障-
穀物需要と供給の解析、過去の傾向と未来の予測-


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**Studies on**

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A dissertation submitted in partial fulfillment of the requirement of the Degree of Doctor of Philosophy in Global Agricultural Sciences,
December 18, 2009, Tokyo

**Dedicated to:**

**My wife Bizuhan Legesse and my children, Deborah and Kaleb**

# Acknowledgement

On the 9 October, 1974 my mother had no idea on what was happening in the world except her small village of few hundred families. She was rather excited that a baby boy was born to her. She dreamed only of him growing and becoming like his father, a successful farmer and have big family like hers. That boy was me. That year was historical in many ways. It was just one year after the global oil crises. It was the year the ravaging Ethiopian famine has occurred. The decade was when environmental movement reached its zenith. It was only three years later that the tragic war between Ethiopia and Somalia started. The tragedy brought a blessing in disguise for me and my parents. We were evicted from our village, Sekere, to a new town called Gursum in East Hararghe, where I got my elementary and secondary education. 35 years later here I am in Japan completing my doctoral degree well aware of most of the significant daily events around the world. I could not be more thankful for all opportunities I am bestowed by my Lord and all my loved once with the challenges.

The generosity of the government and people of Japan has enabled me to live and study in this beautiful country with no worry of financial need. I am also privileged to enjoy first class healthcare and education for my children. With the heartily Japanese gratitude I say *arigato gozaimasu*, thank you very much. I tested the extent of the hospitality of the people in Tokyo and found perfect kindness and cooperation in almost all aspect of my life. What a nation!

When I first moved to my present department to join Professor Hiroyuki Kawashima, I was oblivious of what was ahead of me. I reflect back four years and celebrate my decision. Professor Kawashima is a man of his word who embodies what is authentically

Japanese. He has always been there for me in my academic and daily life's challenges. I have no, really no words to express my thanks. I also thank him for taking time off from his bustling schedule to go to my country Ethiopia and see firsthand its present realities. I want to thank the Central Statistical Agency of Ethiopia, the Food and Agriculture Organization and World Resource Institute for their generosity in allowing the use of their online comprehensive data.

I want to thank the National Institute for Agro-Environmental Sciences at Tsukuba and especially Dr Junko Shindo who generously funded part of my research.

I thank Professor Kobayashi Kazuhiko for allowing me to use his laboratory treating me as one of his advisees. I have learnt a lot from his down to earth approach in handling of complex issues. My thanks also go to Professor Kensuke Okada of JIRCAS for his valuable comments and insights and for the fruitful discussions.

I am deeply indebted to Mr. Takeo Someya, president of BDF Company and his family, for providing me and my family with convenient housing at a much cheaper price than the market and for having confidence in employing my wife and me on part time basis at his company. Without Mr. Someya, I could hardly enjoy Japan as I did it otherwise. My lab mates, especially Honda Manabu san, Hamaguchi Wataru san, Takeshita Kouichiro san, Morimoto Daitsuke san, Sekido Ippei san, Iwade Takuya san, Rou Ukou san, Yamada Yasuo san and Shaghayegh Eskandar made my study such an enjoyable experience. I will treasure the times I had with you everywhere I go. The nomikais (drinking-meeting) where I often eat most of the sashimi dishes and soft drink is unforgettable. I will always remember the kindness and cooperation of our secretary, Kusaka Miyako san. She has always been helping me unreservedly in matters of my study as well as my family. Hontoni arigato gozaimasu (thank you very much).

I thank Dr. Neelam Ramaiah, coordinator of International student center of our graduate school, for her wonderful service that emanate out of deep concern for students.

My wife, Bizuhan Legesse, had to scarify her job and opportunities to pursue further education to be with me. She offered me the best gifts of my life, Deborah and Kaleb. She has been by my side in season and without season to provide me her unconditional support and love. Her invaluable comments on my study were precious. Bez has earned the respect of our friends and family by her diligence in raising our children. She took care of most of family responsibilities. Bezye you are special, thank you so much.

My mother, Zewdie Kelkile, has very special place in my life and character. She raised us by her own in an environment she had little experience after the loss of my father at my age of three. She has always been my inspiration. I learned from her to stay strong in life's many challenges. *Betam amesegnalehu* (thank you so much). I thank my sister Yeshume Betru who helped me and my wife in taking care of the kids and household activities. I want to thank all my parents for supporting and expecting me to succeed.

I cherished the special time I had with Dr Esayas Gebreyohannes while he was a student and staff at Tokyo University. His insightful comments and uplifting encouragements will always be remembered. Thank you so much. I am also highly indebted to Aye Mengistu, for sharing with me his profound expertise on econometric analysis and offering invaluable advices on my research. I am highly indebted to Abrar Juhar and Bisrat Diressa, graduate students in Japan, for offering their precious time in editing my dissertation and giving me valuable comments .Thank you so much. I am also deeply grateful to Dr Getahun Legesse for his advices while publishing an article on a journal.

Tarekegn Nemeta and his wife Adonai Messele were my spiritual backbones in good time as well as in bad. I thank them for their heartily prayers and love. I want to thank my

Chrurch friends Tsion, Johni, Tigist, Athlet Nahom Mesfin, Samrawit, Solome and all members of our Christian fellowship for their prayers and support. I thank our friend Tsigereda (Rosi) for her love and support during and after the birth of our 2nd child. She has been offering my family with a car service to and from church every Sunday.

I am deeply indebted to my South African friend Abraham, who really loves Ethiopia in his bones, for his unreserved love and support throughout my study. Mekdelawit, Seife, Yohannes, Athlete Solomon Gebremariam, Efrem Haile, Athlete Tadesse Gebre and Dr Mohammed Seid of the Ethiopian community members in Tokyo were very helpful to me and my family while in Tokyo. Thank you dears.

I want to thank my friends Atesmachew Bizuwork, Taye Gidyelew, Teshale Woldeamanuel , Almaz Tessema, Dr Mulugeta Lemenih, Dr Bekele Lemma and their families for giving me their never fading love and encouragements throughout my studies. My thanks also go to Dr Menkir Zeleke and his wife Wubalem Yimer for giving me a constant nag to stretch forward for the next prize in each step of my academic endeavors. They were such an inspiration for me since our first acquaintance in 1993.

Rahel Sitot and Andualem Feleke deserve my appreciation for undertaking most of my responsibly in Ethiopia on behalf.

I thank H.E. Ambassador Abdulreshid Dulene, Ato Dawit Asfaw and the Ethiopian embassy staffs in Japan for their cooperation in acquiring data and documents for my study.

My friends at the international church fellowship James (USA), Hiromi (Japan), Kelly (Canada) were my comforts especially in the first years of my stay in Japan. Thank you so much.

I thank my friend Birhane Endale and his wife Tefsit Solomon and the family for their hospitality towards me and my family while visiting them in Washington DC. I am highly indebted to my friend Abera Gebremicheal, his wife Tiruwork Desalegn and their family for inviting me to join them in their family vacation in Canada and gave me one of the best summers in my life. Thank you so much.

All said and done my final and most sacred of thanks is reserved to my Lord and Savior Jesus Christ, who gave me the eternal bread as well as the earthly, and I say "*you are worthy to be praised*".

# Summary

**Food Security in Ethiopia**
**Analysis of cereal demand and supply: past trend and future prospect**

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This thesis investigated food security challenges and potentials in Ethiopia using systems thinking methods in three parts. In the first part (Part I) comparative analysis of Ethiopian cereal supply was made in relation to other African countries. In the second part (Part II), meat consumption pattern in rural and urban Ethiopia was analyzed using cohort and econometric models. The third and final part (Part III) analyzed nitrogenous fertilizer demand in cereal production in Ethiopia. The major data sources were the Food and Agriculture Organization, World Resource Institute, World Bank's World Development Indicators and Central Statistical Agency of Ethiopia.

In Part I, a system model was used to analyze and classify African countries based on level of cropping intensity. First, all countries were divided into three groups based on their level of cropping intensity (CI) which was calculated as a percentage of harvesting to arable land. This index helps to identify the potential of each country for further cropland expansion. Then the possible cereal supply options were discussed based on percentage of population-to-arable land, per capita GDP, water resources and past cereal yield. Countries that will face problem of cereal supply were ranked using combined index of the above variables. The result showed that between 1961 and 2003 most of the North African countries have made significant improvement in per capita cereal supply while decline has occurred in Central African countries, South Africa and East Africa. The future cereal supply prospect of the North Africa seems to rely more on cereal import

and they will face no major problem. Central African countries were found to have sufficient potential arable land and water resource to expand cereal harvesting land. South African countries also will not face cereal supply problem because population growth rate has been low and they have the potential to improve cereal yield. On the other hand, most cereal production factors in East Africa showed that the region will continue to face large gap in demand and supply.

The future projection of cereal demand showed 60% of the countries in Africa will require cereal yield around 2 t/ha in 2030 to enable them contain further expansion of cereal harvesting land. Future supply of two of the most highly populated countries, Egypt and Nigeria will follow different options. While both countries will depend on cereal trade and cereal import, Nigeria will have better potential to improve its cereal yield because Egypt's cereal yield has reached near agronomic maximum.

The analysis of factors of available arable land, per capita income, cereal yield and available water resources showed Ethiopia, Eritrea, Rwanda and Burundi were among the countries that will face higher risk of food insecurity in 2030. Among these countries Ethiopia will face biggest challenge in supplying its large and rapidly growing population.

In Part II the result of analysis of household income, consumption and expenditure survey data of Ethiopia was showed consumption of meat and its response to income change was found to have distinct pattern between urban and rural households. More than 40% of meat in the country was consumed in urban areas. The per capita meat consumption in urban households changes more steeply with change in per capita income compared with rural households. The total national meat consumption made improvement between 1996 and 2000 as a result of improvement in response of rural household meat consumption to income gain. The result of economic analysis revealed that urbanization and income have been found to be positively and significantly correlating with meat consumption in Ethiopia at 1% and 5 % significance level respectively. On the other hand, level of cereal production and price of meat did not have significant correlation with per capita meat consumption. Therefore, improvement in meat consumption in Ethiopia could occur only if rural consumption pattern changes or urbanization is accelerated and income level of urban households is improved. In the study, the result of comparison of meat data sources showed that FAO overestimated the per capita meat in Ethiopia by more than 100% compared to the CSA household survey result. This disparity seems to be caused by overestimation of rate of livestock utilization than number of livestock. Therefore, it is recommended to use CSA's household consumption data along with FAO's data for policy making and research on nutrition in Ethiopia.

In Part III a system model was used to project and analyze the requirement of nitrogen fertilizer needed to improve cereal yield and produce the future demand of cereals in Ethiopia up to 2030. The model considers three GDP growth scenarios with corresponding level of food consumption. GDP was projected using gross annual rate of 2.5, 5 and 10% growth. The total GDP was distributed to households based on level of education. Income for each household under certain level of education, residence (urban or rural) and sex was estimated from literature and was adjusted using total GDP. Population was projected using data on demographic variables from Demographic and Health Surveys and initial population from UN Population Prospect. Per capita food demand was estimated for different meat items, milk and cereals using lin-log models developed from household income and consumption data of Household Income, Consumption and Expenditure (HICE) 2004. In the model the logarithm of income was taken as dependant variables. Cereal feed demand was projected from livestock demands and animal feed/livestock ratios. The result showed that total demand for cereal food and feed in 2030 will increase between 2.5 and 4 times the level in 2005 depending on rate of GDP growth. The cereal yield which was 1.2 t/ha in 2005, is required to grow to 3.6 – 5.7 t/ha in 2030 which in turn requires nitrogenous fertilizer use rate between 160 kg/ha and 290 kg/ha. In order to supply the cereal demand for its growing population while checking expansion of agricultural lands, Ethiopia needs to dramatically increase the use of chemical fertilizer.

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# Abbreviations

**a** = age group (cohort)

**ASF** = animal source food

**BMR** = basal metabolic rate

**CAR** = Central African Republic

**CI**= cropping index

**CSA** = central statistical agency of Ethiopia

**CTR** = ratio between cereal and total harvesting land

**DRC** = Democratic Republic of Congo

**e** = level of education

**ERWR**= external renewable water resources

**FAO** = food and agricultural organization of the UN

**FAOSTAT**= FAO statistics

**FAPRI**= food and agricultural policy research institute

**FBS** = food balance sheet

**FGLS** = Feasible General Least Square

**FPNf**= factor productivity of nitrogen fertilizer

**FR** = fertility rate

**GDP** = gross domestic product

**GoE** = government of Ethiopia

**HDI** = Human development indicators

**IRWR**= internal renewable water resources

**LE** = level of education

**m.a.s.l.** = meter above sea level

**MDG**= millennium development goal

**MR** = morality rate

**Mt**= Million ton

**N-fertilizer**= nitrogenous fertilizers

**NRWR** = non-renewable water resources

**P** = population

**PAR** = population to arable land ration

**PASDEP**= a Plan for accelerated and sustained development to end poverty

**PC**= per capita

**r** = residence (rural/urban)

**RWR**= renewable water resources

**SARD** = sustainable agriculture and rural development

**SR** = sex ratio

**SSA**= Sub Saharan Africa

**t** = ton

**TFR**= total fertility rate

**TRWR**=total renewable water resources

**VBA** = visual basic for application

**WDI**= world development indicators

**WHO** = world health organization

**WRI** = World resource institute

# Chapter 1 : Introduction

## *1.1 Background of the study*

There is no civilization or nation that survived without sustenance of food supply. In his Nobel lecture in 1970, Norman Borlaug said "*Civilization as it is known today could not have evolved, nor can it survive, without an adequate food supply*" (Borlaug, 1970). The inquiry in to man's connection with food goes back to the biblical times. One of the wisest men in the Bible, King Solomon, summed up the search of his lifetime with his apt words: *"A man can do nothing better than to eat and drink and find satisfaction in his work"* (Ecclesiastes 2:24). Solomon contended that, except for contentment in once toil's satisfaction, there is nothing that equals the benefit from food. The 18th century political economist David Ricardo pointed out the preeminence of food in a society by saying: *"To sustain life, food is necessary and the demand for food must continue in all ages and in all countries"* (Ohmae, 2005). For Ricardo, technological innovations, change in human behavior or other cultural advancements could not fundamentally alter man's demand for food. It is for this reason that in some cultures the birth of child is figuratively depicted as addition of more mouths, mouths to eat indeed. In Chinese writing, for example, the word for population is depicted using a character for a person (人) and a mouth (口), vividly reminding writers and readers of the language the significance of food in a society. Therefore, availability and fair distribution of sufficient food among members of a society is essential for its peaceful continuation (Borlaug, 1970).

There are many works that tried to analyze the capacity of natural resources to supply the demand of people for food. One of the earliest of these works is attributed to Thomas R. Malthus in 18 century. In his famous essay, *An Essay on the Principle of Population,* he argued that population grows geometrically while subsistence does arithmetically and this will ultimately leads the population to outgrow the land's capacity to produce. Although he could not foresee the technological innovations that enabled productivity to exceed rate of population growth, his essays profoundly impacted most of the social and economical discourses on the interactions between population and resources in the subsequent decades.

In the late 1960s and early 1970s the ideas of Malthus have reemerged, dubbed as Neo-Malthusian, following the environmental movement that was prevalent at the time. One of its proponents was Paul R. Ehrlich who wrote a very popular book entitled "*Population Bomb*" in 1968 in which he predicted wide scale hunger and deaths in the world as a result of rapid population growth. Although most of his predictions did not come to pass, the so infamous famine in Ethiopia in 1974 and draught in India between 1970 and 1974 (Sen, 1981) alarmed many of the danger of disregarding Malthus's warnings. Lester Brown wrote a book in 1995 with the same tone of alarm in a capturing title, "*Who will feed China: Wake-Up Call for a Small Planet?"* and argued that China's entry into world grain import market will trigger a rise in price of grain and negatively affect the food supply condition in poorer countries that rely on import. Most of these people who doubt the earth's capacity to feed the growing population contend that the carrying capacity of land resource had already been exhausted. Ehrlich (1968) even declared "*the battle to feed all of humanity is over."* This pessimistic view appears to have earned them the nick name "catastrophists" (Smil, 2000).

On opposite side of the argument is Julian Simon who wrote "*The Ultimate Resources*" in 1981 as a refutation of the prevailing fear of overpopulation (Simon, 1981). In it he argued that population growth is the solution to the problem of resource scarcity rather than problem itself. For Simon as the market expands and innovation advances, man's ability to utilize previously inaccessible resources will increases. The idea was later shared by Lomborg (2001) as he asserted that the world has made tremendous improvement in supplying its population with better food in spite of drawbacks here and there. However, there is little disagreement on the fact that the poor people who especially live in poor countries are still lagging behind the other part of the world in acquiring basic needs for sustenance.

## *1.2 Food Security*

Food security is a broad concept that range from global to household and personal levels in its scope. According to FAO (2003) there are over 200 definitions of the concept of food security for policy and research purposes. Two of the commonly referred definitions came from FAO and USDA (1999). FAO's definition considers food security to exist when all people, at all times, have physical and economic access to, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. On the other hand, according to USDA's definition, food security for a household means access by all members at all times to enough food for an active and healthy life. USDA's definition of food security explicitly excludes access to food resulted from food aid. The differences between the two definitions lie with the level of measurement of food security in which while the first considers individuals as opposed to households in the later case. Renzaho and Mellor (2009) argued that food security should be viewed from vantage point of interrelated aspects of food availability, access, utilization and asset creation. The first two aspects refer to physical availability of food and the capability of households to acquire it for consumption. Whereas, the latter two factors indicate cultural and social responses of a society towards food consumption and coping mechanisms in times of deficits. Although food security problem should be evaluated under the prevailing political, cultural and social context (Renzaho and Mellor, 2009), the biophysical as well as economic capacity of a country to avail adequate and stable supply of food could not be over emphasized.

Other definitions of the concept of food security focused on whether it occurs in reality or is only perceived. For example, World Bank (1986) defines food security from the perspective of real availability of and access to food. Maxwell's definition emphasized on the perception of the society towards future lack of food rather than the real deficit that could be predicted (Maxwell, 1996).

The common feature in most of these definitions can be found in the concept of food security discussed in the 1974 World Food Conference where food security was assumed to have tripartite aspects of availability, access and stability. Availability shows the total supply of food in an area that is available for consumption regardless of who consumes it. Access, on the other hand, indicates the capacity of different members of the society or area of a region to acquire the available food through either market or different coping mechanisms. It is the income level that dictates the access in the market, whereas cultural and societal factors determine access through different coping mechanisms. Coping mechanisms include reliance on relatives or government interventions in times of inability to supply once own demand.

These mechanisms are commonly used for measuring the level of food insecurity. The last part of food security concept, stability, deals with availability of food and access to it through time. Stable supply of food is a result of the production capacity of agricultural systems and performance of the economy to affect purchase or import of food. USDA evaluates availability and distribution aspects of food security through two indicators, *Status Quo gap* and *Nutrition gap*. The first indicator measures the difference between future projected food supply and base year per capita consumption. Whereas, the second indicator measures projected food supply and the total demand to support minimum nutritional requirements (FAO, 2003). Status Quo gap helps to provide safety net criteria, whereas Nutrition Gap indicates wellbeing status.

In this dissertation food security is used to refer to the capacity of a country to supply the food demand of its present and future population with food consumption level in commensurate with either through production or import. This concept of food security implicitly considers stability of supply throughout future projection period and excludes supply through food aid in times of acute or chronic food shortage.

## *1.3 Cereals and food Energy*

There are reports of people surviving for up to 40 days without intake of food albeit with substantial loss of body weight and health impairment (Lieberson, 2004). Nonetheless, the human body needs certain amount of daily food to sustain normal functioning of different organs regardless of whether he/she is engaged in light or heavy activities. The energy need for this is referred as basal metabolic rate (BMR) (Smil, 2000). BMR varies depending on age, sex, body weight, environment, level of activity and other factors. Under normal condition, an average of 2,978 and 2,018 kcal are needed for healthy 25 years old man and woman respectively who are engaged in medium level activity. These calories are about 1.78 and 1.64 times of BMR respectively. Estimation of BMR values under certain conditions helps to determine level of nourishment or undernourishment by comparing it with actual energy intake. Human body needs not only energy but also protein, vitamins and other essential nutrients for a proper functioning. Theoretically it is possible to estimate the food requirements necessary to meet daily requirements because the nutritional values of most edible crop and livestock foods have already been done. This will help to determine the quantity of food required for normal daily physiological activities of a person in any society with reasonable range of confidence. This in turn can be used for strategic evaluation of resources and population dynamics through time as well as socioeconomic changes.

Smil (2000) and Dyson (1996) argued that a society that is able to supply its daily calorie needs rarely lacks the other nutrients since the food that is consumed for energy supply would contain enough of all other nutrients. Figure 1:1 clearly shows countries that have higher daily calories have higher protein consumption. There are only very few countries that

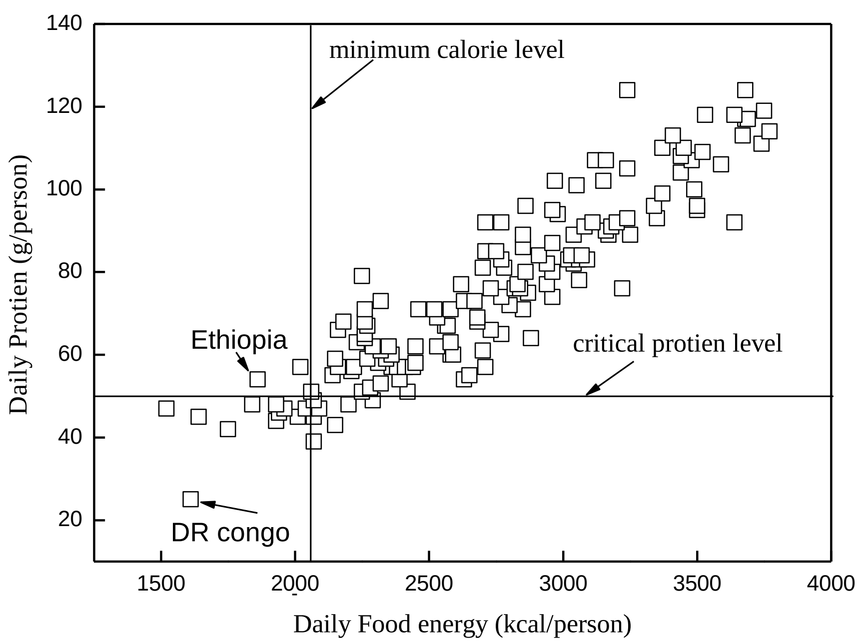



*Figure 1:1 Correlation between daily calorie and protein consumption in the world*

*Data source: FAOSTAT cross sectional data* achieved higher calorie supply and lack sufficient protein supply. In the vast majority of world countries calorie and protein supply goes in unison. Moreover, Smil (2000) contend that it will be much easier to supply protein, vitamin and other nutrients once the calorie demand is met because they are required in less than 200 grams per person per day. It could, hence, be argued that the challenges of meeting food demand of poor people predominantly living in poor countries will lie with primarily on meeting these basic energy requirements.

The present production of world grain is enough to provide sufficient cereal based nutrition to every people on the planet if equally distributed and the waste are reduced. The available food in the world in 2003, for example, can provide average per capita food energy of 2800 kcal to all people in the world that year (FAO, 2005), which is much above the average daily per capita calorie requirement. Practically, however, these values range from as low as 1,520 kcal in Eritrea to as high as 3,770 kcal in USA. The protein intake disparity is also high. For example, while the central African country of Democratic Republic of Congo (DRC) had an average of 25 g/person/day, Israel and Iceland had more than 124 g/person/day in 2002/2003.

Sen (1981) and Rahmato (2003) argued the problem of food energy in poor households does not mainly lie with food availability deficit (FAD) as it is with distribution and entitlement capacity of the people. Their analysis of hunger in Ethiopia and its cause indicated malnutrition and hunger could occur in the middle of abundant food production. This argument could be justified for specific phenomena in certain place. However, it could not answer basic questions that arise from systemic view of the problem at wider longterm scale. For example, as Sen (1981) demonstrated there was no change in production of cereals prior to the 1974 famine in north and east Ethiopia, which led him to conclude the main reason was lack of entitlement for the poor landless farmers rather than problem of FAD. However, this conclusion could hardly be justified in poor countries where the population has been out growing the potential of crop lands. As Webb et al (1992) and Nega (2003) argued in some of the countries lack of sufficient crop production could cause malnutrition, hunger and in some cases famine in poor countries.

Delivering of chronic handouts to the poor in developing countries could not be followed as strategy because it will contribute to the heavy reliance on external sources which has been full of uncertainties that was vulnerable to change (Alexandratos, 1995). Eventually, the domestic supply of essential food need will define the race against food insecurity in poor countries.

There has been a decline in the growth of global agricultural output since 1984. This decline has alarmed some observers to declare the phenomena as harbinger to more decline in the productive power of the agricultural resources (Brown, 2003). But according to Alexandratos (1995) and Dyson (1996) the decline in growth rate of global cereal production was primarily due to demand oriented reduction in cereal production in six of the major cereal exporting countries, i.e., USA, Canada, European community (12 countries), Australia, Argentina and Thailand. On the other hand, they cautioned against the drastic effect of this trend especially when it occurs in the developing countries which heavily depend on agriculture for their livelihood and economy. The effect of the decline will be profound if it is further accompanied by rise in cereal price in the world market.

Agcaoili-sombilla and Rosegrant (1994) argued increasing agricultural production in developing countries particularly in land scarce once lies with increasing the productivity of agricultural lands. For them the yield growth will be essential not only in providing enough food for sustenance but also it will help sustain the livelihood of the people. It is for this reason that the FAO/WHO's international conference on nutrition recognized that access to nutritionally adequate and safe food to be a right of each individual. In order to provide this access, not only does the productivity of agricultural lands in developing countries must be improved but domestic food supply must rely largely on domestic production. One can look on how the idea of providing food for majority of people in developing countries has occupied the forefront of development agendas of their governments. Minor fluctuation in the production or market in these countries will have profound effect on the livelihood of the people with low economic status and stability of governance in the countries.

The significance of increasing agricultural production can be seen from many global initiatives addressing the problem. One of the many intergovernmental efforts to address the problem of low agricultural productivity and the resulting fate of people whose life are attached to agriculture was the SARD (sustainable agriculture and rural development) program as part of the Earth Summit in 1992. This program has incorporated achieving and maintaining sustainable agriculture in the 14$^{th}$ chapter of Agenda 21. The purpose of SARD was to ensure that all rural communities might have access to sufficient and sustainable supply of agricultural products through proper functioning of production, supply and marketing (FAO, 2006). The millennium development goals (MDG) has also envisaged to eradicating extreme poverty and hunger in the process of achieving better human development and environmental sustainability by incorporating improving agricultural productivity in areas where it is low.

The use of chemical fertilizer will be essential factor to increase crop yield in most of countries in Africa where the use is one of the lowest (Doos and Shaw, 1999, Larson and Frisvold, 1996). Larson and Frisvold (1996) argued the notion that African countries could achieve adequate soil fertility without use of inorganic fertilizer is impractical. And they recommend the policies of African government on agricultural production to focus towards increasing the use of chemical fertilizers. Although one could argue for controlling excess use of chemical fertilizers in the developed world, increasing fertilizer application is prerequisite in countries with low present fertilizer use to come out of the dire food insufficiency (Pinstrup-Andersen, 2000; Sanchez, 2006; Larson and Frisvold, 1996).

## *1.4 Systems thinking and scenario development*

Systems thinking have its origin in the fields of electrical engineering where the characteristics of inputs and outputs can readily be empirically predicted. This field of study was pioneered by Jay Forrester in the 1950s at MIT (Fisher, 2005). Systems thinking tries to understand the functioning of a system from different aspects of its parts holistically rather than analyzing individual parts separately. One of the essential tasks of systems thinking is prioritizing factors that influence the working of the system based on level of influence. Basic principles of system thinking can be adopted for agricultural and social systems although components of the systems are much more complicated and hard to manipulate compared to engineering (Gibon, 2006).

One important tool in understanding a system is forming the mental image of interaction and interdependence between its parts which is often done by using models. In modeling a system, interaction between components, the impact of one component on the other and the magnitude and direction of the effect are essential. Evaluation of the effectiveness of a model is dependent on how it affects policy discussion rather than the preciseness of the predicting output (Ryan, 2003). As Carpenter (2005) argues, making statements of fact is not the goal of modeling a system rather alerting policy makers for discussion and taking precautionary actions based on information gained from understanding of the system.

Understanding the trajectory that certain system follows need formulation of scenarios or possible future outcomes of series of actions and it helps to identify and incorporate key drivers of future events. This process in turn depends on identifying interaction and interdependence among various components of the system (Dockerty et al., 2006).

Bouwman **(**1997**)** described scenarios as "*tools to assess and compare assumptions about the future.*" There are a lot of unknowns and uncertainties in the future events. Past trajectory of resembling actions could become useful in these situations. For Schewarts (1996) scenarios are tools for ordering one's perceptions about alternative future environments in which one's decisions might be played out. For both Bouwman and Schewarts, scenarios are not predictions or planning but they are ways to see the future in light of the past experiences, present realities and future informed conjectures.

## *1.5 Modeling food demand and supply*

Food demand is a dynamic phenomenon that changes with social, cultural and economic changes. The amount and type of food consumed by a person or society changes with change in its income and livelihood. This dynamics is termed as dietary transition and has many stages with a final outcome of transforming nutrition into more high quality food composed of livestock products and less coarse grain (Popkin, 2006; Smil, 2000). At the initial stage of dietary transition the quantity of food consumed per person increases linearly with every gain in income. As income grows and quantity of food reaches certain level, the taste for higher quality nutrition will develop gradually. Beside the taste, the ease, time and energy required for preparation of food in the busy environment of urban areas favor contribute for the transition. In the final stage of dietary transition, the response of food consumption to income gain virtually disappears. The initial stage of dietary transition prevails in poor countries; therefore, change in their income will highly affects the quantity of food consumption. However, there is a long way for most of the population in poor countries to make transition to a more livestock dominated nutrition. In such countries population growth and initial level of consumption pattern will play critical role in the demand for food. But this assertion should not undermine the impact of emerging high income households in poor countries on the food supply system.

One of the models widely used in food policy analysis is IMPACT model that was developed by the International Food Policy Research Institute (IFPRI) for projection of global food demand and supply (Rosegrant et al, 2005). The model analyzes crop supply using crop price and exogenous change in crop land and yield response is estimated from price of the crop and prices of inputs. The effect of fertilizer application is incorporated in the price factor for input. In IMPACT model harvested area is determined by the crop's price, the price of competing crops, the projected rate of exogenous (non-price) growth trends in harvested areas and water. Yield is given as a function of commodity price, the prices of labor and capital (including fertilizer). Water and projected non-price exogenous variables are taken as trend factors. This model was applied for regional as well as country level food analysis by IFPRI and others. One of the drawbacks of this model is its dependence on price clearance of demand and supply of commodities. Price is very volatile variable to use for long term projection in countries that depend on food import and inflation is rampant. Moreover, the practices of agricultural protectionism in the developed world distort the true price of agricultural commodities since the price will depend on local policy decisions than interplay between demand and supply. Therefore, use of this model in countries which have less control over prices of production and inputs could not help in the long term projection.

The models used in this study focus on past trends in for consumption and population growth informing possible future trajectories. The models face the problem of using many assumptions and lack detailed incorporation of many variables. But they help in understanding to differentiate between essential and marginal factor in determining future food demand and supply.

## *1.6 Data analysis*

The major source of data for all the studies was acquired from FAOSTAT, WDI, WRI and UN population prospect for cross-country analysis, and CSA household and price survey for Ethiopia specific analyses.

FAOSTAT is a data reservoir on agriculture and related resources for world countries which is available on the Internet as well as on CDs. The source data for compilation of FAO data is normally acquired from national governments' annual reports through submitted questionnaires. In cases where data acquisition is difficult or questionable, estimation and adjustment is made through related resources with expert consultation. Further adjustments are made as new and more reliable information is obtained. The FAO provides agricultural data starting from 1961 depending on country and type of data.

WDI (World Development Indicators) is World Bank's comprehensive annual database that provides development data on more than 800 indicators for 209 economies and 18 regions (WDI, 2008). Like FAOSTAT, the source data is collected from member countries' official reports and therefore, the quality of the data is contingent on the quality of statistics in the country of origin.

World Resource Institute (WRI) provides compilation of information on available water resources and level of irrigation beside other data. Whereas, the UN population prospect provide past population data for all countries of the world on different time scales and age structure.

## *1.7 Research problems*

This thesis tried to analyze past trend, present situation and future prospect of cereal demand and supply system in Ethiopia. It tried to demonstrate the magnitude of cereal supply challenge in Ethiopia in comparison with other African countries. The main research questions addressed are: -

- What is the level of food security problem in Ethiopia compared with other African countries?

- Could Ethiopia supply its cereal demand without expanding croplands for the next two decades? If so,
    - How much cereal yield improvement is required?
    - How much chemical fertilizer is needed to achieve the required yield?
- How much does livestock consumption affect the demand for cereal feed?
    - What are factors that affect livestock consumption in Ethiopia?
    - How does meat consumption pattern vary in urban and rural households?

These questions were tried to be answered in the following chapters. After describing the present conditions of Ethiopian agriculture, population and economy in chapter 2, chapter 3 analyzed Ethiopia's position in cereal production potential in Africa from perspective of population size, per capita GDP, available water and potential arable land. In this chapter the importance of Ethiopia in food security in Africa was assessed and rendered for further investigation in the next two chapters. Chapter 4 inquires meat consumption pattern in rural and urban households in Ethiopia by categorizing them into income groups. Meat consumption determinant analysis was also made for regional states in the country. Livestock consumption data for Ethiopia from FAO was reassessed using consecutive national household surveying information. In Chapter 5 further analysis of per capita consumption of cereals and livestock consumption was made in detail with the objective of estimating demand for nitrogenous fertilizer. In the final chapter conclusion was made and policy recommendation was forwarded.

## *1.8 Significance of the study*

The projection of future prospect of food demand and supply in this study will help to understand the broader problems and opportunities in population and resource interactions in Africa in general and Ethiopia in more detailed way. The models and projections will reveal the complex interplay of different factors and enable to concentrate on critical factors that affect future food security challenge in Africa in general and Ethiopia in particular.

# Chapter 2 : Overview of Ethiopian Population, Agriculture and Economy

## *2.1 Population*

Ethiopia is the second most populous country in Africa with a population of 75 million people in 2007(CSA, 2008) and is continuing to grow unabated at an annual rate of 2.4%. All demographic variables indicate that this high rate of growth will show little change in the foreseeable future. The younger age groups dominate the population which is a typical feature of population in its early phase of transition (Cohen, 1995). For example, 48% of the Ethiopian population was between 15 and 49 years and about 43% of the population was under 15 years of age in 2007 (Figure 2:1). This figure also indicates that the rural population which constitutes around 80% of the population has the typical pyramidal shape peculiar in rapidly growing population. In 2005 the rural and urban total fertility rate (TFR) was 6 and 2.3 respectively. The rural TFR in Ethiopia is one of the highest in Africa. In urban areas there has been decline in the rate of population growth and, therefore, population transition has progressed to the later stages but the percentage of people in urban areas is too low to affect population transition in the country.

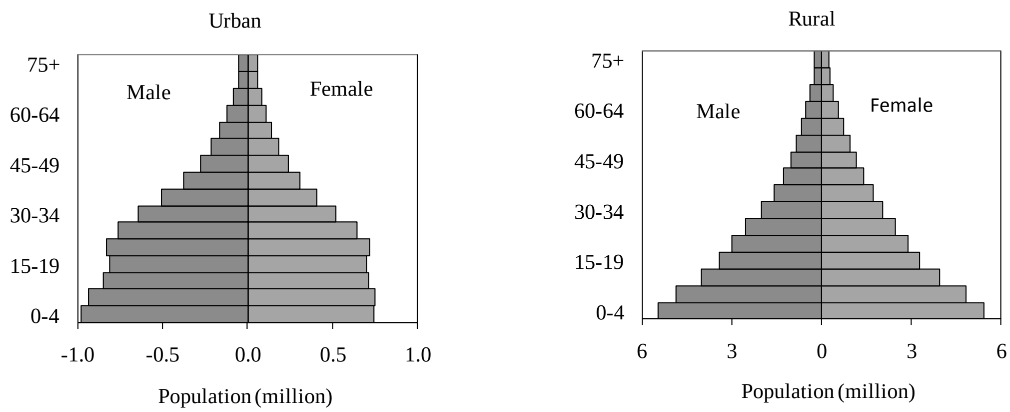



*Figure 2:1***.** *Urban and rural population pyramid of Ethiopia in 2007*
*Data source: CSA population census, 2008*

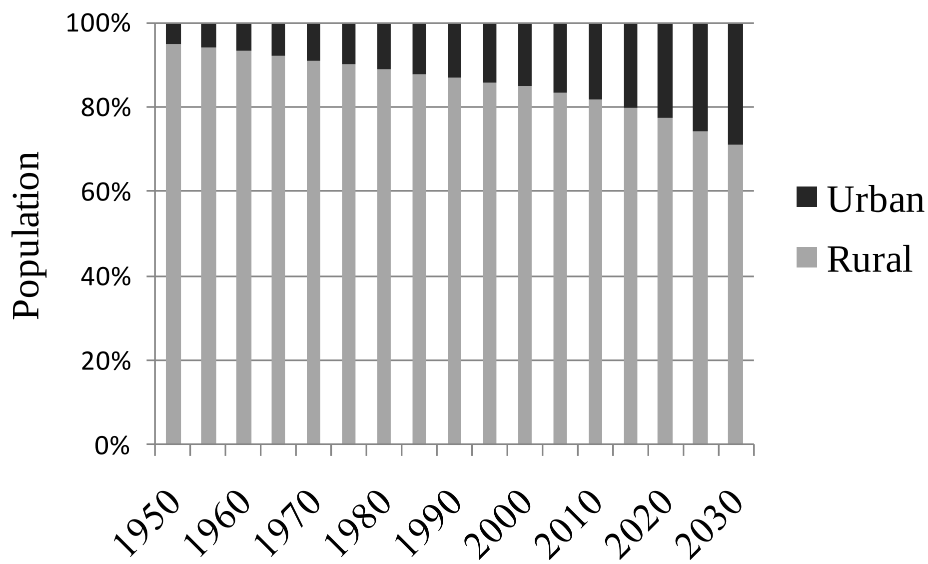



*Figure 2:2 Trend in urban population growth in Ethiopia, 1950-2030*
*Data source: UN population prospect (2005)*

Figure 2:2 shows that although there is gradual increase in the percentage of urban population, in 2007 more than 80% of the people in Ethiopia lives in rural areas and this proportion is not expected to drop below 70% by 2030. The rate of urbanization is one of the slowest in Africa. The official development policy of the government of Ethiopia, ADLI (Agriculture Development Led Industrialization), has given much attention to changing the rural production systems so that agriculture would energize the emergency of strong and sustainable industry (MoFED, 2006).

## 2.2 Land resources

Ethiopia has total land areas of 1.10 million sq. km. In 2007, the total agricultural land area was 35% of the total land. According to FAO's definition, agricultural lands include arable land, permanent crops (such as coffee), and permanent pastures. The size of arable land has grown from 10 Mha in 1993 to 14 Mha in 2007. Expansions of arable lands are mainly occurring into forest and pasture lands most of which were previously left uncultivated for their marginal productivity. As a result the total natural forest of the country has contracted to less than 2 % of the total land from significantly higher percentage in the past (EFAP, 1994; Reusing, 1998). The woodlands which account for about 20% of the total land area are characterized by extensive encroachment and low vegetation density.

## 2.3 Ethiopian economy

Ethiopia has a subsistence economy that highly depends on agriculture for livelihood and export earnings (Feleke and Zegeye, 2006). With an annual per capita GDP of 173 USD and HDI of 0.4, in 2006, it remained one of the six lowest per capita income countries in the world. Agriculture contributes for 55% of the GDP (Figure 2:3) and about 30% of commodity export in 2006 (Figure 2:4). The service sector has been showing steady growth in the aftermath of government change in 1991. The manufacturing sector, on the contrary, has remained underdeveloped and its contribution towards the total GDP stagnated below 10%.

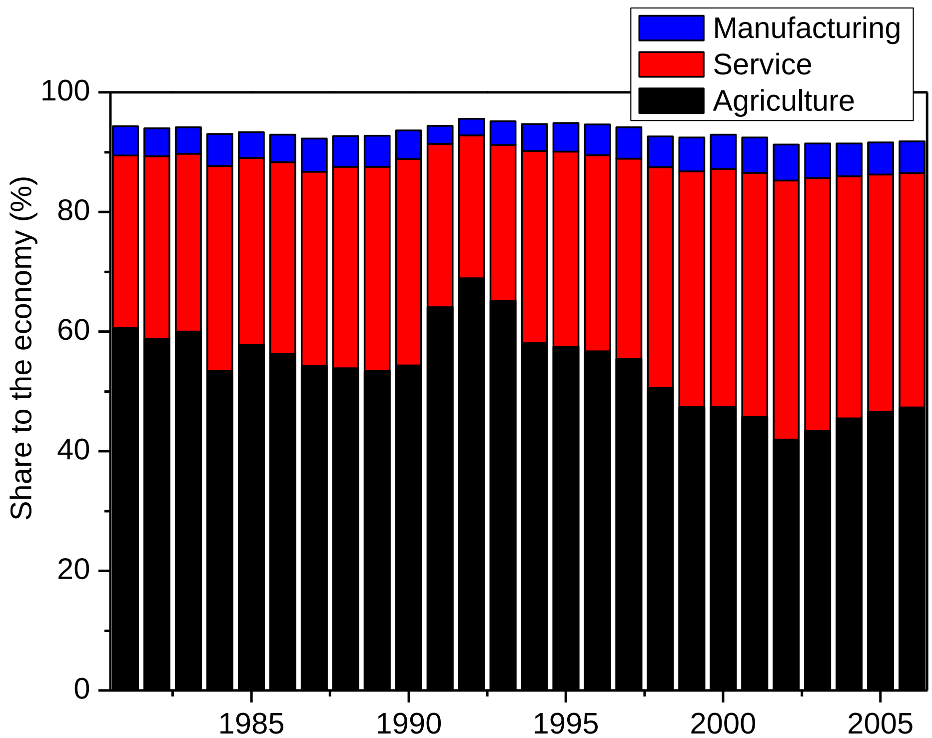



*Figure 2:3 Contribution of different sectors to GDP between 1981 and 2005*
*Data source: WDI, 2008, the total could not add to 100% as a result of external financial support*

Exports of agricultural commodities are mainly composed of coffee, oil seeds, flowers and leather products. Coffee contributes for about 35% of the total export and has been a major source of foreign currency for many decades (IMF, 2008). The country’s little control over export price of coffee and emergency of large scale exporters of coffee in the world market has been endangering Ethiopia's reliance of export earning on coffee. Nevertheless, coffee has remained the single most important commodity in acquiring foreign currency that is essential in servicing the huge external debt the country is encumbered with for the past several decades and financing essential development programs.

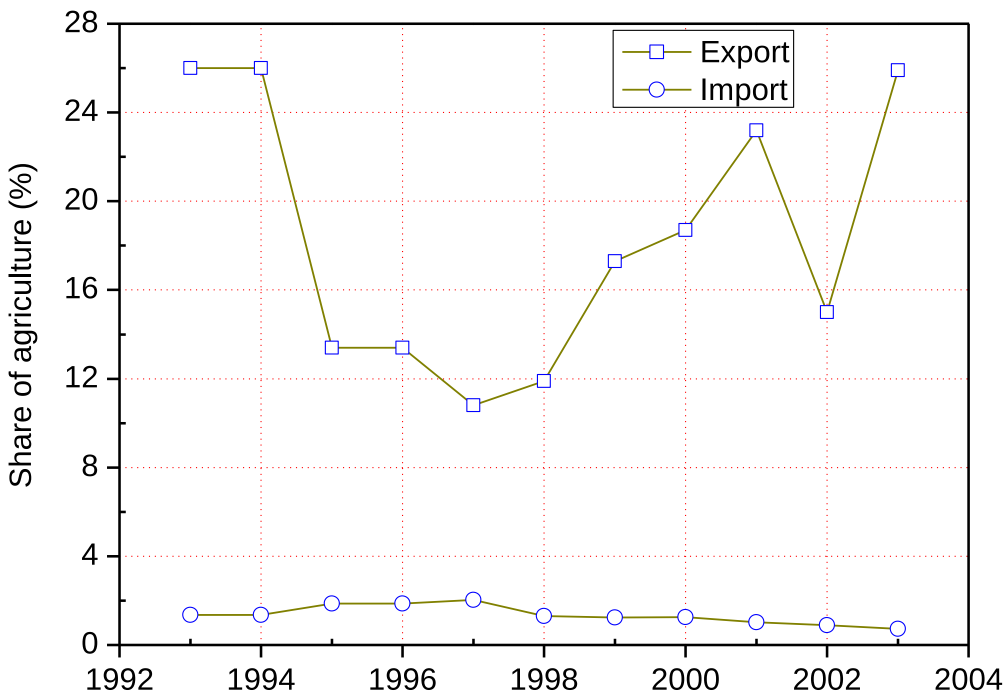



*Figure 2:4 Contribution of agricultural raw materials to commodity import and export in Ethiopia between 1993 and 2003*

*Data source: WDI, 2008*

The import share of agricultural products has not been as noteworthy as the export sector. They account only for less than 5% of the total import (Figure 2:4), of which cereals occupy the larger share.

Balance of payment or trade deficit grew from 1.3 billion in 2003 to around 4 billion in 2007. One of the items that showed major growth was payment for the fuel oil. According to IMF (2008) country report, payment for oil has increased 400% within 10 years. This was largely attributed to hike in the price of petroleum oil in the world market coupled with rise in amount of energy use.

Ethiopia's imports mainly come from China (17%), Saudi Arabia (15%), Italy (7.7%), India (6.9%) and Japan (6.2%). And the major export destinations include China (13.4%), Germany (10.1%) and Japan (7.8%). The notable dynamics observed was China's rapidly increasing participation in Ethiopian economy in recent years (Jenkins and Edwards, 2006). For example, Ethiopian import and export from and to China grew by 89% and 550% between 2001 and 2007 respectively.

## *2.4 Climate and food security*

Ethiopia is endowed with climatic and topographic diversity. It has a tropical climate that is highly modified by altitude. Elevation ranges from 110 meters below sea level in Danakil Depression to 4,620 meters above sea level (m.a.s.l.) in Ras Dashin, the highest mountain in the country. More than 45% of the land is found in the highland where elevation is 1,500 m.a.s.l. The annual precipitation ranges from 400 mm in the north and south eastern lowlands to 1,700 in south western lowlands where most of the remaining natural forests are found (Figure 2:5). Most part of the country experience a bimodal rainfall with erratic annual precipitation. The main rainy season, *Kiremt*, occurs roughly from July to September and smaller rainy season, *belg*, occurs from March to May (AERE, 2006). Variability is higher in areas where annual precipitation is lower and these areas have been facing frequent drought in the past. Most of the crops are grown in the longer rainy season, *Kiremt,* and Ethiopian agriculture largely depends on this rain (Block and Rajagopalan, 2007). As a result of the erratic nature of precipitation in Ethiopia which is highly affected by monsoon climate in the Indian Ocean, the country has faced recurrent drought and ensuing famine over the last many decades with the frequency of recurrence increasing in recent years. As a result of the subsistence nature of Ethiopian agriculture and complex interplay of socioeconomic factors, Wolde-Mariam (2003) argued, a failure in the one rainy season could trigger drought and hunger even, in the worst case, result in famine.

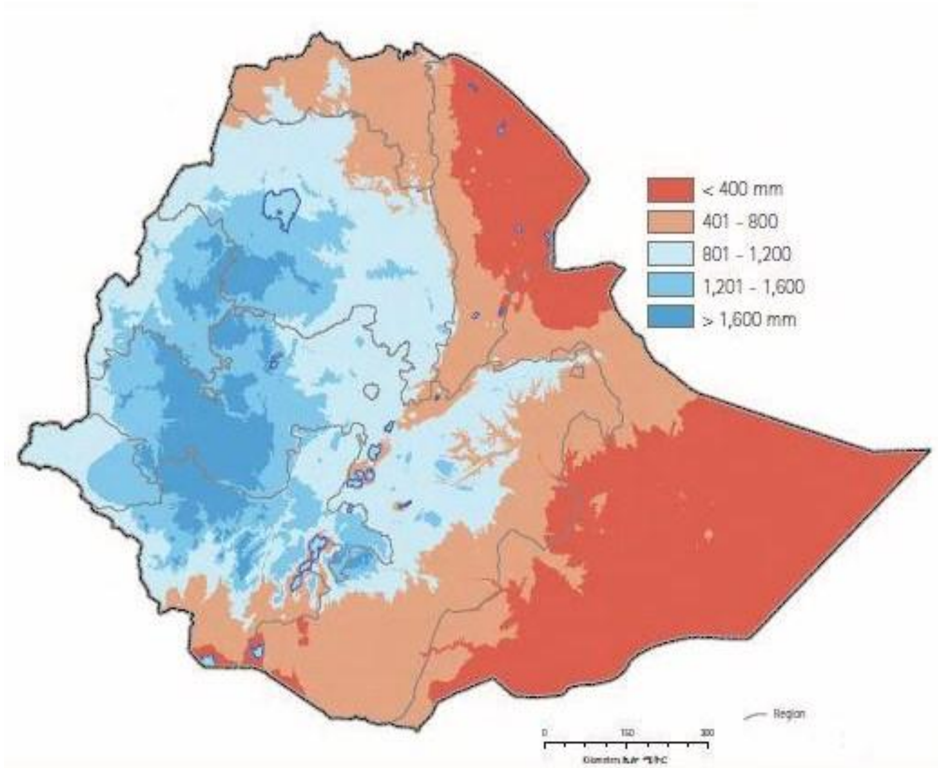



*Figure 2:5 Distribution of annual rainfall in Ethiopia*
*Source: AERE, 2006*

In spite of its vast land as well as human resources, Ethiopia has relied heavily on external assistance for food since 1970s. The amount of food aid has doubled between 1993 and 2003 (WDI, 2008). As a result, Ethiopia has become one of the highest total cereal aid recipients in Africa. Even recently, the government of Ethiopia with its humanitarian partners has reported that the number of people with chronic food support has grown to a staggering 6.2 million in 2008 (OCHA, 2009). Nega (2003) made projection of the number of people in need of food aid to around 50 million in 2030 which is more than the present population of 90% of countries in Africa and nearly 40% of the total population by then. However, Nega (2003) seems to have considered only grain based food demand that did not include livestock foods. The impact of increase in demand for animal food caused by the expansion of urbanization will require allocation of more cereals for livestock production. The growth in livestock cereal feed will in turn drain the cereal supply market and result in more people to be affected by lack of food because, as Sen (1981) argued, those poor households with less entitlement will have little to spend in a more competitive market. This will make the future prospect of domestic supply direr if the present conditions continue as it has been.

## *2.5 Agro-ecological zones*

Ethiopian agricultural system is divided into six major traditional agro-ecological zones each of which are dominated by certain crop types. The map on Figure 2:6 and description on Table 2.1 show the distribution of each system in Ethiopia. About 60% of the land is occupied by *Bereha* and *Kola* agroecological zones, both of which are characterized by hot climate with little annual precipitation and dominated by Sorghum (*S*orghum *bicolor*) and Maize (*Zea mays*) production. These areas are faced with shortage of water and low agricultural productivity. As a result, they are the most sparsely populated parts of the country.

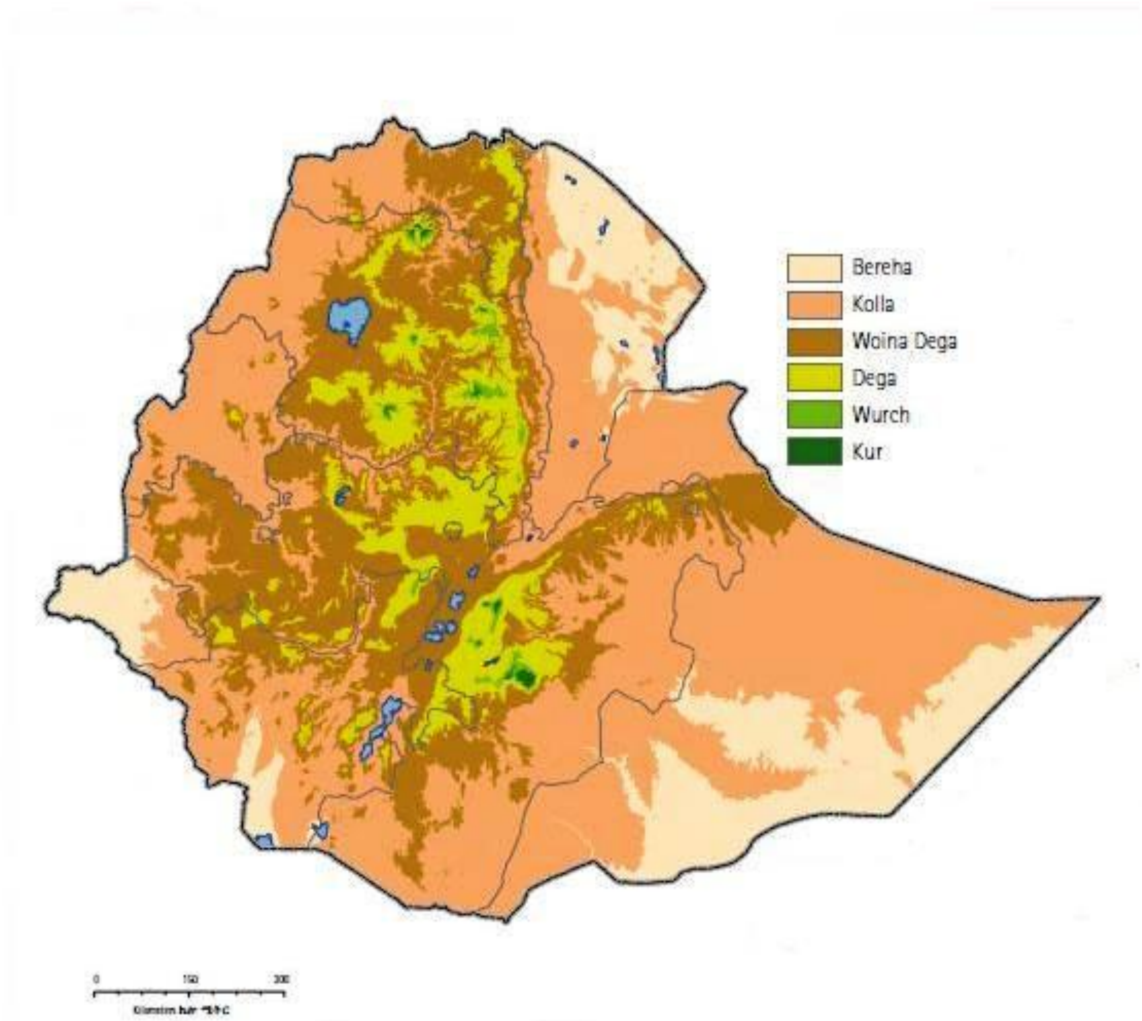



*Figure 2:6 Traditional agro-ecological zones of Ethiopia*
*Source: AERA, 2006*

Cultivation of major crops like wheat (*Triticum* spp), barley (*Hordeum vulgare*) and *teff* (*Eragrostis tef*) are grown in Woina Dega and Dega agro-ecological zones which have mild climate and dominant in the highland where the majority of the population live. As a result of centuries of cultivation with essentially no chemical fertilizer, agricultural lands in the highlands are shrinking due to rampant soil degradation estimated at 100 billion tones every

*Table 2.1 Elevation, climate and major crops in the traditional agro-ecological zones in Ethiopia*

| **Agro ecological zones** | **Elevation (m.a.s.l.)** | **climate** | **Major crops** |
|---|---|---|---|
| Bereha | Less than 500m | Hot lowland | Mixed crop, maize |
| Kolla | 500-1,500m | Hot | Sorghum, finger millet, sesame, cowpeas, groundnuts |
| Woina Dega | 1,500-2,300m | Mild | Wheat, *teff*, barley, maize, sorghum, chickpeas |
| Dega | 2,300-3,200m | Cold | Barley, wheat, oilseeds, pulses |
| Wurch | 3,200-3,700m | Very cold | Barley |
| Kur | Above 3,700m | Hail, extremely cold | No major crop |

year (EFAP, 1994).

## *2.6 Nitrogen fertilizer use*

Cereal production in Ethiopia rely less on use of chemical fertilizer than expansion of harvesting lands. Unlike the environmental problems in most developed and emerging countries that face excessive use of chemical fertilizers, Ethiopian agriculture suffers from the opposite problem of insufficient use that could not replenish the nutrients withdrawn from the soil. As can be seen in Figure 2:7, cereal yield in Ethiopia and the neighboring countries has always been low and resulted in declining per capita cereal production.

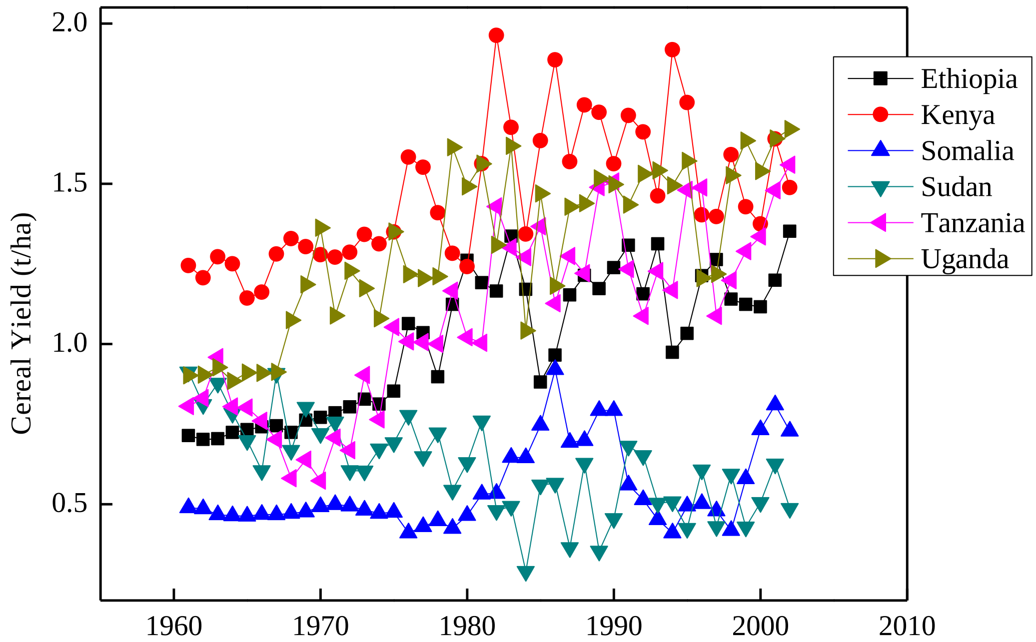



*Figure 2:7 Cereal yield trend in Ethiopia and some neighboring countries, 1961-2002*
*Data source: FAOSTAT, 2005*

Part of the reason for the low cereal yield is clearer when considered on the backdrop of the meager chemical fertilizer use shown on Figure 2:8. This phenomenon is not peculiar of Ethiopia but is prevalent in most of the countries in the region. Except for Kenya, all other East African countries have been using an average of less than 10 kg/ha nitrogenous fertilizers.

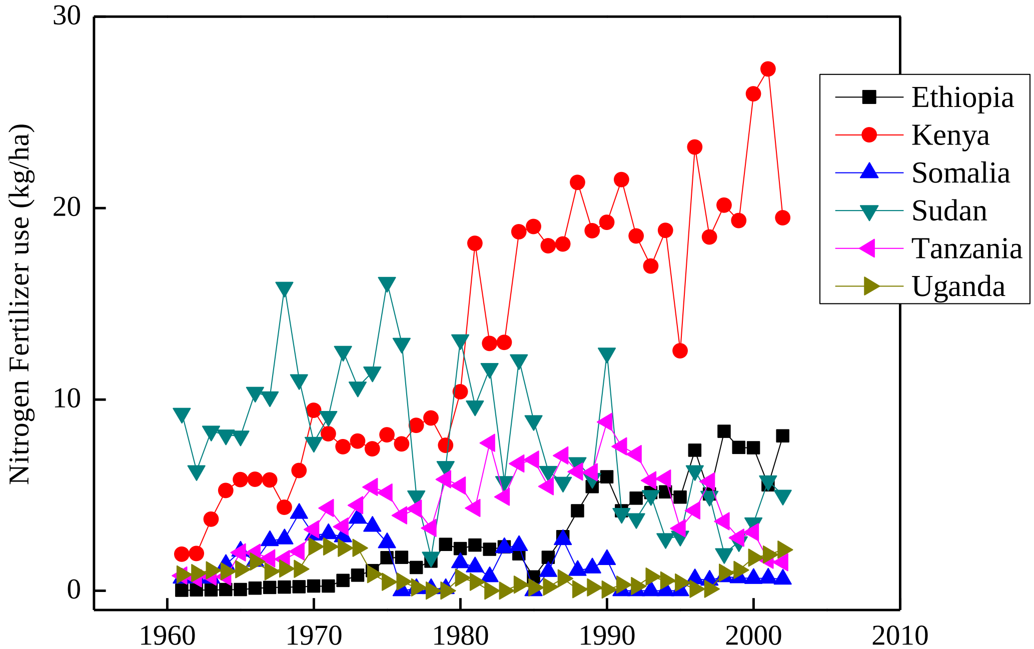



*Figure 2:8 Nitrogenous fertilizer use trend in East African countries from 1961 to 2002*
*Data source: FAOSTAT, 2005*

## *2.7 Land and water scarcity in Gursum, Ethiopia*

This section describes the problem of decline in productivity of cropping and decline in landholding size in small scale study conducted by Betru and Kaji (2004). The surveying was made in summer of 2002 in Gursum district, east Ethiopia to investigate socioeconomic challenges and potential for sustainable watershed management. Gursum is found in the eastern edge of the great Ethiopian Rift Valley at 9° 20'N latitude and 42° 23'E longitude with average altitude of 1,954 m.a.s.l. The total population was 151 thousand people in 1994, with 91% living in rural areas (CSA, 1996). In a recent population estimate by CSA (2008), the population grew to 225 thousand in about a decade time.

The average household land holding was 1.5 hectares (Zonal Office of Agriculture, 1996 cited on Habtemariam et al 2000). The mean annual rainfall was 756 mm for the year 1995/96. The woreda is well known for its erratic rainfall and frequent crop failures. The prevailing production system is a crop-based mixed farming. Chat (*Chata edulis*), sorghum and cattle are the main commodities. Small plot coffee farms also contribute to cash generation for rural households. Fugnanbira town is the nearby urban center in the area and had a population of about 15,000 people that depend on the watershed for water and forest products. There are three peasant associations (Pas) with a total of 20, 000 people which depend on the watershed for livelihood.

In the study a semi-structured questionnaires were employed to understand rural households' level of satisfaction on their landholding size, water resources and level of cereal production among other things. Moreover, interview was conducted with government officials and experts on agriculture and water resources.

The result showed that 80% of respondents were dissatisfied with their present landholding size. They expressed willingness to cultivate into the forest although some of them expressed their knowledge of the negative effect of their actions. Moreover, the problem of scarcity of water for irrigation and irregularity of rainfall were mentioned as major reasons for decline in crop production.

Interview result showed that there are a lot of disappointments on performance of agricultural productivity in the past. Most of them were found to have a pessimistic view of the future prospect citing that there is little progress of action. The study indicated a need to intensify wide range of appraisal on resource management and enhancing participation of the people at different stages of decision making. It also exemplifies the gravity of continued loss of productivity of agricultural lands.

# Chapter 3 : Comparative analysis of Ethiopian food security in African context

**Summary**

For the past four decades there has been an overwhelming dependence on cereals for daily direct human food energy in Africa. Most of these demands were met largely through domestic production, albeit the contribution of import started to grow in recent years. In this chapter, cereal production and import trend from 1961 to 2003 were analyzed for 51 countries in Africa. A system model was used to analyze the future prospect of demand and supply scenarios in each country up to 2030. The UN population projection, WRI water and the FAO agricultural data were used. The result showed that 60% of the countries in Africa requires cereal yield less than 2 t/ha in 2030 with no expansion of agricultural land. Most countries, with the exception of small countries, will have enough agricultural land for further expansion of cereal harvesting land or could easily improve cereal yield which has been very low in the past. Moreover, cereal import will continue to occupy major part of domestic supply in Africa. The contribution of cereal aid will gradually become insignificant in most countries except East Africa. Based on factors of available arable land, per capita income, cereal yield and available water resources, Ethiopia, Eritrea, Rwanda and Burundi were found to be among the countries that will face higher risk of food insecurity. Among these countries, Ethiopia with its huge and growing population will be the most important country in addressing the problem of food security in the region and in the continent as a whole.

**Keywords**: *Per capita cereal, cereal yield, Africa, Harvesting land, import, aid*

## *3.1 Introduction*

The world food security has made significant progress since the Green Revolution in 1960s (Grigg, 2001). This was partly achieved as a result of an unprecedented cereal yield improvement initiated and fueled by the use of improved seeds and large amount of chemical fertilizers (Gilland, 1993; Borlaug, 1970). Nevertheless, the revolution was not uniformly experienced in all countries and regions. Most countries in Africa could not participate in this revolution (Bumb, 1991), as a result remained with one of the least per capita cereal production in the world (Islam, 1995).

Cereals play essential role in African nutrition, constituting larger portion of daily calorie and protein. In 2003, for example, 50% of food calorie and 53% of protein came from cereals (FAO, 2005), rates which were much higher than cereal's contribution in developed countries (Alexandratos, 1995). Although, economic growth in some parts of Africa is poised to affect dietary transition to a more livestock dominated nutrition in the foreseeable future, the vast majority of countries will continue to depend highly on cereals for direct food energy.

Past cereal demands in Africa were largely met through continuous expansion of harvesting lands with little improvement in cereal yields. There is uncertainty on how the past trends in agricultural lands could be continued in many of the countries as a result of limited land area, economic feasibility of potential lands and availability of sufficient water.

Cereal yields did not show improvement partly because of distinctively low level of chemical fertilizer use (Larson and Frisvold, 1996; Bumb, 1991; Ladha et al, 2005). The use of chemical fertilizers that fueled much of crop production in other parts of the world (Gilland, 1993) has been in limited use in Africa. Although, some small positive growth was observed in recent years (Naseem and Kelly, 1999) per hectare application rate still remain insignificant in comparison with required quantity. In 2002 the average chemical fertilizer use in Africa was only 8 kg/ha far less than the world average of 91 kg/ha that year (FAO, 2005). It was argued that increasing cereal yield in Africa requires significant improvement in the use of chemical fertilizers from the present level (Larson and Frisvold, 1996; FAO, 2004; Kelly and Crowford, 2005).

The argument against increasing the use of chemical fertilizer because of deleterious environmental effects could not be applied in most African countries, albeit not in all, as a result of the present low use level. The study by Kawashima et al (1996) demonstrated that the contribution of Africa to aggregate nitrous oxide in the world was insignificant. Moreover, as Bumb and Baanante (1996) argued there is little dispute on the indispensability of increasing the use of fertilizers in food-deficit low crop yield countries.

The problem in Africa is rather the availability and affordability of chemical fertilizer since only few countries produce chemical fertilizers; therefore most of them rely on import. The price of chemical fertilizer, especially nitrogen fertilizer which is needed in higher proportion, has been rising in the world market with the price of fuel. Therefore, the capacity of a country to increase import and use of chemical fertilizer is interrelated with its economic performance.

In the past, in addition to increasing cereal production some countries have also increased cereal import either through trade or/and aid. Even some of the previously net cereals exporting countries like Botswana, Zimbabwe, Malawi and South Africa eventually became net importers (FAO, 2005). The capacity of increasing cereal import is affected by economic performance a country. Increasing cereal supply through trade has less appeal in poor countries as a result of the volatility of price of cereals in the international market.

The major challenge for most African countries will be how to keep the level of cereal supply and transition to a better nutrition while safeguarding the sustainability of the resource use in commensurate with population growth either through domestic production or import from other countries.

In order to understanding the state of cereal demand and supply in Africa, analyzing specific conditions in each country differentially and systematically is required rather than treating the whole continent as a homogeneous unit. Most of the countries did not have similar experience in cereal supply in the past and will not obviously follow the same route in the future. Therefore, analyzing the past trends will help understand what possible future they might follow.

This study analyzed past trends and future prospect of cereal demand and supply in 50 countries in Africa (See Appendix 2) with special emphasis on Ethiopia. These countries were grouped based on their level of cropping intensity as indicator of potential for future expansion of agricultural land based of which possible future cereal supply options were discussed. The result of the study will help identify countries which will face major challenge in cereal food supply system and broaden our understanding macro level food security condition in Africa from the perspective of potential of expansion of crop lands, improving cereal yield and potential to increase cereal import. Moreover, understanding of Ethiopia's cereal supply position could be better understood from the result of the comparative analysis. The result can also be used as input in formulating strategic cereal aid policies in the worst case where countries could not increase their supply through the other means.

## *3.2 Materials and methodology*

A country-wide system model shown in Figure 3:1 was used to analyze and classify countries based on their past trends and future scenarios of cereal demand and supply. Firstly, the past regional cereal production and net import trend was described and analyzed. The five categories of regions in FAOSTAT were used.

Secondly, future cereal demand of each country was projected using rate of population growth and per capita cereal consumption. Input for future population was taken from the middle variant of the UN population prospect (UN, 2005). The per capita cereal consumption level in 2003 was assumed to continue unchanged throughout the projection period. The future supply of cereals was estimated from local production and import on international market. The potential of local production was assessed using available arable land, renewable water and cereal yield. The potential of each country for cereal yield increament and cereal import was inferred from their level of per capita GDP. The choice between improving cereal yield and cereal import was assessed using level of cropping intensity and available unused land which is suitable for agriculture.

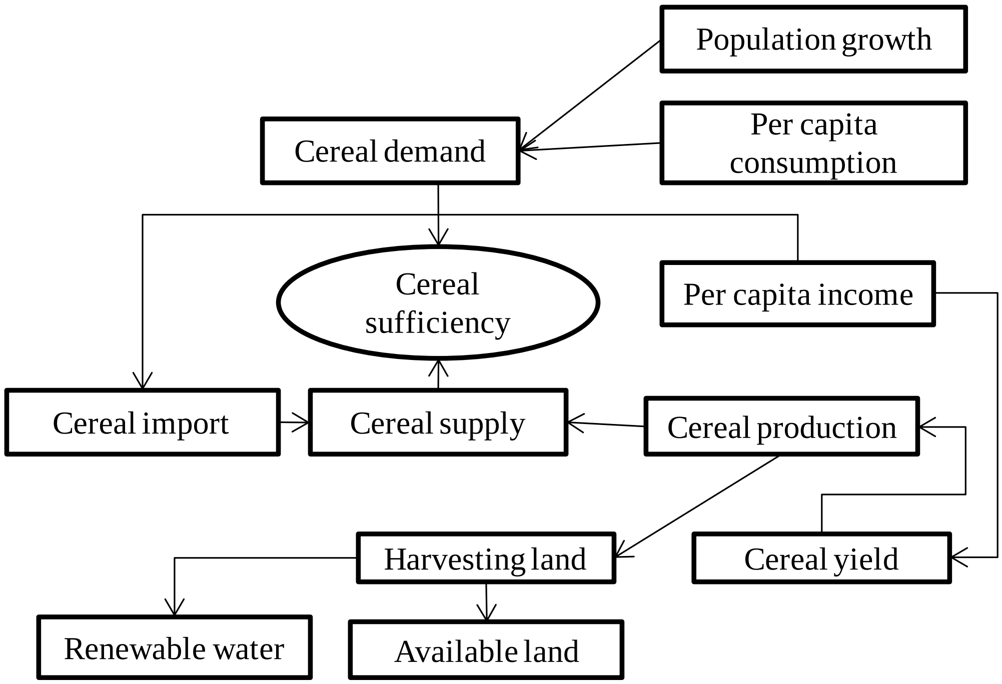



*Figure 3:1 Scheme of cereal demand and supply analysis model*

Countries were divided into three groups based on their level of cropping intensity (CI) which was calculated by dividing harvesting land to arable land. CI shows the percentage of arable land that is used for cropping. The value of CI could also incorporate lands under double cropping and should be interpreted cautiously especially when the value is more than 100%.

On the supply side, the possibilities for each group of countries were analyzed based on their available and potential arable land, ability to improve cereal yeild and possibility of expanding cereal import from international market. Potential arable land was estimated from available forest land, woodland and pasture lands. Available average per capita water was also used for assessment of possibility of expansion of croplands. The potential for cereal yield imporvement and import was evaluated from the countries' per capita GDP.

Finally, cereal sufficiency was used as indicator of food security level and calculated as a factor of cereal yield, per capita GDP, per capita available water, total population and population growth rate. Except the last two variables the other variables were considered to have affected cereal sufficiency positively. Countries were ranked according to their level of food security index calculated by adding the above indexes. Food security index ranged from 1 to 10, from highly secure to highly insecure countries.

## *3.3 Result and discussion*

### 3.3.1 Past cereal demand and supply

Analysis of past cereal trend showed that in most countries in Africa there has been a decline or stagnation of per capita production (The summary of result is given on Appendix 2 A, B, C and D). Per capita cereal supply, however, has increased by more than 10% between 1961 and 2003 as a result of 1100% increase in mostly traded cereal import. Cereal production grew by an annual rate of 2.02% from 46.3 Mt in 1961 to 130.5 Mt in 2003. On the other hand, the population has grown from 289 to 906 million people between 1961 and 2007, i.e., average of 2.6% annual growth. This disparity in growth rate between population and cereal production led to a 43.5% decline in per capita cereal production between 1961 and 2003. The decline was compensated by considerable rise in traded cereal import in most except some food aid dependent countries like Ethiopia and Sudan which accounted for about half of food aid in Africa in 2003. The total annual cereal import has increased from 5 to 47 Mt between 1961 and 2003, of which food aid accounted for only between 1.7-3.3 Mt.

Expansion of harvesting land was responsible for 56% of growth in cereal production between 1961 and 2003, while cereal yield improvement accounted for the rest 44% of the growth. Cereal harvesting land grew from 57 Mha in 1961 to 106 Mha in 2007, whereas, cereal yield rose from 0.8 t/ha to 1.3 t/ha during the same period. Much improvement in cereal yield could have been achieved fairly easily because the initial levels in most of the countries were very low. In the past only Egypt and South Africa achieved an average cereal yield more than 3 t/ha that affected production and supply of cereal for domestic as well as export market.

The change in per capita cereal production has not been uniform in all regions of Africa. Figure 3:2 shows the regional differences in per capita cereal. North Africa was the only region where growth of cereal production exeeded population growth between 1961 and 2003. In West and Central Africa cereal production grew at similar rate with population growth keeping the per capita production unchanged. In the remaining two regions, rate of population growth superseded the rate of cereal production which resulted in declining per capita cereal production.

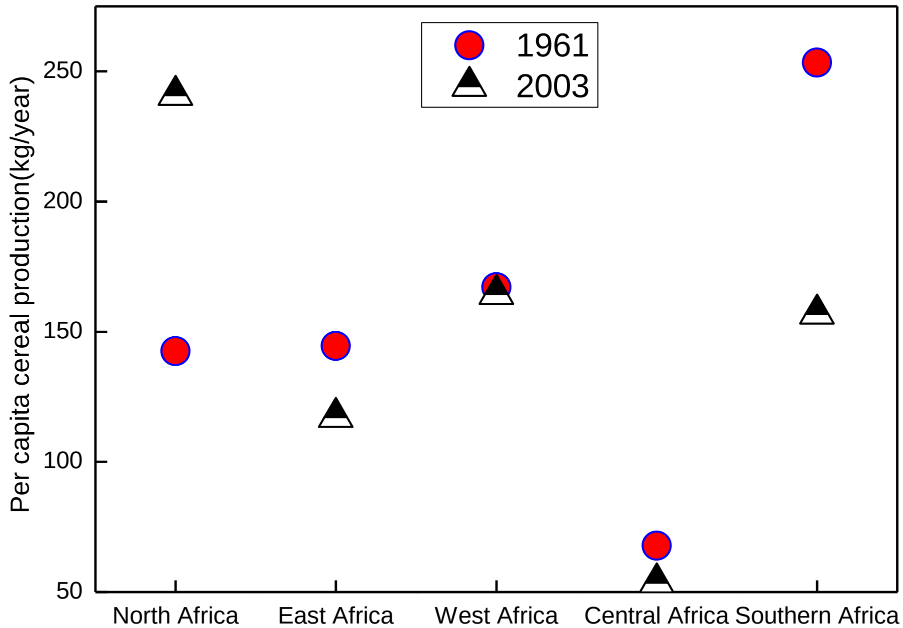



*Figure 3:2 Change in per capita cereal production among African regions in 1961 and 2003 Data source: FAOSTAT*

African countries have been heavily relying on domestic cereal production for food in the early 1960s when import was accounting only for about 10% of the total domestic supply. The import itself was in turn dominated by cereal aid that accounted for 34% of the 5 Mt imported cereal in 1961. On the contrary, while the proportion of cereal import grew to 28% of the total domestic supply in 2003, the contribution of external cereal aid declined to only 6%. In 1961, the North African countries of Egypt, Morocco, Tunizia and Alegeria were the major recipients of food aid in later years. Gradually, the East African countries became major recipients of cereal aid. Two of the countries in this region, Ethiopia and Sudan, accounted for half of the total cereal aid in Africa. This was also in line with the assessment by Omamo (2006) which categorized the region as one of food deficit areas.

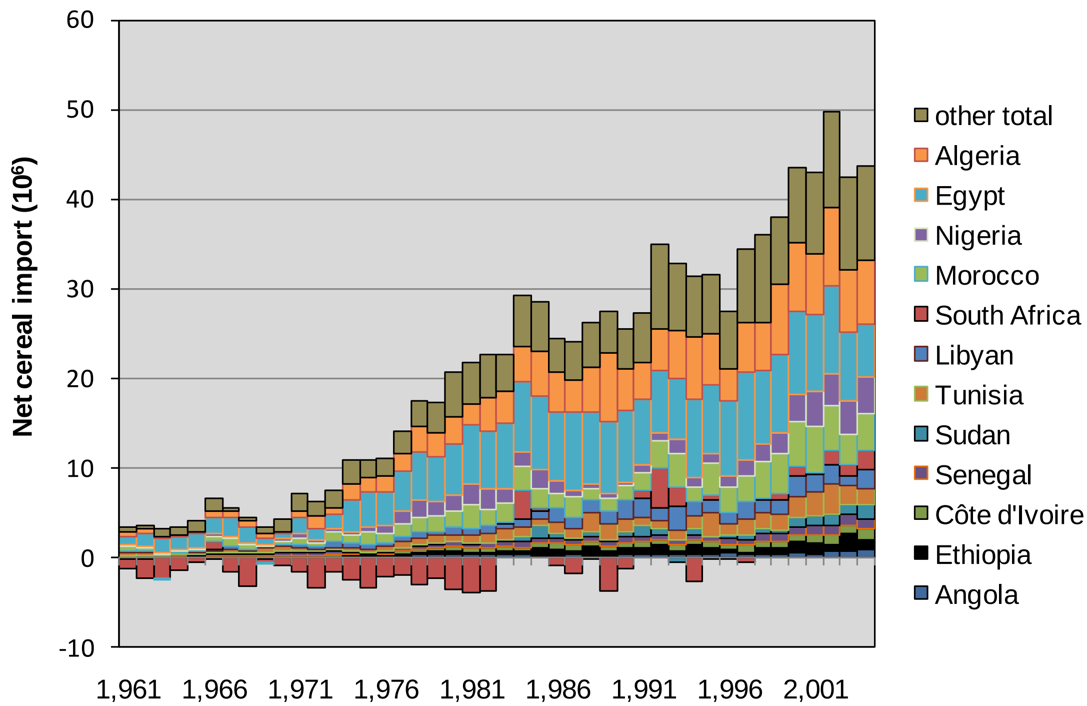



*Figure 3:3 Net cereal import in major importing countries from 1961-2005*
*Data source: FAO, import in metric ton*

Cereal import was dominated by few countries mainly from North Africa. In 2003 only twelve countries acounted for 75% of the African cereal import (Figure 3:3). Among these countries, Egypt, Morocco, Algeria and Nigeria have experienced major growth in cereal import which significantly affected their per capita supply and offset the effect of high population growth. These countries accounted for more than half of the total cereal import in the continent. It can be argued that in most of the remaining highly populated countries, traded cereal import did not have major impact on dometstic cereal supply that most of them have had to rely on domestic production or supplemented by cereal aid from international donors.

### 3.3.2 Potential cereal cropping land

The countries were categorized into three groups based on their potential for expansion of harvesting land or increasing cropping intensity, i.e., the percentage of harvesting land to arable land. The first group is comprised of countries with cropping intensity less than 0.5 and was called Low CI countries. The second group had CI between 0.5 and 1 and was called Intermediate CI countries. The third and final group had CI above 1 and was categorized as High CI countries. Each category is discussed below in detail.

#### Low CI countries

This group was dominated by southern and central African countries which were characterized by maize production and availability of abundant potential agricultural land respectively. The South African countries were the major net exporters of cereals in Africa before 1990s. However, as can be seen from Figure 3:3, all of these countries became net importers of cereals thereafter. But from the low CI level in these countries it can be argued that scarcity of agricultural land was not the main reason for contraction of production. Economic development and resulting better purchasing power in some of the countries could be among the reasons for this change in cereal trade balance. The central African countries in this group, on the other hand, have abundant potential arable land for future expansion although they have had limited reliance on cereals in the past and their future expansion of cereal harvesting land will depend on dietary transition, population growth and export market.

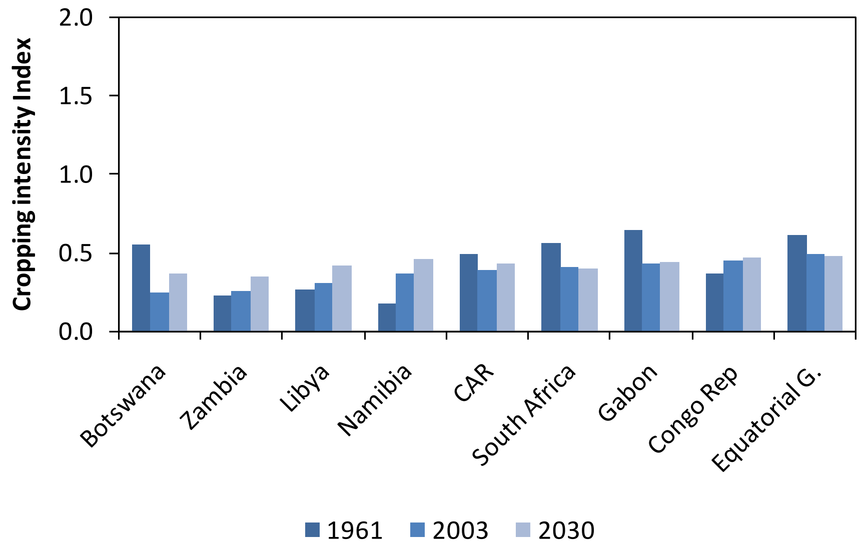



*Figure 3:4 Changes in cropping intensity in countries with low CI between 1961 and 2030*

It can be seen from Figure 3:4 that in five out of the nine countries in the group, CI has declined between 1961 and 2003. Although CI is expected to increase in countries like Libya, Namibia and Congo Republic, it will still remain below 0.5 by 2030. At the end of the projection period, the countries in this group will most likely remain under low CI and face insignificant challenge in expanding cropping area.

Figure 3:5 and Figure 3:6 shows the change population per arable land and cereal yield respectively. Population growth in the four decades after 1960s has resulted in population-arable land density below 10 people/ha for majority of the countries. Except for Congo

Republic, this density will remain relatively unchanged within the projected period as a result of slowing of population growth.

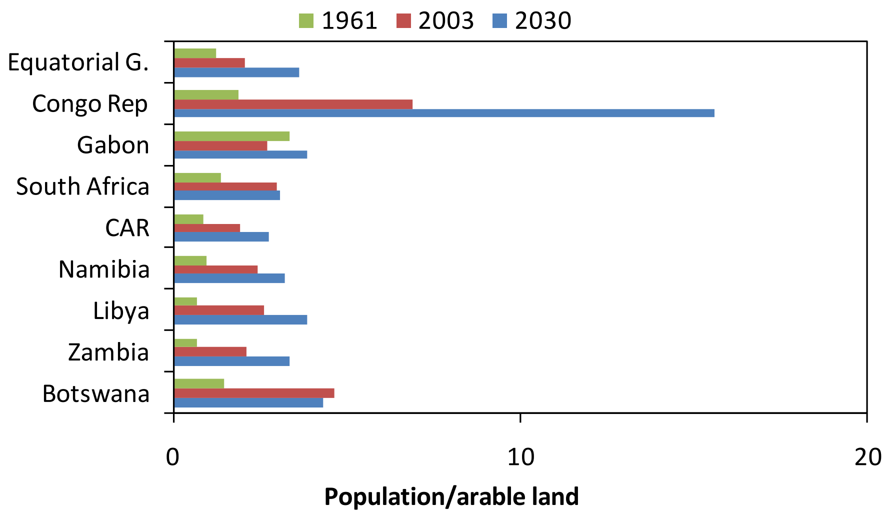



*Figure 3:5* Changes in population per arable land (person/ha) density in low cropping intensity countries between 1961 and 2030

Cereal yield in these countries has been low as was common in most Sub-Sahara Africa (Figure 3:6). South Africa and Gabon have had relatively better cereal yield in the group. The two countries have maintained good economic growth for many years enabling the necessary agricultural inputs for yield improvement.

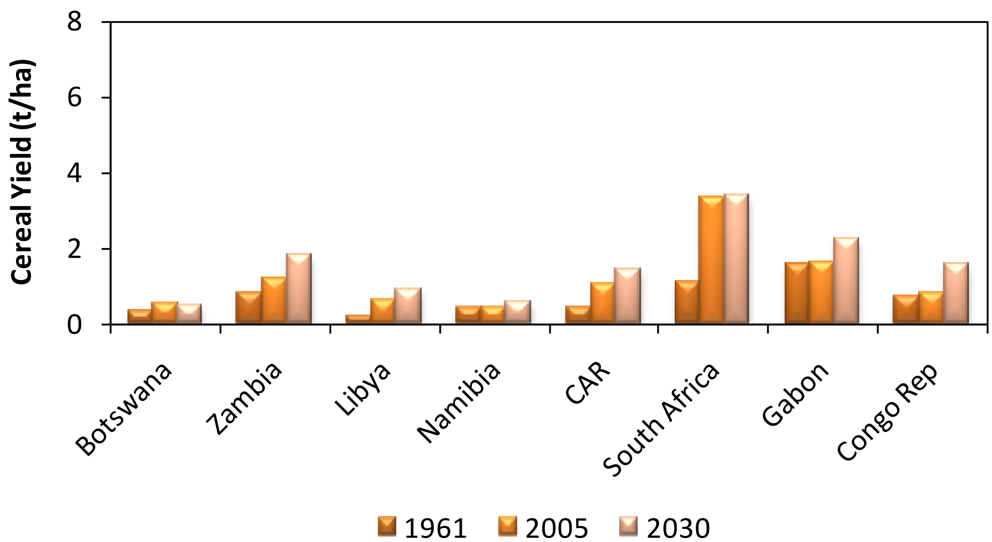



*Figure 3:6 Cereal yield change needed in low CI countries between 1961 and 2030*

In this group cereal yield needed will not surpass 4 t/ha in 2030 under a scenario with no expansion harvesting land in the extreme case and will largely remain below 2 t/ha for most of the countries.

## Countries with intermediate cropping intensity

More than 60% of countries in Sub-Saharan Africa have intermediate level of cropping intensity, i.e., between 0.5 and 1 in 2003 and lie in this group. Figure 3:7 clearly shows the change in CI between 1961 and 2003 and future CI in 2030 if cereal yield is kept at 2003 level. Major increases in CI were observed in Niger, Ethiopia, Democratic Republic of Congo (DRC), Sudan and Kenya countries which had population more than 10 million people in 2003.

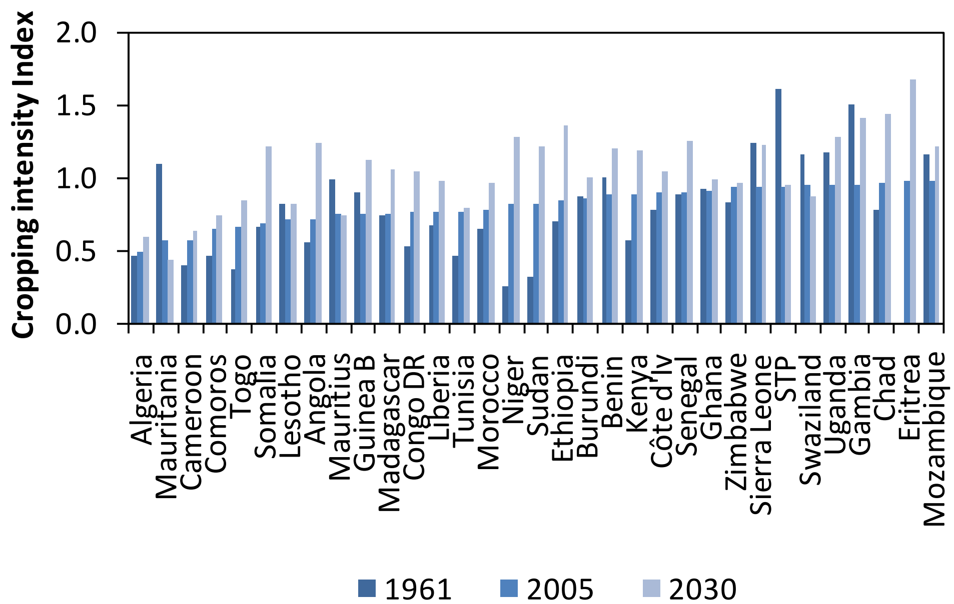



*Figure 3:7.* Changes in cropping intensity in intermediate CI between 1961 and 2030

If expansion of agriculture is envisaged it will be into land areas occupied by forests or grazing lands in the land abundant countries in Central and West Africa like DRC and CAR. In the small land scarce countries like Mauritius, Sierra Leone and Eritrea strategy of land expansion has little bearing compared to yield improvement or enhancing cereal importing capabilities (see Figure 3:9).

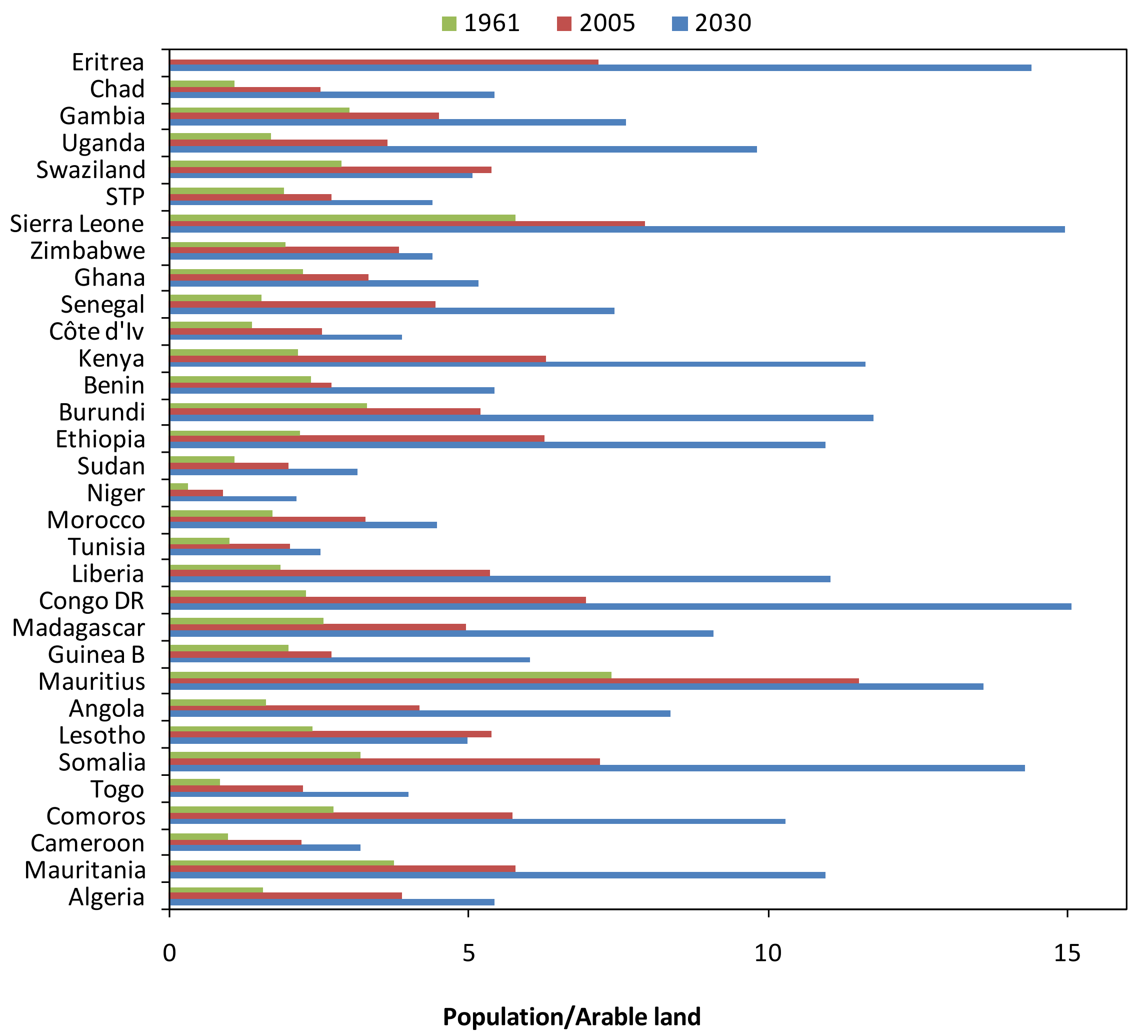



*Figure 3:8.* Changes in population per arable land (person/ha) density in intermediate cropping intensity countries between 1961 and 2030

Figure 3:9 shows historical and future cereal yield growth under the assumptions in the model. As a result of initially low cereal yield, most of the countries in the group seems to have the potential to improve cereal yield through better use of agricultural inputs.

Like low CI countries, the cereal yield needed to keep harvesting land at 2003 level will not surpass 4 t/ha in 2030 in the land scarce countries and remain below 2 t/ha for most in this group too. Beside small countries which normally are constrained by scarcity of arable land, only Madagascar and Uganda need to improving the yield to this level. More than 60% of the countries in this group could maintain base year harvesting or cropping intesity by simply improving cereal yield up to 2 t/ha by 2030.

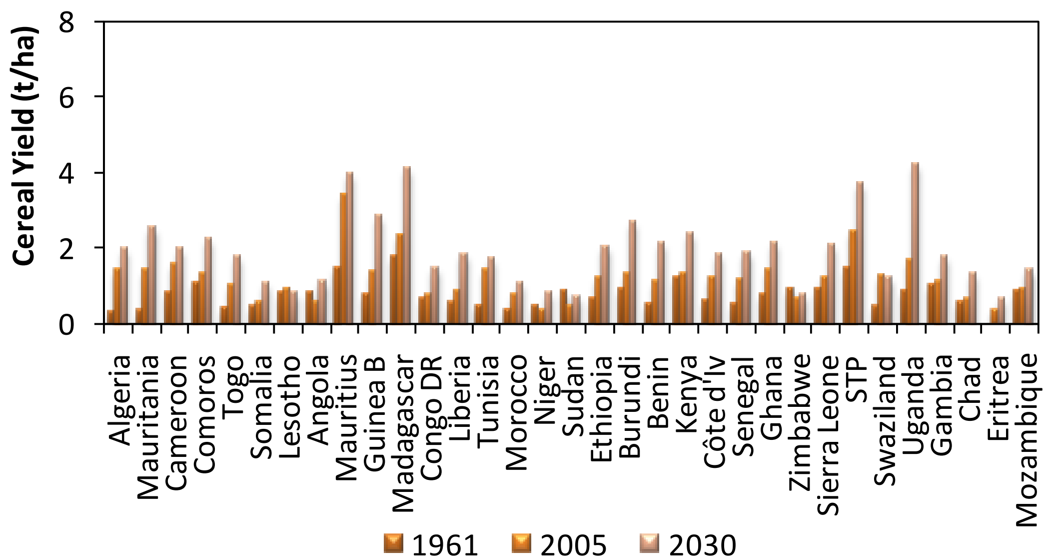



*Figure 3:9.* Cereal yield change needed in intermediate CI countries between 1961 and 2030

## Countries with high cropping intensity

Figure 3:10 shows all countries except Rwanda and Nigeria had some level of double cropping between 1961 and 2003. This group is dominated by countries with large population. All of the nine countries in the group have population more than 10 million people. Between 1961 and 2003 cropping intensity has declined in Egypt, Mozambique, Malawi and Mali, whereas it has increased in Nigeria, Rwanda and Burkina Faso.

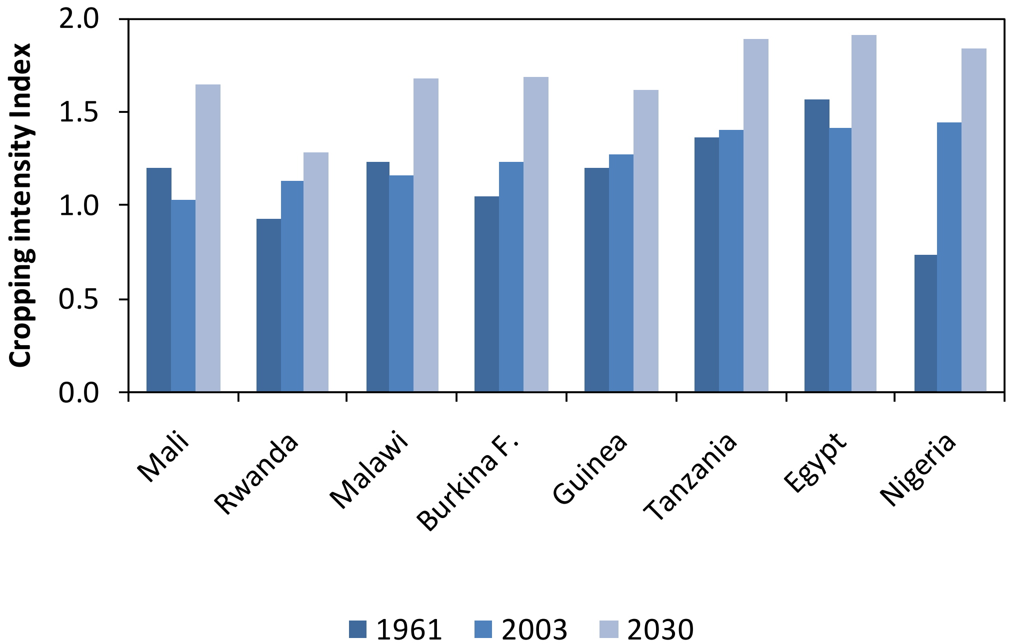



*Figure 3:10. Changes in cropping intensity in countries with high CI  between 1961 and 2030*

Egypt has had the highest cropping intensity since 1961 and slightly declined over the years which could be attributed to scarcity of water. Egypt's cereal demand was, therefore, met largely through cereal yield improvement (Figure 3:12) and cereal import growth (Figure 3:3). The prospect of converting lands under other crops to cereal in Egypt is highly unlikely as the demand for fruits, oils crops, sugar and others will continue to remain high. Improving cereal yield above its present level of around 7 t/ha in 2003, that was more than twice the world average, would be difficult to achieve. Therefore, the only viable option for Egypt to increase its future cereal supply lies on increasing its annual net cereal import. This could readily be achieved as long as it maintains past trend of economic growth. On the positive side, the rate of population growth in Egypt has been gradually declining and is projected by UN to decline further. Moreover, this decline besides its saturating per capita cereal consumption could help constrain growth of cereal demand. Nonetheless, with a population of more than 100 million in 2030, Egypt's cereal demand and supply system will face one of the biggest challenges in the Africa.

Nigeria, on the other hand, experienced the highest increase in cropping intensity and

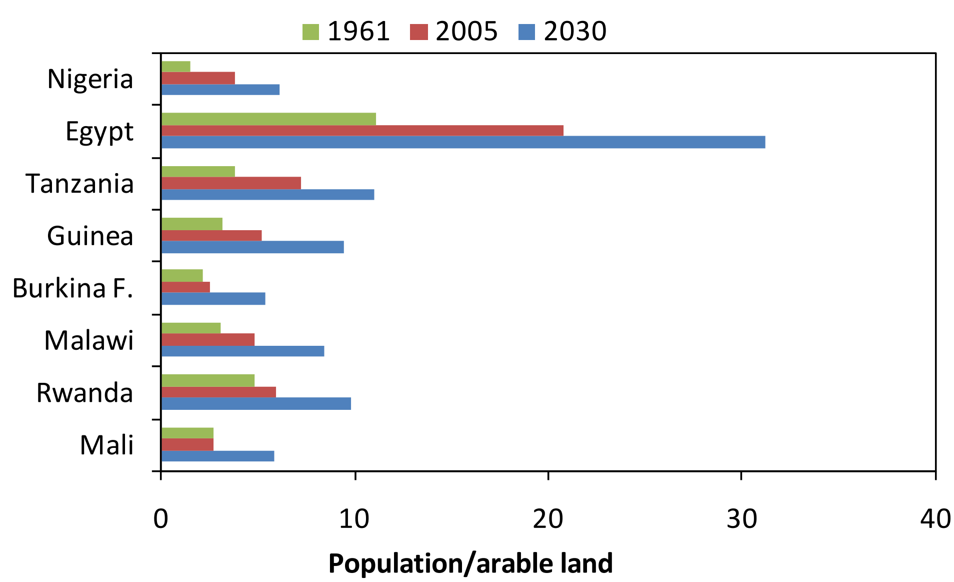



*Figure 3:11 Changes in population per arable land density in high cropping intensity countries between 1961 and 2030*

population per arable land density between 1961 and 2003 (Figure 3:10 and Figure 3:11). Its cereal harvest has not been growing in proportion to its population growth; therefore, it had to rely on increasing its cereal import to meet domestic demand.

The countries in the group have different possibilities to supply their cereal demand. Guinea, Mozambique and Mali, for example, have sufficient water resource to expand their arable land and/or increase level of double cropping. Nigeria, Burkina Faso and Malawi, on the other hand, are constrained by availability of water to expand into new harvesting land so that they have to focus on improving cereal yield in present cropping lands.

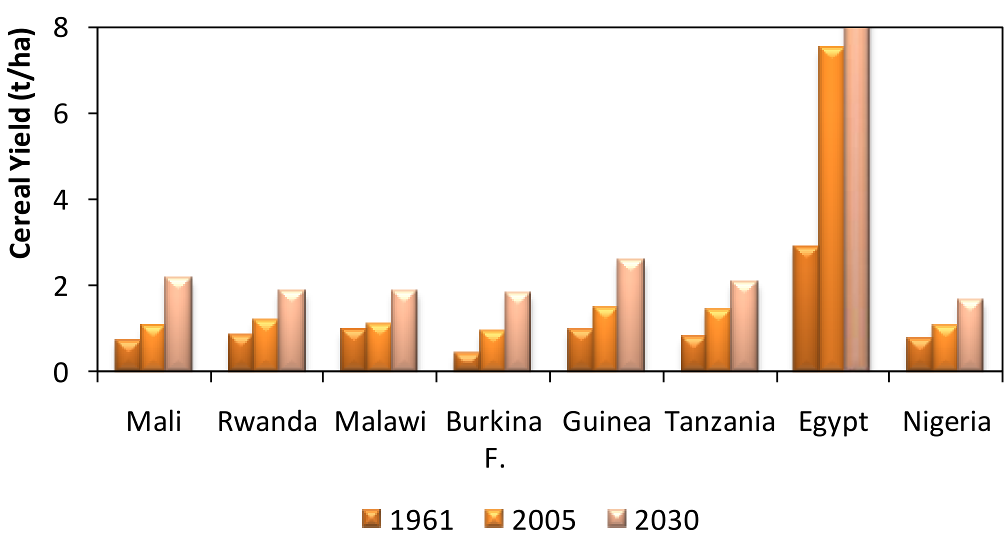



*Figure 3:12  Cereal yield change in high CI countries between 1961 and 2030*

Nigeria also has one of the largest population and cereal demand in the group as well as in Africa. Between 1961 and 2003, Nigerian population grew from 42 million to 134 million.

During this period cereal production grew by 0.25% less than population growth. However, the per capita cereal supply grew by annual rate of 0.1% as a result of cereal import growth. The cereal import grew from 100 thousand tons in 1961 to 4 million tons in 2003. To supply the future cereal demand Nigeria has a wide range of options. Firstly, it could readily improve cereal yield by improving use of chemical fertilizer. Secondly, its present economic growth could readily increase cereal import at international market. What is difficult to achieve in Nigeria is expansion of cereal cropping land because of the already high CI and absence of abundant water resource for irrigation.

Tanzania also has large population and high cropping intensity. The population of Tanzania has grown from 10 million in 1961 to 39 million in 2003 and is projected to grow to 56 million by 2030. The country has water limitation to expand arable area into uncultivated lands. Cereals import and yield improvement is also limited as a result of low economic growth. Balancing demand and supply of cereals should, therefore, primarily focus on slowing the rate of population growth.

Smaller countries in the group are increasingly becoming self-insufficient in cereal supply in spite of high cropping intensity and cereal yield. The future of cereal supply in these countries will be contingent up on their economic performance and price of cereals in the world market rather than their domestic production potential. In these countries unchecked population growth will lead to mass migration and internal instability as the one witnessed in the 1994 Rwandan genocide that was partly attributed to scarcity of agricultural land (Verpoorten and Berlage 2004, Diamond 2004).

### 3.3.3 Cereal harvesting land

Figure 3:13 shows the percentage of cereal to total harvesting land (CTR) in highly populated countries where cereal crop dominate agriculture in 2003. It can be observed that most of highly populated countries which face cereal supply problems have CTR value above 0.6 with the exception of Nigeria which has low CTR value because it utilizes large portion of its land for production of crops other than cereals especially roots and tubers. The high CTR value indicates the narrowing of the possibility of expanding cereal production in the future.

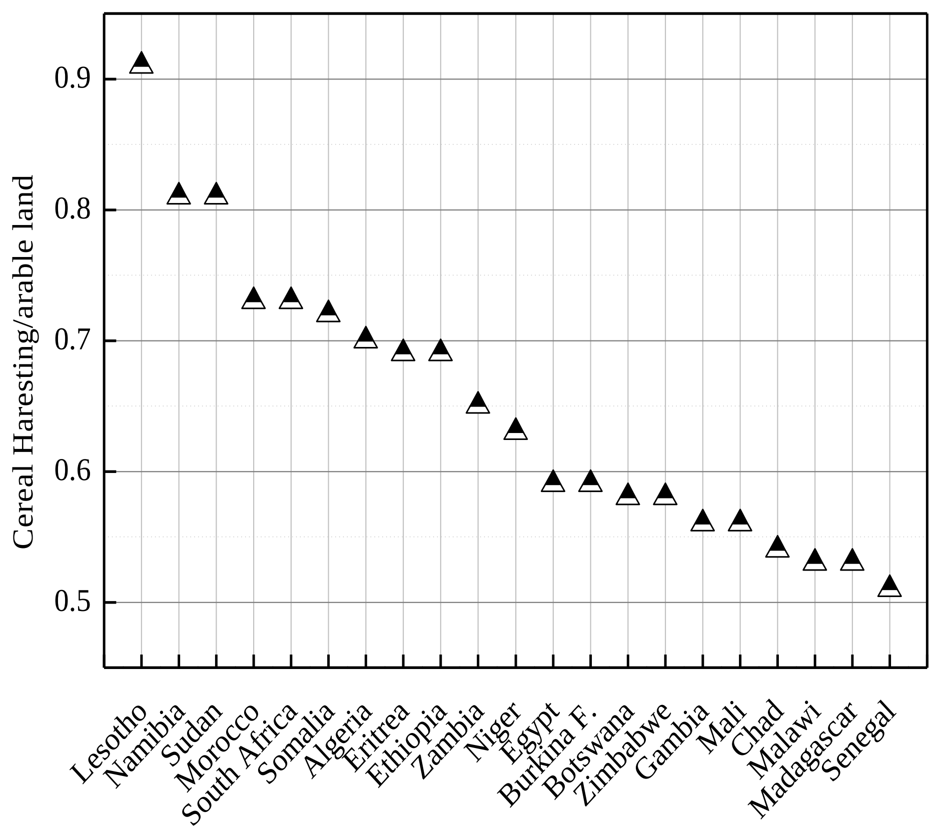



*Figure 3:13 Proportion of harvesting land planted by cereal crops in highly populated countries in 2003*

### 3.3.4 Ranking countries based on cereal supply challenge

Figure 3:14 shows the level of cropping intensity of 17 countries with population of more than 1 million people that had the highest population/arable land percentage (PAR). Except for Congo Republic, all other countries have cropping intensity above 50% in 2003 and six of these countries surpass the 100% level in the same year. Further analysis of available water resource, per capita GDP and cereal yield has revealed different supply scenarios. Five of these countries, namely: Egypt, Rwanda, Mauritius, Burundi and Ethiopia were found to have the highest cropping intensity even after considering all potential arable lands that include forests and pasture lands (Figure 3:15).

Of all the countries, Egypt's exceptionally large PAR value made it a conspicuous outlier with proportionally high level of cropping intensity. The country has already been exhaustively using all its available arable lands with more than 50% double cropping in 2003. Cropping intensity has reached its peak level and there seems to be very little room for further intensification. Egypt has also one of the least per capita available water in Africa which will be a major factor in constraining the expansion of cereal production in the future. Its cereal yield, as discussed above, has also been one of the highest in the world making significant improvement very difficult to materialize. Although most of the biophysical and demographic variables of agricultural production render Egypt as food insecure country, it will offset it by possibly continuing the past trend of expansion of cereal import on the international market.

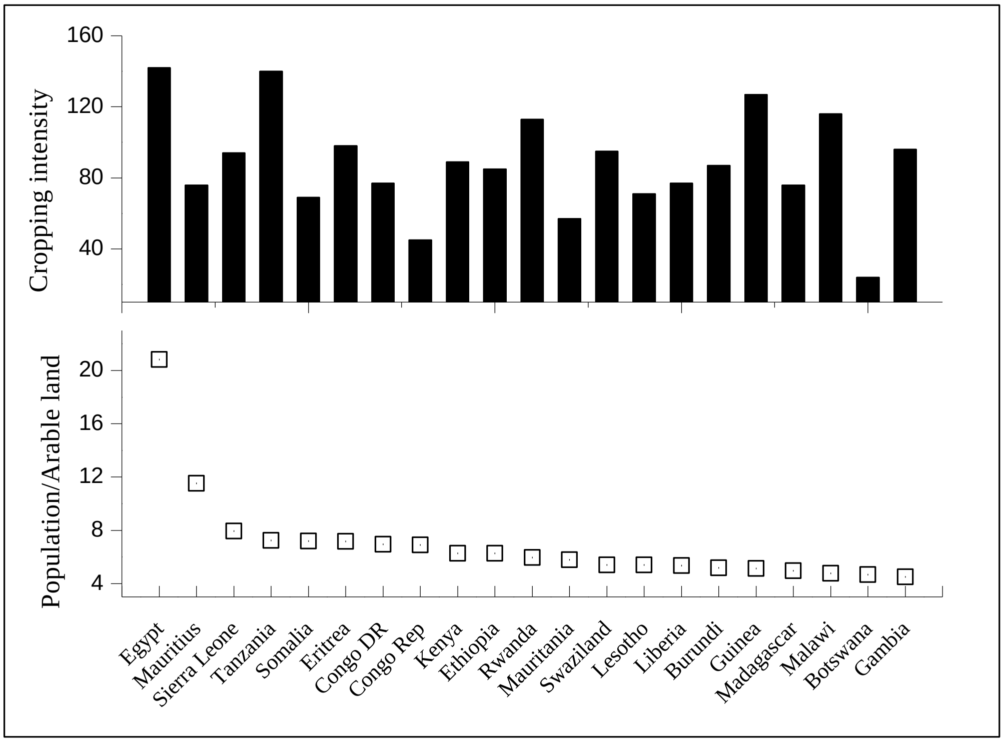



*Figure 3:14**.** Population-arable land density verses level of cropping intensity in low per capita arable land countries*

Rwanda and Burundi, the two small and densely populated central African countries have already been using much of their arable lands and continue to have one of the highest population growths in Africa. On the other hand, they have limited potential arable land and water resource to be able to expand harvesting land. Their per capita GDP is not in a position to practically affect cereal import through trade (see Table 3.1). They will be forced to continue depending on international cereal food aid. On the contrary, Mauritius could readily meet domestic cereal demand by importing cereals as a result of favorability of its location for trade as well as its well performing economy (Table 3.1). From past progresses in cereal yield improvement one can argue that it could also improve its cereal yield to increase its domestic production.

Lastly but most importantly, Ethiopia faces a daunting task of balancing population growth and cereal supply. With a population of about 80 million people in 2005, the country highly depended on expansion of cereal harvesting land since 1961. Its cereal yield did not show much improvement and stays at present level of 1.2 t/ha. Without further expansion of cereal cropping to lands that are under forest and pasture land use, the country has few other easily

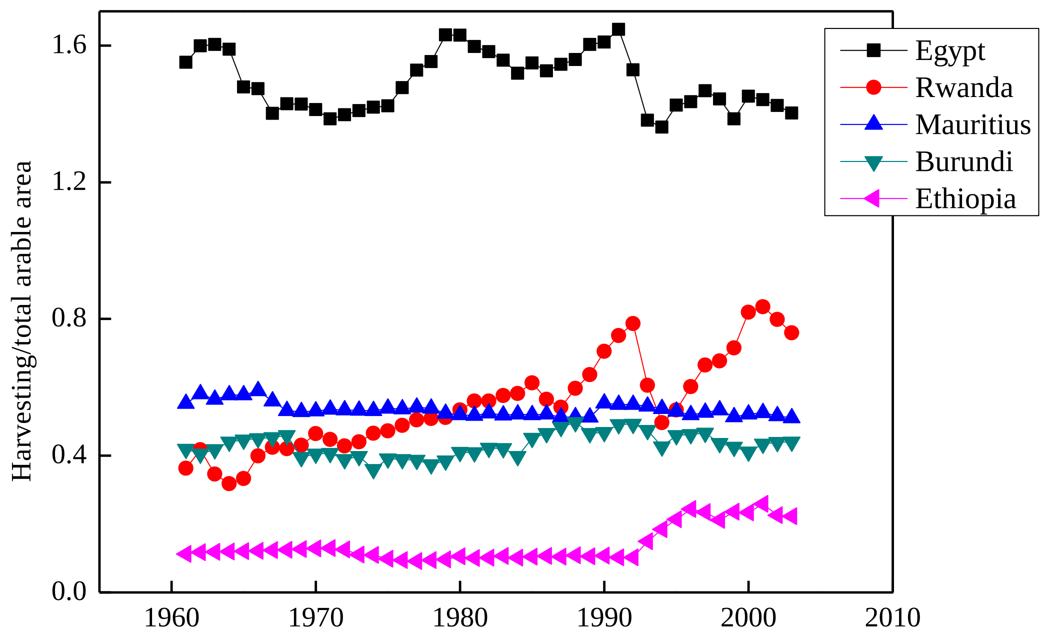



*Figure 3:15 Percentage of harvesting land to actual and potential arable land in five high density countries*

accessible lands that are suitable for agriculture. Most of its easily accessible and fertile lands have already been over cultivated in the densely populated highlands of the country.

All available arable land, forest and pasture lands put into consideration, only five countries, with low per capita harvesting lands, had more than 20% ratio. Except for Ethiopia, all the four countries have already faced the dual pressure of population and saturated actual and potential arable land. Although Ethiopian actual arable land has been cultivated near saturation level, it has enough room for expansion to hitherto uncultivated lands except for limitation on availability of renewable water (Table 3.1). This by itself comes at heavy environmental price and a great deal of uncertainty. Ethiopia's declining per capita water has always been under use conflict for thousands of years among other lower riparian countries like Egypt and Sudan. Although expansion of agricultural lands seems inevitable in Ethiopia, it could not sustain continuation of past trends. The possibility of importing cereal on the international market appears less likely considering past experience and its low per capita GDP. Therefore, Ethiopia will continue to rely on international cereal aid for the years to come. The level of cereal aid demand will be much more difficult to meet in the future as the number of people with little access to land increases and dynamics of food price in the world become less predictable.

*Table 3.1* Ranking of countries based on derived food insecurity index

| Countries | Annual Cereal yield (t/ha) | Per capita GDP (USD) | Population (1000) | Population growth rate (%, annual) | Per capita annual water (M3) | Cereal security indicator |
|---|---|---|---|---|---|---|
| Burundi | 1.34 | 90 | 7,834 | 2.88 | 460 | 8.40 |
| Eritrea | 0.37 | 219 | 4,560 | 3.10 | 1,382 | 8.40 |
| Rwanda | 1.18 | 208 | 9,230 | 2.67 | 563 | 8.00 |
| Tanzania | 1.43 | 288 | 39,025 | 2.88 | 2,332 | 7.60 |
| Ethiopia | 1.24 | 106 | 79,289 | 2.59 | 1,387 | 7.40 |
| Kenya | 1.35 | 481 | 35,106 | 2.64 | 860 | 7.40 |
| Liberia | 0.92 | 152 | 3,356 | 4.14 | 69,123 | 7.20 |
| Mauritania | 1.45 | 515 | 3,158 | 2.40 | 3,610 | 6.40 |
| Sierra Leone | 1.22 | 202 | 5,679 | 2.67 | 33,237 | 6.20 |
| Lesotho | 0.94 | 730 | 1,791 | 0.87 | 1,687 | 5.80 |
| Congo, DR | 0.77 | 119 | 8,496 | 2.27 | 21,629 | 5.60 |
| Congo, Rep | 0.81 | 1,118 | 59,320 | 1.91 | 202,089 | 5.40 |
| Guinea | 1.47 | 421 | 4,117 | 2.76 | 23,533 | 5.20 |
| Egypt | 7.52 | 1,085 | 9,603 | 2.26 | 773 | 5.10 |
| Swaziland | 1.31 | 2,317 | 75,437 | 1.81 | 2,785 | 4.20 |
| Mauritius | 3.45 | 4,893 | 1,029 | 1.33 | 1,873 | 2.50 |

## *3.4 Conclusion*

Supply of cereals in most countries in Africa was made through domestic production by expansion of crop lands while cereal trade and aid supplemented the deficit. There were distinct characteristics in the supply. The North African countries have made significant improvement in per capita cereal supply while decline has occurred in South Africa, East Africa and Central African countries. Central African countries have sufficient potential arable land and water to expand cereal harvesting. By 2030, 60% of the countries in Africa require cereal yield under 2t/ha to limit further expansion of cereal harvesting land. The three highly populated countries, Egypt, Nigeria, and Ethiopia will follow different supply scenarios. Egypt will depend on cereal import through trade. Likewise, Nigeria will depend on cereal import on top of improving cereal yield. On the contrary, Ethiopia will be restricted by its scarce water resource and absence of agricultural inputs like chemical fertilizers to increase cereal production through expansion of harvesting land or improving cereal yield. It is highly likely that it will continue with its external cereal aid dependence. Moreover, unlike the above two populous countries, Ethiopia will face one of the highest challenge in meeting domestic cereal supply unless it change the past trend of low input agriculture and intensify its production system.

# Chapter 4 : Pattern and determinants of meat consumption in urban and rural Ethiopia


## Summary

Per capita meat consumption in Ethiopia has declined from 20 kg/capita/year in 1961 to 8 kg/capita/year in 2004. FAO has been the prime source of Ethiopian livestock data though it has been acquiring the information through estimation of related resources. Central Statistical Agency of Ethiopia (CSA) started undertaking nationwide household surveys in 1996 and its result on livestock consumption data differed from FAO. In this paper, patterns of meat consumption in urban/rural Ethiopia between 1996 and 2004 were analyzed using cohort specific model by categorizing households according to level of income. Feasible general least square (FGLS) estimation technique was conducted to identify the key determinants affecting meat consumption in Ethiopia. Comparison of meat consumption by FAO and CSA was also done. The result showed that the response of meat consumption to income was higher in urban than in rural areas. Rural meat consumption made significant improvement between 1996 and 2000 but lost the momentum between 2000 and 2004. In urban areas, on the contrary, there was continual improvement throughout this period. The result of economic analysis revealed that urbanization and income have been found to be positively and significantly influencing meat consumption in Ethiopia at 1% and 5 % significance level respectively. On the other hand, level of cereal production and price of meat did not significantly affect per capita meat consumption. The comparison between FAO and CSA data showed that the former overestimated the per capita meat in Ethiopia by more than 100% compared to the CSA household survey result. The disparity arose from overestimation of rate of livestock utilization than number of livestock. Therefore, the level of consumption in Ethiopia must have been lower than commonly reported by FAO.



**Keywords:** Cohort model, CSA, FAO, household income, meat consumption

## *4.1 Introduction*

There has been a positive trend of meat consumption in the developing countries. Delgado (2003) called this trend a *Livestock Revolution*. This *Revolution*, Delgado (2003) argued, has been driven by population growth, urbanization and income change. He advises governments and development partners in developing countries who want to help the malnourished people to follow the *Revolution* closely. Observations like this often understate the unequal distribution of income growth and non-uniformity of rate of urbanization in different parts of the developing countries. For example, the projection by Alexandratos (1995) suggested that the poor developing countries will remain dependant more on cereals and less on livestock consumption for daily energy in the future.

However, developing countries with well performing economies will drive the world meat demand in the future. Steinfeld (2002) reported that in the next 20 years the demand for livestock products will double in developing countries as a result of population growth and income improvement. He pointed out the need to address the problem of lack of competitiveness and higher risk on small holder producers which have the potential to increase livestock productions. After analyzing the impact of population pressure on livestock production in smallholder farmers in Tanzania, Ogle (1990) recommended intensive production that is integrated with crop production system.

Ethiopia has the largest number of livestock population in Africa (Solomon et al, 2003). However, consumption of animal source food (ASF) has always been low and declining as a result of the low production and continuously growing population (FAO 2005; UN 2005). Ethiopia’s per capita consumption in 2004 declined by more than 100 % from an average of

20kg in 1961 (FAO, 2005; Solomon et al, 2003). In contrary, the average world meat consumption doubled during this period (FAO, 2005).

The UN's FAOSTAT has been the major source of livestock data for Ethiopia and most countries of the world. This database heavily relies on national statistical agencies for source of information and its reliability depends on the quality of statistics in those countries (Speedy, 2003). In the absence of reliable data from national statistical sources, FAO makes estimations using available related information. This has been the case for Ethiopian livestock data for many years. Aklilu (2002) argued that estimates for Ethiopian livestock were made based on insufficient information. Further assumption of slaughter rates and livestock yields has been performed to estimate the total livestock production. It is, therefore, highly unlikely that Ethiopian livestock products' consumption estimates from FAOSTAT had been satisfactorily reliable.

Ethiopian household income, consumption and expenditure (HICE) survey was started in 1996 and have been undertaken every four years (HICE 1996, 2000 and 2004). These surveys provide comprehensive nationwide information on livestock consumption beside other data. It appears that FAO has also adjusted some of its statistics such as the number of livestock population based on CSA publications but continues to publish estimate of meat consumption as previous.

There are scarce literatures on system wise analysis of meat production and consumption in Ethiopia to address the aforementioned problems. Most of the livestock studies were done at smaller scale and focused on livestock yield, pricing and specific projects (For example, Guru et al, 2008; Ayele and Peacock, 2003) but did not address the problem directly.

However, some related studies have been done at country level and provided indispensible information. For example, Jabbar et al (2007) tried to identify and map geographic distribution and market routes of livestock in Ethiopia using CSA's livestock surveying data.

Nell (2006) made a quick review of the state of livestock production and consumption in Ethiopia for a project by the government of the Netherlands. The report suggested that livestock disease, lack of livestock nutrition, subsistence animal husbandry and weak market were the main constraints to livestock development in the country. Avery (2004), on the other hand, studied red meat and poultry consumption in Addis Ababa, the Ethiopian capital. Although the study relied on unstructured interviews and limited personal observation, it illuminated the state of meat production and consumption pattern in urban areas.

Aklilu (2002) did a survey of livestock marketing and status audit in Sudan, Ethiopia and Kenya. The study focused on export of live animals and meat produces and found that Sudan was performing better than the other two countries in livestock husbandry and suggested regional collaboration to address the gap in internal and external market information.

The CSA surveys provides meat consumption values according to urban/rural residence and income groups which helps in the analysis of factors that determine meat consumption and formulation of policies. This chapter tried to achieve the following objectives: -

- analyzing patterns of urban and rural meat consumption in Ethiopia using cohort specific model
- investigating factors that determine level of meat consumption among regional states in Ethiopia and
- comparing meat consumption data from CSA and FAOSTAT.

The result is expected to help understand patterns of meat consumption in rural and urban households and factors that determine the level of consumption in Ethiopia. The cohort meat consumption analysis will contribute to our understanding of the dynamics of present and future nutrition challenges and thereby, formulate appropriate policy measures. The comparison of CSA and FAO data will help clarify the discrepancy of data on the level of meat consumption in Ethiopia.

## *4.2 Materials and methodology*

A cohort specific consumption model depicted on Figure 4:1was used to estimate the aggregate meat consumption of urban and rural population in Ethiopia. The population was categorized into five income groups or quintiles under urban and rural residence. Average per capita meat consumption for each income quintiles in each residence was estimated from CSA survey data. These average consumptions were used to estimate age specific consumption within a household by adopting the Japanese[1] household consumption pattern (MHLW, 2000) in which consumption rises up to 15-19 years age group and stays relatively unchanged up to 65 years age and finally drops gently. The total meat consumption was calculated for each cohort group under respective income and residence.

[1] Age specific consumption data on developing countries could not be found to be adopted for this study.

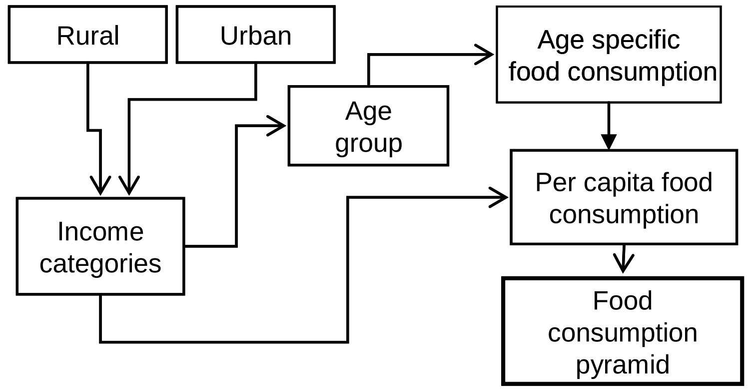



*Figure 4:1 Scheme of model for estimation of meat consumption for urban and rural cohort population*

Periodic household data from 1996-2004 was acquired from Central Statistical Agency (CSA) of the Government of Ethiopia (GoE). CSA undertook three consecutive household income, consumption and expenditure (HICE) surveys in 1996, 2000 and 2004. These surveys were done nationwide and represented all major urban and rural areas of the country. In 2004 survey, for example, 9,564 rural and 12,160 urban households were involved. The number of income groups was different among the surveys. In 1996 and 2000 surveys, households were categorized into 14 household income groups, whereas in 2004 the categories were only five. In the later survey, all households in the country were arranged according to level of income and then divided into five equal parts and ascribed quintile 1 to 5, i.e., quintile 1 represents low income households while quintile 5 represents high income households. Then the households in each income quintiles were separated under urban/rural population. Because of difference in the number of household members and income inequality in urban and rural areas, the number of people in each quintile varies between residence and survey years. The average incomes of each quintile in 2004 were used to regroup the 1996 and 2000 households.

Feasible General Least Square (FGLS) estimation technique was used to analyze factors that influenced meat consumption among the different regional states in Ethiopia using Stata/SE 10.0 statistical software for window. FGLS is a regression technique similar to generalized least square (GLS) method except it uses estimated variance-covariance matrix because the true matrix is not known. GLS technique in turn is used to estimate unknown parameter in regression model where ordinary least square (OLS) method could not be used, i.e., where the data has unequal variability of dependant variable, which was per capita meat consumption in this study.

## *4.3 Result and Discussion*

### 4.3.1 Population and income change

It is evident from Figure 4.2 that Ethiopian population either in rural or urban areas is dominated by younger cohort groups. The fundamental structure of the population pyramid did not change in all the three surveys. This kind of population structure shows demographic transition is not yet set out and the population momentum is still building.

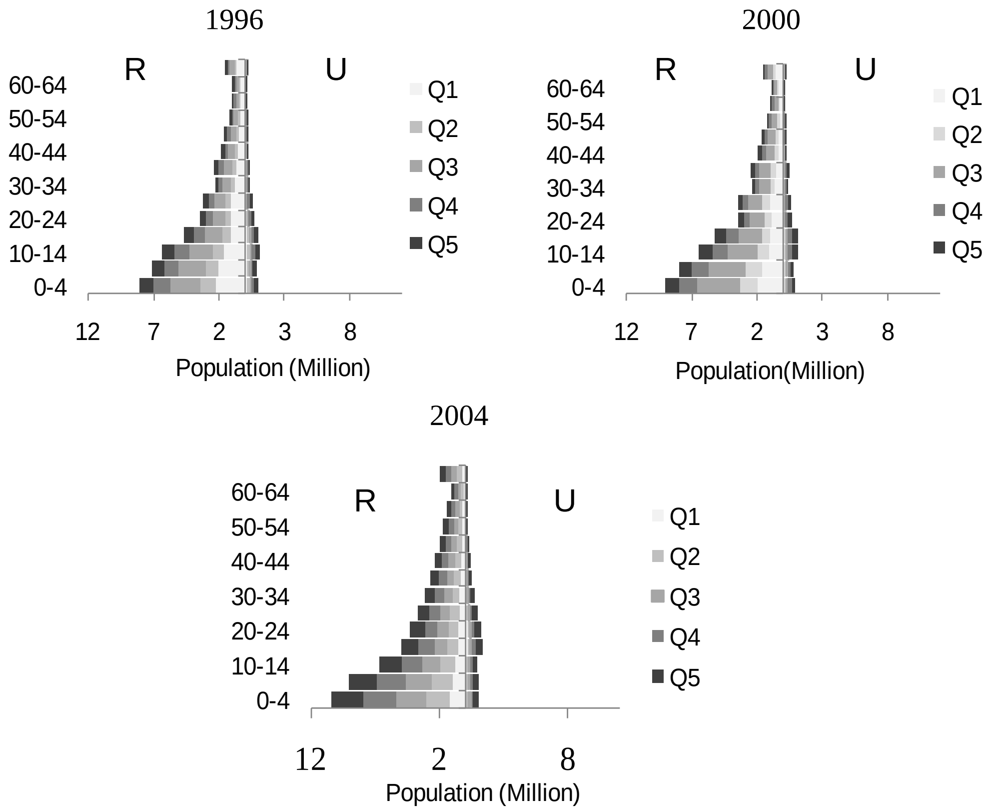



*Figure 4:2 Population cohort pyramids of rural and urban households in Ethiopia.*

*Note: the legends Q1-Q5 stand for the five income quintals. U and R stand for urban and rural respectively*

The rural households account for the majority of the population in Ethiopia (Figure 4:2). Urban population showed no growth between 1996 and 2000, but it grew by 5.3 % a year between 2000 and 2004 (Table 4.1). On the other hand, rural population grew continually in both periods at a rate of 1.9% and 3.5% respectively. In the later period the rate of urban population growth exceeded that of rural population.

There was change in the distribution of households along income groups between urban and rural population among surveys. Between 1996 and 2000, there was a 7% and 6 % increase in the first and third income quintiles of rural households respectively. On the other hand, at the same period, urban income quintile 1, i.e., low income households, declined by 13%, while quintiles 4 and 5 increased by 7% and 4% respectively. There was more homogenization in rural areas and a shift towards upper income quintiles in urban households. Because of change in household grouping method in 2004, direct comparison was difficult and requires caution in the interpretation of the result. Nonetheless, the trend appeared to follow the pattern observed between 1996 and 2000, i.e., further income homogenization in rural areas and accumulation in higher quintiles in urban households.

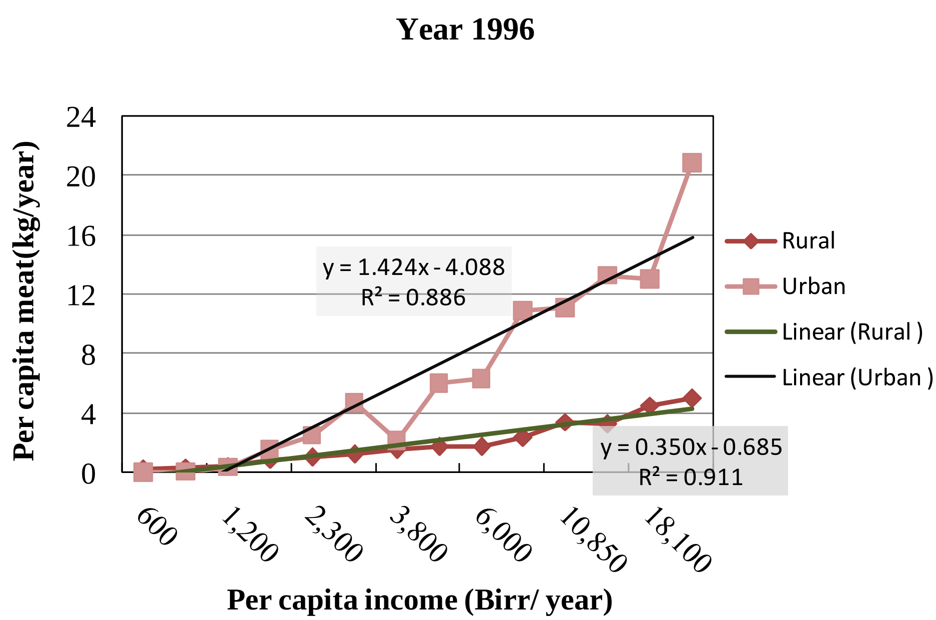
*Table 4.1 Summary of per capita meat and populations of urban and rural Ethiopia*

| **Residence** | **Year** | **Per capita meat (kg/capita/year)** | **Population (million people)** |
|---|---|---|---|
| Urban | 1996 | 7.8 | 7.6 |
| | 2000 | 7.6 | 7.6 |
| | 2004 | 9.7 | 9.1 |
| Rural | 1996 | 1.7 | 45.1 |
| | 2000 | 2.7 | 48.4 |
| | 2004 | 2.6 | 55.3 |
| Country | 1996 | 2.7 | 52.7 |
| | 2000 | 3.3 | 56.0 |
| | 2004 | 3.5 | 64.4 |

*Sources: Data obtained from CSA 1996, 2000 and 2004*

### 4.3.2 Household income and per capita meat consumption

There was distinct pattern in urban and rural meat consumption in Ethiopia in 1996, 2000 and 2004. For a given level of income, urban households consumed more meat than rural households. Figure 4:3 demonstrates the changes in per capita meat consumption response to change in income among the three surveys. In all the surveys, these responses were higher in urban households and the change was steep between quintile 4 and 5.



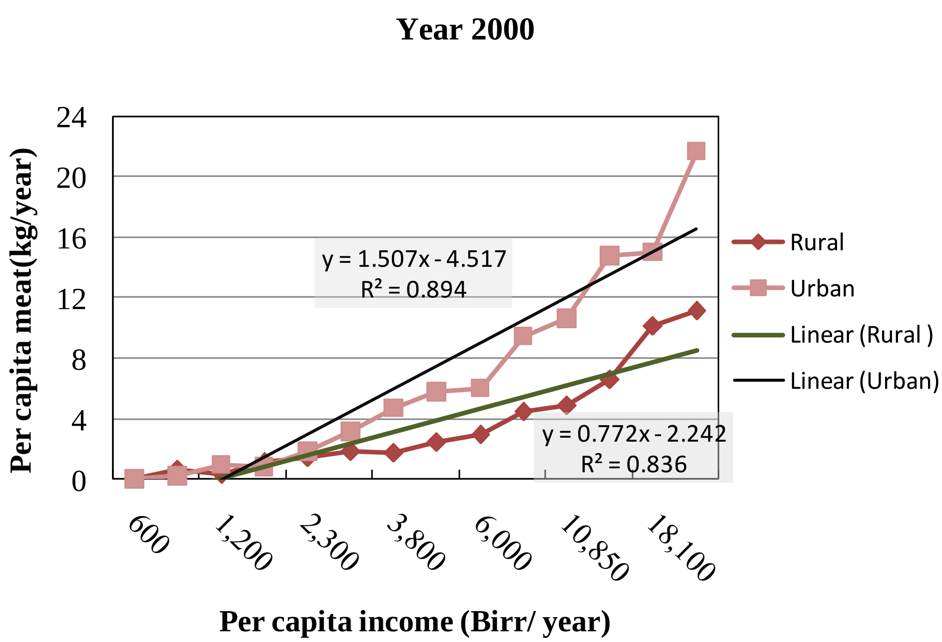




*Figure 4:3 Patterns of per capita meat consumption change among rural and urban household income groups in 1996, 2000 and 2004.*

*Note:U and R stand for urban and rural respectively. Note: There were 14 data points in 1996 and 2000, whereas 5 data points in 2004.*

In rural households, there is change in meat consumption response among the surveys although the consumption responses were lower than urban once. Rural meat consumption showed considerable improvement between 1996 and 2000 but lost most of the gain between 2000 and 2004. The average per capita rural meat consumption increased by 11% between 1996 and 2000, whereas, urban per capita consumption remained relatively unchanged from the 1996 level (see Figure 4:4).

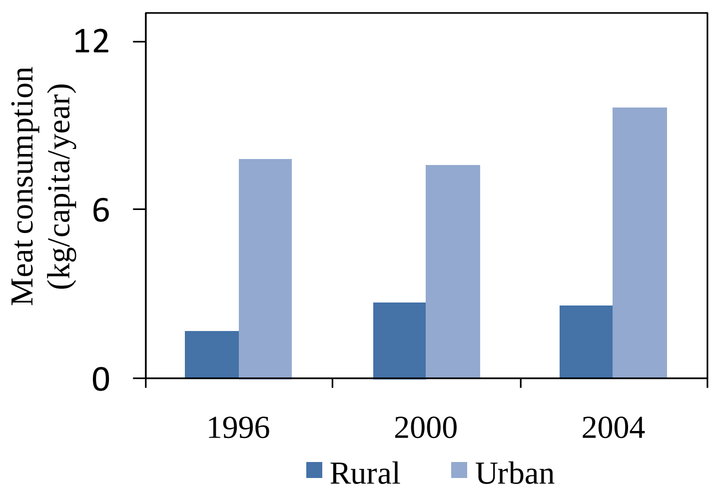



*Figure 4:4 Changes in average urban and rural per capita meat consumption between 1996 and 2004*

Both urban and rural households in the lower quintiles have had very low meat consumption because they had little extra income to spend on meat. However, with small change in household income, urban households showed rapid increase in meat consumption compared to rural households. Moreover, the change in consumption between consecutive income groups in rural households was smaller.

One of the factors that limit meat consumption in rural Ethiopia has been the absence of meat retail market. In rural areas people often consume meat during holidays or special occasions and it is considered rather as luxury food than essential component of daily household nutrition. During these occasions, commonly, a group of 10 to 20 people buy a live animal, slaughter and divide the meat among them. Therefore, the change in household income alone can hardly change rural meat consumption unless accompanied by change in market arrangements and culture of food consumption.

The consumption pyramids in Figure 4:5 show that the total urban meat accounts for bigger share of meat consumption relative to its population size.

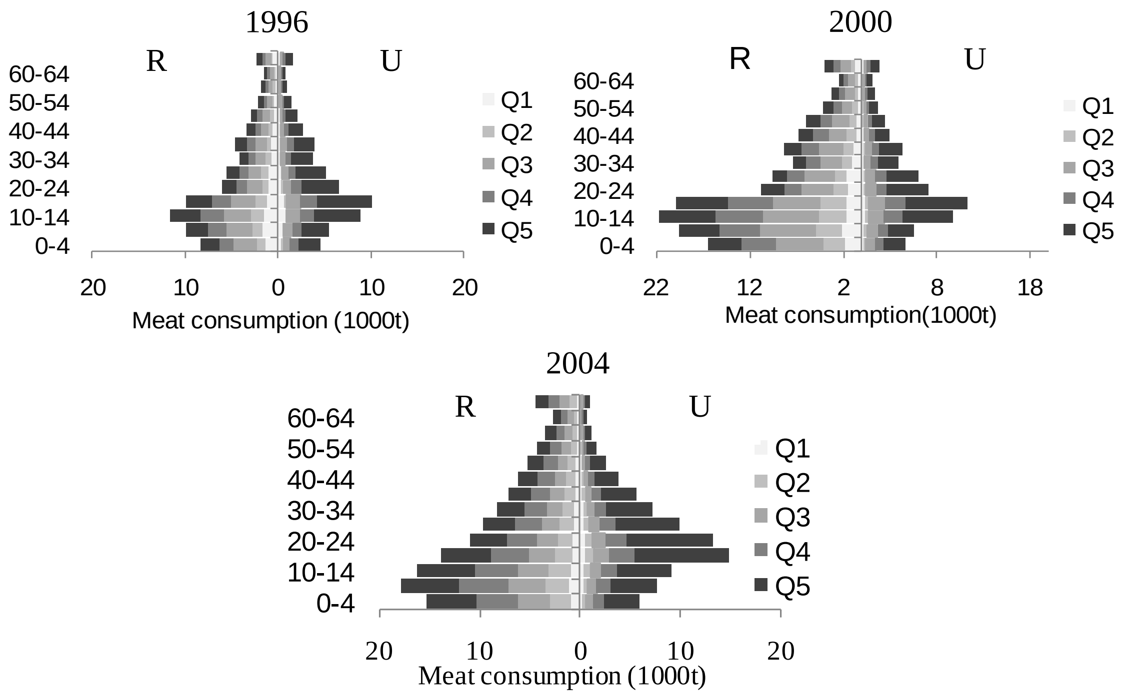



*Figure 4:5. Meat consumption in rural and urban Ethiopia disaggregated by income quintile and cohort groups.*

*Note: The symbols Q1-Q5 stand for the five income quintals*

In rural households, gain in meat consumption occurred between 1996 and 2000. This improvement was attributed to two factors. In 2000, firstly, rural household's meat consumption response to change in income increased considerably. Secondly, the proportion of upper income households increased. This phenomenon was partly reversed between 2000 and 2004 where response of meat consumption in relation to household income returned to the 1996 level. As a result the total rural meat consumption in the country decreased from 2000 level (Table 4.1).

### 4.3.3 Determinants of meat consumption in regions

Determinants of meat consumption was identified using an econometric model (equation 4.1) that allows the explanatory variables explaining meat consumption differences in regional states of Ethiopia (i) at period t and takes the form:

$$Y_{it} = X_{it}\beta + \varepsilon_{it} \qquad (4.1)$$

Where:

- Y is regional per capita meat consumption,
- β is a vector of regression coefficients to be estimated;
- $X_{it}$ is a matrix of explanatory variables displayed in Table 4.2; and
- $\varepsilon_{it}$ is a vector of disturbances or random error terms.

*Table 4.2 Summary of variables used for statistical analysis*

| Variable | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Per capita meat, kg/yr | 4.30 | 2.72 | 1.00 | 11.0 |
| Meat Price, ETH Birr/kg | 13.9 | 3.70 | 7.00 | 21.0 |
| Log Income, Birr/person | 3.22 | 0.13 | 2.99 | 3.41 |
| Log Cereal Production, t | 5.03 | 1.11 | 3.46 | 6.79 |
| Urban Population, % | 0.31 | 0.33 | 0.07 | 1.00 |

Table 4.2 presents summary of statistics of the variable used to analyze the meat determinants. There was greater variability in per capita meat and percentage of urban population among regions as indicated by high standard deviation.

The result of cross-sectional time-series FGLS regression analysis in Table 4.3 shows regional per capita household income and percentage of urban population had significant effect on level of per capita meat consumption among regions in Ethiopia. These two variables are highly significant because most of meat consumption occurs in the upper income households in urban areas. Therefore, as urbanization proceeds in the country the demand for meat will increase to certain level and income growth will take consumption to a higher level if accompanied by other changes as discussed earlier. The result of regional consumption agrees with consumption elasticity shown in Figure 3.

*Table 4.3 Coefficients of Generalized Least Squares of determinants of Meat consumption among regions in Ethiopia*

| **Variables**[a] | **Coefficient** | **Standard Error** | **Z score** | **P>z** |
|---|---|---|---|---|
| Meat Price | -0.11 | 0.14 | -0.78 | 0.44 |
| Income | 6.95 | 3.58 | 1.94* | 0.05 |
| Urban Population, % | 5.43 | 1.20 | 4.53*** | 0.00 |
| Cereal Production | -0.03 | 0.27 | -0.12 | 0.91 |
| Constant | -18.0 | 9.89 | -1.82 | 0.07 |

[a] *Number of observations was 20*

The price of meat and cereal production did not significantly affect consumption of meat. This could be because, firstly, most of meat consumption occurred in upper income households of urban areas (see Table 4.3), and secondly, the level of consumption was very low to be affected by price. Quantity of cereal production that goes to livestock feed was insignificant and could not affect meat production.

### 4.3.4 FAO versus CSA meat consumption data

FAO's estimate of Ethiopian per capita meat was 8 kg/year in 2004, whereas CSA's HICE survey estimate was about 3.5 kg/year in 2004, i.e., a 100% difference (Table 4.4). This difference is significant when considered on the backdrop of the size of Ethiopian population.

*Table 4.4 Comparison of per capita meat consumption (kg/year) estimate by FAO and CSA*

| **Year** | **Data Source** | |
|---|---|---|
| | **FAO** | **CSA** |
| 1996 | 8.0 | 2.5 |
| 2000 | 7.0 | 2.0 |
| 2004 | 8.0 | 3.5 |

Although, comprehensive understanding of the discrepancy is difficult, partial explanation could be found from FAO's estimation methodology for Ethiopia. FAO (2004) reported a relatively constant slaughter rate and livestock yield (carcass weight per live animal). However, there is little information on how these indices were calculated. Since, livestock numbers reported on FAOSTAT were similar with CSA's livestock survey data, at least since 1996, the year CSA started the first livestock survey, the difference must have resulted from over estimation of the livestock utilization indices. The three consecutive HICE surveys of CSA have resulted in consistently lower per capita meat consumption compared to FAO. Therefore, it is highly unlikely that Ethiopian per capita meat was accurately estimated by FAO and must have been different from what has been reported. This assertion could not imply that the average meat consumption in Ethiopia that was reported by FAO was high in absolute terms. However, it illuminates the extent of the level of Ethiopian meat consumption being lower than what has been commonly reported and expected.

## *4.4 Conclusions*

- Ethiopian per capita meat consumption has been very low and could not be considered as essential part of daily household nutrition. The consumption and its response to income change has distinct pattern between urban and rural households.
- More than 40% of meat in the country is consumed in urban areas. Per capita meat consumption in urban households changes more steeply with change in per capita income compared with rural households.
- The total national meat consumption made improvement between 1996 and 2000 as a result of improvement in response of rural household meat consumption to income gain.
- Per capita meat consumption in Ethiopia is significantly affected by urbanization and level of income than meat price and cereal production. Therefore, improvement in meat consumption in Ethiopia could occur only if rural consumption pattern changes or urbanization proceed at faster rate and income level of urban households get better.
- FAO's seems to overestimate the per capita meat consumption in Ethiopia and therefore, it will be prudent to use the CSA's household consumption data along with FAO's data for policy making and research on nutrition in Ethiopia.

- Research and policy interventions are needed to address the problem of meager meat consumption in rural and low income urban households. These could include market incentives, education on nutrition and improving household income. It is very important for policy makers to understand the state of meat consumption in the country and devise mechanisms to improve it.

# Chapter 5 : Demand for nitrogen fertilizer in cereal production in Ethiopia toward 2030


**Summary**

We analyzed nitrogenous fertilizers demand for production of cereals for food and livestock feed in Ethiopia toward 2030. The demands were determined by the change in per capita GDP and population growth. Per capita GDP was projected using three annual growth scenarios of 0, 5, and 10%. Population was projected using education, level of household income and urban/rural residence variables to determine total fertility rate. Only urban to rural migration was assumed to happen as a result of change in level of education. A material balance system model with three major assumptions was used. Firstly, Ethiopia will totally depend on domestic supply of cereals in the future. Secondly, the carrying capacity of Ethiopian pasture lands is saturated so that further livestock production depend on cereal feed, and thirdly, nitrogenous fertilizers are determinants for cereal yield growth. The result showed that total demand for cereal food and feed in 2030 will increase between 2.5 and 4 times the level in 2005 depending on rate of GDP growth. Cereal yield which was 1.2 t/ha in 2005, is required to grow to 3.6 – 5.7 t/ha in 2030 which in turn requires nitrogenous fertilizer use rate between 160 kg/ha and 290 kg/ha. In order to supply the cereal demand for its growing population while checking expansion of agricultural lands, Ethiopia needs to dramatically increase the use of chemical fertilizer to a level unprecedented in the past decades.



**Keywords**: *Cereal yield, Nitrogen fertilizer, Per capita GDP, System analysis*


## *5.1. Introduction*

Ethiopia is a predominantly agrarian country with a population of around 74 million people in 2008 that heavily depends on agriculture for livelihood and economy (CSA, 2008). For the last 40 years the population has been growing at an average of 2.4% and is expected to continue growing with no sign of deceleration (UN, 2005). Ethiopian agriculture is characterized by low productivity rain-fed cropping with irrigation accounting for only 2% of the croplands (Rahmato, 1999). Chemical fertilizer use has been as low as 10 kg/ha which left cereal yield to stagnate around 1 t/ha (Howard et al, 1995). As a result, cereal production could not increase on a par with population growth and as, Byerlee (2007) argued, Ethiopia faces one of the most serious food supply challenges in the world. The country has one of the lowest per capita food supplies in the world: 1850 kcal/day and 50g of protein/day in 2005 (FAO, 2006).

Most efforts to address the problem of food insufficiency in Ethiopia by the last three regimes focused on increasing the domestic supply (Demeke, 2003). But most of these efforts failed to address the problem of malnourishment and prevent the recurring drought and famine. The frequency of famine has increased in recent years where 18 famines were recorded since 1900 (Nega, 2003). Nega (2003) argued that famine has denigrated human dignity and national morale in and outside the country. Not only does the frequency increased but the number of people affected by famine increased from less than 3 million to more than 10 million in early 2000s. In early 1970s famine was restricted to the northern and eastern part of the country, whereas later it has spread to the southern and western part of the country.

The demand for cereal in Ethiopia has remained very strong (Shideed et al, 2009). Direct cereal consumption account for large part of daily calorie and protein as has been the case in most poor countries. About 65% of both food energy and protein is originated from cereals. The percentage of cultivated land occupied by cereal crops has been nearly 70%. Therefore, it could be argued that achieving sufficient cereal foods production is central to food security in Ethiopia.

As discussed in Chapter 4, the total and per capita consumption of meat has been increasing with change in income level of households. Although, the change is not as big as urban households', meat consumption in rural households also showed positive response to income change. These changes, coupled with population growth, income rise and urbanization, have the potential to push dietary transition into a more livestock dominant nutrition. This in turn will put more pressure on the pasture lands and crop residues which are the only sources of livestock feeds in Ethiopia (Keftasa, 1988).

The production and consumption of meat and milk in Ethiopia on per capita bases remains low despite the fact that it has had one of highest number of livestock in Africa (Abegaz et al, 2006; Keftasa, 1988). The per capita consumption was estimated between 4 and 8 kg $y^{-1}$ in 2003 compared to the world average of 40 kg $y^{-1}$ (FAO, 2006; Betru and Kawashima, 2009; see also Figure 5:1).

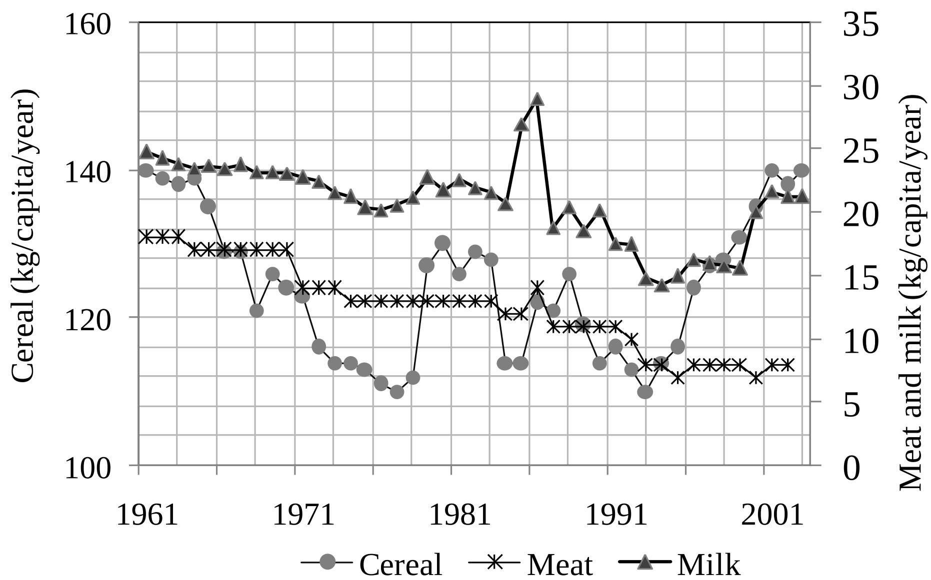



*Figure 5:1 Per capita cereal and meat consumption trend in Ethiopia between 1961 and 2003.*

Dairy products constitute an important part of nutrition (Ketema and Tsehay, 1995), especially in nomadic communities in the lowlands of Ethiopia (Mohammad et al, 2004). As a result of large number of livestock, dairy products could play a very important role in addressing food security problem and poverty reduction (Mohammad et al, 2004). The total production of milk grew by an average of 2% a year between 1961 and 2003 (see Figure 5:2). However, as a result of rapid population growth, the per capita milk declined to 20 kg by 2003, i.e., about 6 kg less than the 1961 consumption.

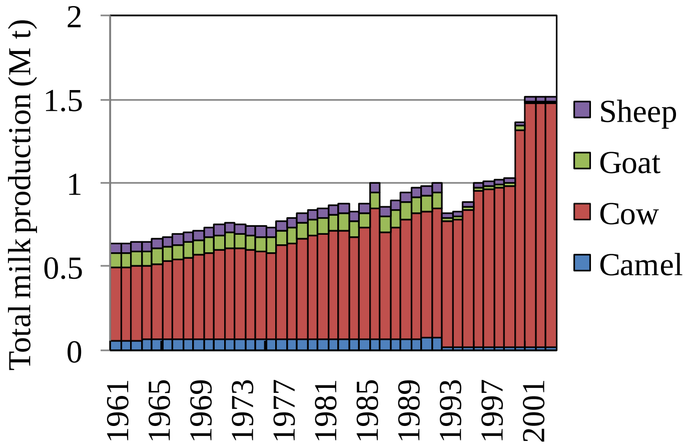



*Figure 5:2 Total milk productions in Ethiopia between 1961 and 2003.*
*Data source: FAOSTAT (2005)*

Figure 5:2 shows that cow milk constitutes more than 95% of milk production in Ethiopia. The abrupt decline in milk types other than cow milk could be attributed to change in method of estimation by FAO after Eritrean independence in early 1990s. Commercialized dairy production showed gradual improvement after the present government took power in 1991 (Pratt et al., 2008).

*Table 5.1 Ethiopian food consumption in 2005*

| Items | Consumption(Mt) | Per capita (kg/y) |
|---|---|---|
| Food Cereals | 7.5 | 120.9 |
| Feed Cereal | 0.1 | - |
| Meat | 0.6 | 8.3 |
| Milk | 1.7 | 22.3 |

Beside high rate of population growth, the other reason for the low per capita consumption appears to be scarcity of animal feed that limited proportional growth of livestock products. As indicated in Table 5.1 FAO's estimate of cereal use for food is limited to a mere 0.1 Mt which was about 1% of total cereal production. This estimate of cereal feed could enable production of only around 0.02 Mt of meat, i.e., about 3% of total meat production in 2003. The total production of meat between 1961 and 2003 has peaked around 0.6 Mt (Figure 5:3) and the carrying capacity of pasture lands seems to have already been exhausted (WRI, 2008; USDA, 2008). Expansion of pasture lands or their productivity, however, could hardly result in any major appreciation of total livestock supply because of the inherent low calorie productivity of grassland land use system. Besides, this option poses huge opportunity costs on the forest resources. Therefore, the rise in livestock demand will require feed sources other than the pasture lands that are already being utilized to their full capacity. In this kind of circumstances, cereals become the most viable option in providing continuous source of livestock feed.

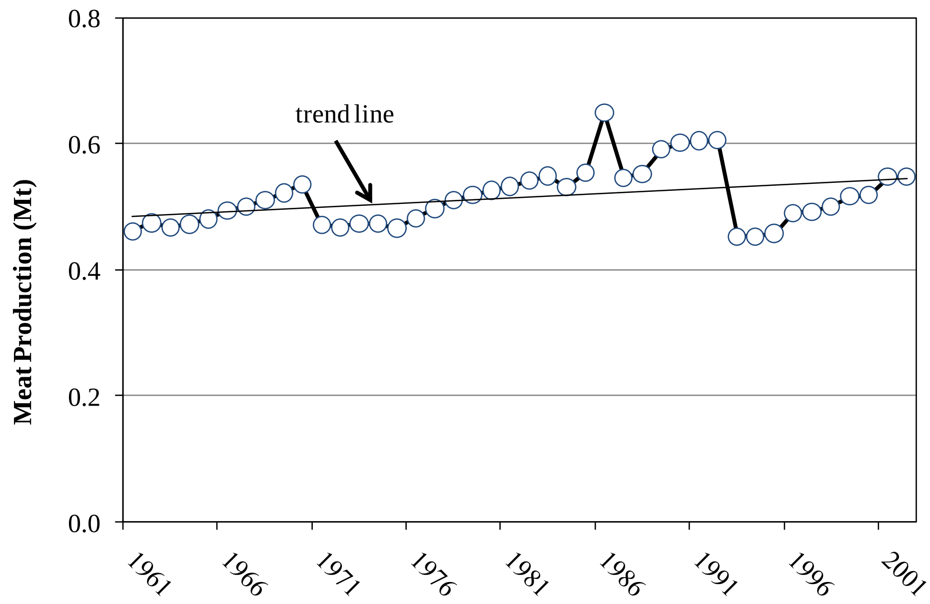



*Figure 5:3 Meat production trend in Ethiopia between 1961 and 2003*

*Data source: FAO (2005)*

The combined demand for cereal food and feed put more pressure on the cereal supply system as the population grows further. As discussed in Chapter 3, cereal import and expansion of croplands is not the best supply options and therefore, improving cereal yield will be critical in providing the projected cereal demand. The productivity of cereal harvesting lands responds very well to use of chemical fertilizers especially when cereal yield is low (Dyson, 1996) because nitrogen is the most important nutrient for quality and quantity of crop yield (Mengel and Kane, 2006; Dawson et al, 2008)

After investigating the national Sasakawa Global2000 agricultural package's fertilizer performance, Howard *et al.* (1999) reported that use of higher chemical fertilizer has resulted in significant cereal yield which was also economically feasible in many parts of Ethiopia.

Farm level experiments done in many parts of the world also provided useful information on yield response to fertilizer use for many food crops (FAO, 1989). Endale (2009) also made statistical test on the relationship between chemical fertilizer use and cereal production value using data from Central statistical authority (CSA) and the Ethiopian Rural Household Survey (ERHS). The result of his study showed chemical fertilizer use was significantly correlated with cereal production.

Nitrogen is the major component of chemical fertilizer and constitute about 70% of the total fertilize use by crops (IFIA, 2007; Smil, 2000; Gilland, 1993). At the initial stage of fertilizer use, nitrogenous fertilizers determine the rate of cereal yield improvement and are needed in larger proportion compared with phosphorous and potassium nutrients depending on the types of the soil and crop.

As the government of Ethiopia made agriculture the centerpiece of its development policies in the country, a lot has been tried to enhancing productivity of cereals and increase production to tackle persistent food shortage in large portion of its people and achieve food self-sufficiency. However, the average fertilizer use could not grow to a level of increasing the yield needed to improve cereal supply significantly. In 2005 the government has put forward a five year plan of action on agriculture as a part of an overall economic development strategy called PASDEP (a Plan for accelerated and sustained development to end poverty). In the plan, the total cereal production growth sought in 5 years is projected at 35 million tons by the end of 2010 with 0.8 million tons of fertilizer use and improving cereal yield to 3.5 t/ha. The plan pronounced the exigency of fundamentally changing the cereal production system. However, it lacks detailed analysis of past trends and available resources.

There is lack of studies on chemical fertilizer demand and supply which employ systems approach in Ethiopia. Most of the studies were done at small scale level and focused on marketing and affordability to farmers (Belete et al, 1992; Demeke et al, 1997).

In this chapter, estimation of nitrogenous fertilizers demand was made for production of cereals for direct food consumption as well as livestock production in Ethiopia towards 2030 at varying per capita GDP growth and levels of food consumption. The result of the analysis will help strengthening our understanding of the complex future interaction between population growth, food demand and need for agricultural inputs and, thereby, contribute in the mitigation of unwanted social and environmental consequences.

## *5. 2. Materials and methodology*

A system model was used to project and analyze the requirement of nitrogen fertilizer needed to improve cereal yield and produce the future demand of cereals in Ethiopia up to 2030. The model shown on Figure 5:4 considers three GDP growth scenarios with corresponding level of food consumption. GDP was projected using gross annual rate of 2.5, 5 and 10% growth. The total GDP was distributed to households based on level of education. Income for each household under certain level of education, residence (urban or rural) and sex was estimated from literature and was adjusted using total GDP.

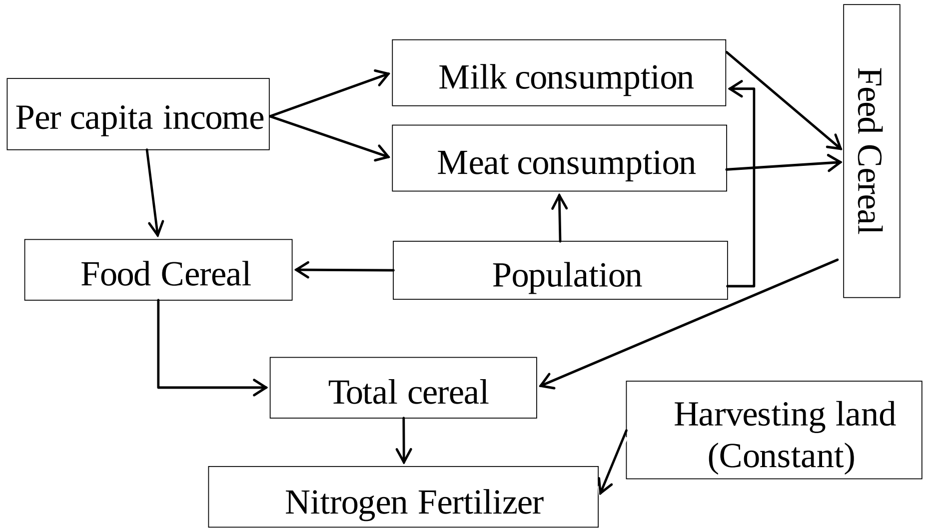



*Figure 5:4 Scheme of Nitrogen fertilizer projection model.*

*Note: cereal harvesting land area was set constant at the 2005 level.*

### 5.2.1 Population Model

Population was projected using data on demographic variables from Demographic and Health Surveys (DHS, 2005) and initial population from UN Population Prospect (UN, 2005). Fertility related to women's levels of educational, age and residence was used to project number of babies born in the projection period (see Table 5.2, Table 5.3). The four levels of education were adopted from DHS, namely, no-education, elementary, secondary and tertiary. The rate of change of the level of education was established from two consecutive DHS surveys in 2000 and 2005.

Firstly, the base year, 2005 (*t*), population was disaggregated into the four categories of levels of education. Population age structure information was obtained from UN Population Prospect database. Some computations were made on the level of education to adjust non-uniformity in age grouping of DHS to a commonly used five year cohort grouping. For example, DHS's begins education data from 6-9 years, whereas, most demographic cohort groups start from 0-4 years and continue at five years interval. Hence, the population in age group 6-9 years was adjusted to include starting from age 5 years. The baseline population, $P_0$, was categorized by residence, sex, cohort and level of education. Based on these data, the future population at every five years was projected accordingly.

Age specific fertility rate (FR) of both urban and rural resident (r) population was determined based on level of education (LE) of the female cohort groups in the reproductive age groups (15-49 years) at base year (*t*) (see Table 5.2 and Table 5.3).

The model began by projecting the number of babies born every five years within the projection period by using Equation 5.1.

$$P_{t+1,e,0,r,s} = P_{t,e,a,r,s1} * FR_{t,,e,a} * SR_f \qquad (5.1)$$

Where:-

- $SR_f$ = the female sex ratio
- P = population, 0 indicate the first cohort groups, i.e., 0-4 years
- e = 0, 1, 2 and 3 represent levels of education, i.e., no-education, elementary, secondary and tertiary respectively
- S1 = female population in the reproductive age, and
- t +1 is the next 5 projection periods from 2010 to 2030 and,
- a = 5 years cohort age group

Table 5.2 Total fertility rate (TFR) in residence and level of education in Ethiopia in 2003

| **Sector (r)** | **Total fertility rate (TFR)** |
|---|---|
| Rural | 2.4 |
| Urban | 6 |
| **Level of Education (LE)** | |
| No- education | 6.1 |
| Primary | 5.1 |
| Secondary | 2.2 |
| Higher | 1.8 |

*Table 5.3 Age specific fertility rate of female in reproductive cohort group in Ethiopia in 2005*

| **Age group** | **Fertility rate (per 1000 female)** |
|---|---|
| 15-19 | 104 |
| 20-24 | 228 |
| 25-29 | 241 |
| 30-34 | 231 |
| 35-39 | 160 |
| 40-44 | 84 |
| 45-49 | 34 |
| TFR | 5.4 |

The population of age groups 5-24 years was calculated by using equation 2. The rate of progression (RP) from one level of education to the next was estimated using trend variables estimated from consecutive DHS surveys. The population that will remain at the same level of education in the next projection period was estimated by using RP and mortality rates (MR). MR was calculated from UN population data. For e = 0 (the number of people who will remain at no-education category) and e = 1 to 3, the population was estimated by using equations 5.2 and 5.3 respectively.

$$P'_{t+1,e,a+1,r,s}= P_{t,e,a,r,s}*(1-RP_{e,a,s})*(1-MR_{t,a,r,s}) \quad (5.2)$$

$$P'_{t+1,e,a+1,r,s}=\{(P_{t,e-1,a,r,s}*RP_{e-1,a,s}) + P_{t,e,a,r,s}*(1-RP_{e,a,s})\}*(1-MR_{t,a,r,s}) \quad (5.3)$$

Where, P' is the population before migration. The model assumed that the levels of education of cohort groups 25-79 years will remain the same as it was before entering this age, therefore, Equation 5.4, which did not involve change in the level of education, was used to estimate the population of these cohort groups.

$$P'_{t+1,e,a+1,r,s}= P_{t,e,a,r,s}* (1-MR_{t,a,r,s}) \quad (5.4)$$

And for age group above 80 years, population was calculated by using equation 5.5 as follows,

$$P'_{t+1,e,a17,r,s}=P_{t,e,a16,r,s}*(1-MR_{t,a16,r,s}) + P_{t,e,a17,r,s}*(1-MR_{t,a17,r,s}) \quad (5.5)$$

Where, a16 and a17 are age groups 75-79 and 80+ respectively.

The population projection model assumed migration from rural to urban areas to occur between 15-19 and 20-24 age groups. It also assumed that the babies born in a migrating group to move to urban areas together with their parents. The population that remains in rural areas was calculated using equation 5.6. This equation accounted for population that moves to urban area in respective age and education groups. These migrating rural populations were added to the urban population using equation 5.7.

$$P_{t+1,e,a+1,r(R),s} = P'_{t+1,e,a+1,r,s} * (1-RM_{t,a+1,r,s}) \quad (5.6)$$

$$P_{t+1,e,a+1,r,s} = P'_{t+1,e,a+1,r(U),s} + P'_{t+1,e,a+1,r-1,s} * RM_{t,a+1,r,s} \quad (5.7)$$

Where, P is final population after incorporating migration; r(R) and r (U) represent rural and urban residence respectively.

### 5.2.2 Food Demand and Supply models

Per capita food demand was estimated for different meat items, milk and cereals using logarithmic regression equations developed from household income and consumption data of HICE 2004 (see Table 5.4).

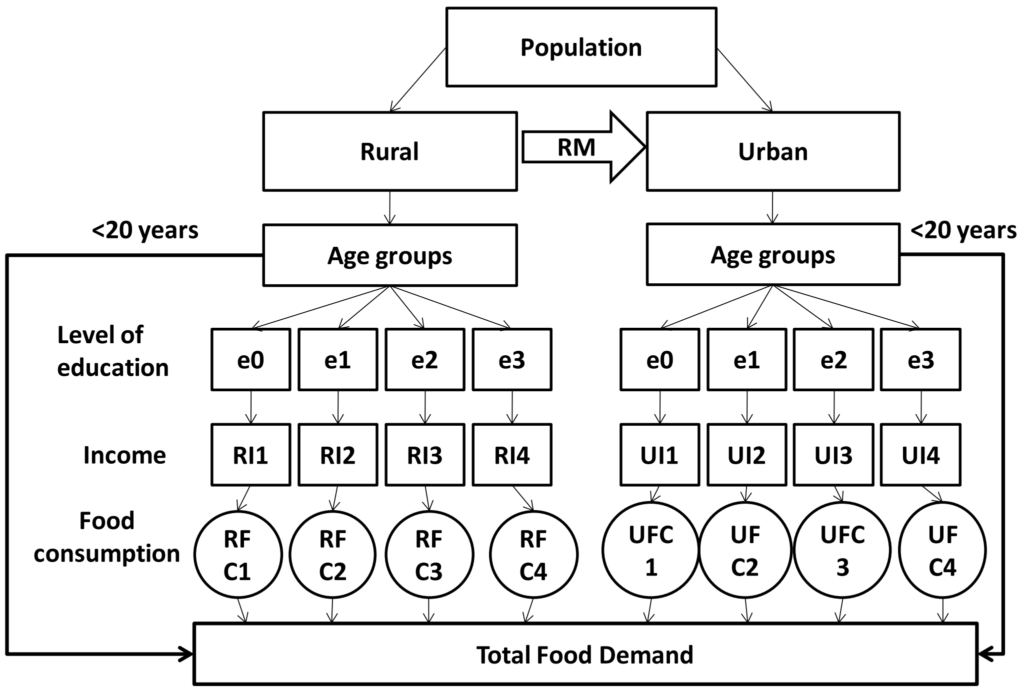



*Figure 5:5 Detailed outline of estimation of food cereals based on age, level of education, residence and income.*

*Note:* e0-e3 represents the four education levels. RI1-RI4 and UI1-UI4 represent corresponding income levels in rural and urban areas respectively. RFC1-4 and UFC1-4 represent food consumption in rural and urban households respectively. RM stands for rural migration. For age groups less <20 years food demand was estimated from parents level of consumption

In this estimation, age dependant consumption rate, urban/rural consumption pattern, sex and income level differences were incorporated in model as shown in the expanded illustration on Figure 5:5.

*Table 5.4 Coefficients Regression between food consumption and household income*

| | rural | | | urban | | |
|---|---|---|---|---|---|---|
| | a* | b* | $r^{2*}$ | a | b | $r^2$ |
| Cereal | 156.58 | -339.47 | 0.85 | 93.61 | -190.60 | 0.93 |
| Beef | 2.83 | -7.66 | 0.90 | 18.72 | -55.16 | 0.97 |
| Mutton | 1.20 | -3.47 | 0.72 | 11.02 | -33.56 | 0.99 |
| Chicken | 0.49 | -1.29 | 0.85 | 3.23 | -9.25 | 0.99 |
| Goat | 1.01 | -2.92 | 0.81 | 2.38 | -7.13 | 0.99 |
| Milk | 24.71 | -67.99 | 0.91 | 21.63 | -63.83 | 0.94 |

**a, b and $r^2$ represent regressand, constant term and coefficient of determination respectively*

Two assumptions were made on income. Urban income is assumed to be 1.5 times more than rural income and men get 1.3 times women in the same educational groups (Temesgen, 2006). The consumption level of population above 20 years age groups was estimated using logarithmic function shown in equation 5.8 and income and food consumption coefficients in Table 5.4. Food demand of age group below 20 was estimated from age specific per capita food consumption ratios adopted from the Japanese nutrition survey (MHLW, 2000).

$$Y_{ijt} = \beta_0 + \beta_1 \log (X_{it}) \qquad (5.8)$$

Where: Y is food demand for each food items (i) and year (t). $\beta_0$ and $\beta_1$ are consumption intercepts and income elasticity of food demand to income change.

Cereal feed demand was projected from livestock demands and animal feed/livestock ratios derived from Smil (2000). Accordingly, edible livestock to cereal feed ratio of 8 (beef), 4 (goat meat and mutton), 2.5 (poultry) and 2 (milk) were used to estimate amount of animal feed. The total cereal demand was estimated by aggregating food cereal and animal feed together.

In the analysis of cereal supply, three assumptions were considered in order to estimating cereal yield and nitrogen fertilizer demands. Firstly, Ethiopia will depend entirely on domestic supply of cereals, i.e., there will be no cereal import either through trade or food aid. Secondly, as a result of saturation of the carrying capacity of Ethiopian pasture lands additional meat and milk products will be produced by feeding livestock with cereals. Thirdly, cereal yield will respond to application of nitrogenous fertilizers uniformly.

The amount of Nitrogen fertilizers was estimated using a productivity of nitrogen equation 5.9 developed from world counties' data and East African countries pas cereal yield and nitrogen use correlation. As indicated in the assumptions, constant harvesting area at 2005 was set unchanged throughout the projection period.

$$N_{fert} = (Y_c - 0.84)*1000/17.5 \quad (5.9)$$

Where: $N_{fert}$ (kg/ha) = nitrogenous fertilizer, $Y_c$ = cereal yield (tons/hectare). The denominator, 17.5, is the yield (in kg) that is attributed to a kg of nitrogenous fertilizer use. The sensitivity of the denominator, factor productivity of nitrogen fertilizer, was test using different values.

The major sources of data for this study were obtained from report of Demographic and Household surveys in 1996, 2000 and 2004, FAO (2005), UN population prospect (2006) and WDI (2008). Microsoft Excel's VBA was used to execute sets of models discussed above.

## 5. 3. Result and Discussion

### 5.3.1. Population projection

The result showed there is clear convergence between population projection of this model and UN medium variant (Figure 5:6). The total population will grow from 78 million in 2005 to 130 million people in 2030. An average of 2 million people will be added to the population annually. There will be 52 million additional people in Ethiopia in 2030 most of which will live in rural areas with educational level below junior high school (Figure 5:7).

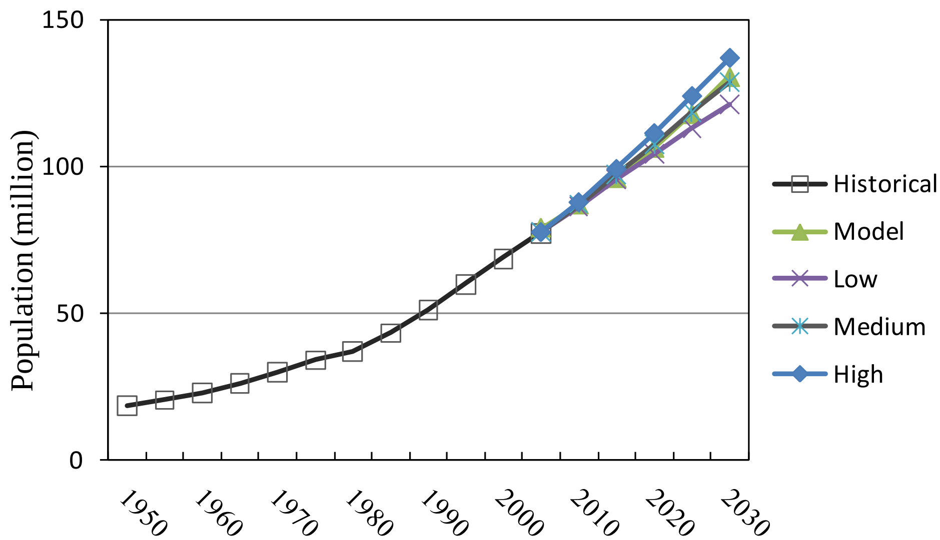



*Figure 5:6 Comparison between population projection by UN and the present model*

There will not be significant change in the proportion of urban and rural population within projection period 2030 (Figure 5:7). Percentage of urban population increases only by 2% at the end of this period. In urban areas the number of people with elementary education or above will grow significantly as opposed to rural once. This affects further reduce the fertility rate of urban female. This trend is evident in recent national census report of Ethiopia (CSA, 2008) where the population of Addis Ababa had the lowest growth rate.

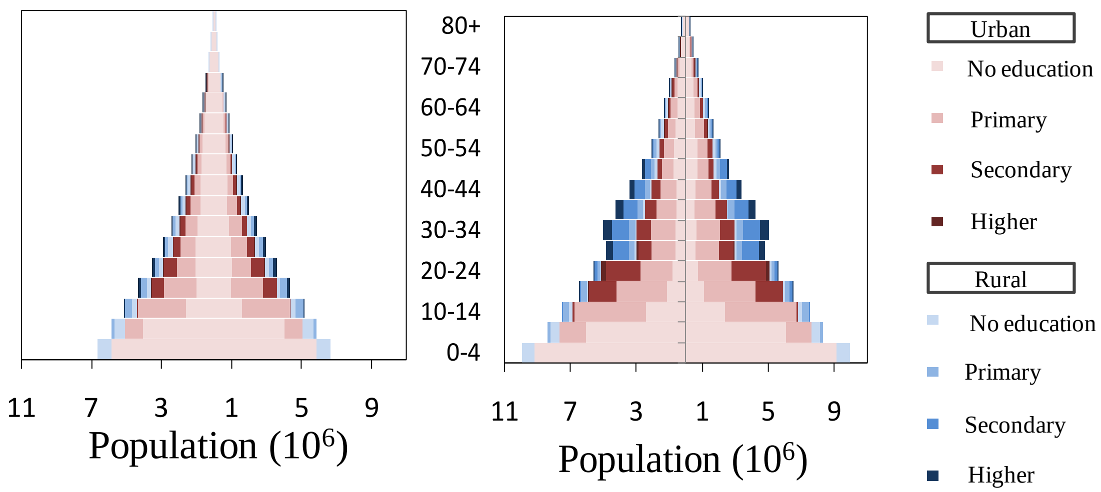



*Figure 5:7 Demographic change in urban and rural Ethiopia between 2005 and 2030*

Rural and urban population will grow to about 105 million and 24 million people by 2030 respectively. The additional 40 million people added in rural areas will add a total of 5.3 million more households (average number of households at 7.4). This will affect land holding size of farmers or put pressure on expansion of agricultural land. The proportion of rural population with no education will decline and most of the population will remain under primary education. Since the fertility rate corresponding to lower education level is high (refer Table 5.2), rural population will likely continue to grow rapidly.

### 5.3.2. Food demand projection

#### 5.3.2.1. Cereal food demand

The total food cereal demand will be between 20 Mt (scenario 1) and 26 Mt (scenario 3) in 2030 which is 2 to 2.5 times more than the base year consumption level (see Table 5.1and Table 5.5). The cereal food demand gorwth resulted from population growth will be two times the demand change between scenario 1 and 3. GDP growth that mostly benefit the well-off households and has limited effect on consumption of direct cereal food. In contrary, each person added, wheather in poor or rich households, will affect cereal food demand linearly to certain level.

*Table 5.5 Food and livestock feed cereal projection in five years period between 2005 and 2030*

| Projection year | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|
| | Food | Feed | Food | Feed | Food | Feed |
| 2,005 | 11.4 | 3.2 | 11.4 | 3.2 | 11.4 | 3.2 |
| 2,010 | 12.7 | 3.8 | 13.3 | 4.3 | 14.2 | 5.2 |
| 2,015 | 14.2 | 4.4 | 15.3 | 5.5 | 16.9 | 7.5 |
| 2,020 | 15.7 | 5 | 17.6 | 6.8 | 19.5 | 10.3 |
| 2,025 | 17.6 | 5.8 | 20.2 | 8.5 | 22.3 | 13.7 |
| 2,030 | 19.6 | 6.6 | 23.1 | 10.4 | 25.3 | 17.6 |

Food cereal growth will be highly affected by population growth and economic growth in rural areas. Firstly, most of the population growth comes from rural households. Over 80% of the 50 million addition people in 2030 will be added in rural areas. Secondly, small change in income of this population will be directly translated into more cereal consumption.

### 5.3.2.2. Meat demand

The total meat demand in 2030 will grow between 200 to 700% of the base year consumption. Most of the growth will come from urban areas (see Table 5.6). In Chapter 4, it was indicator that urban households' meat consumption rate is higher at extra income gain than rural households. The effect of income on meat consumption was also found to be higher than its effect on cereal consumption. Migration of households with higher education and better earning potential will also drives the demand for meat products in urban areas.

*Table 5.6 Total meat demand in 2030 under different scenarios*

| Meat demand (thousand t) | Rural | Urban | Total | Urban% |
|---|---|---|---|---|
| Base year | 145,901 | 97,986 | 243,886 | 0.40 |
| Scenario 1 | 241,095 | 293,042 | 534,137 | 0.55 |
| Scenario 2 | 397,426 | 592,099 | 989,525 | 0.60 |
| Scenario 3 | 676,524 | 1,027,500 | 1,704,024 | 0.60 |

Table 5.6 shows as the rate of GDP increases, the consumption of meat in urban households increases which was demonstrated by the difference in urban consumption share among the three scenarios. Although 80% of the population growth happen in rural areas, all the three scenarios resulted in increased proportion of urban meat consumption.

Unlike cereal food demand, GDP growth has more impact on total meat demand than population growth. The difference between scenario 3 and 1 has more than twice meat demand compared to difference between base year and 2030 under Scenario 1. With only 20% of the population urban households will consume about 60% of total meat in the country.

Table 5.7 shows the proportion and amount of different food types in base year and under different scenarios. Beef represent 60% and 70% of total meat consumption in 2005. This proportion declined in the projected demand in both urban and rural areas. In both rural and urban areas more than types of meat are mentioned in the order of significance: beef, mutton, poultry and goat meat. Beef occupy by the far the largest share of meat consumption.

In rural areas goat meat, mutton and poultry consumption were better than cattle meat consumption (Figure 5:8). This is partly, as explained in Chapter 4, the difficulty of getting cattle meat in the market. In rural areas households could relatively get meat of small sized animals. High income rural households, for example, afford slaughtering a goat or sheep for private consumption or divide among relatives. In spite of its size convenience consumption of poultry was small in rural areas. One of the reasons is the complex procedures required in preparing poultry food in Ethiopia which requires a lot of spices and extending cooking.

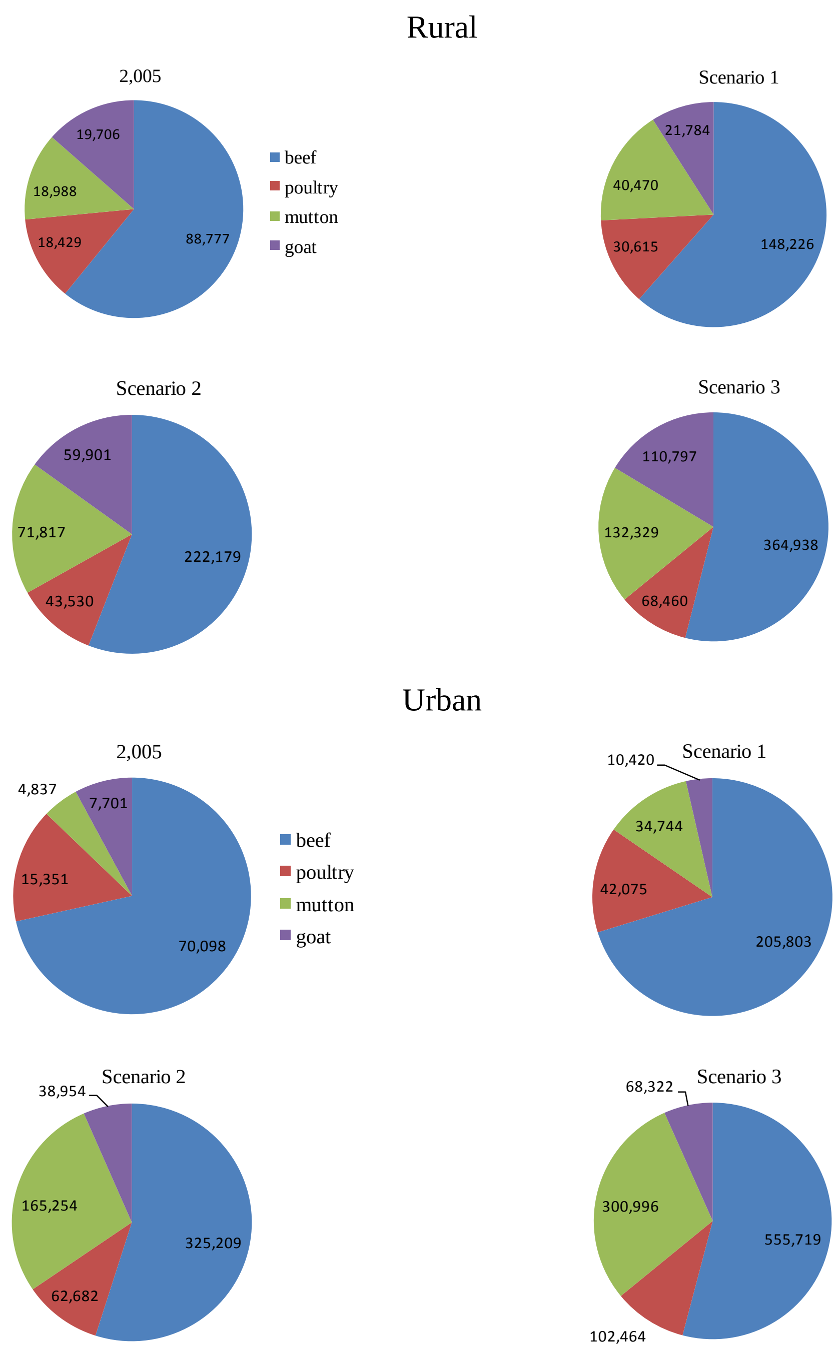



Figure 5:8 Proportion and amount of different meat types in future demand in rural and urban population areas in 2005 and 2030

#### 5.3.2.3. Milk demand

The demand of milk will rise by 81% under scenario 1 to 375% under scenario 3. The total milk demand will be between 1.4 and 3.7 Mt in which case the per capita consumption increases between 9 and 24 kg/year/person. Although, FAOSTAT's FBS reported the per capita milk consumption to be 21 kg/year, as was the case for meat consumption, this study found much lower consumption value. It can be argued though, using the FBS data that Ethiopian per capita milk consumption is less than half of SSA consumption that was more than 50 kg/year/person in 2001. The per capita consumption gap between urban and rural households is not as big in the case of milk as meat consumption. Rural households proportionally increase their consumption of per capita milk as the income of the household rises. This could be attributed to the ease of getting milk at the market or producing it in the household. The possibility of households with better income level to have livestock holding is high compared with poorer households. Unlike meat, they do not need to slaughter the animal for milk production. The similarity between milk and meat consumption pattern is that higher income households account for much of the consumption leaving the low income households for low quality food.

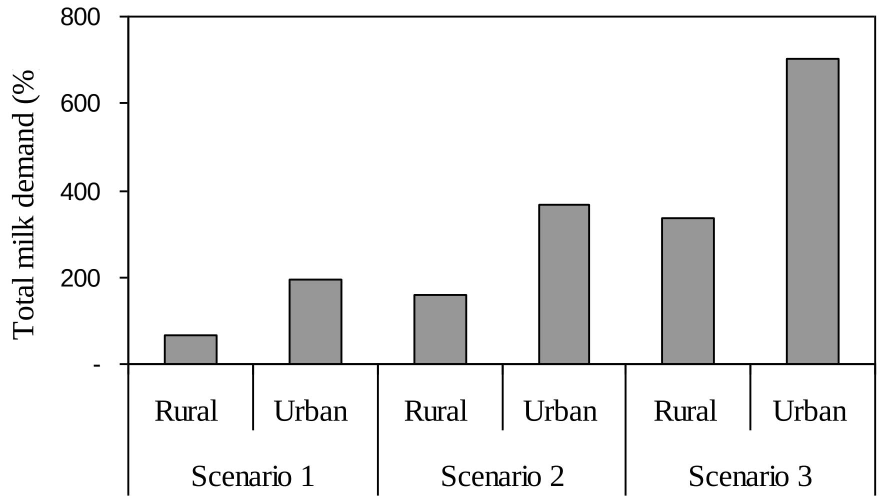



*Figure 5:9 Milk demand projection difference in urban and rural areas under the three scenarios between 2005 and 2030*

Figure 5:9 shows the milk demand projection in rural and urban areas under the scenarios. The change in total GDP assumed in consecutive scenarios favor more consumption in urban than rural households. Unlike meat, however, affecting milk consumption in rural areas will be insurmountable.

### 5.3.3. Feed demand

Livestock cereal feed required to produce the beef, goat meat, mutton, poultry and milk was estimated between 7 and 18 Mt (Table 5.5). The present level of cereal feed or the reported data by FAO is too low to compare with the amount estimated by this study. The cereal feed equivalent meat that can be produced from the pasture lands was around 2 Mt which then reduce the total cereal demand to 5-16 Mt in 2030 under scenario 1 and 3. There is big variation among the three scenarios which was resulted in the combined effect of meat and milk consumption change with GDP growth change. Another reason could be found in the type of meat predominantly consumed in Ethiopia, i.e., beef. Beef is the most preferred meat in urban areas and is widely available one. Beef consumption response to income change is higher than other meat types. On the other hand, beef production needs more per unit cereal feed than all other livestock products. Therefore, change in consumption pattern to more energy efficient meat types like poultry will reduce the demand for animal feed considerably.

### 5.3.4 Total cereal demand

The total cereal demand was projected to be between 26 and 43 Mt under scenario 1 and 3 in 2030 (Table 5.5). This demand is between 2 and 4 times the present level of production in the country. The proportion of direct food and livestock food vary among the three scenarios. As the GDP growth increases from 2.5 to 10% the share of cereals that has to be allocated for livestock consumption will increase significantly (Table 5.6). Nonetheless, the total cereal needed for direct food consumption will be much higher than livestock feed within the projection period and under considered GDP growth scenarios.

*Table 5.7 Cereal and nitrogen fertilizer demand in Ethiopia in 2030*

| (Mt) | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Food (Mt) | 19.62 | 23.06 | 25.26 |
| Feed (Mt) | 6.60 | 10.37 | 17.65 |
| Total cereal (Mt) | 26.22 | 33.43 | 42.91 |
| Yield needed (t/ha) | 3.49 | 4.45 | 5.71 |
| N-fertilizer (kg/ha) | 158.34 | 214.78 | 289.02 |
| N-fertilizer (Mt) | 1.19 | 1.61 | 2.17 |

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### 5.3.5. Nitrogen demand

The total nitrogen demand will grow to 1.2-2.2 Mt in 2030 (see Figure 5:10, Table 5.7). In all the three scenarios the rate of nitrogen fertilizer use need to increase to more than 150 kg/ha by 2030 (Table 5.7). While this rate is common in many countries in the world including some African countries like Egypt, it is going to be a new phenomena that require greater attention in terms of fertilizer marketing, distribution, use efficiency and waste management.

Nitrogen demand projections are to be highly sensitive to cropping intensity, factor productivity of nitrogen fertilizer and natural yield of the harvesting land. They are also sensitive to the movement in cereal demand which in turn is affected by food consumption pattern in rural as well as urban households. In which ever case, though, the present chemical fertilizer use rate need to be dramatically altered as the population and the economy grow. With the price of cereals rising in the world as well as in Ethiopia, increasing the use of fertilizer will be both profitable and indispensable to match demand of growing population and shrinking agricultural lands.

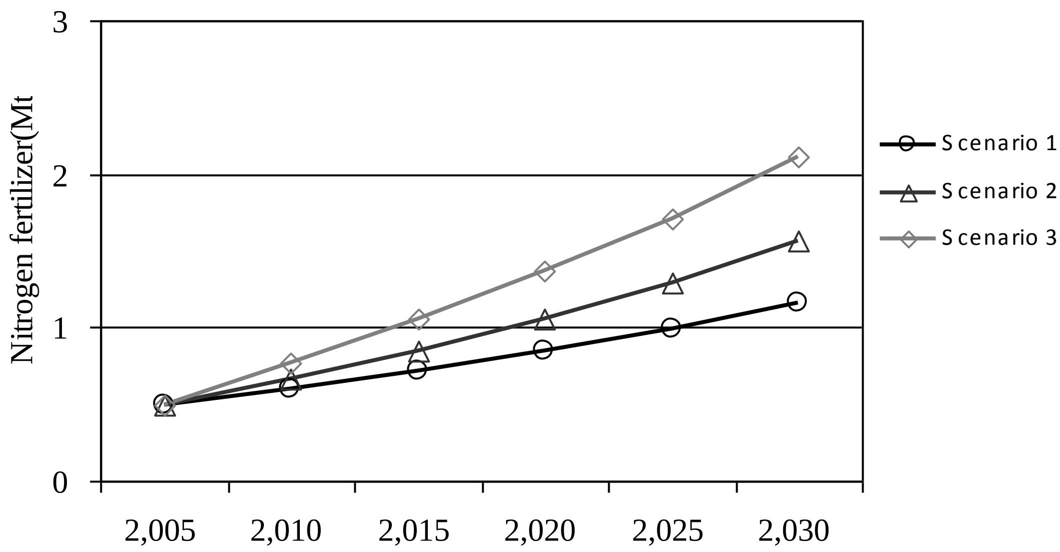


*Figure 5:10 Projected nitrogen fertilizer demand for cereal production between 2005-2030*

#### 5.3.5.1 Sensitivity Analysis of Nitrogen fertilizer productivity

The demand for fertilizers was found to be highly sensitive to change in factor productivity of fertilizers on cereals. Figure 5:11 shows for scenario 1, i.e., 2.5% GDP growth, the difference in total fertilizer demand between lowest and highest productivity of nitrogen was about 0.9 Mt in 2030. But as the productivity rises, the effect of the total fertilizer demand starts to fall gradually. However, the difference between first and third scenarios is comparable with the the effect of total cereal demand on demand for nigrogen fertilizer.

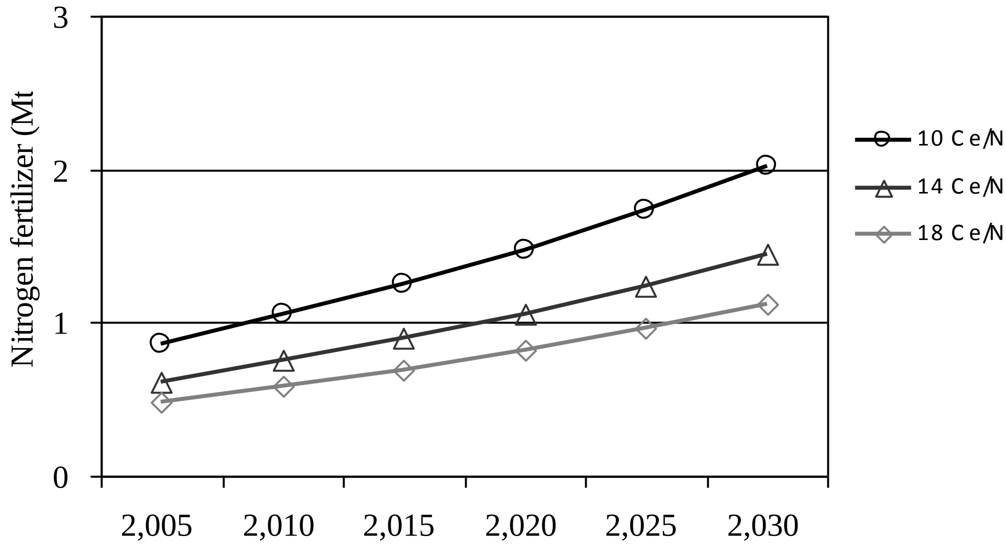


*Figure 5:11 Sensitivity of nitrogen fertilizer demand to change in fertilizer productivity.*

*Note:10 Ce/N, 14 Ce/N and 18 Ce/N stand for the three level of nitrogen fertilizer productivity (Ce/N stand for cereal produced as a result of a unit of Nitrogen fertilizer used).*

## 5. 4. Conclusion

Cereal demand for food in Ethiopia in 2030 will grow between 20 and 25 Mt which is 2 and 2.5 times the base year level. Population growth will have twice more contribution to cereal food demand than change in the rate of economic growth considered in the projection. This has been resulted from inequality of resource distribution that favors the high income households which have little response of food consumption to additional household income. On the other hand, livestock cereal demand will grow between 7 (lower estimate) and 18 Mt (higher estimate) in 2030 from the present near zero level of consumption. The differences among the three scenarios cereal feed projection was higher than the differences among cereal food projection. This is because in the former case additional income in higher income households has better response for livestock products than direct cereals.

In order to produce the total cereal demand, i.e., food and feed, while keeping the cereal harvesting land unchanged Ethiopia needs to increase its present 1.2 t/ha of cereal yield to between 3.4 and 5.7 t/ha which requires nitrogen fertilizer level between 158 and 290 kg/ha. Improving productivity per se could not be solving the problem of cereal supply unless it is accompanied by measures to stabilize the rate of population growth in the long term.

The result of this study has important implication on the extent of the challenge in cereal supply with the population growing and nutrition style changing in the Ethiopia. The country has few alternatives to improving productivity of cereal production. The first alternative is expansion of crop lands to other land uses, the productivity of which is marginal and entail huge opportunity costs. In this option forests will be cut, pasturelands will shrink and their services will be lost as a result. The second alternative is reducing population growth to a level that matches production capacity of land resources. This option has long term significance but will take a couple of decades to take effect because of demographic momentum that has already being built in the country. The solution for securing the growing food demands in Ethiopia lies on reducing the rate of crop land expansion and controlling population growth while improving cereal productivity.

# Chapter 6 : Conclusion and recommendations

Cereal demand and supply condition of African countries had different trajectories in the past and likewise will follow divergent prospect in the future. It could be said that most countries in Africa have sufficient arable land to expand cropping area within projection period if not for scarcity of water in some of them. Moreover, 60% of the countries in Africa can contain expansion of crop lands by improving cereal yield to about 2 t/ha.

Improvement in domestic supply of cereals showed big improvement in North African countries. These countries were major recipients of cereal aid in the 1960s but gradually become more importers of cereals from international market and improved their domestic production. Their per capita consumption of cereal products also showed significant improvement. This improvement occurred in conjunction with enhancement in GDP growth in these countries. In spite of all the progresses, scarcity of available renewable water remains one of the biggest challenges in these countries. Besides, instability in world cereal market should be considered in food policy formulation process.

There is a shift in Southern African countries from being major exporters to net importers of cereals. However, the production potential of countries in this region has not yet been exhausted although there is a sign of declining per capita available water. Most of the West African countries also are well endowed with land as well as water resource to expand agriculture in the short term and could readily expand crop productivity from its present low level.

The most important region in food security in Africa is Central and East Africa. The region is dominated by countries with low per capita income and persistent food insecurity. Supply of per capita food has regressed to level decades ago. Dependence on foreign food aid has been growing every year since early 1970s. The distinctively high rate of population growth in the poor rural areas of these countries wiped out any progress achieved in food security. The central African countries, despite the present low level of food supply, have immense potential to expand agriculture withstanding the prevailing fragile ecosystems.

Ranking of countries based on availability of water, arable land and cereal yield showed Ethiopia, Rwanda, Burundi and Eritrea were the top four countries in food self insufficiency. Ethiopia, as a result of its huge and growing population, is the most critical country in food security in the region. It has already faced chronic need of external cereal aid and suffered couples of worst famines.

One of the factors that will drive future demand of cereals in Ethiopia will be expansion of meat consumption. Meat consumption has distinct pattern in rural and urban areas of Ethiopia. There is higher response of meat consumption for a gain in household income in urban area than in rural for similar income groups. Among meat types cattle meat is consumed in higher proportion in urban areas compared with poultry, goat meat and mutton. In the past eight years, the consumption of meat has improved in both urban and rural areas. Among regional states, urban population rate, household income had positive significant correlation with per capita consumption. In contrary, amount of cereal production and price of meat had little no significant correlation with the amount of meat consumption. Ethiopian meat consumption has been overestimated by FAO. The result of the comprehensive national household surveys revealed lower level of meat consumption. It is, therefore, important to revise meat consumption assessment in Ethiopia rather than relying on estimates that heavily rely on remote information and expert opinion.

Having nutrition with less livestock products would be beneficial in the long run for an efficient food production system of a country. Nonetheless, the very low intake of meat consumption prevalent in the rural areas of Ethiopia seems to be a nutritional quagmire that entails adverse effect on health and well being of the people. It will also affect productive human capita which is essential to agricultural development that the country desperately needs.

There is a need to revolutionize the cereal production sector in Ethiopia. GDP growth differences bear high impact on quantity of demand for cereals. Economic growth in Ethiopia will likely be accompanied by agricultural development for the sector contributes greatly to GDP as well as export commodities. However, the growth in income does not translate to better nutrition for all parts of the society. The present level of chemical fertilizer use could not sustain supply of domestic cereal production. There is a need to significantly improve cereal productivity in the country in order to restrict the expansion of croplands and reduce the pressure on the natural forests and woodlands. In order to achieve the growth in cereal yield, Ethiopia needs to fundamentally change its system of fertilizer input system. The present cereal yield level of 1.2 t/ha need to improve to between 3.4 and 5.7 under different scenarios, and this requires increasing chemical fertilizer application of between 158 and 290 kg/ha from the present level of less than 10 kg/ha. Moreover, with the prospect of population growing to around 130 million in 2030 and potential to expand crop land shrinking, the need to increase availability and marketing of chemical fertilizers become indispensable. The strategy that was followed over the past five decades to partly rely on cereal food aid in Ethiopia has a lot of repercussion besides the psychological and social crises it produced. As the size of population increases and prospect of cereal aid diminishes from donor countries, it will be to the peril of the country to incorporate food aid as part of overall long-term food security strategy.

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## *Appendix 1: Overview of Nile water use challenges*

The objective of this Appendix is to give an overview of the complexity of problem of water use in Ethiopia and neighboring countries which made incorporating water use in the cereal demand and supply difficult. It is important to understand that 70% Ethiopia's renewable water is found in Nile basin (Rahmeto, 1999) and except for few inland flowing rivers, most of its rivers are transboundary with many claims from different countries.

A country's water resource comprises of renewable and non-renewable. The non-renewable water resources are the non-conventional resources such as brackish water and salty sea water. These resources contribute small fraction of national water supply. The renewable water resources (RWR) are the major sources of water for a country. These resources could originate from inside or outside of the country: internal renewable water resources (IRWR) and external renewable water resources (ERWR) respectively. The size of ERWR to total renewable water resources (TRWR) determines the water dependence of a country. When a country is highly dependent on external water resources, it faces a great deal of uncertainty in supplying its water demand. The ERWR is obtained either through formal treaty, informal inter-country agreement or non-treaty use. This water resource is commonly the cause for conflict and tension in areas of scarcity.

Water is considered to be one the most important factors in achieving food security and development in Africa (Rached et al. 1996). Half of the African continent is considered to be arid to semi-arid, where as the remaining half encompasses land with very humid to good rainfall. Rached et al (1996) stated that the per capita available water in Africa and Middle

East will decrease by 80% from 3,430 in 1990s to 667 $m^3$ by 2025. The decline will put more pressure on the already scarce resource.

One of the rivers that are characterized by high demand and use conflict is the Nile River. The water of Nile River comes from two major rivers: White Nile and Blue Nile. White Nile originates in Burundi and flows through five countries until it reaches Sudan and meets Blue Nile to flow into Egypt and finally enters the Mediterranean Sea. The Blue Nile flows from Ethiopia and constitutes more than 86% of the Nile water (Kindie, 1999). Nile River is 6,671 km long, the longest in the world, and the basin covers an area of 3.3 million $km^2$. While the White Nile loses most of its water by evaporation as it passes through the hot lowland and swamplands of Sudan, there is little evaporation loss in Blue Nile because it flows through the mild climate of the highlands of Ethiopia.

There is seasonal variability of amount of water in Nile River. The flow is at its maximum from July to November peaking between August and September. The contribution of Blue Nile increases during this peak season when the Ethiopian highlands get their major rainfall. Not only do Ethiopian rivers contribute through Blue Nile but also through River Atbara which at peak season contributes for 20% of the Nile water at Aswan dam, which is the major reservoir since its construction 1970s. Before its construction, areas around the Nile River in Egypt were suffering from annual flood.

The utilization of the water of Nile has always been full of problem. One could perceive the gravity of the problem of water use in Nile basin from political statements made by leaders in the region with stake. For example Ex-Egyptian president Anwar El Sadat declared: "*Any* *action that would endanger the waters of the Blue Nile will be faced with a firm reaction on the part of Egypt, even if that action should lead to war*" (Kindie, 2005).

As early as 5th century the Greek philosopher Homer observed that Egypt is the gift of Nile. Most political analysts contend that Egypt's predominant foreign policies geared towards safeguarding the uninterrupted flow of the Nile water. Annually Egypt enjoys 58 Cubic km of water which almost entirely comes from Nile watershed to which Egypt claims a non-negotiable right. It uses about 82% of this water for agriculture. As a result Egypt cultivates about 3.5 million hectares of land under irrigation and incomparably higher than irrigated cropping in other African countries.

Sudan, the other lower riparian country, also considerably depends on the Nile water. About half of the 65 cubic km of the annual renewable water in the country comes from external resources. Although Sudan uses much water from Nile, it also channels most portion of the Nile water to Egypt.

Sudan and Egypt share historical, social and religious commonalities that enabled them to develop alliance to defend their interest on Nile water against other claimants. The two countries, for example, have been colonized by Great Britain; they have been governed by apparently friendly governments. Hence, they exclusively formulated in times with the direct or indirect involvement of Great Britain and benefited from the treaties of the Nile River in the last one century. Hence, as Kindie (1999) argued that the policy of the two countries has been to see a weak or friendly subservient government in Ethiopia and other lower riparian countries so that it will continue its hegemony over the Nile River.

**Nile water treaties**

There have been three major international treaties on the use of Nile River. The first treaty was signed in 1902 between Egypt and Sudan under the colonial rule of Great Britain. In 1920 the Nile Projects Commission with representatives from UK, India and the United States estimated the average annual flow of Nile at 84 BCM (billion cubic meters per year) (Kindie, 1999). The commission estimated an annual water demand of 58 BCM for Egypt and 4 BCM for Sudan and the annual fluctuation to be divided equally between the two countries. The recommendations of the commission, though not implemented at the time, led to the May 7, 1929's Nile Waters Agreement between Egypt and Sudan. The agreement gave Egypt an uninterrupted access throughout a year to Nile water, on-site inspection outside of Egypt (i.e., in Sudan) and the right to challenge any work on the river or elsewhere that threaten Egyptian water interest. The treaty did not consult any of the other riparian countries including the major source of Nile, Ethiopia. The 1929 agreement resulted in the construction of one dam and a reservoir and opened the door for further agreements.

After a long negotiations and delayed agreements the Agreement for the Full Utilization of the Nile Waters (Nile Water Treaty) was signed on November 1959. And the Aswan Dam was constructed with a yearly storage capacity of 156 BCM. The 1959 treaty assumed an average annual flow of 84 BCM at Aswan and considered 10 BCM losses through evaporation at the reservoir. In the treaty Egypt and Sudan get annual water of 55.5 and 18.5 BCM respectively. The treaty considers acquired right of 48 BCM and 4 BCM for Egypt and Sudan respectively. The remaining 22 BCM divided at a ratio of 7 ½ and 14 ½ for Egypt and Sudan respectively and the final share being 55.5 BCM for Egypt and 18.5 BCM for Sudan.

The treaty assumed uninterrupted flow of the Nile River estimated in 1920s. However, the annual flow of Nile has been dropping while the demand for Agriculture and household water use is rising. The mean annual flow decreased from the 1920 estimated level of 84 BCM to 72 BCM in 1970s and further to 52 BCM in late 1980s (Howell and Allen, 1994). Although Ethiopia is not legally bound by any of the treaties because it was not under British colony or was not active party to the treaties, it could not neither practically utilize the water. Since Blue Nile represents significant portion of Ethiopia's water resources, fair access to it will be essential in the long run. Irrigation in Ethiopia accounts for only about 2 % of Ethiopian crop production, whereas the figures were 14% for Sudan and near 100% for Egypt (Rahmato, 1999). Ethiopian has used less than one percent of the Blue Nile (Abbai in Amharic) for irrigation while it has 58% of the estimated potential irrigable water in the basin (Rahmato, 1999). The treaties of Nile water in the past and specially the one in 1959 hinder irrigation development in the Blue Nile basin through international political and economic machinations. For example, World Bank requires riparian countries, practically Egypt and Sudan, to give approval or agreement to any projects proposed on development of sizable dams on Nile which mostly these countries don't allow to happen. Although, the World Bank's optimistically put "the Nile has the potential to catalyze sustainable economic growth for all 10 countries with benefits far beyond those that can be derived from the river itself" (World Bank 2007), its policy actions does not match its claim.

In conclusion, increasing water use in Ethiopia is beyond capacity building for irrigation agriculture than bypassing geopolitical hurdles. Therefore, water use could be better dealt with a model which thoroughly considers these geopolitical factors which was beyond the scope of the present study.

## *Appendix 2 A: Cereal yield and production change between 1961 and 2030*

| | | **Cereal yield** | | | | | **Cereal production** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **(t/ha)** | | | **Annual change (%)** | | **1000 (t)** | | | **Annual change (%)** | |
| Regional code | Countries | 1961 | 2005 | 2030 | 2005-1961 | 2030-2005 | 1961 | 2005 | 2030 | 2005-1961 | 2030-2005 |
| 5 | Botswana | 0.3 | 0.5 | 0.5 | 1 | -0.2 | 62 | 45 | 42 | -0.7 | -0.2 |
| 5 | Zambia | 0.8 | 1.2 | 1.8 | 0.8 | 0.9 | 767 | 1,028 | 1,559 | 0.7 | 0.9 |
| 1 | Libya | 0.2 | 0.6 | 0.9 | 2.4 | 0.8 | 105 | 213 | 304 | 1.6 | 0.8 |
| 5 | Namibia | 0.4 | 0.4 | 0.6 | 0.2 | 0.6 | 36 | 109 | 142 | 2.5 | 0.6 |
| 4 | CAR | 0.4 | 1 | 1.4 | 1.9 | 0.7 | 68 | 192 | 265 | 2.3 | 0.7 |
| 5 | South Africa | 1.1 | 3.3 | 3.4 | 2.5 | 0 | 6,696 | 14,707 | 15,009 | 1.8 | 0 |
| 4 | Gabon | 1.6 | 1.6 | 2.3 | 0.1 | 0.7 | 9 | 32 | 44 | 2.8 | 0.7 |
| 4 | Congo Rep | 0.7 | 0.8 | 1.6 | 0.3 | 1.5 | 5 | 9 | 19 | 1.2 | 1.7 |
| 1 | Algeria | 0.3 | 1.5 | 2 | 3.3 | 0.7 | 938 | 3,996 | 5,438 | 3.3 | 0.7 |
| 3 | Mauritania | 0.4 | 1.4 | 2.6 | 3.1 | 1.3 | 91 | 76 | 137 | -0.4 | 1.3 |
| 4 | Cameroon | 0.9 | 1.6 | 2 | 1.4 | 0.5 | 704 | 1,660 | 2,322 | 1.9 | 0.7 |
| 5 | Comoros | 1.1 | 1.3 | 2.3 | 0.4 | 1.2 | 11 | 21 | 36 | 1.4 | 1.2 |
| 3 | Togo | 0.5 | 1.1 | 1.8 | 1.9 | 1.2 | 171 | 787 | 1,343 | 3.5 | 1.2 |
| 2 | Somalia | 0.5 | 0.6 | 1.1 | 0.4 | 1.4 | 255 | 345 | 642 | 0.7 | 1.4 |
| 5 | Lesotho | 0.8 | 0.9 | 0.9 | 0.3 | -0.2 | 227 | 248 | 229 | 0.2 | -0.2 |
| 5 | Angola | 0.8 | 0.6 | 1.1 | -0.7 | 1.4 | 544 | 871 | 1,641 | 1.1 | 1.4 |
| 5 | Mauritius | 1.5 | 3.5 | 4 | 1.9 | 0.3 | 0.18 | 0.19 | 0.22 | 0.1 | 0.3 |
| 3 | Guinea B | 0.8 | 1.4 | 2.9 | 1.2 | 1.7 | 79 | 213 | 444 | 2.2 | 1.7 |
| 5 | Madagascar | 1.8 | 2.4 | 4.1 | 0.6 | 1.2 | 1,585 | 3,391 | 5,889 | 1.7 | 1.2 |
| 4 | Congo DR | 0.7 | 0.8 | 1.5 | 0.2 | 1.5 | 483 | 1,573 | 3,211 | 2.7 | 1.6 |
| 3 | Liberia | 0.6 | 0.9 | 1.8 | 1 | 1.6 | 115 | 110 | 223 | -0.1 | 1.6 |
| 1 | Tunisia | 0.5 | 1.5 | 1.8 | 2.4 | 0.5 | 562 | 1,833 | 2,246 | 2.7 | 0.5 |
| 1 | Morocco | 0.4 | 0.8 | 1.1 | 1.5 | 0.6 | 1,538 | 4,448 | 5,938 | 2.4 | 0.6 |
| 3 | Niger | 0.5 | 0.4 | 0.9 | -0.5 | 1.8 | 1,065 | 2,654 | 5,826 | 2.1 | 1.8 |
| 2 | Sudan | 0.9 | 0.5 | 0.7 | -1.4 | 0.9 | 1,683 | 5,368 | 8,075 | 2.6 | 0.9 |
| 2 | Ethiopia | 0.7 | 1.2 | 2.1 | 1.2 | 1.1 | 4,203 | 9,340 | 15,557 | 1.8 | 1.1 |
| 4 | Burundi | 0.9 | 1.3 | 2.7 | 0.8 | 1.6 | 130 | 281 | 592 | 1.7 | 1.7 |
| 3 | Benin | 0.5 | 1.1 | 2.1 | 1.7 | 1.4 | 290 | 1,109 | 2,080 | 3 | 1.4 |
| 2 | Kenya | 1.2 | 1.4 | 2.4 | 0.2 | 1.3 | 1,376 | 2,869 | 5,075 | 1.6 | 1.3 |
| 3 | Côte d'Iv | 0.6 | 1.3 | 1.9 | 1.6 | 0.9 | 294 | 2,205 | 3,265 | 4.6 | 0.9 |
| 3 | Senegal | 0.5 | 1.2 | 1.9 | 1.7 | 1.1 | 528 | 1,406 | 2,252 | 2.2 | 1.1 |

| | | Cereal yield | | | | | Cereal production | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (t/ha) | | | Annual change (%) | | 1000 (t) | | | Annual change (%) | |
| 3 | Ghana | 0.8 | 1.5 | 2.2 | 1.3 | 0.9 | 436 | 1,943 | 2,906 | 3.4 | 0.9 |
| 5 | Zimbabwe | 0.9 | 0.7 | 0.8 | -0.6 | 0.3 | 1,266 | 1,187 | 1,342 | -0.1 | 0.3 |
| 3 | Sierra Leone | 0.9 | 1.2 | 2.1 | 0.6 | 1.2 | 298 | 309 | 540 | 0.1 | 1.2 |
| 4 | STP | 1.5 | 2.5 | 3.7 | 1.1 | 0.9 | 0.4 | 3 | 4 | 4.3 | 1 |
| 5 | Swaziland | 0.5 | 1.3 | 1.2 | 2.3 | -0.1 | 50 | 76 | 71 | 0.9 | -0.1 |
| 2 | Uganda | 0.9 | 1.7 | 4.2 | 1.4 | 2.1 | 895 | 2,625 | 6,566 | 2.4 | 2.1 |
| 3 | Gambia | 1 | 1.1 | 1.8 | 0.2 | 1.1 | 80 | 213 | 342 | 2.2 | 1.1 |
| 4 | Chad | 0.6 | 0.7 | 1.4 | 0.3 | 1.6 | 756 | 1,213 | 2,457 | 1.1 | 1.6 |
| 2 | Eritrea | - | 0.4 | 0.7 | - | 1.3 | 0 | 152 | 280 | - | 1.4 |
| 5 | Mozambique | 0.9 | 1 | 1.4 | 0.2 | 0.9 | 642 | 2,015 | 3,014 | 2.6 | 0.9 |
| 3 | Mali | 0.7 | 1.1 | 2.2 | 0.9 | 1.6 | 1,107 | 3,131 | 6,349 | 2.3 | 1.6 |
| 4 | Rwanda | 0.9 | 1.2 | 1.9 | 0.7 | 1 | 133 | 413 | 657 | 2.5 | 1 |
| 5 | Malawi | 1 | 1.1 | 1.8 | 0.2 | 1.2 | 865 | 1,860 | 3,131 | 1.7 | 1.2 |
| 3 | Burkina F. | 0.4 | 0.9 | 1.8 | 1.9 | 1.5 | 726 | 2,902 | 5,748 | 3.1 | 1.5 |
| 3 | Guinea | 1 | 1.5 | 2.6 | 0.9 | 1.3 | 469 | 1,142 | 2,003 | 2 | 1.3 |
| 2 | Tanzania | 0.8 | 1.4 | 2.1 | 1.3 | 0.9 | 1,015 | 5,090 | 7,460 | 3.6 | 0.9 |
| 1 | Egypt | 2.9 | 7.5 | 10.9 | 2.1 | 0.8 | 5,009 | 22,284 | 32,224 | 3.4 | 0.8 |
| 3 | Nigeria | 0.7 | 1.1 | 1.6 | 0.8 | 1 | 7,891 | 22,783 | 35,417 | 2.4 | 1 |
| 3 | Cape Verde | 0.7 | 0.2 | 0.2 | -3.1 | 1 | 13 | 4 | 6 | -2.6 | 1 |

## *Appendix 2 B: Population per arable land in African countries*

| Regional code | Countries | 1961 | 2005 | 2030 | 2005-1961 | 2030-2005 |
|---|---|---|---|---|---|---|
| | | Population / arable land | | | Annual change (%) | |
| 5 | Botswana | 1.5 | 4.7 | 4.3 | 2.6 | -0.2 |
| 5 | Zambia | 0.7 | 2.1 | 3.3 | 2.6 | 1 |
| 1 | Libya | 0.7 | 2.6 | 3.9 | 2.9 | 0.9 |
| 5 | Namibia | 1 | 2.4 | 3.2 | 2.1 | 0.6 |
| 4 | CAR | 0.9 | 1.9 | 2.8 | 1.7 | 0.8 |
| 5 | South Africa | 1.4 | 3 | 3.1 | 1.7 | 0.1 |
| 4 | Gabon | 3.4 | 2.7 | 3.9 | -0.5 | 0.8 |
| 4 | Congo Rep | 1.9 | 6.9 | 15.6 | 2.9 | 1.8 |
| 1 | Algeria | 1.6 | 3.9 | 5.4 | 2 | 0.8 |
| 3 | Mauritania | 3.8 | 5.8 | 11 | 1 | 1.4 |
| 4 | Cameroon | 1 | 2.2 | 3.2 | 1.8 | 0.8 |
| 5 | Comoros | 2.7 | 5.7 | 10.3 | 1.7 | 1.3 |
| 3 | Togo | 0.9 | 2.2 | 4 | 2.1 | 1.3 |
| 2 | Somalia | 3.2 | 7.2 | 14.3 | 1.8 | 1.5 |
| 5 | Lesotho | 2.4 | 5.4 | 5 | 1.8 | -0.2 |
| 5 | Angola | 1.6 | 4.2 | 8.4 | 2.1 | 1.5 |
| 5 | Mauritius | 7.4 | 11.5 | 13.6 | 1 | 0.4 |
| 3 | Guinea B | 2 | 2.7 | 6 | 0.7 | 1.8 |
| 5 | Madagascar | 2.6 | 5 | 9.1 | 1.5 | 1.4 |
| 4 | Congo DR | 2.3 | 7 | 15.1 | 2.5 | 1.7 |
| 3 | Liberia | 1.9 | 5.4 | 11.1 | 2.4 | 1.6 |
| 1 | Tunisia | 1 | 2 | 2.5 | 1.5 | 0.5 |
| 1 | Morocco | 1.7 | 3.3 | 4.5 | 1.4 | 0.7 |
| 3 | Niger | 0.3 | 0.9 | 2.1 | 2.4 | 1.9 |
| 2 | Sudan | 1.1 | 2 | 3.1 | 1.4 | 1 |
| 2 | Ethiopia | 2.2 | 6.3 | 11 | 2.4 | 1.2 |
| 4 | Burundi | 3.3 | 5.2 | 11.8 | 1 | 1.8 |
| 3 | Benin | 2.4 | 2.7 | 5.4 | 0.3 | 1.5 |
| 2 | Kenya | 2.1 | 6.3 | 11.6 | 2.4 | 1.4 |
| 3 | Côte d'Ivoir | 1.4 | 2.6 | 3.9 | 1.4 | 0.9 |
| 3 | Senegal | 1.5 | 4.4 | 7.5 | 2.4 | 1.2 |

| Regional code | Countries | Population / arable land<br>1961 | 2005 | 2030 | Annual change (%)<br>2005-1961 | 2030-2005 |
|---|---|---|---|---|---|---|
| 3 | Ghana | 2.2 | 3.3 | 5.2 | 0.9 | 1 |
| 5 | Zimbabwe | 1.9 | 3.8 | 4.4 | 1.5 | 0.3 |
| 3 | Sierra Leone | 5.8 | 7.9 | 15 | 0.7 | 1.4 |
| 4 | STP | 1.9 | 2.7 | 4.4 | 0.8 | 1.1 |
| 5 | Swaziland | 2.9 | 5.4 | 5.1 | 1.4 | -0.1 |
| 2 | Uganda | 1.7 | 3.7 | 9.8 | 1.7 | 2.2 |
| 3 | Gambia | 3 | 4.5 | 7.6 | 0.9 | 1.2 |
| 4 | Chad | 1.1 | 2.5 | 5.4 | 1.9 | 1.7 |
| 2 | Eritrea | - | 7.2 | 14.4 | - | 1.6 |
| 5 | Mozambique | 2.9 | 4.2 | 6.5 | 0.8 | 1 |
| 3 | Mali | 2.6 | 2.7 | 5.8 | 0.1 | 1.7 |
| 4 | Rwanda | 4.8 | 6 | 9.8 | 0.5 | 1.1 |
| 5 | Malawi | 3 | 4.8 | 8.4 | 1 | 1.3 |
| 3 | Burkina F. | 2.1 | 2.5 | 5.3 | 0.4 | 1.7 |
| 3 | Guinea | 3.1 | 5.1 | 9.4 | 1.1 | 1.4 |
| 2 | Tanzania | 3.8 | 7.2 | 11 | 1.4 | 0.9 |
| 1 | Egypt | 11.1 | 20.8 | 31.3 | 1.4 | 0.9 |
| 3 | Nigeria | 1.5 | 3.8 | 6.1 | 2.1 | 1.1 |
| 3 | Cape Verde | 5.1 | 9.9 | 16.5 | 1.5 | 1.1 |

## *Appendix 2 C: Population of African countries between 1961 and 2030*

| | | Population(1000) | | | Annual change (%) | |
|---|---|---|---|---|---|---|
| Regional code | Countries | 1961 | 2005 | 2030 | 2005-1961 | 2030-2005 |
| 5 | Botswana | 586 | 1,760 | 1,642 | 2.5 | -0.2 |
| 5 | Zambia | 3,235 | 11,861 | 17,706 | 2.9 | 0.9 |
| 1 | Libya | 1,400 | 5,968 | 8,345 | 3.3 | 0.7 |
| 5 | Namibia | 614 | 2,052 | 2,641 | 2.7 | 0.6 |
| 4 | CAR | 1,558 | 4,093 | 5,572 | 2.2 | 0.7 |
| 5 | South Africa | 17,864 | 47,594 | 48,405 | 2.2 | 0 |
| 4 | Gabon | 488 | 1,406 | 1,907 | 2.4 | 0.7 |
| 4 | Congo Rep | 1,029 | 4,117 | 8,551 | 3.1 | 1.6 |
| 1 | Algeria | 11,007 | 33,354 | 44,706 | 2.5 | 0.7 |
| 3 | Mauritania | 1,024 | 3,158 | 5,482 | 2.5 | 1.2 |
| 4 | Cameroon | 5,408 | 16,601 | 22,821 | 2.5 | 0.7 |
| 5 | Comoros | 219 | 819 | 1,357 | 3 | 1.1 |
| 3 | Togo | 1,594 | 6,306 | 10,486 | 3.1 | 1.1 |
| 2 | Somalia | 2,886 | 8,496 | 15,304 | 2.4 | 1.3 |
| 5 | Lesotho | 866 | 1,791 | 1,663 | 1.6 | -0.2 |
| 5 | Angola | 5,109 | 16,400 | 30,050 | 2.6 | 1.4 |
| 5 | Mauritius | 679 | 1,256 | 1,443 | 1.4 | 0.3 |
| 3 | Guinea B | 556 | 1,634 | 3,317 | 2.4 | 1.6 |
| 5 | Madagascar | 5,504 | 19,105 | 32,317 | 2.8 | 1.2 |
| 4 | Congo DR | 15,857 | 59,320 | 117,494 | 3 | 1.5 |
| 3 | Liberia | 1,080 | 3,356 | 6,655 | 2.6 | 1.5 |
| 1 | Tunisia | 4,297 | 10,210 | 12,379 | 1.9 | 0.4 |
| 1 | Morocco | 11,948 | 31,943 | 42,016 | 2.2 | 0.6 |
| 3 | Niger | 3,542 | 14,426 | 30,637 | 3.2 | 1.7 |
| 2 | Sudan | 11,787 | 36,992 | 54,511 | 2.6 | 0.9 |
| 2 | Ethiopia | 23,517 | 79,289 | 128,979 | 2.7 | 1.1 |
| 4 | Burundi | 2,993 | 7,834 | 15,930 | 2.2 | 1.6 |
| 3 | Benin | 2,356 | 8,703 | 15,820 | 2.9 | 1.3 |
| 2 | Kenya | 8,373 | 35,106 | 60,606 | 3.2 | 1.2 |
| 3 | Côte d'Iv | 3,689 | 18,454 | 26,883 | 3.6 | 0.8 |
| 3 | Senegal | 3,596 | 11,936 | 18,678 | 2.7 | 1 |

| | | Population(1000) | | | Annual change (%) | |
|---|---|---|---|---|---|---|
| Regional code | Countries | 1961 | 2005 | 2030 | 2005-1961 | 2030-2005 |
| 3 | Ghana | 7,349 | 22,556 | 33,075 | 2.5 | 0.9 |
| 5 | Zimbabwe | 3,864 | 13,085 | 14,700 | 2.7 | 0.3 |
| 3 | Sierra Leone | 2,294 | 5,679 | 9,650 | 2 | 1.2 |
| 4 | STP | 65 | 160 | 241 | 2 | 0.9 |
| 5 | Swaziland | 362 | 1,029 | 973 | 2.3 | -0.1 |
| 2 | Uganda | 6,833 | 29,857 | 72,078 | 3.3 | 2 |
| 3 | Gambia | 365 | 1,556 | 2,439 | 3.3 | 1 |
| 4 | Chad | 3,136 | 10,032 | 19,751 | 2.6 | 1.5 |
| 2 | Eritrea | 1,455 | 4,560 | 8,138 | 2.6 | 1.3 |
| 5 | Mozambique | 7,758 | 20,158 | 29,604 | 2.1 | 0.9 |
| 3 | Mali | 4,412 | 13,918 | 27,413 | 2.6 | 1.5 |
| 4 | Rwanda | 2,951 | 9,230 | 14,368 | 2.6 | 1 |
| 5 | Malawi | 3,611 | 13,166 | 21,687 | 2.9 | 1.1 |
| 3 | Burkina F. | 4,524 | 13,634 | 26,199 | 2.5 | 1.5 |
| 3 | Guinea | 3,309 | 9,603 | 16,492 | 2.4 | 1.2 |
| 2 | Tanzania | 10,310 | 39,025 | 56,178 | 3 | 0.8 |
| 1 | Egypt | 28,549 | 75,437 | 107,056 | 2.2 | 0.8 |
| 3 | Nigeria | 41,819 | 134,375 | 204,465 | 2.6 | 0.9 |
| 3 | Cape Verde | 202 | 519 | 808 | 2.1 | 1 |

### *Appendix 2 D: Cropping intensity in African countries*

| | | Cropping Intensity | | | Annual change (%) | |
|---|---|---|---|---|---|---|
| Regional code | Countries | **1961** | **2003** | **2030** | **2003-1961** | **2030-2005** |
| 5 | Botswana | 0.6 | 0.2 | 0.4 | -56.07 | 50.91 |
| 5 | Zambia | 0.2 | 0.3 | 0.3 | 14.56 | 37.60 |
| 1 | Libya | 0.3 | 0.3 | 0.4 | 13.20 | 37.15 |
| 5 | Namibia | 0.2 | 0.4 | 0.5 | 116.50 | 24.30 |
| 4 | CAR | 0.5 | 0.4 | 0.4 | -20.65 | 10.76 |
| 5 | South Africa | 0.6 | 0.4 | 0.4 | -27.59 | -2.37 |
| 4 | Gabon | 0.6 | 0.4 | 0.4 | -33.40 | 3.50 |
| 4 | Congo Rep | 0.4 | 0.4 | 0.5 | 23.20 | 5.01 |
| 1 | Algeria | 0.5 | 0.5 | 0.6 | 6.34 | 19.34 |
| 3 | Mauritania | 1.1 | 0.6 | 0.4 | -47.73 | -24.02 |
| 4 | Cameroon | 0.4 | 0.6 | 0.6 | 43.65 | 10.09 |
| 5 | Comoros | 0.5 | 0.7 | 0.7 | 42.17 | 12.72 |
| 3 | Togo | 0.4 | 0.7 | 0.9 | 77.48 | 28.13 |
| 2 | Somalia | 0.7 | 0.7 | 1.2 | 4.37 | 77.58 |
| 5 | Lesotho | 0.8 | 0.7 | 0.8 | -13.52 | 14.47 |
| 5 | Angola | 0.6 | 0.7 | 1.2 | 27.70 | 72.15 |
| 5 | Mauritius | 1.0 | 0.8 | 0.7 | -23.68 | -1.32 |
| 3 | Guinea B | 0.9 | 0.8 | 1.1 | -15.65 | 48.11 |
| 5 | Madagascar | 0.7 | 0.8 | 1.1 | 2.19 | 39.06 |
| 4 | Congo DR | 0.5 | 0.8 | 1.0 | 42.66 | 35.73 |
| 3 | Liberia | 0.7 | 0.8 | 1.0 | 13.57 | 27.97 |
| 1 | Tunisia | 0.5 | 0.8 | 0.8 | 66.57 | 2.68 |
| 1 | Morocco | 0.7 | 0.8 | 1.0 | 20.32 | 23.64 |
| 3 | Niger | 0.3 | 0.8 | 1.3 | 218.47 | 58.03 |
| 2 | Sudan | 0.3 | 0.8 | 1.2 | 155.48 | 47.11 |
| 2 | Ethiopia | 0.7 | 0.9 | 1.4 | 21.15 | 59.29 |
| 4 | Burundi | 0.9 | 0.9 | 1.0 | -1.43 | 16.53 |
| 3 | Benin | 1.0 | 0.9 | 1.2 | -11.79 | 35.40 |
| 2 | Kenya | 0.6 | 0.9 | 1.2 | 56.06 | 33.61 |
| 3 | Côte d'Ivoir | 0.8 | 0.9 | 1.0 | 15.64 | 15.76 |
| 3 | Senegal | 0.9 | 0.9 | 1.2 | 1.46 | 38.30 |
| 3 | Ghana | 0.9 | 0.9 | 1.0 | -1.52 | 7.87 |
| 5 | Zimbabwe | 0.8 | 0.9 | 1.0 | 11.70 | 3.23 |

| | | Cropping Intensity | | | Annual change (%) | |
|---|---|---|---|---|---|---|
| Regional code | Countries | **1961** | **2003** | **2030** | **2003-1961** | **2030-2005** |
| 3 | Sierra Leone | 1.2 | 0.9 | 1.2 | -24.79 | 30.48 |
| 4 | STP | 1.6 | 0.9 | 1.0 | -41.32 | 1.53 |
| 5 | Swaziland | 1.2 | 1.0 | 0.9 | -18.38 | -8.17 |
| 2 | Uganda | 1.2 | 1.0 | 1.3 | -19.51 | 34.11 |
| 3 | Gambia | 1.5 | 1.0 | 1.4 | -36.29 | 47.44 |
| 4 | Chad | 0.8 | 1.0 | 1.4 | 23.78 | 48.68 |
| 2 | Eritrea | 0.7 | 1.0 | 1.7 | 39.17 | 71.45 |
| 5 | Mozambique | 1.2 | 1.0 | 1.2 | -15.23 | 23.82 |
| 3 | Mali | 1.2 | 1.0 | 1.6 | -14.24 | 60.53 |
| 4 | Rwanda | 0.9 | 1.1 | 1.3 | 22.19 | 13.84 |
| 5 | Malawi | 1.2 | 1.2 | 1.7 | -5.95 | 44.73 |
| 3 | Burkina F. | 1.0 | 1.2 | 1.7 | 17.80 | 37.43 |
| 3 | Guinea | 1.2 | 1.3 | 1.6 | 5.59 | 27.35 |
| 2 | Tanzania | 1.4 | 1.4 | 1.9 | 2.71 | 34.95 |
| 1 | Egypt | 1.6 | 1.4 | 1.9 | -9.81 | 35.20 |
| 3 | Nigeria | 0.7 | 1.4 | 1.8 | 97.55 | 27.30 |
| 3 | Cape Verde | 2.6 | 1.9 | 2.1 | -26.22 | 9.62 |

## *Appendix 3: Panel data for determinants of regional meat consumption analysis*

| Regions | CD | Year | Per person meat consumption (kg/cap) | Price of meat (Eth Birr/kg) | Expenditure (per person | Urban population (%) | Cereal production (t) |
|---|---|---|---|---|---|---|---|
| Addis | 1 | 1996 | 8 | 13 | 2208 | 0.99 | 632 |
| Addis | 1 | 2004 | 11 | 15 | 2573 | 1 | 435 |
| Afar | 2 | 1996 | 1 | 10 | 1520 | 0.08 | 17 |
| Afar | 2 | 2004 | 5 | 16 | 1923 | 0.09 | 10 |
| Amhara | 3 | 1996 | 1 | 8 | 974 | 0.1 | 3,762 |
| Amhara | 3 | 2004 | 4 | 14 | 1548 | 0.11 | 2,478 |
| Benshangul | 4 | 1996 | 3 | 7 | 1075 | 0.08 | 6,232 |
| Benshangul | 4 | 2004 | 4 | 11 | 1822 | 0.09 | 3,650 |
| Dire | 5 | 1996 | 6 | 17 | 1557 | 0.7 | 45 |
| Dire | 5 | 2004 | 5 | 21 | 2283 | 0.74 | 70 |
| Harari | 6 | 1996 | 9 | 17 | 2192 | 0.59 | 170 |
| Harari | 6 | 2004 | 6 | 19 | 2524 | 0.62 | 113 |
| Oromia | 7 | 1996 | 2 | 11 | 1283 | 0.11 | 1,027 |
| Oromia | 7 | 2004 | 2 | 14 | 1736 | 0.13 | 725 |
| Snnp | 8 | 1996 | 3 | 11 | 1021 | 0.07 | 5 |
| Snnp | 8 | 2004 | 3 | 14 | 1590 | 0.08 | 3 |
| Somalia | 9 | 1996 | 2 | 14 | 1975 | 0.15 | 13 |
| Somalia | 9 | 2004 | 3 | 19 | 1651 | 0.16 | 15 |
| Tigray | 10 | 1996 | 2 | 11 | 1210 | 0.16 | 5 |
| Tigray | 10 | 2004 | 6 | 15 | 1771 | 0.18 | 7 |

*CD= code used for stata software*