A CRITICAL ANALYSIS OF CROP PRODUCTION, YIELD RESPONSE TO FERTLIZER AND RAINFALL, YIELD VARIABILITY FACTORS AND THEIR INFLUENCE ON FOOD SECURITY EFFORTS OF ETHIOPIA

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MAJOR FIELD: AGRICULTURAL ECONOMICS

ABSTRACT

For the past three decades, African agricultural crop production has been increasing. However, much of exhibited growth has come from additional harvested land rather than the increased yield per hectare. This paper studies crop production of the world, African in general, East Africa, and then gives particular focus on Ethiopia. In addition to crop production comparison, the economics of fertilizer, the yield trends and best operating condition under yield and price risk are examined. Moreover, it aims to determine the crop yield response to fertilizer and optimum level of fertilizer under risk. The data were obtained from the Ethiopian statistical agency yearly survey. The fourteen-year daily rainfall data were obtained from Global weather for SWAT database. Time series cross section regression were used to determine the crop yield response to fertilizer. Based on Dillon's analysis the best operating conditions under risk were determined. The variance of product price risk was used to determine the marginal cost of risk. The value cost ratio (VCR) method, which has been used in several studies to recommend profitable quantity of fertilizer was rejected in this study. The limitations of VCR are discussed based on economic theories. Results indicated there were significant differences between crop yield responses to fertilizer. Oromia and SNNPR regions give greater yield response to fertilizer for teff and wheat than other regions respectively. However, the crop price risk of wheat and teff was estimated to cause 316,000 quintals less use of fertilizer to be used in the four major crop growing regions than would have been used in the absence of price risk. Consequently, the four regions lost about 178,488 quintals of teff and 401,624 quintals of wheat that would have been gained from 1,502,249 and 1,122,969 hectares of fertilized portion of land in the year 2012. If product prices had been stable and 15% more land was fertilized, about 5.9%, 5.6 %, 4.4 % and 4.8 % more production from teff and 5.1%, 5.3%, 3.2% and 2.6% more wheat production would have been gained in Tigray, Amhara, Oromia and SNNPR regions respectively. This indicates that in the prevailing condition, maintaining only crop price stability would help more land to be fertilized and to increase the supply of food for the country while endeavoring to attain sustainable food security.

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ACRONYMS

AU	African Union
CASDEP	Comprehensive African Agriculture Development Program
ESA	Ethiopian statistics agency
ESE	Ethiopian seed enterprise
FAO	Food and agriculture organization
IFPRI	International food policy research institute
MC	Marginal cost
Meher	Season is the main crop harvesting season from the months of September to February
MP	Marginal production
MPP	Marginal physical production
MR	Marginal revenue
NEPAD	New partnership for African development
SSA	Sub Saharan African
VCR	Value cost ratio
VMP	Value of marginal production

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CHAPTER I

INTRODUCTION

1.1. Background

For the past three decades, African agricultural crop production has been increasing. However, much of exhibited growth is derived from additional harvested land rather than from the increased yield per hectare of land. (Asenso-Okyere and Jemaneh, 2012). Moreover, African crop yields lag behind the rest of the world in terms of level of productivity. Almost all African countries suffer from a lack of farm inputs used such as: fertilizers, pesticides, improved seed, other modern technologies, knowledge about improved farm practices, and other capital related resource problems(FAO, et al., 2000).

Though, the magnitude and the context of the problems are different, each country passed through diverse input market regimes, including liberalization of fertilizer market, and the removal of subsidies. Furthermore, a united endeavor to achieve improved crop productivity to attain sustainable development and reduce poverty[1], NEPAD (new partnership for African development) was established in 2001. Subsequently, in 2013

[1] The UN definition: Fundamentally, poverty is a denial of choices and opportunities, a violation of human dignity. It means lack of basic capacity to participate effectively in society. It means not having enough to feed and cloth a family, not having a school or clinic to go to, not having the land on which to grow one's food or a job to earn one's living, not having access to credit. It means insecurity, powerlessness and exclusion of individuals, households and communities. It means susceptibility to violence, and it often implies living on marginal or fragile environments, without access to clean water or sanitation

NEPAD launched a Comprehensive African Agriculture Development Program (CAADP) to raise agricultural productivity. This effort is a target to increase agricultural productivity by at least six percent per year. Though, the countries have agreed to allocate 10% of their national budgets within five years by 2008, only ten countries, including Ethiopia, have made progress towards the goal of allocating of ten percent of the national budget. Only nine countries achieved more than a 6% increase in agricultural growth, and four countries scored between 5 and 6 percent (NEPAD, 2010-2012).

This study begins by a review of crop production and yield levels for the world, East Africa, and Ethiopia. Particular focus is given to the economics of fertilizer in different regions of Ethiopia. To help the country's vast efforts to attain food security, this study examines the yield response among regions and the factors of variability that are limiting the farmers' use of fertilizer. The major price risk and yield risk impacts are also assessed. Finally, some policy implications are derived from potential increases from reducing the variance of crop prices and from the expansion of the fertilized area

1.2. Problem statement

Can increased productivity in Africa and particularly in Ethiopia, solve the prolonged food insecurity problem? For the past three decades, African agricultural crop production has been increasing. However, much of exhibited growth is derived from additional harvested land rather than the increased yield per hectare of land. (Asenso-Okyere and Jemaneh, 2012) Moreover, African crop yield lags behind the rest of the world in terms of level of productivity. Almost all African countries suffer from lack of farm inputs such as: fertilizers, pesticides, improved seed, modern technologies, knowledge about improved farm practices, and other capital related resource problems. The study by Asenso-Okyere and Jemaneh (2012) on increasing African agricultural productivity and enhancing food security listed several challenges and opportunities.

> *The large gap between potential and current crop yields in Africa means that increased food production is attainable. Africa's low agricultural productivity has many causes, including scarce and scant knowledge of improved practices, low use of improved seed, low fertilizer use, inadequate irrigation, conflict, absence of strong institutions, ineffective policies, lack of incentives, and prevalence of diseases. (Asenso-Okyere and Jemaneh, 2012)*

Like all other African countries, Ethiopia has not yet achieved food security. However, the Ethiopian Government has implemented several agricultural policies and strategies to tackle the food security problems of the country by improving productivity of major crops. So far, the country's strategies have not yet achieved the level of productivity that can provide enough food for the nation. As a result, Ethiopia has continued to depend on food aid.(Spielman, et al., 2011). In fact, the countries' food security problems are more complicated than crop productivity issues. However, the main problems from a productivity standpoint range from farmers' resource limitations, government policy and uncontrollable climatic risks. The (Devereux and Sussex, 2000) food security[2] study explained that the Ethiopian farmers, whose livelihood is reliant on low-input, low-output rain fed agriculture, do not produce enough amount of food to meet the consumption needs even in the good rainfall years.

> *Given the fragile natural resource base and climatic uncertainty, current policy emphases on agricultural intensification are misguided, while institutional constraints such as inflexible land tenure and ethnic federalism perpetuate this unviable livelihood system.(Devereux and Sussex, 2000)*

To increase crop yield per hectare, a developing country like Ethiopia needs to work on farm input provision, output market regulation, and the allocation of adequate capital to supply enough inputs, knowledge, technology and machinery. Most importantly, the yield and output market risk has to be addressed appropriately. Unless the marginal value exceeds the marginal cost including marginal cost of risk (MCR)[3] the farmer won't use more fertilizer. Despite several endeavors tried by different political regimes, Ethiopia is still suffering from long existing food insecurity. The improved seed supply in 2011 was 15 % of the demand or 105,796 tons compared to an estimated demand of 700,000 tones. Due to a delay in the supply of fertilizer, price increases, and late 'meher' season rainfall, only 43% of farmers received fertilizer in 2011.(Mario Zappacosta, et al., 2012). The economics of fertilizer will be further examined in this study.

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2 According to (declaration of world food summit held in (1996),Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life

3 MCR is marginal cost of risk in this context is the price of fertilizer plus the associated calculated costs that comes from variance of output price, and yield.

Due to the risk situation and shortage of resources the profit- maximizing amount of farmers' yield in developing countries are less than the potential level to maximize yield than the developed countries. Recently, the Ethiopian government launched the Growth and Transformation Program (GTP)[4]. Fertilizer imports increased from 440,000 tons in year a 2008 to 890,000 tons in year 2012 to expand crop productivity. However, fertilizer availability (imported plus net remained in stock) greatly exceeded the total fertilizer used. This abrupt increase in fertilizer did not increase the fertilize use level as intended, rather it resulted in a huge carry-over stock in the year 2012 reaching half a million tons of fertilizer worth about $ 350 million.(Rashid, et al., 2013). This indicates that the supply of fertilizer by itself couldn't make a farmer to apply enough fertilizer to maximize yield.

Ultimately, a developing country's ability to gain productivity relies on the capacity of increasing farmers' profits from using fertilizer and other inputs. In a developing country like Ethiopia, where fertilizer is imported, both variability of input and output price are problematic.

This study first compares long term crop production and crop yield trends among Ethiopia, Africa, East Africa, and the rest of the world. Further, it examines the regional level of crop yield response to fertilizer at given level of rainfall.

The purpose of this paper is to provide information in support of the country's endeavor to attain food security at the household level by estimating crop yield responses

[4] (GTP) growth and transformation plan of Ethiopia launched for 2010-2015. The plan targeted increased crop productivity by increasing the distribution of chemical fertilizer and improved seed.

at different levels of fertilizer in each of the crop growing regions. In addition, it examines the variability in crop productivity among regions in Ethiopia. It evaluates in which region crop yields response best to fertilizer. The particular focus throughout this study is to evaluate the possible increase in production that could have been attained if price risks were eliminated and from an increase adoption of fertilizer.

1.3. Research Objectives

The overall objective of this study is to determine the potential to improve productivity through the use of fertilizer in Ethiopia. The research examines the major crop production trends and makes yield comparisons with the world, Africa in general, East Africa, and Ethiopia. The underlying assumption of the research is that increasing the fertilizer use level of private holder farmers in Ethiopia will increase the crop productivity in Ethiopia.

The specific objectives of this research are:

- To examine crop production trends of Ethiopia versus other counties of the world.
- To determine regional crop yield response to fertilizer in Ethiopia.
- To determine the crop yield response variability due to rainfall level with and without fertilizer.
- To determine the quantity of fertilizer necessary for farmers to maximizing profit in different regions of Ethiopia.
- To test trends of average production and yield in different years.

1.3.1. Research questions

Some of the basic research questions to be assessed in this study include the following:

- Are world crop production trends significantly different between Africa, East Africa, and Ethiopia?
- Are average yields of unfertilized crops, significantly different from one region of Ethiopia to another?

- Are fertilizer responses of different crops with in a given region, significantly different in consecutive years? In this study the crop yields without fertilizer with in the regions can be examined.
- To what extent does yield and price risk affect the quantity of fertilizer the farmers to use?

1.4. Literature Review

Previous studies (Reardon, 1995; Reardon, 1999; Kelly, 2005; Yanggen, 1998) examined Africans' farmer's fertilizer demand and assessed factors affecting the demand to fertilizer. Additional studies made by (Demeke, 1997) and (Nigusie Tefera, 2012) studied about the profitability of fertilizer and crop productivity, how market failures and associated risks affected the farmers' decision to use fertilizer, and how the capacity of the farmers to bear risk affected fertilizer demand.

Spielman, et al. (2011)**,** examined whether the limitations with the supply of improved seed, chemical fertilizer, extension application schemes, and other input market problems were holding back increases in agricultural productivity in Ethiopia. They discussed the lessons learned from the past performance of the government indicating the weaknesses of past government efforts. Finally, their suggestion emphasized on further studies to be done and government efforts to focus on encouraging private involvement in the input markets and extension services.

The value cost ratio (VCR) approach is the ratio of value gained by the increased yield due to additional fertilizer use, divided by the cost of the additional fertilizer. The VCR[5] is an average concept, or the measure of average returns to fertilizer. It has a couple of major differences from the marginal analysis (MR=MC). First, it doesn't

[5] The Value cost ratio (VCR) is a partial budgeting technique and it only calculates the change in yield with and without fertilizer. The higher VCR indicates only investing on more fertilizer will make a farmer better off than not to use it.

evaluate marginal changes in returns as fertilizer use increases up to recommended dose[6]. Second, counts only the cost of fertilizer (i.e. it excludes associated costs of fertilizer, for example, labor cost).

The VCR approach is used by different studies to calculate profitability of fertilizer. (Spielman, et al.2011; Demeke, et al., 1998; Nigusie Tefera, et al., 2012; Kelly, 2005; David, 1986; Yanggen, et al., 1998) conducted similar studies on profitability of fertilizer to small holder farmers. Their studies were helpful to develop a lot of questions about value cost ratio method the commonly used and to scrutinize the gap on maximum profit analysis versus maximum productivity.

Studies by (Demeke, et al., 1997; Spielman, et al., 2011; Kelly, 2005; Nigusie Tefera, et al., 2012; Yanggen, et al., 1998) recommended farmers use fertilizer if the returns from increased crop yields are at least twice the cost of fertilizer (VCR>2). They also suggest VCR greater than 3 or more is preferred in the risky environment. The VCR method does provide producers some margin from lower than expected yields. But as can be shown in a simple example in conceptual framework section, it doesn't preclude farmers from applying more than the profit maximizing level of fertilizer or even from producing in stage III (economically un-recommended stage).

The VCR method is the arguable idea in this study. That is because the underlining strong assumption embedded in VCR>=2 assume the value gained from each

[6] Recommended dose of fertilizer is level of fertilizer recommended by agronomists to attain maximum yield. Note that, the maximum dose use of fertilizer is not necessarily profit maximizing level unless fertilizer is costless.

fertilizer treatment is greater than or equal to two times the cost of fertilizer. That means, all other costs (labor and capital) to generate one more value is greater than or equal to the cost of fertilizer. Furthermore, the possibility of profitable points under VCR less than two are ignored. The optimum quantity of fertilizer suggestions about profit maximization point with VCR>=2 lack precision. To maximize profit, it demands double criterion of attaining VCR> 2 and checking marginal profitability not to be negative while applying the next unit of additional fertilizer use.

In fact, it is impossible to derive marginal values from VCR method, because the model function could only have two points on the x- y plane. That means, yield where fertilizer is zero (intercept at X=0) and average yield response on certain quantity of fertilizer (x= qty of fertilizer). This means, two points can only make linear relationship. Therefore, it is difficult to determine whether the average quantity of fertilizer used lie in stage I, II or III.

Dillon and Anderson (1990), analyzed the response of crop production under risk and without risk based up on the utility function of a farmer. Considering the effect of both price and yield uncertainty, he numerically illustrated risk averse farmer's optimum utility and profit maximizing point, which is less than the risk loving and risk neutral farmers. He also numerically expressed the price and yield risk scenarios and the best operating condition under risk. It will be further explained in the subsequent section.

Alem, et al. (2010), studied whether the variable pattern of rainfall can affect optimum fertilizer use level of farmers. They examined selected central highlands of Ethiopia, whether if rainfall variability affects the farmer's decision to use fertilizer.

Hypothesizing the higher the rainfall induces the more fertilizer to be applied; they found significant results, which indicate the current-year fertilizer use decision of the farmers, was positively dependent up on the previous year's rainfall level. Meaning, fertilizer use increases when the past year's rainfall was good and decreases when the past year's rainfall was lower. That means, the good rain fall season for the farmer is a better harvest period to secure more disposable income to spend on next year's fertilizer.

Besides examining, the price and climatic related factors influencing fertilizer demand, (Gebremedhin, et al., 2009) and (Spielman, et al., 2011) examined the role of the input supply system, credit service institutes, and extension efforts on the total transformation of small holder agriculture in Ethiopia. Their study empirically showed that a farmer who had access to credit supply used more fertilizer and chemical inputs and achieved higher crop yields.

Several studies (Demeke, et al., 1997; Gebremedhin, et al., 2009; Mwangi, 1997; Spielman, et al., 2011) found the fertilizer use quantity of small holder farmers, was influenced by cost of fertilizer, expected product price, level of infrastructure, access to credit service facilities, knowledge, and the input supply system. Finally, they recommended policy changes to alleviate the fertilizer use problems such as an insufficient input supply system, untimely supply of fertilizer, limited credit availability, inadequate extension support, expensive transaction and distribution costs, imperfect markets in the public and private sectors, limited research, and other development problems.

The study conducted by (Yu, et al., 2011) reached similar findings as the above authors and noted that wealthier farmers, who have more cattle or relatively more land, used more fertilizer. They found that farmers who received agricultural extension had increased fertilizer use and attained better productivity. Therefore, they recommended a government policy that gave priority to the input supply system with an expansion of extension support.

The current study will compile Ethiopian statistical survey panel data, to examine the regional differences on crop yield response of a given level of fertilizer. Basically, this study is different from the above studies in a couple of ways. First, to maintain economic concepts of optimum level of fertilizer, under price and yield risk condition, Dillon's analysis of the best production environment under risk will be used. Second, this study will incorporate regional level rainfall variability in the calculation of crop yield response to fertilizer. Fourteen years of daily rainfall data for 'Meher' season were compiled on monthly basis. The rainfall level used in the crop growing season 'Meher' encompasses selected months: June, July, August, September, and October. These months are crop planting months and the rain fed agriculture of small holder farmers' yields and fertilizer demand is argued to depend on rainfall amounts of this season.

Giving particular focus to the regional rainfall variability in a major productive season, this study goes further to examine the long-run yield differences of crops due to rainfall inconsistency, and the corresponding year fertilizer use quantity. It also tests whether crop productivity varies among the four crop growing regions within a country in a given rainfall and fertilizer level.

1.5. Conceptual framework

To maintain food security in an ever growing population, increasing the crop yield per hectare is a necessary condition. For the developing countries, crop yields are lagging behind the rest of the world. Increasing crop yield is a possible and potential means of increasing food security in Ethiopia (Demeke, et al., 1997). Towards this end, assessment of the production environment of private holder farmers is inevitably important, because they generate 95 percent of the total production of Ethiopia.(Taffesse, et al., 2012). Furthermore, to increase crop productivity using more fertilizer, the farmers' profit maximizing quantity of fertilizer and other influential factors of yield need to be determined.

From a purely economic perspective, in the absence of market failure, the amount of fertilizer a farmer would purchase equal to the profit-maximizing quantity of fertilizer. In the case of small holder farmers in Ethiopia, the prevailing condition is far from this idea.(Nigusie Tefera, et al., 2012). Several studies (Reardon, et al., 1995; Reardon, et al., 1999; Kelly, 2005) added more analytical frameworks in the prevailing African farmers' production environment. These studies discussed about incentives and capacity of a farmer, they examined additional factors that weaken African farmers' fertilizer demand. Incentives are factors determining profitability depending on input and output prices. Capacities are the farmer's position in terms of human capital such as: health, family labor, educational skill and financial resources or assets, income, access to credit.

> "*There is an important distinction between researchers' perceptions of incentives (which shape potential demand) and farmers' perceptions of the incentives (which shape effective demand.*

> *Improvements in human capital are more likely to shift the demand curve out by moving farmers' perceptions of agro-economic potential (and effective demand) closer to the true agro-economic potential. Improvements in financial capital will not shift the demand curve out but will move a farmer along the same demand curve to a higher quantity of fertilizer used*"(Kelly, 2005)

According to (Kelly, 2005)The decisive questions in a farmers mind before purchasing fertilizers are

- *Will fertilizer use be profitable (both in absolute and relative terms than the alternative investments)?*
- *Can I acquire the desired amount of fertilizer and use it efficiently?*

Most importantly a farmer worries about what happens if the crop yield or prices are too low to repay the loan.

Attractive agricultural incentives are the driving forces, which can motivate a farmer to build a capacity towards getting more fertilizer to attain a possible increase of yield with maximum profit. Studies shown there are many factors that affect farmers demand f fertilizer. The main factors are credit constraints related to risk factors from weather variability, timely availability of fertilizer, and input and output prices.(Nigusie Tefera, et al., 2012).

Hypothesis 1 low use of fertilizer in east African and by Ethiopia farmers causes crop production and yield to lag behind the rest of the world.

Hypothesis 2 Small holder farmer's crop productivity in Ethiopia is significantly different from region to region.

Hypothesis 3 In all regions of Ethiopia, farmers' reaction to yield and price is different due to the regional yield to fertilizer differences.

1.5.1 Measuring demand for fertilizer

Theoretically, the fertilizer demand determined largely by the shape or the marginal physical product. However, the fertilizer demand comes from the intent of the final output produced; the fertilizer demand function is often mentioned to as a “derived” demand. It depends on:

(1) The price of the crop(s),

(2) The price of fertilizer,

(3) Prices of other inputs that substitute for or complement fertilizer, and

(4) The parameters of the production function that describe the technical transformation of the inputs into an output (i.e., the fertilizer response function)(David, 1986).

Fertilizer demand can be expressed in different ways based on the underlying assumptions behind the function. Commonly we can measure farmers’ fertilizer demand from the value of marginal production (VMP).

1.5.2. Value of marginal Production Method (VMP*).*

VMP is a simple derivation of a profit-maximizing function of a single input and output function. It evaluates marginal benefit obtained from the last unit of additional fertilizer use. However, for the African small holder farmer suffering from several market failure issues, it is difficult to get the experimental data to investigate factors of fertilizer controlling other effects. To determine the optimum level of fertilizer, different quantities of fertilizer levels in a similar producing environment must be tested.

> *Because of numerous underlying assumptions, this profit maximizing framework tends to be a theoretical concept that seldom matches perfectly with real farm decision making processes. The theory assumes that the farmer (a) seeks to maximize profits from fertilizer use, (b) knows the physical response curve, (c) is able to estimate output prices for the upcoming marketing season, and (d) faces no input purchase, production, or output marketing constraints or risk.*(David, 1986)

Some of the problems of profit maximizing analysis are differences on farmers' labor availability, farm land, credit access, and fixed assets. As a result, the fertilizer level to maximize profit may well differ across farms with differences in resources.(Yanggen, et al., 1998)

1.5.3. Value Cost Ratio (VCR) method

The value cost ratio (VCR) is the ratio of value gained by the increased yield due to fertilizer use and the cost of fertilizer. The (VCR) is an approach to evaluate financial incentives of farmers from using fertilizer. Theoretically, in the absence of transaction costs to sell out and to buy inputs and in the absence of yield and price risks, a farmer can maximize profit at marginal factor cost (MFC) equal to value of the marginal revenue(VMP).

The VCR method has a couple of important differences from marginal analysis of profit maximization (VMP=MFC).

- It measures average rather than marginal change in profitability. It does not examine incremental changes in returns as doses increase.

- The costs included in a value/cost ratio are generally limited to the expenditure on fertilizer rather than the full range of costs (including labor) associated with fertilizer use.(Kelly, 2006).

To account these differences and the farmers' unawareness about output prices and yield responses, analysts with empirical investigations, established VCR equal to two as a minimum requirement to apply fertilizer. However, in the presence of risk, VCR greater than three or four is recommended.(Kelly, 2005).

Numerically, based on farmer's farm management practice, VCR is calculated using two similarly cultivated experimental plots. The experiment made by planting the same crop in both plots, treating the first plot with fertilizer and the second without fertilizer. Then let the fertilized plot output be 'Q' , and the unfertilized plot be (Q-X), assuming price of fertilizer ' P_f ', quantity of fertilizer 'q_f' and price of output ' P_o', where $X \geq 0$. The VCR can be calculated as follows.(Nigusie Tefera, et al., 2012)

$$VCR = \frac{P_o * Q - P_o \, (Q - X)}{P_f * q_f}$$

$$VCR = \frac{P_o * X}{P_f * q_f}$$

Where:

Q= Fertilized plot Output.

Q-X= Unfertilized plot output

P_o= Price of output

P_f= price of fertilizer

q_f= quantity of fertilizer

X= fertilizer incremental effect of output.

As a rule of thumb, many researchers (Kelly , 2005; Demeke, et al. 1998; Nigusie Tefera, et al. 2012) used VCR greater than two as an economically feasible point to maximize farmers' profit.

The "VCR>2" rule should be used carefully by controlling the MVP >=MFC, otherwise following the recommendations will end up with negative VMP and MPP.(Kelly, 2006). Even though the double criterion, choose fertilizer (F) such that Min (VMP=MFC, VCR (F)>2) there is no consideration of risk.

There is the possibility a farmer can attain profit maximizing level of fertilizer that can be VCR>2 due to price, yield and other risk situations. On the other hand, recommendation based on VCR>2 is vague in terms of precision. Because addition of more and more fertilizer maintaining VCR>2 may surpass the maximum profitable yield at some point and the producer may end up with negative marginal profit. The VCR is a partial budgeting technique it only calculates the change in yield with and without fertilizer. The higher VCR indicates that investing in more fertilizer will make a farmer better off than not using fertilizer it. So, the ratio doesn't address the overall profitability of the farm practice.(Yanggen, et al., 1998)..

1.6. Method and Procedure

1.6.1. Purpose of Method and procedure

In order to study the crop yield response to fertilizer in different regions of Ethiopia, the research method requires collecting crop yield data, harvested area, and fertilizer use level of major crops in all regions of the country. To determine the crop yield response to fertilizer, the fertilized and unfertilized portions of land, the amount of fertilizer applied, geographic region and rainfall amount are important explanatory variable inputs to build a regression function. Crop yield is the dependent variable of the model. To calculate the profit maximizing level of fertilizer for small holder farmers under risk, input and output prices, crop response to fertilizer, variances of output price, and the concept of substitution between the level of profit and the variance of profit are used.

1.6.2. Data, the Model and procedures

The data were obtained from the Central Statistical Authority of Ethiopia (CSA), which conducts two separate crop surveys. The surveys report annual farm management practices and production of major crops. The survey data are collected from private holdings of the country in Meher season. According to CSA's definition:

Holder: **-** *a holder is a person who exercises management control over the operation of the agricultural holding and makes the major decision regarding the utilization of the available resources.*

Meher *(Main) Season Crop: - any temporary crop harvested between the months of Meskerm (September) and Yekatit (February) is considered as meher season crop (CSA (1995-2011))*

In both surveys, the word "holdings" refers to all land and/or livestock owned by one person that is fully or partly used for agricultural production purpose. (CSA, 1995-2011)

The first annual survey is conducted to estimate the quantity of farm inputs applied to each crop and total area covered by farm inputs. The farm inputs are fertilizer, improved seed, and pesticides. From this second survey, fertilized areas, total area of fertilized and unfertilized crops for each region are obtained. The second annual survey is conducted to estimate yield of major crops, total production and area planted. From this survey, the annual crop yield per hectare of major crops and the total area harvested of each crop are obtained by region. The output crop prices are obtained from the country database of CSA (CSA, 1999-2012)

The yields observed from the survey data are a mixture of yields from the fertilized and unfertilized area. To differentiate the fertilizer effect on the yield, a production function is derived with some algebraic transformation.

First, total production is conceptually separated into production where fertilizer is used and production without fertilizer,

$$Q_t = Q_{ft} + Q_{nft} \quad \ldots\ldots (1)$$

Q_t = *Reported total production of crop in year t.*

Q_{ft} = *Unknown total production from Fertilized area.*

Q_{nft} = *Unknown total production from unfertilized area.*

Divide equation (1) by total harvested hectare to get:

$$Q_t/Ha=Q_{ft}/Ha+Q_{nft}/Ha \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Average yield is total quantity produced divided by total area which is the summation of fertilized quantity per hectare and unfertilized quantity per hectare.

Multiplying terms on the right hand side by 1,or (H_{ft}/H_{ft}) and (H_{nft}/H_{nft}) gives

$$Q_t/Ha=Q_{ft}/Ha\,(H_{ft}/H_{ft}) + Q_{nft}/Ha.(H_{nft}/H_{nft}) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Rearrange to get

$$Y_t = Q_t/Ha= Q_{ft}/H_{ft}\,(H_{ft}/Ha) + Q_{nft}/H_{nft}(H_{nft}/Ha) \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$Y_t= Y_{ft}\,((H_{ft}/Ha) + Y_{nft}\,(H_{nft}/ Ha) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Let ρ_t = the portion of the area fertilized in in t.

Ha = Total Hectares of the crop in year t.

H_{ft} = Hectares of the crop fertilized in year t.

H_{nft}= Hectare of the crop not fertilized in year t.

Yt= Total yield from fertilized and unfertilized Ha.

$\rho_t = H_{ft}/Ha$ and $1-\rho_t = H_{nft}/ Ha$, substitute into(5) to get

$$Y_t = \rho_t\, Y_{ft} + (1-\rho_t)\, Y_{nft} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Assume the yield response to fertilizer is given by a second order function, or

Let $Y_{ft}= Y_{nf} + \beta_1.F+ \beta_2.F^2$ and assuming fertilized yield is greater than unfertilized yield.

$$Y_t = \rho_t\,(Y_{nf} + \beta_1\, F+ \beta_2\, F^2) + (1-\rho_t)\, Y_{nft} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

So, regional Yield is equal to

$$\mathbf{Y_t = Y_{nf}+ \beta_1\, \rho_t\, F + \beta_2\, \rho_t\, F^2} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where; ρ_t= *fertilized proportion of the total area in year t.*

Y_{nf} = *intercept, yield without fertilizer*

F= Quantity of fertilizer applied.

Fourteen-years of data for each of eleven regions of the country were collected. Variables such as: fertilized area, quantity -fertilized, total area, and yield are calculated from the survey data. Linear and quadratic terms of production function were estimated along with dummy variables to test for differences by for regions, regional linear response differences, and for regional differences in the quadratic term for each crop.

For example, the regression model for crop Teff is coded as follows

$$\begin{aligned} \mathrm{YTf}_{\mathbf{it}} = {} & \beta_0 + \beta_1\,\mathrm{FtTf}_{1i} + \beta_2\,\mathrm{FtTf}^2{}_{1i} + \beta_3\mathrm{JJASO}_{1i} + \beta_4\mathrm{JA}_{1i} + \delta_1\,\mathrm{JJASOr}_{1i} + \cdots \\ & + \delta_9\mathrm{JJASOr}_{1i} + \delta_{10}\mathrm{R}_{1i} + \cdots + \delta_{19}\mathrm{R}_{9i} + \delta_{20}\mathrm{R}_1.\mathrm{FtTf}_i + \cdots \\ & + \delta_{29}\,\mathrm{R}_9\,.\mathrm{FtTf}_{\,i} + \delta_{30}\,\mathrm{R}_1.\mathrm{FtqTf}_i + \cdots + \delta_{39}\mathrm{R}_9.\mathrm{FtqTf}_i + \delta_{40}\mathrm{Y}_{95} + \cdots \\ & + \delta_{53}\,\mathrm{Y}_{07-10} + \varepsilon_{it} \end{aligned}$$

Where dummies;

- JJASO is an average rainfall amount of national rainfall for the month June, July, August, September and October.
- JJASOr is an average rainfall amount of each region for the month June, July, August, September and October.
- Dummies R_2 – R_9F are region dummies.
  - R.No. 1= Tigray, R.No. 2=Afar, R.No.3 = Amhara,
  - R.No. 4 =Oromia, R.No. 5= Somalia, R.No.6= B.Gumuz
  - R.no .7= SNNPR, R.No. 8= Harar, R.No. 9= Dire Dawa,
- Dummies R_2Ft…R_9Ft test the difference in the linear fertilizer slope between each region.
- Dummies R_2Fq…R_9Fq tests the difference in the quadratic term for fertilizer response between each region.

- Dummies $Y_{95} \ldots Y_{07-10}$ are year dummies to test for country wide differences between years.

The regional dummies ($R_{2\,-}\,R_9$) tests if the intercept for Afar is different from that of Tigray. For example,

- If the t-value for R_2 is significant, the unfertilized yield in Afar is intercept plus the coefficient for R_2. For R_3, if t-value for R_3 is significant, the unfertilized yield in Amhara is intercept plus the coefficient for R_3. The same logic works up to R_9. Otherwise, the unfertilized yield in Afar is equal to that for Tigray.

The fertilizer linear term for each region (R_2Ft- R_9Ft) tests if the linear response to fertilizer coefficient (β_1 in the above equation) for Afar region is significantly different from the coefficient for Tigray. For example,

- If the t-value for R_2Ft is significant, β_1 of (Afar) = β_1 + Coefficient of (R_2F), and so on.
- R_2Ftq tests if the quadratic response to fertilizer coefficient of (β_2 in the above equation) for Afar is significantly different from the coefficient for Tigray. If the t-value for R_2Fq is significant, then β_2 of (Afar) = β_2 + coefficient of (R_2Fq), otherwise β_2 (afar) = β_2 (the overall model coefficient).

Panel data were used to build the regression model. To improve the degrees of freedom on searching for expected significant variables, insignificant variables (at 10% level) were deleted and from the regression rerun final significant variables retained. The actual results are interpreted in the summary and result section.

For the second objective to determine profit maximizing level of small holder farmers in Ethiopia, Dillon's best operating environment under risk is implemented. Due to the aforementioned criticism the VCR was not used in this study.

1.6.3 Best operating environment under yield and price risk environment and under without dealing with the VCR.

In addition to the presence of input and output price variability, weather induces yield variability. The economic concept of maximizing profit where marginal revenue is equal to marginal cost is not practical for risk-averse farmers. According to the study of (Binswanger and Sillers, 1983), Farmers in developing countries are universally risk averse regardless of cultural, agronomical environment, and level of wealth. Farm size has substantial influence on the use of more fertilizer due to the fact that lenders are more inclined to give loans to larger producers.

Since, the small holder farmers' are assumed risk-averse, they would apply less than the profit maximizing level of input. To determine the demand for fertilizer; it is important to look at farmers' best operating condition under risk. Considering the effect of both price and yield uncertainty (Dillon, 1977) numerically illustrated the risk-averse farmers optimum utility and profit maximizing input levels are less than those of risk loving and risk neutral farmers.

> *Hence, under risk aversion, risk implies a lower level of input use than in the absence of risk. With risk preference, the reverse would apply. And with indifference, best operating condition would be as in riskless cases.(Dillon, 1977).*

The empirical expression of risk response characteristics of a farmer can be illustrated in a quadratic utility functional form, which helps to satisfy the marginal condition of profit, revenue and costs corresponding with utility. Using simple quadratic utility function (Dillon, 1977) expressed utility coefficients as follows:

$$U = \pi + b\pi^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where; U= utility

π = *profit*

b= coefficient of profit

Accordingly, depending on $(d^2\, U/d\pi^2)$ the quadratic utility function indicates if b< 0, risk aversion, if b>0 risk preference, and if b=0 risk neutral. Further, assume mean and thevariance of profit are the only parameters relevant to enter the utility function.

We can write

$$U = f(E(\pi), V(\pi)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The First order condition with respect to input X1(Dillon, 1977) is

(dU)/(dX1) = 0=dE(π)/dX1 + ([(∂U/(∂V(π)) / [(∂U/∂E(π)]) [dV(π))/(dX1])……….(3)

Where the square brackets contain the negative of the rate of substitution in utility of E(π) $for\ V(\pi)$,written RSU_{EV} and defined as the slope of $\frac{dE(\pi)}{dV(\pi)}$ of utility curve in mean variance profit space. It can be seen as the total implicit deferential and rearranged as.

$$dU = \left[\frac{\partial U}{\partial E(\pi)}\right]\left[\frac{dE(\pi)}{dV(\pi)}\right] + \frac{\partial U}{\partial V(\pi)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

To keep utility fixed set $dU = 0$, and solve for U^*

$$RSU_{EV} = \left[\frac{dE\ (\pi)}{d\ V(\pi)}\right] U = U^* \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$=-[\frac{\partial U}{\partial V(\pi)]} / [\frac{\partial U}{\partial E(\pi)}] \; U = U^{*} \quad \ldots\ldots (6)$$

Thus the utility maximizing condition criterion of equation (3) will be

$$RSU_{EV} = \frac{dE(\pi)}{dX1} / \frac{dV(\pi)}{dX1} \ldots\ldots (7)$$

$$RSU_{EV} = \frac{dE\ (\pi)}{d\ V(\pi)} \ldots\ldots (8)$$

when the only relevant parameters are the variance of profit and the mean, the best operating environment under risk infer RSU(rate of substitution in utility) of E(π) for V(π), and the substitution rate of response E(π)for V(π). (Dillon, 1977)

For example taking quadratic expected utility function

$$U = E(\pi) + bE(\pi^2) \ldots\ldots (9)$$

$$U = E(\pi) + b\ [E(\pi)^2] + bV(\pi)] \ldots\ldots (10)$$

Corresponding to equation (1),

$$RSU_{Ev} = -\, b/[1 + 2bE(\pi)]$$

Accordingly, the farmer’s risk aversion is exhibited as (b<0), risk indifference as (b=0), and risk preference as (b>0).

The expected profit function is

$$E(\pi) = E(Py)E(Y) - p1 * x1 - F \quad \ldots\ldots (11)$$

The variance of profit function is

$$V(\Pi) = [E(Py)]^2\ V(Y) + [E(Y)]^2\ V(py) + V(py)\ V(Y) \text{ ....} (12)$$

Substituting equations (11 & 12) into equation (3) we will have

$$E(P_y)\ [dE(Y)/dx1] = P_1 + (RSU_{EV})[dV(\pi)/dx_1] \text{ ....} (13)$$

More fully, the expression that shows both yield and price uncertainty is:

$$E(P_y)\ [dE(Y)/dx1] = P_1 + (RSU_{EV})[[E(Py)]^2 + V(py)][dV(Y)/dx1]$$

$$+2V\ (p_y)\ E(Y)\ [dE(Y)/dx1]] \text{ ....} (14)$$

In the case of only yield is risk, where the price of the product, Py, is constant, this equation will collapse to:

$$Py[dE(Y)/dx1] = P_1 + (RSU_{EV})\ [Py^2\ dV(Y)/dX1] \text{ ....} (15)$$

Similarly, when only product price is risky, and the variance yield is constant over the input range for a given level of input, the equation becomes.

$$E(P_y)\ [dE(Y)/dx1] = P_1 + (RSU_{EV})\ 2V(Py)*Y*dY/dx1 \text{ ....} (16)$$

Where;

Py= price of yield

P_1 = price of input

Y=Yield

In this case based on equation (16) with the sum of equations (14) & (16), the best operating condition in the presence of both price and yield risk, is where the expected VMP+MFC+ risk aversion term times twice the variance of price times the yield times MPP of fertilizer.(Dillon, 1977).

Thus, as revealed in equation (16), RSU_{EV} is the decision maker's risk evaluation which depends on the individual's subjective probability distribution of expected output price and yield. Conceptually, to meet the best operating condition, it requires equating the marginal expected value of the product to be equal to marginal factor cost (i.e. direct marginal cost, P_1) plus the marginal cost of risk. The economic optimum point is found where the last additional unit cost incurred, generates revenue equals to that cost. Graphically, the optimum quantity of input is the intersection point of value of marginal production curve and marginal factor cost curve. In this study the value of expected marginal product was obtained from the average crop prices multiplied by marginal physical product. Marginal factor cost (P_1) is the average fertilizer cost and price variability was calculated from fourteen years of the reported crop prices. From the reported average quantity of fertilizer and estimated crop yield response function of each crop, profit and marginal profit were calculated from the regression coefficients. Based on the above example, average RSU_{EV} is calculated for each region from the difference between the actual and profit maximizing fertilizer levels. The optimum levels of fertilizer with risk and without risk are described in result section.

CHAPTER II

INTRODUCTION

2.1. Production and yield trends of major crops for the world, Africa, east Africa, and Ethiopia

Production trends in African countries are lower than the trends among most world countries for the major crops of wheat, maize and sorghum. However, productivity problems have both common and specific contexts for each African country. Primarily, the failure to achieve at least the world average yields for Africa throughout several decades has aggravated the problem of food insecurity. On top of that, the increasing population pressure, the environmental change, and numerous political conflicts are threatening future development efforts to manage food security both at the country and household level. The FAO (Technical Cooperation Department, 2000) summary report on the elimination of food insecurity in the horn of Africa, described the productivity problems in the horn of Africa.

> *"Crop yields in the Horn of Africa are among the lowest in the world. This is largely due to inadequate water control, as less than 1 percent of cultivable land is irrigated, compared with 37 percent in Asia. Yet, even farmers who have the benefit of a more reliable rainfall tend to lack access to knowledge, finance and markets. Moreover, they usually have very little land.".(FAO, et al., 2000)*

According to UN summary report (2000), the main reasons for poor productivity and the failure to attain food security are summarized as follows:

- *Low-productivity in agriculture*
- *Weak knowledge and information systems*
- *Weak infrastructure*
- *Low standards of education*
- *Fragile ecosystems*
- *Natural hazards*
- *Narrow livelihood base*
- *Poor health*
- *Neglected pastoralism*
- *Conflict*
- *Population growth*
- *And the uneven effects of liberalization. (FAO, et al., 2000)*

The joint program in African countries to maintain food security by focusing on agricultural productivity, the ‘‘AU 2003 Maputo Declaration on Agriculture and food security’’ is a step forward to fight the multifaceted problem of poverty. By this declaration in July 2003, all African heads of states and governments agreed to allocate at least 10 percent of their national budget to agriculture and rural development within five years until 2008(African-union, 2003). Their united endeavor was to achieve sustainable development and to reduce poverty, NEPAD (NEPAD) was established in 2001.

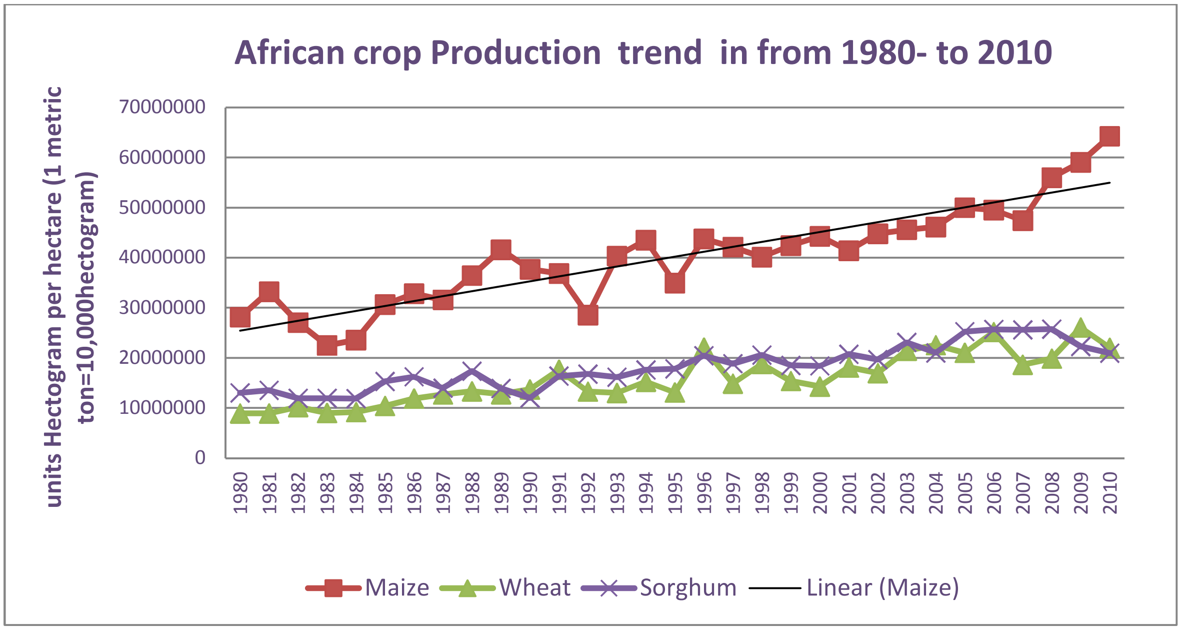
Consequently, NEPAD in 2003 launched a Comprehensive Africa Agriculture Development Program (CAADP) to raise agricultural productivity. This effort is progressively working towards a target to achieve at least six percent rate of increase in agricultural productivity per year. Furthermore, CAADP requires 10% of the countries' national budget to be allocated to the agricultural sector, which was already endorsed by African union declaration. (NEPAD, 2010-2012).

Although, the countries agreed to allocate 10% of national budget within five years until 2008, only ten countries, including Ethiopia made progress towards this goal. Only nine countries achieved the goal of 6% agricultural growth rate. Four countries scored between 5 and 6. percent.(NEPAD, 2010-2012). Moreover, the countries are also trying to reduce some impeding factors of productivity through efforts such as: input cost reductions, building of infrastructure, skill development, and women empowerment, combating HIV/Aids, boosting private investors, and developing small holder farmers. (NEPAD-Newsletter, June 2013).According to the NEPAD report, the agricultural productivity still needs a lot more efforts and it will take several years to achieve the intended level of crop productivity to maintain food security.

2.2. Crop production Trends of Africa for the last three decades.

To examine the status of the productivity of countries in the horn of Africa and Ethiopia in particular, it is worth looking at the following Tables and Figures, which exhibit the crop production, yield, and harvested area trends in the horn of Africa as compared to the trends for all of Africa and the world in general. The following Figure 4 shows that total production of maize is greater and increasing faster than are wheat and sorghum.

Figure 1. Production trend of Maize, wheat and sorghum for the whole Africa from 1980 to 2010.



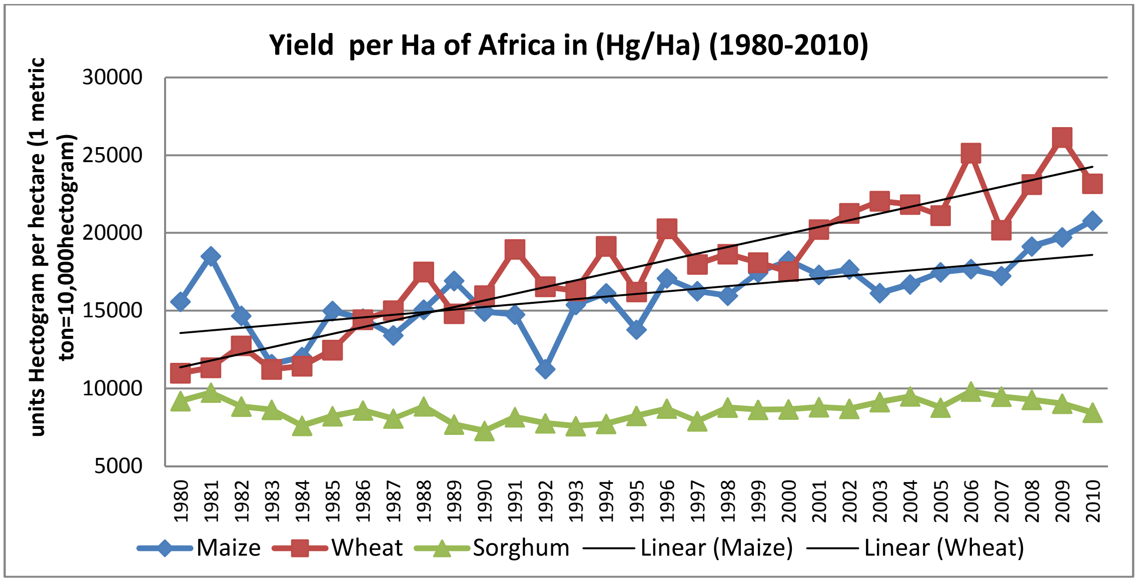
Source: (FAOSTAT, 2010)

2.3. Crop Yield trends in Africa from 1980 to 2010.

Crop production quantity data only shows the amount of crops produced in a given year. To determine economic efficiency, it is essential to calculate production per hectare for each year (i.e. yield or productivity). Moreover, to compare the efficiency of resource use and to examine the economics of productivity, the resource availability and the response of yield to particular inputs needs to be assessed.

For the past three decades, African agricultural crop production has been increasing. However, much of exhibited growth is derived from additional harvested land rather than from the increased yield per hectare of land. (Asenso-Okyere and Jemaneh, 2012). Moreover, despite several efforts were made in the past decades, African crop yields lag behind the rest of the world. Figure 5 shows the crop yield trends of the past three decades in Africa.

Figure 2. Production trend of Maize, wheat and sorghum for the whole Africa from 1980 to 2010.



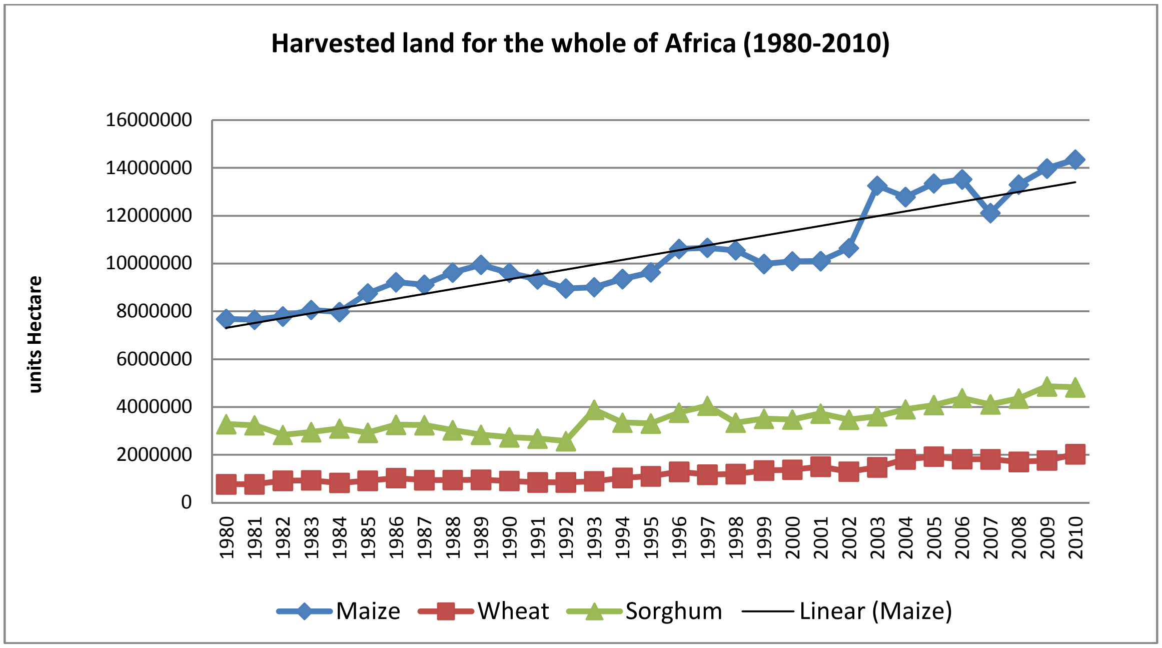
Source: (FAOSTAT, 2010)

Figure 6 below, shows that the harvested area of maize in Africa is larger and increasing more rapidly than the area of wheat and sorghum. The area harvested for maize has also been increasing faster over the years than the area for wheat and sorghum. This indicates the increased quantity of maize production in Africa (shown in Figure 4) is due to both increases in the harvested area and increases in yield per hectare. Figure 5 shows wheat yields have increased more rapidly than those of maize. This also indicates that more progress has been achieved on wheat productivity than for maize and sorghum.

From the trend shown in Figure 5, even though the productivity of wheat is growing faster than for maize, however, more land is allocated to maize than wheat.

Because, as shown in Figure 6 below, within the last three decades, the additional land allocated for maze production is by far larger than the additional land allocated to wheat and sorghum.

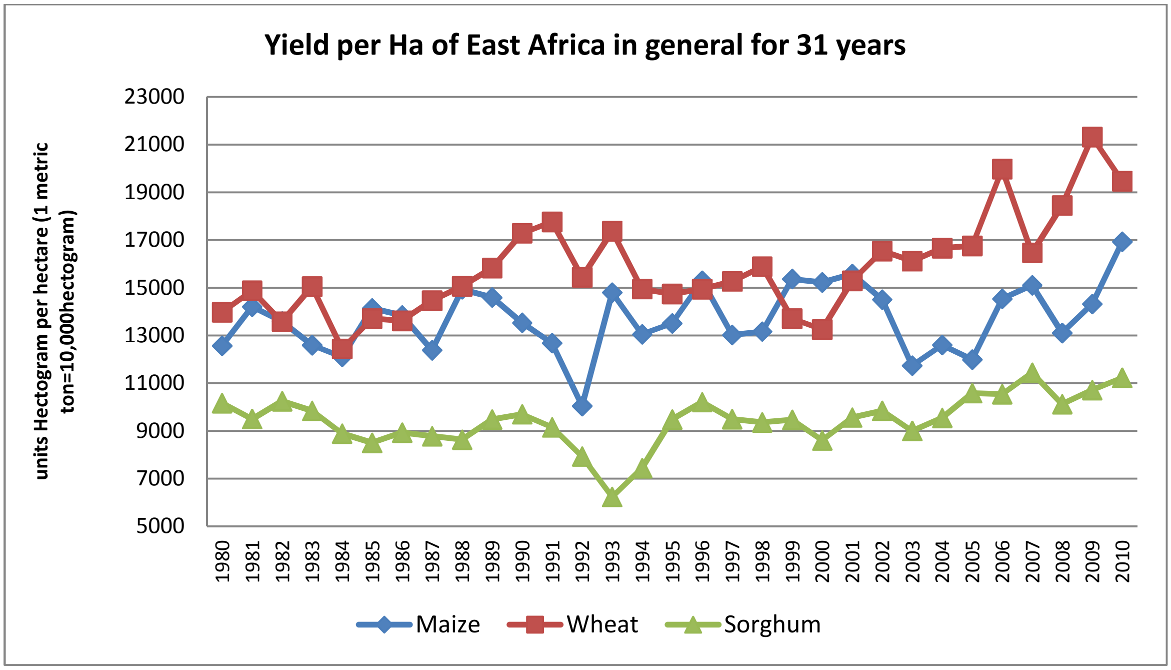
Figure 3. Harvested land for major crops in Africa (1980-to 2010.



Source:(FAOSTAT, 2010)

Therefore, by comparing Figure 5 with Figure 7, the African yield trend with the East Africa yield trend, we can see productivity in East Africa is lagging behind from the whole of Africa. This trend indicates, East Africa needs more effort to achieve better yields than Africa in general. As a result, food security may become more severe in East Africa than for the whole of Africa.

Figure 4. Yield trends for maize, wheat and sorghum in East Africa from 1980 to 2010.



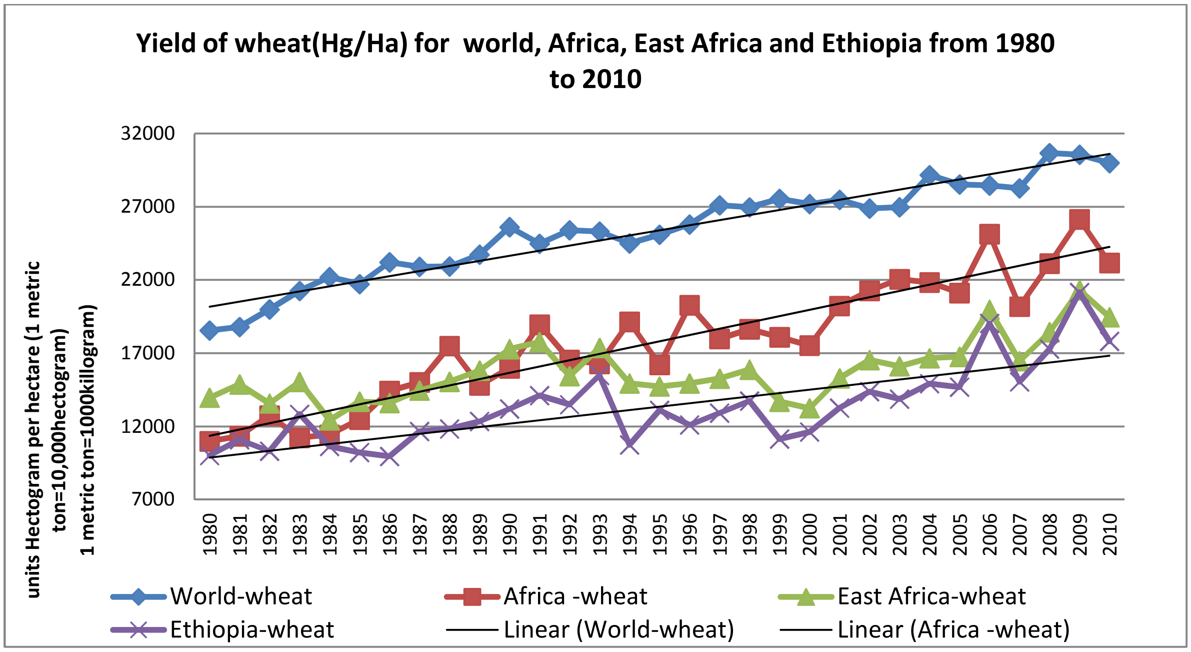
Source: (FAOSTAT, 2010)

2.4. General comparison of crop yield of the whole world, Africa, east Africa, and Ethiopia.

To demonstrate the potential for crop productivity in East Africa, it is worth comparing the worldwide maximum productivity of the similar crops. Nonetheless, the soil fertility, seed use, fertilizer, technology and other input factors vary among countries. It is possible to differentiate the effect of each factor that affects yield. Later in the subsequent chapter the yield response to fertilizer will be discussed. Through the last three decades, the world, Africa, East Africa, and Ethiopia have exhibited significantly different levels of productivity.

Figure 8 below shows that the world yield for wheat exceeds the yield of wheat for all of Africa, East Africa, and Ethiopia.

Figure 5. Yield trends of wheat compared with the yield trend of the world, Africa, Eastern Africa and Ethiopia

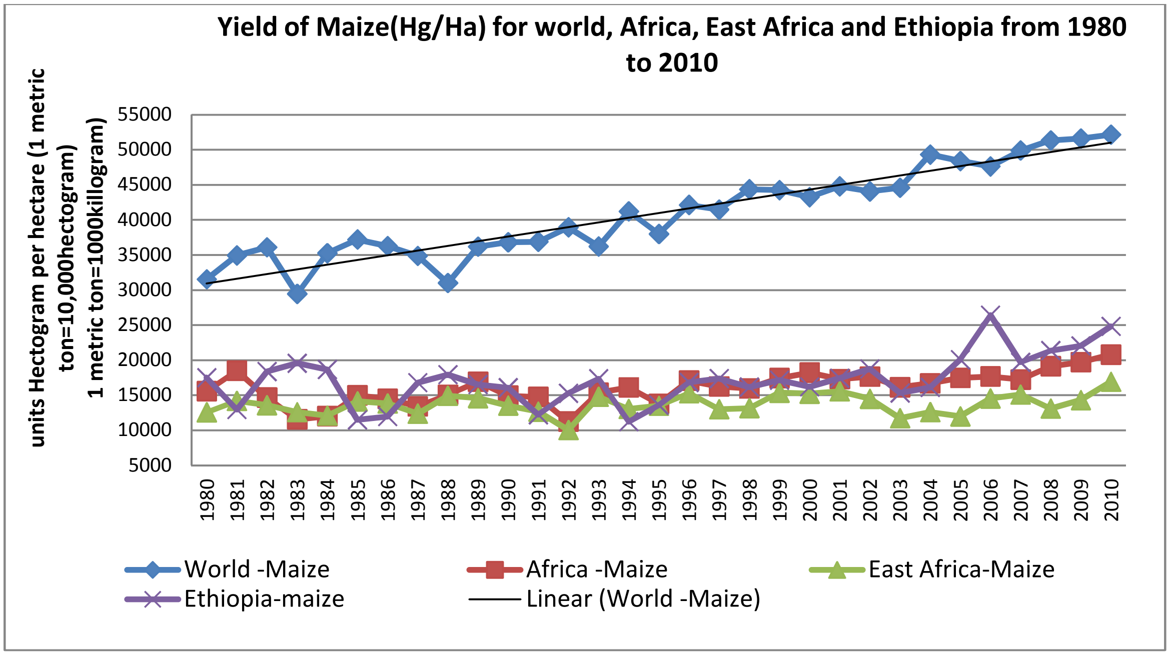


Source: (FAOSTAT, 2010)

Furthermore, in the last two decades, the yield for wheat in Africa has increased relative to East Africa and Ethiopia. The wheat yield for East Africa is increasing faster than Ethiopia.

Figure 9 below shows that the quantity and rate of increase in world maize yields exceeds those of Africa, East Africa, and Ethiopia. However, the Ethiopian yield for maize has been greater than the yield from East Africa and the whole of Africa since 2005.

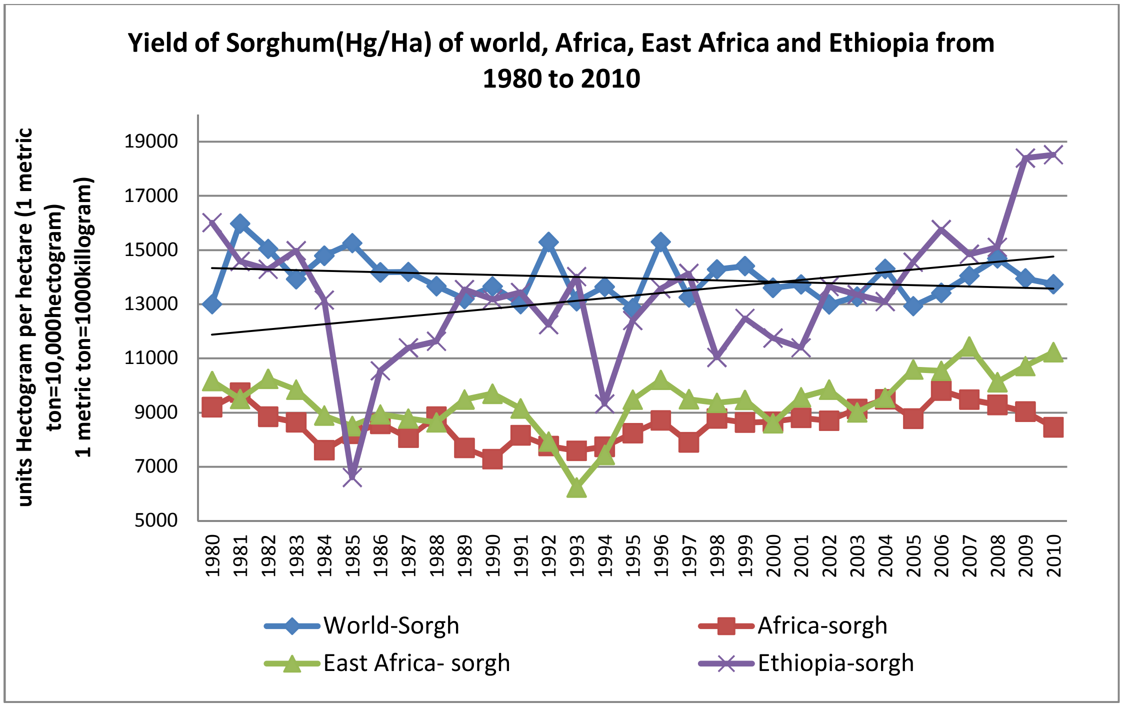
Figure 6. Yields of Maize for the world, Africa, East Africa and Ethiopia



Source: (FAOSTAT, 2010) units hectogram per hectare (1 metric ton=10,000hectogram or 1000killogram)

Figure 10 below shows that the yield trend for sorghum in Ethiopia compares favorably with world sorghum. Ethiopian sorghum yield is higher than yields for Africa and East Africa.

Figure 7. Yield of sorghum for the world, Africa, East Africa and Ethiopia



Source: (FAOSTAT, 2010)

To summarize the above crop yield trends, as shown in the above Figure 10, the Ethiopian wheat yield is exhibiting more improvement than is its yield for maize. Nevertheless, the yield for wheat in Ethiopia is lagging behind the rest of the world. The trend shown on Figure 9 above indicates the world maize yields are higher and increasing faster than for the whole of Africa; However, African maize production has increased over the last decades. Total production of maize has increased partly through additional land use and partly through increased yields per hectare. But African maize yields remained below those in the rest of the world. In contrast, the sorghum productivity trend was higher in Ethiopia than for the rest of the world. This indicates that Ethiopia has attained better productivity on sorghum than for maize and wheat.

2.5. Result summary of crop production and trends of yield.

The linear yield trends for maize, wheat, and sorghum for the world, East Africa, and Ethiopia are compared in the Tables, 2 and 3. The trends for all three crops are positive and significantly greater than zero at the 10 percent level or better except for the world trend for sorghum, which is negative but not significantly different from zero. The linear crop yield trend of wheat shows that the world yield of wheat is increasing by 34.75 kg per annum or 347.5hg/ha, Africa's yield trend at 43kg is caching up. But the wheat yield in East Africa and Ethiopia is increasing by 15 and 23kg per annum respectively. That means, they are falling farther behind.

Likewise, the world maize yield is increasing significantly faster than the maize yields for Africa, East Africa, and Ethiopia. Africa, East Africa and Ethiopia are lagging farther behind. Especially East Africa's yield level is less than for Ethiopia. The sorghum yield trend in Ethiopia is better than for all Africa and East Africa. East Africa is catching up doing better than the whole Africa.

Table 1. Comparison of linear trends for wheat yields per hectare, in the world, Africa, East Africa, and Ethiopia

Wheat	Intercept (Hg/ha)	Trend	Pr- Value trend	Area- World	Pr- Value Area-world
World	20182	347.5	0.0001		
Africa	11352	430	0.0001	82.47	0.046
East Africa	11352	151	0.0001	(196.44)	0.0001
Ethiopia	13546	231.76	0.0001	(115.82)	0.005

Source: Authors calculation from (FAOSTAT, 2010). Unit hectogram per hectare (1hg =0.1kg)

Table 2. Comparison of linear trends for maize yields per hectare (Hg/ha), in the world, Africa, East Africa, and Ethiopia

Maize	Intercept (Hg/ha)	Trend	Pr- Value trend	Area-World	Pr- Value Area-world
World	30919.88	669.87	0.0001		
Africa	13567.68	167.09	0.0001	(502.78)	0.001
East Africa	13046.26	44.31	0.1204	(625.5)	0.001
Ethiopia	14100.9	206.93	0.002	(462.9)	0.001

Source: Authors calculation from (FAOSTAT, 2010) Unit hectogram per hectare (1hg =0.1kg)

Table 3. Comparison of linear trends for sorghum yields per hectare, in the world, Africa, East Africa, and Ethiopia

Sorghum	Intercept (Hg/ha)	Trend	Pr- Value trend	Area-World	Pr- Value Area-world
World	14334.79	-25.06	0.132		
Africa	8214.68	24.19	0.0675	49.26	0.195
East Africa	8745.48	46.19	0.0275	71.51	0.06
Ethiopia	11881.85	95.96	0.0421	121.02	0.042

Source: Authors calculation from (FAOSTAT, 2010) Unit hectogram per hectare (1hg =0.1kg)

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CHAPTER III

INTRODUCTION

3.1. Crop Productivity and Food Security in Ethiopia

African countries have had a chance to improve their productivity by using improved seed, fertilizers, and associated agricultural knowledge and technologies. The horn of Africa especially is suffering from low productivity due to lack of adequate knowledge, improved seed, and fertilizer in addition to price, and climate induced yield risks.

In Ethiopia, like other African countries, the reported crop yields per hectare are still below their potential. The Ethiopian Agriculture research institutes, ESE (Ethiopian Seed Enterprise), an international and national research & development organizations, and NGOs (non-government organizations) are exerting several efforts. Their joint and individual efforts basically aim to improve seed supply, to relieve fertilizer market problems, and to access credit and extension services. However, crop productivity is still lagging behind. Table 4 and Figure 11 show the crop yield trends of the past ten years.

In addition to poor productivity and population pressure, several other factors are keeping the country food insecure. According to the (Devereux and Sussex, (2000) food security study, the problems are identified as follows.

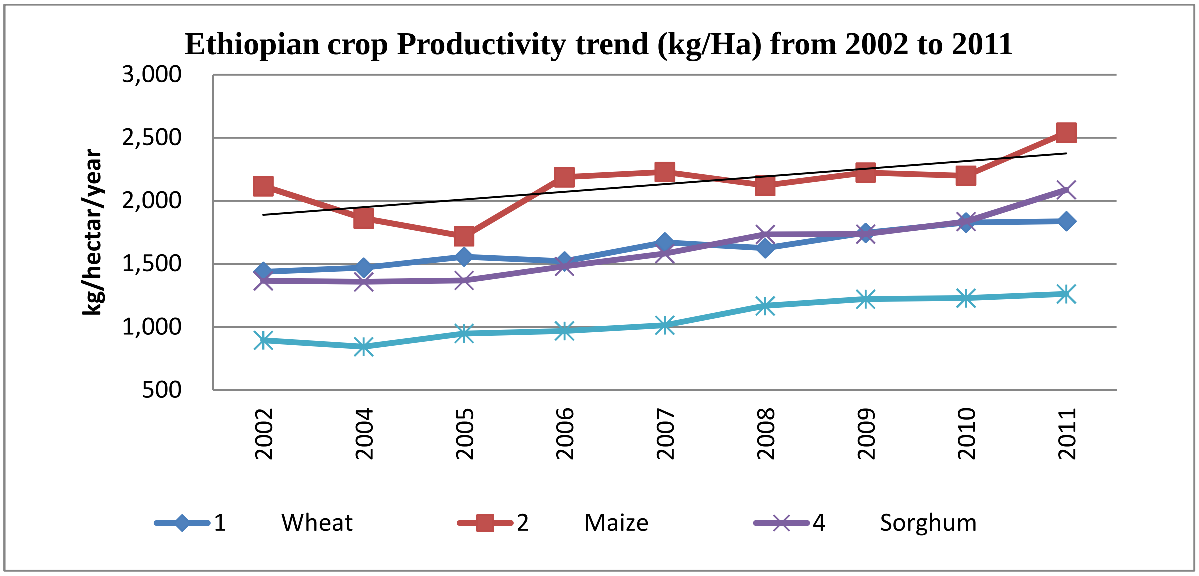
- *Landholdings are too small - although (or because) unusually evenly distributed –to allow most farming households to achieve food production self-sufficiency;*
- *Population increases reduces landholdings per capita further and places intolerable stress on an already fragile natural resource base;*
- *Soil fertility, already very low, is declining due to intensive cultivation and limited application of yield-enhancing inputs; Recurrent droughts add food production shocks to abnormally low yields;*
- *Limited off-farm employment opportunities restrict diversification and migration options, leaving people trapped in increasingly unviable agriculture.(Devereux and Sussex, 2000)*

Table 4. Crop yield trends in Ethiopian from 2002 to 2011

Crop	**2002**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Wheat	1,437	1,469	1,557	1,520	1,671	1,625	1,746	1,827	1,839
Maize	2,117	1,860	1,719	2,186	2,229	2,122	2,224	2,199	2,540
Barley	1,208	1,173	1,212	1,273	1,327	1,376	1,554	1,550	1,628
Sorghum	1,365	1,357	1,369	1,481	1,582	1,734	1,736	1,836	2,087
Teff	895	843	948	969	1,014	1,167	1,220	1,228	1,262

Source: FAOSTAT,(2010) Unit kg/ha

Figure 8. Crop yield trends for wheat, maize, and sorghum in Ethiopia from 2002 to 2011



Source: FAOSTAT,(2010) Unit kg/ha

3.1.1 Improved Seed in Ethiopia

Even if using improved seed is one of the important factors to improve yield, only 10 percent of the farmers use improved seed in Ethiopia,(Mario Zappacosta, et al., 2012). The following Table 5, taken from (Spielman, et al., 2011) compares the possible level of productivity that could have been attained by improved seeds. The possible productivity level by using improved seed is about more than two times better than the productivity level from the traditional seed. This is the gap that needs to be investigated to determine whether or not Ethiopia can attain better productivity . Thus, it indicates that expanded seed supplies are an intervention that can better help to enhance productivity to achieve food security.

The wheat, teff, and barley seed supply of Ethiopia is less than ten percent of the demand; however, improved seed for maize has reached more than ten percent of the demand. (Spielman, et al., 2011). Though, it is believed that the demand for improved seed is ever increasing, due to the additional cultivated land and farmer's awareness to use improved seed, the supply of seed in Ethiopia has always failed to satisfy the increasing demand of seed.

> "*The responsibility of responding to these demand estimates lies primarily with the state-owned Ethiopian Seed Enterprise (Gebreselassie). On the supply side, production and distribution of improved seed has been stagnant since about 2000. At about this same time, the supply of improved seed channeled through the regional extension and input supply system began to fall short of official estimates of demand (with a 72 percent shortfall in 2008 for the five major cereals). Limited production capacity at ESE(Ethiopia Seed Enterprise) for certified seed, combined with insufficient provision of breeder and pre-basic seed from the research system, contribute much to these shortfalls".(Spielman, et al., 2011)*

CHAPTER IV

INTRODUCTION

4.1. Input Supply and Consumption Trends for Major Crops for the World in General, Africa, East Africa, and Ethiopia

Globally, agricultural productivity is increasing. The progress in productivity is exhibited due to the use of improved seeds, adequate fertilizers, effective pesticides, sufficient level of water use either by irrigation or rainfall, and application of appropriate technologies. Besides these, the natural abundances among the countries such as soil type and climate conditions are the main factors vary among the countries. In fact, some of the factors of production are commonly available, manageable, and affordable by almost all counties. For example; the soil fertility level can be improved by organic fertilizers or soil nutrients. The water precipitation can also be obtained from rainfall or through irrigation. But, the improved seed supply, and technological adoption to enhance productivity, ample scientific knowledge, and capital investments can divide the countries into two categories called developed and underdeveloped or poor and rich. In this regard, in adequate knowledge and poverty level of the developing countries become the bigger challenge even to use the existing resources efficiently.

This part of paper analyzes the relative input levels of East African countries focusing on the cases of Ethiopia. Thus, the likely yield level that could have been achieved by using fertilizer and other inputs is examined. To attain better precision on the economics of fertilizer for productivity, this paper studies regional level survey data from Ethiopia on the use of fertilizer, the effects of both input and expected future output prices.

4.1.1 Fertilizer consumption trends before and after market reform in Africa and East African

African fertilizer supply and consumption has passed through different regimes, which are mainly influenced by the aftermath of colonialism, era of subsidies, and influence of international development agencies. The small holder farmers, who represent the major portion of production in Africa are still suffering from input and output market failures.

> *According to Jemaneh et al. (2012), Poor resource endowments, minimal use of inputs (fertilizer, improved seeds, and irrigation), and adverse policies that have continued for a long period have been identified as the major causes of the low and declining performance of the agricultural sector in SSA. Continuing environmental degradation, high population growth, and low levels of investment in agricultural infrastructure also aggravate the resource limitations of agriculture in Africa.*

Historically, since the 1970s, the sub-Saharan African (SSA) countries' have had a monopoly power on agricultural commodities by importing inputs, processing, and controlling export (Kherallah, 2000). Currently in most countries there are structural shifts that increase private sectors involvement in agricultural markets. This effort is exhibiting an increase in supply of agricultural inputs and better market price opportunities for the product markets.

> *Under previous arrangements, fertilizers, pesticides and seeds were supplied to farmers, usually free of charge, by state agencies or "official" cooperatives. The farmers paid for the inputs after harvest, through deductions made from the price paid for the crop. Parallel with the liberalization of cash-crop marketing, the marketing of all types of agricultural inputs were also liberalized. The private sector became or, at least, was meant to become an active participant in input procurement and sale.(Andrew W. Shepherd and Stefano Farolfi, 1999)*

The agricultural reform programs that have been introduced by the World Bank, and IMF in early 1980s, brought mixed outcomes in the first introduction periods. There has been a resistance from the governments of different countries. The liberalization had noticeable effects depending on the country's economic stand, natural resource abundance, and other compatibility issues with the former market structures. The aim of the World Bank and IMF on market liberalization was based on a couple of beliefs: to reduce or eliminate government control from the market to increase private-sector involvement; and to create a competitive market in order to increase agricultural productivity. These reform procedures need four main types of measures:

- *Liberalizing input and output prices by eliminating subsidies on agricultural inputs. These includes Item such as fertilizer and credit, by bringing domestic crop prices in line with world prices, and by ending the practice of imposing a single price for all regions and seasons*
- *reducing overvalued exchange rates by partially liberalizing the market for foreign Exchange*

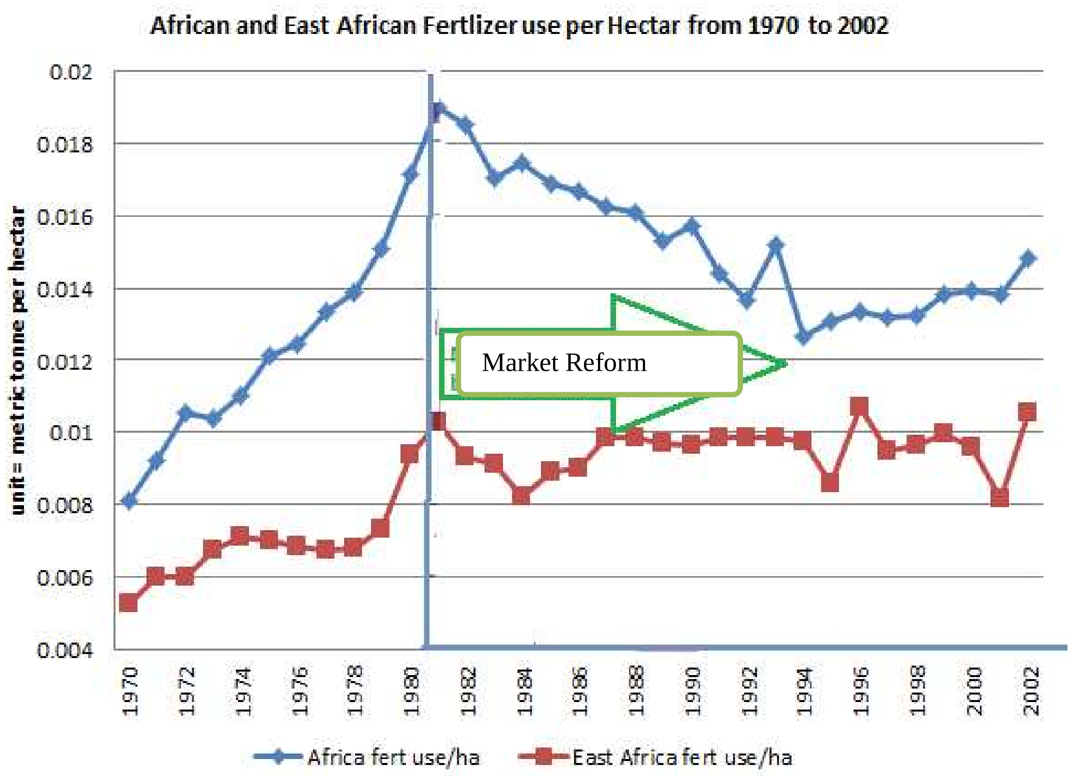
- *Encouraging private-sector activity by removing regulatory controls in input and output markets, lifting restrictions on the internal movement of food crops, and Relaxing delivery quotas, licensing arrangements, and similar regulations*
- *Restructuring public enterprises and restricting marketing boards to activities such as providing market information and maintaining security stocks. (Kherallah, 2000)*

The reform affected the long existing input and output prices. The elimination of fertilizer subsidies raised the price of fertilizers, and the farmers tended to use less fertilizer. This increased the real challenge to increase the yield of cereal crops. Then, in the following year an increase in output prices and fertilizer-crop yield ratio improved the utilization of fertilizers for major crops. In 1994 and 1995 the fertilizer consumption in SSA countries was decreased by about 20%.(Kherallah, et al., 2000). Nonetheless, due to the market reforms, the export crops began getting better prices and the fertilizer use on these crops was increased.

Figure (12) below shows the total African fertilizer consumption trend during the period of subsidization and after the subsidization. The rising pattern of fertilizer consumption during 1970s was helped by the government subsidy after the post-colonial times of most African countries. In fact, the subsidies assisted the farmers to get fertilizer. As a result of low priced fertilizer provided by the government, the price of output crop is kept lower to keep the food price cheaper for the consumers. In the early 1980s, the introduction of market reform which is partially implemented among the countries begun to remove the subsidies.

Consequently, for all of Africa, the fertilizer price escalated and the trend of consumption per hectare decreased for about two decades. In the case of East Africa, the effect of market liberalization initiated the output crop price to increase. In the following years, the increased output price started to offset the raise in the fertilizer price. At this point, the fertilizer use per hectare in East Africa declined more rapidly than for Africa in general.

Figure 9. Total fertilizer consumption trends for Africa from 1971 to 2002 and effect of fertilizer market reform in 1980.



Source: FAOSTAT 2012

4.1.3. Economics of fertilizer use

The small holder farmers' analysis of fertilizer profitability can be viewed from absolute and comparative perspectives based on the farmers' actual and potential resources and market information. The absolute perspective considered by the farmer is whether fertilizer use has net profit over cost or not. And the comparative perspective attests whether the farmer can invest the same resource in another alternative and more profitable, on-farm or off-farm activates. (Yanggen, et al., 1998).

In other words, crop producers base the fertilizer use on the prevailing market price and the expected forthcoming output prices; the annual potential yield of crops inevitably depends up on the prices of both crops and fertilizers. The farmers' demand for fertilizer is derived from the profitability of the fertilizer use on any crop. Thus, farmers would only use a recommended level of fertilizer when they think the crop output price will pay back the cost of fertilizer used.(Yanggen, et al., 1998)

4.2. The economics of fertilizer in the case of Ethiopia

The Ethiopian fertilizer market has passed through different kinds of policy reforms based on the government's policy regimes under the influence of IMF and World Bank to liberalize agricultural markets. As a result of this, the elimination of the fertilizer subsidy was fully implemented after 1997. The following Table 7 explains the policy regime from 1991 to 2008.

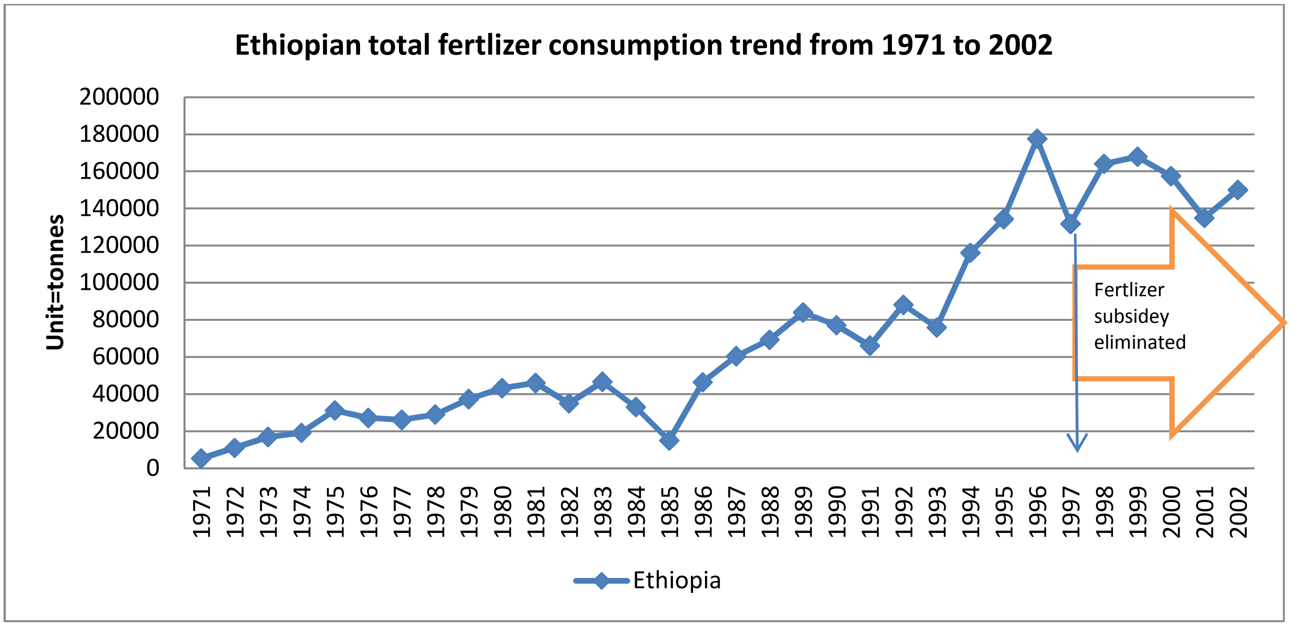
Table 5. Policy regimes and development programs in agricultural input systems and markets from 1957 to 2007

Period	Intervention/Event	Focus/Objectives	Remarks
1957-1967	First and Second Five Years Development Plans	Develop large-scale commercial farms and coffee exports	Subsistence farming was neglected
1968-1973	Third Five Year Development Plan (Comprehensive Integrated Package Projects)	Transport infrastructure development; dissemination of high-input technologies, credit, and extension; formation of cooperative societies.	Implementation revolved around three comprehensive extension programs that focused on high-potential areas only.
1971-1979	Minimum Package Program I (MPP-I)	Expand geographic coverage of the comprehensive extension programs; provide fertilizer, credit, and extension to "minimum package areas."	Fertilizer procurement is managed by Agricultural and Industrial Development Bank (AIDB), distribution managed by Ministry of Agriculture (MoA).
1978	Agricultural Marketing Corporation (AMC)	Improve management of agricultural input importation, storage, and transport by handing over control of these tasks to the AMC.	MoA maintains role of distributing fertilizer to farmers, disbursing credit, and estimating fertilizer demand through approximately 18,000 peasant associations.
1980-1985	Minimum Package Program II (MPP- II)	Expand input supply and extension service coverage three-fold.	Actual provision of inputs and extension was limited due to: lacking financial support for MPP-II; increasing inefficiency in MoA and AMC; fertilizer overstocking due to inaccurate demand estimates; and poor institutional coordination of input deliveries.
1984	Agricultural Input Supply Corporation (AISCO)	Improve the importation and distribution of fertilizer and marketing of other agricultural inputs.	As a successor to AMC, AISCO was limited by lengthy bureaucratic process needed to secure foreign exchange, high freight costs, and lack of proper port facilities, high inland transport costs, inaccurate demand estimates, and organizational inefficiency.
1986-1995	Peasant Agricultural Development Program (PADEP)	Provide inputs, credit, and extension services to smallholders organized into approximately 2,900 farmer service cooperatives (SC) using a Training and Visit (T&V) extension approach.	As a successor to MPP-II, PADEP aimed to cover 8 development zones across the country, but only received financing sufficient for 3 zones, all located in high potential area.
1991-1995	Partial liberalization of the **fertilizer** market	Open the importation, wholesaling, and retailing of fertilizers to private companies.	Undertaken by the Transitional Government of Ethiopia (TGE.). Fertilizer prices remained pan-territorial and subsidized
1993–1999	Participatory Demonstration and Training Extension System (PADETES)	Promote improved seed-fertilizer-credit packages (primarily for maize and wheat) through a "training and visit" Approach piloted by Sasakawa Global 2000.	PADETES demonstrated on a pilot basis that yields could be doubled with the application of modern inputs in Ethiopia.
1995–present	National Agricultural Extension Intervention Program (NAEIP)	Scale up the PADETES approach to the national level as a means of boosting cereal yields and output.	Efforts to scale up the PADETES approach were less successful than the piloting demonstrated by Sasakawa Global 2000.
1997-98	Fertilizer price liberalization	Eliminate subsidies and deregulate the price of fertilizer at the wholesale and retail levels.	Liberal prices have not resulted in competitive market due to the government's continued control over marketing and ccredit.
2000-07	Shifting industry structure	Private companies withdraw from the fertilizer market in 2000, succeeded by "holding" companies; cooperative unions enter the market in 2005, followed by the withdrawal of "holding" companies" in 2007.	The Agricultural Input Supply Enterprise (AISE) and cooperative unions emerge as the only actors engaged in fertilizer importation, and are also the largest players in the wholesale and retail markets, in conjunction with the regional input supply and extension systems

Source:(Spielman, et al., 2011) page 8:Adopted from Stepanek 1999; Demeke 1995; Gebremedhin et al. 2006; Abate 2008; and authors

As described in Figure 13 when fertilizer subsidies were eliminated, the import quantity declined in 1997; however, it increased in the following year 1998. Similarly as shown in the Figure 13, consumption was declined accordingly

Figure 10. Ethiopian total fertilizer consumption per harvested land from 1970 to 2005



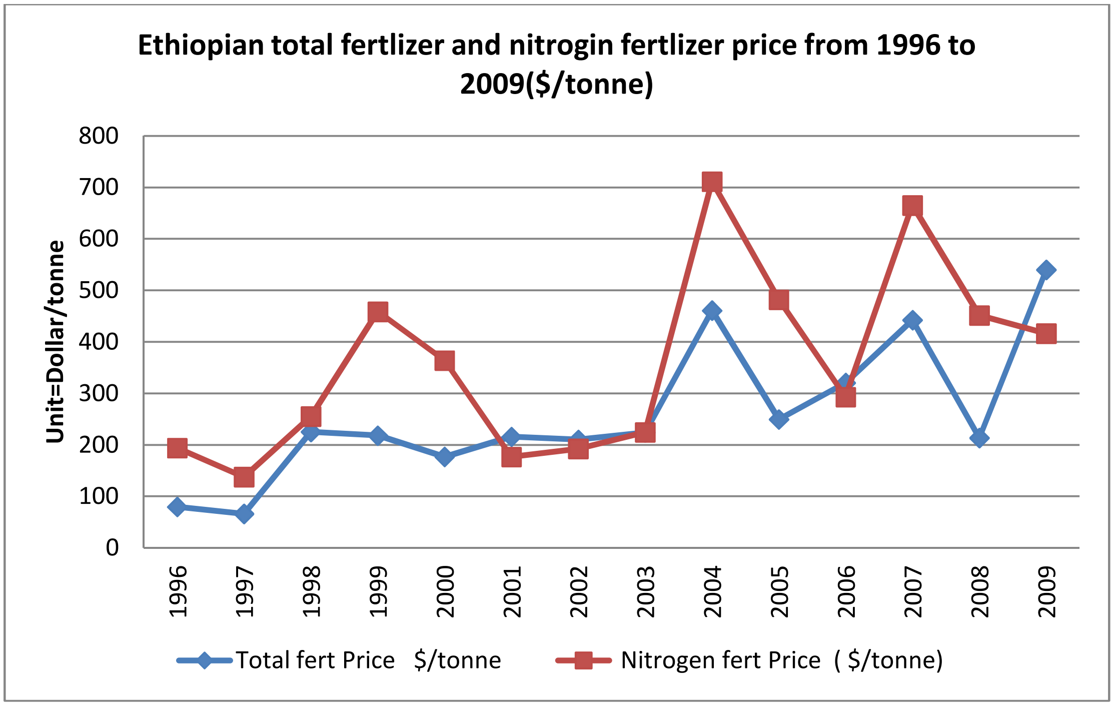
Source: FAOSTAT 2012

In years before the elimination of subsidies, the amounts of subsidies were a tool to regulate fertilizer prices.

> *Fertilizer subsidies ranged from 20 percent to 39 percent across the country until January 1997. The subsidy was a reaction to the fertilizer price rise that followed the devaluation of the Birr in the early 1990s.(Stepanek, 1999)*

The following Figure 15 shows, fertilizer price variations after market reform from 1993 to 2009. In 1996, 1998 and 2002 the price was down and the consumption was increased as compared to other consecutive years. Generally, as shown in the Figure (14), before the market reform, the consumption was showing an increasing trend. However, the trend after the reform was decreased for some time and later begun to increase.

Figure 11. Ethiopian total fertilizer price and nitrogen fertilizer price



Source: FAOSTAT 2012

The Ethiopian small holder farmers, who have less than one hectare per head, operate on their own survival first struggle with in uncertainties.

> *Almost 40% of farms are less than 0.5 hectares and about 60% are less than one hectare. Any farm more than 5 hectare is in the largest 1% of farms.(Demeke, et al., 1998)*

Nonetheless, if some occurrence happens to create an attractive profitability, which can motivate a risk-averse farmer to decide using more fertilizer, getting the fertilizer itself wouldn’t be that easy. Besides the challenge to get fertilizer on time, acquiring fertilizer depends on the farmer’s income, credit access or collateral.

Among several common reasons that make Ethiopian farmers to be a risk-averse are:

- Uncertainty of the upcoming output price which fluctuates over time, because in good harvest season when production increases the output price goes down. The problem is the input price has already been incurred without the clear knowledge about future crop price and production quantity.
- The Small holder farmer in Ethiopia hesitates to bear a burden of loan to arrange credit to buy more fertilizer, because the money for additional fertilizer may come from credit services, which have no insurance if some things go wrong. Therefore, a farmer fears such a risk and prefers to keep the subsistent level of production.

According to the (Demeke, et al., 1998) study, in addition to product and input price risks, Ethiopian farmers’ risk factors also include:

- *moisture stress and drought,*
- *excess rains,*
- *hailstorms,*
- *flooding,*
- *frost,*
- *crop pests such as armyworm*
- *and grasshoppers and abnormal weed infestation.(Demeke, et al., 1998)*

In such a case, only consistent and very attractive marginal revenue over the costs can break the small holder farmer’s fear of different uncertainties. If stable and profitable output prices and timely supply of inputs are maintained, a farmer will allocate more fertilizer to maximize his profit and yield also increases.

4.3. Fertilizer levels

Different rules are implemented to determine the optimum level of fertilizer to be used for different crops in different situations. Agronomy literature tends to focus on maximum yields and the economic literatures focus on profit maximizing level of fertilizer level as recommendation. The more conservative view takes into account the risk and yield gap between on farm real practices and research trials.(marginal rate of return of 100% or value/cost ratios equal to 2.(Yanggen, et al., 1998). Ethiopia has different agro ecological environments that make the crop yields to vary from region to region. Based on soil-and crop-specific nutrient requirement the fertilizer recommendations shoulde also vary among regions.

> *The new extension program is based on the application of 100 kg of DAP (46 kg P2 O5 and 18kg N) and 100 kg urea (46 kg N) per hectare. While the recent recommendation states that DAP and urea should be applied in equal proportion (100 kg DAP and 100 kg urea), the farmers' practice is heavily biased towards one type of fertilizer use, mainly DAP(Demeke, et al., 1997).*

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CHAPTER V

RESULTS

5.1 Mean of the Regression Variables

Table 7 shows the means and standard deviations of variables used in the regression analysis. It presents the average total hectares harvested for each crop, average quantity of fertilizer (only for fertilized area), and average number of hectare receiving fertilizer. The average quantity of fertilizer applied per fertilized hectares for the four regions is less than one quintal for teff and about one quintal for wheat. This is less than the recent recommended fertilizer level. The recent extension program suggests one quintal of urea and one quintal of dap to be used per each hectare (Demeke, et al., 1997). However, in the past few years little urea has been used. In 1996 about 56 percent of lands received only dap and another 8.5 percent received only urea. (Demeke, et al., 1997)

The average fertilized proportion of land for teff is about 50 percent and about 60 percent for wheat. Annual survey data for fourteen years were compiled to calculate the variables average values for the four regions. The unit of fertilizer used are quintals per hectare.

Table 8. Average hectares fertilized, proportion of hectares fertilized (fertilized hectare per total hectare) of regression variables for the year 1995 to 2010.

Region	Average of	Teff	Wheat
AMHARA	Total area	918,691	358,392
	Proportion of area fertilized	0.50	0.64
	fertilizer per hectare	0.74	1.07
OROMIA	Total area	979,637	670,101
	Proportion of area fertilized	0.61	0.72
	fertilizer per hectare	0.80	0.91
SNNPR	Total area	189,383	103,839
	Proportion of area fertilized	0.54	0.78
	fertilizer per hectare	0.74	1.00
TIGRAY	Total area	143,141	81,341
	Proportion of area fertilized	0.48	0.62
	fertilizer per hectare	0.70	0.91

5.2. Teff response to fertilizer by region

Table 8 indicates the coefficients for the quadratic response to fertilizer in the four major regions of Ethiopia were of the correct sign and significantly different from zero at the one percent level. That is the linear term was positive and the quadratic term was negative as expected. As discussed in the model section, the statistical model use in the regression analysis was specified as:

$$YTf_{it}= \beta_o+\beta_{1.}FtTf_i + \beta_2.FtTf_i^2 + \delta_1 JA + \delta_{20} FtTf_i + \delta_2 Y_{07\text{-}10}$$

- The linear response of teff to fertilizer in Oromia region was significantly greater than for Tigray, Amhara and SNNPR regions at 10% level of probability Average rainfall in the months of July and August had significant and positive effect on yield for all regions.

- Ethiopian teff yields in year 2000 were significantly lower than the average and significantly above average from 2007 to 2010.

Table 9. Regression results of Teff-yield response to fertilizer by region.

Variable	Definition	Parameter estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	4.34	0.73	5.95	<.0001
FtTf	Fertilizer applied	18.96	3.84	4.94	<.0001
FtTfsq	Applied fertilizer squarede	-11.51	2.45	-4.7	<.0001
JA	July, Aug rainfall	0.05	0.02	2.62	0.0143
R4FTf	Oromia linear fertilizer	0.897	0.519	1.76	0.0869
Y00	Year 2000	-0.705	0.375	-1.88	0.0892
Y07-10	Years 2007 up to 2010	2.976	0.286	10.42	<.0001

The following Table 8 shows the estimated teff response to fertilizer in each region of Ethiopia. Further, dummy variables were used to test the intercept, changes by region and by weather throughout the years in the model. The intercept in this model is yield without fertilizer. The differences in regional intercepts (tested by using dummy variables), were not significantly different at the 10% level. From the year (from 1995-2010) dummies, the annual intercept for (1997-2000), were positively significant. It indicates, teff yield exhibited significant unexplained increases in those three years.

Table 10. Teff yield response to fertilizer function of regions based on Table 9

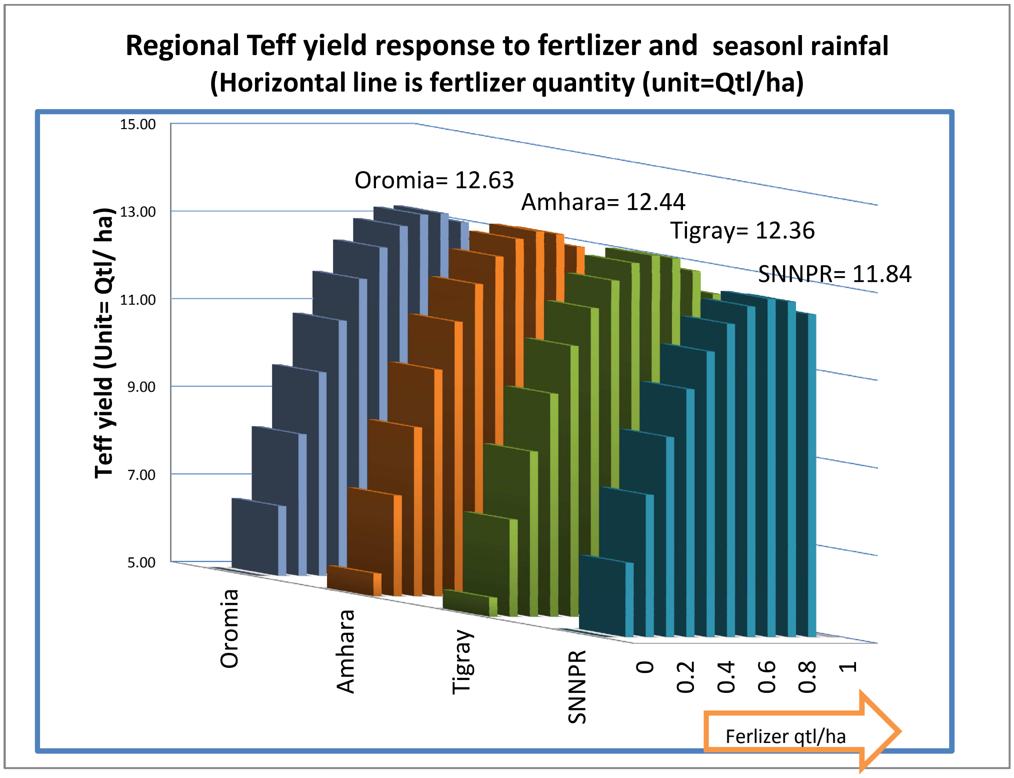
Region	YTf t= βo+β1(FtTf)+ β2(FtTf)2 + R4Ftf + δ1(JA) + δ2(Y07-10)				Quantity of fertlizer(qtl/ha) applied and the teff yield response by region											
	intercept	linear	Quadera	Rainfall	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1
Tigray	4.34	18.96	-11.51	0.05	5.43	7.21	8.76	10.08	11.17	12.03	12.66	13.06	13.23	13.17	12.88	12.36
Amhara	4.34	18.96	-11.51	0.05	5.51	7.29	8.85	10.17	11.26	12.12	12.75	13.15	13.32	13.26	12.96	12.44
Oromia	4.34	19.86	-11.51	0.05	4.71	6.59	8.23	9.64	10.82	11.77	12.49	12.98	13.24	13.26	13.06	12.63
SNNPR	4.34	18.96	-11.51	0.05	4.91	6.69	8.24	9.56	10.65	11.51	12.14	12.54	12.71	12.65	12.36	11.84

Table 9 describes the yield response function of each region per unit fertilizer increase. Even though, the fixed effects of coefficients for the three regions are the same, the linear fertilizer term for Oromia and the average regional rainfall amount for all regions created the exhibited yield differences in each region. The following are the reasons:

- Since overall rainfall coefficient multiplied by the average rainfall of each region, each region's gets different rainfall and so does the yield.
- The average rainfall for the month of June, July, August, September, and October for the regions Tigray, Amhara, Oromia, and SNNPR is 27, 32, 17, and 19 millimeters respectively.
- The difference of the linear term for Oromia, which is 19.86 is the sum of the overall linear fertilizer coefficient 18.96 plus the regional linear fertilizer term of Oromia 0.897, described in the Table 8.

The predicted teff yields in Table 9 are shown graphically in Figure 16. The calculation of yield response to fertilizer indicates, teff in Oromia performs better at higher fertilizer levels than the other three regions (Amhara, Tigray, and SNNPR). As displayed in Figure 16, the fixed effect of the yield model is the same for Amhara, Tigray and SNNPR even though the maximum yield differences are due to differences in the average regional rainfall.

Figure 12. Regional Teff yield response to fertilizer and seasonal rainfall



5.3. Wheat response to fertilizer by region

The results for wheat in Table 10 indicates the coefficients for the quadratic response to fertilizer in the four major regions of Ethiopia were of the correct sign and significantly different from zero at the one percent level. That is the linear term was positive and the quadratic term was negative as expected. As discussed in the model section, the statistical model use in the regression analysis was specified as:

$Ywh_{it}=\beta_o+\beta_{1.}Ftwh_i+\beta_{2.}Ftwh_i^2 + \delta_{27.}R_7Fwh + \delta_1\ JJASOr_{4i} + \delta_2Y_{07\text{-}10}$

- The linear fertilizer term for wheat in the SNNPR region is significantly greater than Oromia, Tigray, and Amhara regions at one percent level.
- Average rainfall of the months June, July, August, September and October had significant and positive effect on the yield in Oromia but not in the other regions.
- The overall rainfall coefficient was not significantly different from zero at the 10% level.
- The wheat yields from year 2007 to 2010 were significantly above the average.
- Dummy variables were used to test for the differences in the intercept and for the variability of yield throughout the years in the model.
- The intercept in this model is the yield for wheat without fertilizer. The regional intercepts (which were tested by using different dummy variables), were not significant from each other at the 10% probability level.

Table 6. Regression results of Wheat yield response to fertilizer by region.

Variable	Definitions	Parameter estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	7.8222	0.9882	7.92	<.0001
FtWh	fertilizer applied yield	11.608	3.2699	3.55	0.0009
FtWhsq	fertilizer square applied yield	-4.1403	1.5612	-2.65	0.011
JJAS0r4	Oromia region rainfall)	0.1513	0.03514	4.31	0.0002
R7FWh	SNNPR fertilized	2.746	0.5912	4.64	<.0001
Y7-010	Year 2010	2.9928	0.5482	5.46	<.0001

Table 11 presents a unit by unit response of wheat yields to fertilizer in each region using the coefficients in Table 10. The SNNPR region wheat yield difference came from the linear fertilizer term, which is the sum of the overall coefficient 11.61 plus its significant regional coefficient 2.746 as shown in Table 10. Though, the overall rainfall coefficient is not significant; average rainfall of Oromia region was significant and raised the yield response to wheat relative to to other regions. However, the wheat predicted yield in SNNPR was higher when one quintal or more fertilizer was used than in Oromia, Amhara, and Tigray.

Table 72. The regression model of regions and comparison of calculated wheat yield response to fertilizer.

Region	$YWht=\beta o+\beta 1(Ftwh)+\beta 2(Ftwh)2 + R7Fwh + \delta 1(JJASOr4) + \delta 2(Y07-10)$				Quantity of fertlizer(qtl/ha) applied and the estimated yield of Wheat by region											
	intercept	linear	Quaderatic	Rainfall	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1
Tigray	7.82	11.61	-4.14	0.00	7.82	8.94	9.98	10.93	11.80	12.59	13.30	13.92	14.46	14.92	15.29	15.58
Amhara	7.82	11.61	-4.14	0.00	7.82	8.94	9.98	10.93	11.80	12.59	13.30	13.92	14.46	14.92	15.29	15.58
Oromia	7.82	11.61	-4.14	2.57	10.39	11.51	12.55	13.50	14.37	15.16	15.86	16.49	17.03	17.48	17.86	15.58
SNNPR	7.82	14.35	-4.14	0.00	7.82	9.22	10.53	11.76	12.90	13.96	14.94	15.84	16.66	17.39	18.04	18.60

Figure 17 is a graphical representation of the wheat yield calculations of the four regions, which are described in Table 11.

Figure 13. Regional wheat yield response to fertilizer and seasonal rainfall

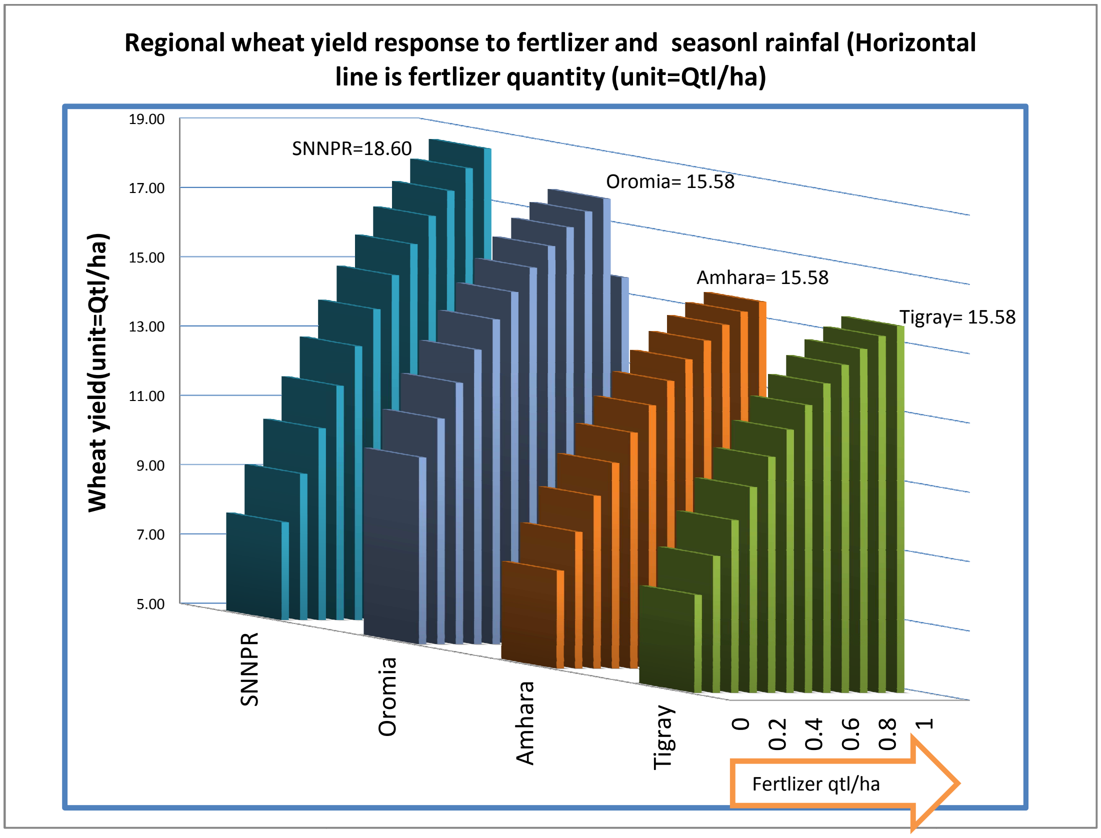


Table 12 presents a comparison between the 14 year average level of fertilizer used per fertilized hectare, the profit maximizing level for 2012, and the yield maximizing level. The recommend application levels are also shown. As anticipated, the actual levels are below the profit maximizing levels. The profit maximizing levels are below the recommended levels. The average application levels for teff appear to be closer to the profit maximizing levels for teff than they are for wheat.

Table 8. Comparison of actual, profit maximizing, and recommended levels of fertilizer for wheat and teff by region.

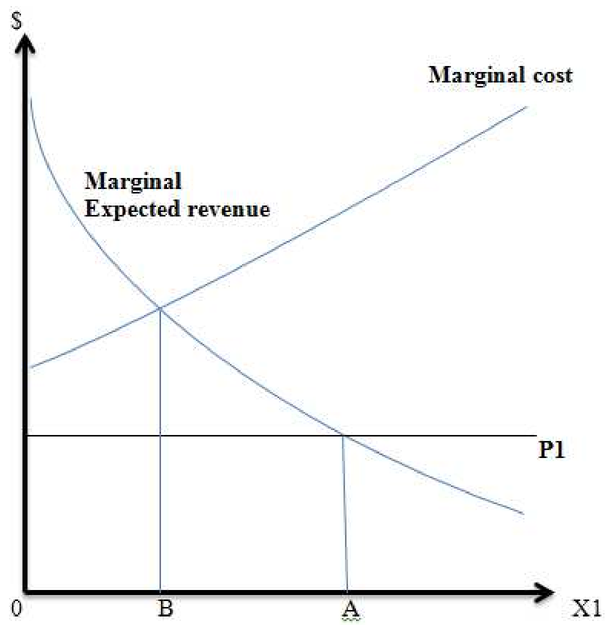
Region	Crop	Fertilizer Quantity Per Hectare(Urea+Dap)			
		Actual Average	Profit Maximizing	Recommended	Maximizing Yield
Tigray	Teff	0.70	0.78	2.00	0.82
	Wheat	0.91	1.26	2.00	1.40
Amhara	Teff	0.74	0.78	2.00	0.82
	Wheat	1.07	1.24	2.00	1.40
Oromia	Teff	0.80	0.83	2.00	0.86
	Wheat	0.91	1.22	2.00	1.40
SNNPR	Teff	0.74	0.79	2.00	0.82
	Wheat	1.00	1.55	2.00	1.70

The reasons that actual fertilizer levels are below the profit maximization level are often attributed to risk aversion and capital limitation. However, the regions agro-ecological environment is different; the national extension program recommendation is about two quintals (1 qtl urea+1 qtl dap) of fertilizer per hectare. (Demeke, et al., 1997). This quantity is far beyond from the actual average and the estimated profit maximizing, and the yield maximizing level of fertilizer.

5.4 Operating conditions under risk and optimum quantities.

The expected sources of risk that would retard fertilizer use are variations in prices of inputs and outputs, and from yield variability (heterogeneity) that either increases or decreases with the level of fertilizer. Input price risk was ignored because it was assumed the producer knew the cost of fertilizer at the time of application. The data were insufficient to detect any change in the variance of yield with the level of fertilizer. However, analysis of national prices did detect the presence of significant price variability for both wheat and teff. The effect of this product price variability on the use of fertilizer is analyzed below. From the 1994 through 2010 the variance in the annual prices for wheat and teff were 20,011 and 45980 respectively. The graphical concept of total MFC with risk is shown in Figure 18, which is taken from Dillon's book (Dillon, 1977, Dillon and Anderson, 1990). In this concept while a risk neutral producer would apply quantity A, while a risk-averse producer would apply only quantity B.

Figure 14. Effect of risk on best operating condition for a risk-averse decision maker



To meet the best operating condition under risk, it requires equating the marginal expected value of the product to be equal to marginal cost of risk (i.e. direct marginal cost, P_{1}, plus price variability).

$$MVP= MFC + (RSU_{EV)}\, 2{*}Var\,(Py){*}Y{*}MPP$$

MPP= (d Y/d f_t) can be expressed as MPP= $b+2Cf_t$

Where; Var (Py) = Variance of product price

Py = price of yield

MFC = price of input

MPP =Marginal physical product

MVP =Marginal Value of the product

Y =Yield

- In the presence of only price risk, as used in this this study, the marginal risk component added to regular MFC is the ($RSU_{EV)}$ 2*Var (Py) Y MPP interaction element of price risk. RSU_{EV} is the decision maker's risk evaluation, which depends of the change in profit and the variability of product price, yield and marginal yield.

$$RSU_{EV} = \frac{dE(\pi)}{2*Var(Py)*Y*MPP} \quad \text{Where; } dE(\Pi) = VMP - MFC$$

- Following Dillon's formula, the vertical distance between the VMP curve [Py_t ($b+2*\beta_2 f_t$)] and the MFC_t curve in year t (VMP_t-MFC_t) is equal to

$$RSU_{EV}\,[2*Var(Py)*Y_t*MPP_t\,]$$

- The values in the square brackets are known or can be estimated. Thus the regression of the form is:

$$VMP = MFC + (RSU_{EV})\,[2*Var(Py)*Y*MPP]$$

Or $(VMP_t - MFC_t) = \beta X_t$

Where; $X_t = 2*Var(Py)*Y*MPP$ and $B = RSU_{EV}$

This process has two major limitations. The first one is other factors such as credit limits and or lack of knowledge are incorporated into the estimate of RSU_{EV}. However, in this sense, the estimate of RSU_{EV} can be taken as an upper bound. A second limitation is that the estimate of RSU_{EV} is recursive. It relies on the previous estimate of the response function. The equation above represents a wedge between the risk and profit maximizing levels of fertilizer. All of the terms in equation above are known except the producer's tradeoff between risk and profit (RSU_{EV}). This is a term that depends on individual preferences.

(Binswanger and Sillers, 1983) argued that farmers in developing countries are risk-averse. Thus, it was felt that an empirical estimate of the term RSU_{Ev} could be obtained by comparing differences between applied and profit maximizing levels of fertilizer. The process involves the derivation of a term that explains the effect of price risk on the gap between the optimal and the actual fertilizer level or rather the vertical distance between the VMP curve and the price of fertilizer. Table 13 shows the calculation of optimum quantities under risk and marginal cost of risk.

Based on the actual average quantity of fertilizer for teff (0.8) and for wheat (0.91) The RSU_{EV} for teff (0.00027) and for wheat (0.00063) is determined for Oromia.

For Teff $RSU_{EV} = \frac{562.81}{2070641} = 0.00027$

For wheat $RSU_{EV} = \frac{1533.8}{2449976} = 0.00063$

The Average $RSU_{EV} = (0.0027+0.00063)/2 = 0.00045$

- The average RSU_{EV} (0.00045) of the above calculation is used to calculate the farm level optimum level of fertilizer with risk and to determine marginal cost of risk.

- The optimum quantity of fertilizer with risk, 0.7472 for teff and 1.0633 for wheat are calculated using Excel solver tool by equating the (MVP-MFC of risk =0) and solving for the quantity.
- The optimum quantity of fertilizer without risk, 0.8287 for teff and 1.2247 for wheat are also calculated by Excel solver tool by equating (MVP-MFC=0).

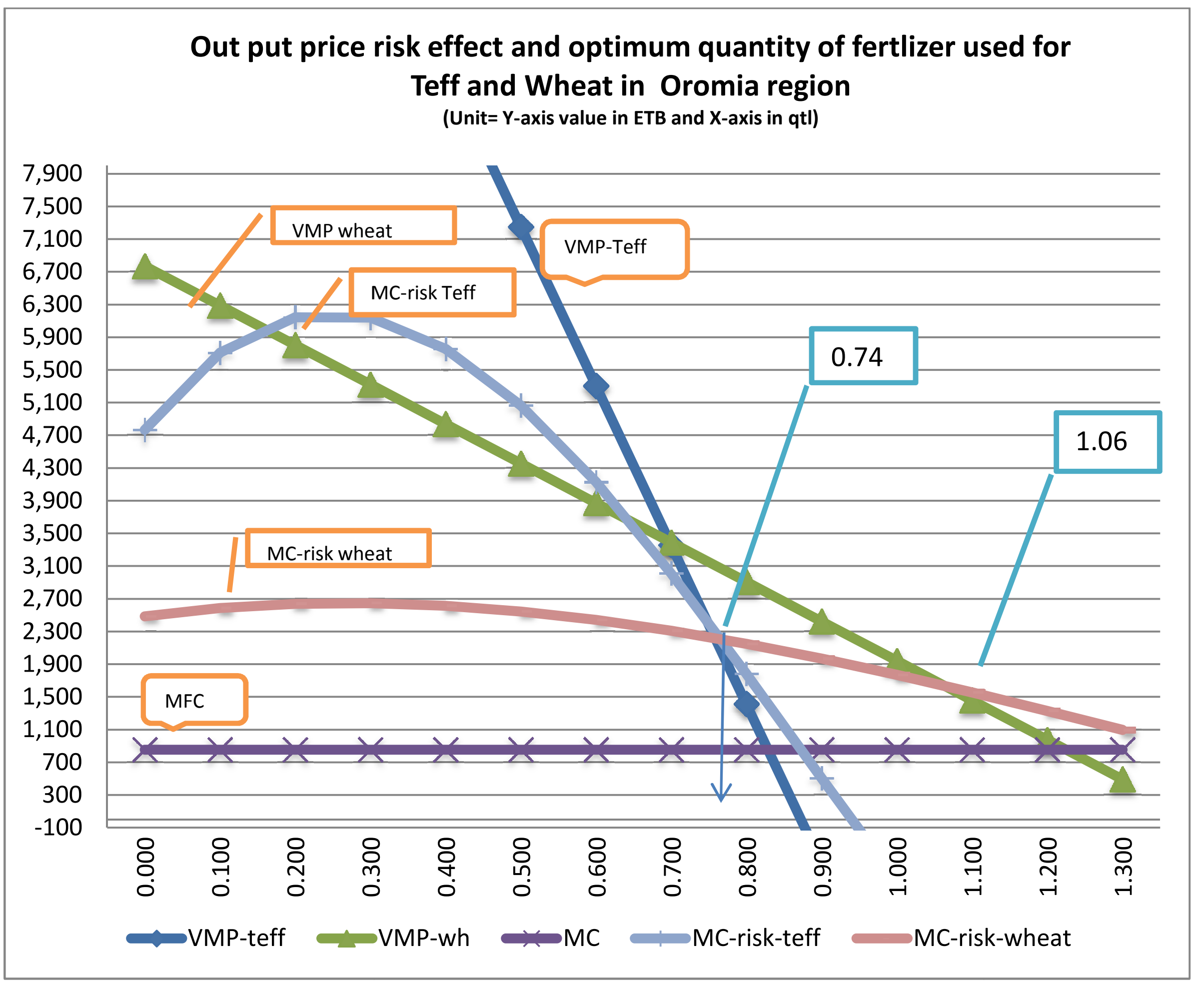
Table 9. the optimum fertilizer level and risk calculation for teff and wheat in Oromia region

	Fert qtl/ha	Yeild-teff/ql	Exp-prof-teff	MPP-teff	VMP-teff	Mar Pro-teff	Yeild-wh/ql	Exp-prof-wh	MPP-wh	VMP-wheat	Mar Pro-wheat	2(Var(py)* Yld*MPP.teff	RSU-teff	RSU-wh	MC	MC-risk-teff	MC-risk-wheat
Oromia	0.00	4.71	2,983	20.09	16,979	16,124	7.82	3562	11.61	6,770	5,915	3,634,092			855	4766	2486
	0.10	6.61	4,484	17.79	15,033	14,179	8.94	4129	10.78	6,287	5,432	3,857,812			855	5709	2587
	0.20	8.27	5,790	15.49	13,088	12,233	9.98	4648	9.95	5,804	4,949	3,974,353			855	6145	2639
	0.30	9.71	6,902	13.19	11,142	10,287	10.93	5119	9.12	5,321	4,466	3,991,948			855	6139	2647
	0.40	10.91	7,818	10.88	9,196	8,342	11.80	5541	8.30	4,838	3,983	3,918,830			855	5757	2614
	0.50	11.88	8,541	8.58	7,251	6,396	12.59	5916	7.47	4,355	3,500	3,763,232			855	5064	2544
	0.60	12.63	9,069	6.28	5,305	4,450	13.30	6241	6.64	3,872	3,017	3,533,387			855	4127	2441
	0.70	13.14	9,402	3.98	3,359	2,505	13.92	6519	5.81	3,389	2,534	3,237,528			855	3011	2308
	0.80	13.42	9,541	1.67	1,414	559	14.46	6748	4.98	2,906	2,051	2,883,887			855	1782	2149
	0.90	13.47	9,485	-0.63	(532)	(1,387)	14.92	6929	4.16	2,423	1,569	2,480,699			855	505	1968
	1.00	13.30	9,234	-2.93	(2,478)	(3,332)	15.29	7062	3.33	1,940	1,086	2,036,194			855	-755	1769
	1.10	12.89	8,789	-5.23	(4,423)	(5,278)	15.58	7146	2.50	1,458	603	1,558,608			855	-1930	1555
	1.20	12.25	8,149	-7.54	(6,369)	(7,224)	15.79	7183	1.67	975	120	1,056,172			855	-2957	1329
	1.30	11.38	7,315	-9.84	(8,315)	(9,169)	15.92	7170	0.84	492	(363)	537,119			855	-3768	1096
Actual Avge	0.80	13.42	9,540	1.68	1,418	563	14.46	6748	4.99	2,907	2,052	2,884,647	0.00027		855	1784	2150
qty for RSU	0.91	13.47	9,473	-0.80	(672)	(1,527)	14.95	6940	4.10	2,389	1,534	2,449,976		0.00063	855	413	1955
																	0
with risk	0.75	13.30	9,492	2.89	2,441	1,586	14.18	6633	5.42	3,161	2,307	3,077,346			855	2441	2236
optimum	1.06	13.06	8,975	-4.39	(3,710)	(4,565)	15.48	7121	2.80	1,635	780	1,737,019			855	-1513	1635
																	0
without	0.83	13.46	9,544	1.01	855	(0)	14.60	6805	4.75	2,768	1,913	2,772,778			855	1417	2100
risk	1.22	12.05	7,961	-8.11	(6,852)	(7,707)	15.83	7184	1.47	855	(0)	928,593			855	-3181	1272

Source: Author's calculation based on regression results

Figure 18 shows the graphic presentation of the above Table 12. The intersection point of VMP-teff and MC-risk teff, which is 0.74 is the optimum quantity of fertilizer for teff. The intersection point of VMP-wheat and MC-risk which is 1.06 quintals is the optimum quantity of fertilizer for wheat. The Horizontal line is the Marginal cost (cost of fertilizer).

Figure 15. Output price risk effect and optimum quantity of fertilizer used for teff and wheat in the Oromia region



Source: Author’s calculation based on regression results

Figure 14 shows the optimum level of fertilizer under risk to produce teff and wheat in SNNPR region as it calculated in similar manner for Oromia.

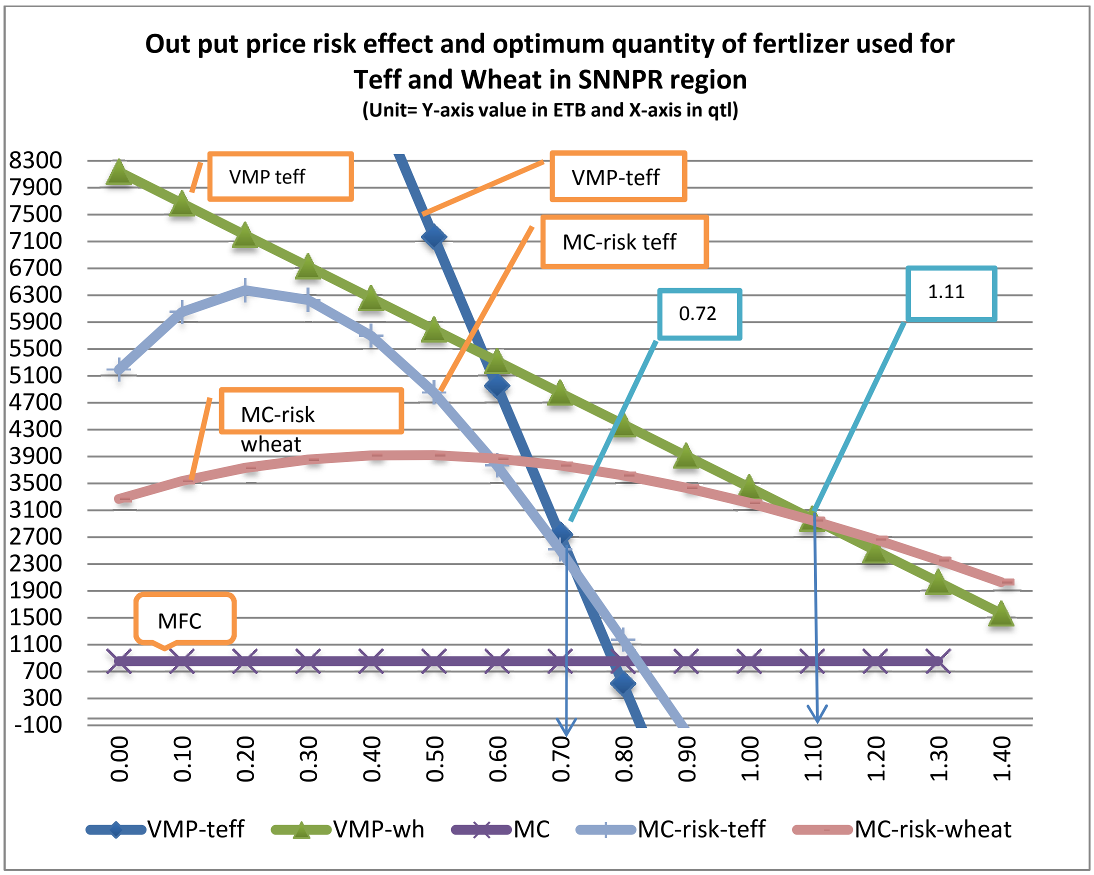
Table 10. The optimum fertilizer level and risk calculation for teff and wheat in Oromia region

	fert qtl/ha	yeild-teff/ql	yeild-wh/ql	ExP-proF-teff	ExP-proF-wheat	MPP-teff	MPP-wheat	VMP-teff	VMP-wheat	Mar Pro-teff	Mar Pro-wheat	2(Var(py)* Yld*MPP.teff	2(Var(py)* Yld*MPP.wh	RSU-teff	RSU-wheat	MC	MC-risk-teff	MC-risk-wheat
SNNPR	0.00	4.91	7.82	2722	6436	18.97	14.35	18249	8140	17395	7286	8477601	4717284			854	5195	3269
	0.10	6.69	9.22	4351	7141	16.66	13.53	16033	7671	15180	6817	10151976	5237323			854	6053	3536
	0.20	8.24	10.53	5758	7799	14.36	12.70	13818	7201	12964	6347	10777874	5616193			854	6373	3730
	0.30	9.56	11.76	6944	8411	12.06	11.87	11602	6731	10748	5878	10500192	5862536			854	6231	3856
	0.40	10.65	12.90	7908	8975	9.75	11.04	9386	6262	8532	5408	9463826	5984994			854	5700	3919
	0.50	11.51	13.96	8650	9492	7.45	10.21	7170	5792	6317	4938	7813670	5992210			854	4855	3922
	0.60	12.14	14.94	9171	9962	5.15	9.39	4955	5323	4101	4469	5694620	5892826			854	3770	3871
	0.70	12.54	15.84	9470	10386	2.85	8.56	2739	4853	1885	3999	3251572	5695484			854	2519	3770
	0.80	12.71	16.66	9548	10762	0.54	7.73	523	4383	-331	3530	629421	5408828			854	1176	3624
	0.90	12.65	17.39	9404	11092	-1.76	6.90	-1693	3914	-2546	3060	-2026937	5041499			854	-184	3436
	1.00	12.36	18.04	9039	11374	-4.06	6.07	-3908	3444	-4762	2590	-4572607	4602140			854	-1488	3211
	1.10	11.84	18.60	8452	11610	-6.36	5.25	-6124	2975	-6978	2121	-6862694	4099394			854	-2660	2953
	1.20	11.09	19.09	7643	11798	-8.67	4.42	-8340	2505	-9194	1651	-8752302	3541902			854	-3628	2668
	1.30	10.10	19.49	6613	11940	-10.97	3.59	-10556	2035	-11410	1182	-10096535	2938307			854	-4316	2359
	1.40	8.89	19.80	5361	12035	-13.27	2.76	-12771	1566	-13625	712	-10750499	2297252			854	-4651	2030
Actual Avge	0.74	12.63	16.16	9525	10532	1.98	8.25	1909		1055		2282907	5598142	0.00046		854	2023	3721
qty for RSU	1.00	12.35	18.05	9028	11380	-4.11	6.06		3434		2580		4591730		0.00056	854	-1515	3205
		4.91																
with risk	0.72	12.60	16.05	6187	10483	2.28	8.35	2195	4738	1341	3884	2618876	5633052			854	2195	3738
optimum	1.11	11.77	18.66	8374	11633	-6.62	5.15	-6368	2923	-7222	2069	-7092863	4040571			854	-2778	2923
without	0.79	12.70	16.54	9551	10709	0.89	7.85	854	4454	0	3600	1026499	5456947			854	1379	3648
risk	1.55	6.62	20.13	3041	12089	-16.76	1.51	-16131	854	-16985	0	-10101312	1273111			854	-4319	1506

Source: Author's calculation based on regression results

Figure 19 below presents the intersections of the optimum quantities of fertilizer calculated in the Table 14 above. The intersection point of VMP-teff and MC-risk teff , 0.72 quintals is the optimum quantity of fertilizer for teff. The intersection point of VMP-wheat and MC-risk, 1.11quintals is the optimum quantity of fertilizer for wheat.

Figure 19. Output price risk effect and optimum quantity of fertilizer used for teff and wheat in SNNPR region



Source: Author's calculation based on regression results

5.5. Price risk effect on fertilizer use and crop yield by regions

Based on the above yield response to fertilizer of the two crops in four regions the economic optimum quantity of fertilizer under price risk is determined. Since, the variance of yield to additional units of fertilizer couldn't be significantly estimated; this study measured the effect of product price risk effect only. The consequence of product price risk is assessed from three major economic points of view as listed below

- The effect of product price risk on farm level income
- The quantity of yield that would have been gained if the product price risk was absent
- Possible gain would have been achieved if 15% more land were fertilized in the past year.

Table 15 compares the optimum quantity of fertilizer with risk, without risk and its consequence on reducing farmers' net income. The optimum quantity of fertilizer with risk for both crops calculated based on Dillon's example is taken from Table 13 and 14. Oromia and SNNPR actual average fertilizer level for teff and wheat is greater than other regions respectively.

Table 11. Estimated farm level net income lost due to price risk in the four regions

Region	Crop	Fertilizer Quantity Per Hectare				MPP Difference With And Without Risk Qty/Ha	Value Of Marginal Yield Qty/Ha	Marginal Cost In ETB	Increase In Net Farm Income In ETB
		Actual Average	Optimal Without Risk	Optimal With Price Risk	Reduced Due To Price Risk				
TIGRAY	TEFF	0.697	0.784	0.690	0.094	2.162	2066	83	1983
	WHEAT	0.911	1.258	0.934	0.324	2.683	1975	285	1691
AMHARA	TEFF	0.737	0.780	0.691	0.089	0.735	648	79	569
	WHEAT	1.072	1.238	1.129	0.110	0.908	594	97	497
OROMIA	TEFF	0.800	0.829	0.747	0.082	1.878	1586	70	1517
	WHEAT	0.907	1.225	1.063	0.161	1.337	780	138	642
SNNPR	TEFF	0.737	0.785	0.725	0.061	1.394	1341	52	1289
	WHEAT	1.002	1.552	1.111	0.441	3.649	2069	376	1693

Source: Author's calculation based on regression results.

Table 16 below displays, the estimated quantity of yield would have been gained in year 2012 if price risk was avoided. Moreover, it indicates the potential marginal production gain among four regions. For example SNNPR and Oromia regions exhibited higher marginal production advantages for wheat and teff respectively. This implies, from the countries' and the farmers' economic point of view on missing opportunities, the price risk effect has had a more adverse impact in regions that have higher relative advantage in yield response to fertilizer. Oromia and SNNPR actual average fertilizer level for teff and wheat is greater than other regions respectively

Table 12. Estimated quantity of crop that would have been gained if price risk were absent

Region	Crop	Total Hectare Planted In Year 2012	Estimated Portion Fertilized Per Ha In Year 2012	Estimated Hectare Fertilized In Year 2012	Reduced Qty Of Fertilizer Due To Price Risk	Estimated Total Qty Of Fertilizer Reduced	MPP Difference With And Without Risk (Qtl/Ha)	Estimated Qty Of Yield Would Have Been Gained If Price Risk Was Avoided	
								Teff (Qtl/Ha)	Wheat (Qtl/Ha)
Tigray	Teff	161,798	0.483	78,206	0.094	7,344	2.162	15,880	
	wheat	111,846	0.617	69,009	0.324	22,359	2.683		59,988
Amhara	Teff	1,090,140	0.500	544,634	0.089	48,313	0.735	35,488	
	wheat	498,192	0.636	316,651	0.110	34,703	0.908		31,494
Oromia	Teff	1,256,565	0.613	770,184	0.082	62,799	1.878	117,907	
	wheat	872,972	0.720	628,851	0.161	101,546	1.337		135,780
SNNPR	Teff	202,376	0.540	109,225	0.061	6,611	1.394	9,213	
	wheat	138,351	0.784	108,458	0.441	47,789	3.649		174,362
	Total quantity of crop					***331,463***		***178,488***	***401,624***

Source: Author's calculation based on regression results and CSA (2012).

Table 17 shows the possible increase in production per hectare by increasing fertilized land by 15%. It also shows that the proportional fertilized land differences between the regions. It also shows regional yield differences from fertilized and unfertilized land. For example, the estimated fertilized wheat yield to exceeds the unfertilized wheat yield by 10.12 kg/ha in Tigray, 11.01 kg/ha in Amhara, 10.2 kg/ha in Oromia, and 11.37 kg/ha in SNNPR.

Table 13. Estimated quantity of yield that would have been added if 15% more land were fertilized.

Crop	Average Actual Hectare			Estimated Yield Per Hectare(Qtl/Ha)		Yield Gain Due To Fertilizer Per Hectare	Allocated Hectare In Year 2012	Estimated Unfertilized Portion	Possible Gain In Yield Per Qtl If 15% More Land Was Fertilized
	Region	Portion Fertilized	Fertilizer Qty	From Fertilized	From Unfertilized				
Wheat	Tigray	0.62	0.91	17.18	7.01	10.17	111,846	42,837	65,321
	Amhara	0.64	1.07	18.02	7.01	11.01	498,192	181,541	299,761
	Oromia	0.72	0.91	18.54	8.35	10.20	872,972	244,120	373,453
	SNNPR	0.78	1.00	18.38	7.01	11.37	138,351	29,894	50,976
Total Wheat									***789,511***
Teff	Tigray	0.48	0.70	10.48	6.61	3.87	161,798	83,592	48,491
	Amhara	0.50	0.74	10.56	6.61	3.95	1,090,140	545,506	323,251
	Oromia	0.61	0.80	10.93	5.83	5.10	1,256,565	486,380	372,167
	SNNPR	0.54	0.74	10.59	6.61	3.98	202,376	93,151	55,555
Total Teff									***799,464***

Source: Author's calculation based on regression results and CSA (2012).

Table 18 shows the percentage increase in total production of wheat and teff if price risk was absent and 15% more land was fertilized than in year 2012. In this case, it is necessary to notice that the actual calculation applies only to 15% of unfertilized land. Thus, the total projected increase is less than 15% of the total hectare allocated in 2012. For example, in the Tigray region, the unfertilized portion of land for wheat is equal to 0.383 % (1-0.617) of the total hectare, which is 42,837 hectares. Then, this unfertilized portion (42,837* 15%=6,426) hectares of land were actually proposed to receive fertilizer. It was about 5.7% (6,426/111,846) of the total hectares allocated for wheat.

Table 14. Percentage estimated production gain that could have been achieved in year 2012 if price risk was absent and 15% additional land was fertilized.

Region	Crop	Estimated Hectare Fertilized In Year 2012	Estimated Fertilized Yield (Qtl/Ha)	Estimated Total Yield (Qtl/Ha)	Possible Gain In Yield Per Qtl If 15% More Land Was Fertilized	Estimated Qty Of Yield Would Have Been Gained If Price Risk Was Absent (Qtl)	Total Percentage Gain That Would Have Been Added: If Price Risk Was Absent (Qtl)	If 15% More Land Was Fertilized (Qtl)	If 15% More Land Was Fertilized And Price Risk Was Absent (Qtl)
Tigray	Teff	78,206	10.48	819,493	48,491	15,880	1.94	5.92	7.85
	wheat	69,009	17.18	1,185,420	65,321	59,988	5.06	5.51	10.57
Amhara	Teff	544,634	10.56	5,752,312	323,251	35,488	0.62	5.62	6.24
	wheat	316,651	18.02	5,706,016	299,761	31,494	0.55	5.25	5.81
Oromia	Teff	770,184	10.93	8,421,582	372,167	117,907	1.40	4.42	5.82
	wheat	628,851	18.54	11,661,538	373,453	135,780	1.16	3.20	4.37
SNNPR	Teff	109,225	10.59	1,156,400	55,555	9,213	0.80	4.80	5.60
	wheat	108,458	18.38	1,993,464	50,976	174,362	8.75	2.56	11.30

Source: Author's calculation based on the results and CSA (2012).

Finally, the result of this study shows, from the four of major crop growing regions, Oromia and SNNPR have exhibited a significantly different crop yield response to fertilizer in teff and wheat respectively. Consequently, in addition to many other problems, the countries food security efforts are affected by the instability of prices. Numerically, the crop price risk of wheat and teff estimated to cause 331,468 quintals less use of fertilizer in the four major crop growing regions. Consequently, these four regions lost about 178,488 quintals of teff and 401,624 quintals of wheat that would have been gained from 1,502,249 and 1,122,969 hectares of fertilized portion of land in the year 2012. This indicates that holding all other factors the same, maintaining only crop price stability can increase the supply of food for the country while striving to attain sustainable food security. Furthermore, keeping all other thing the same including the existing price risk, increasing 15% of fertilizer use in year 2012 would have been added 789,511 quintals of wheat and 799,464 quintals of teff for the four regions. This quantity account for the potential production lost out of total production in 2012 was about 5.92%, 5.62 %, 4.42 %, and 4.8 % from teff production and 5.1%, 5.25%, 3.2%, and 2.56% from wheat production in region Tigray, Amhara, Oromia and SNNPR respectively.

5.6. Policy Implications

Ethiopian food security endeavors have taken place over several political regimes and changes in policies all designed to increase the availability and use of fertilizer. However, the recent experience, where large amount of fertilizer was imported and made available to farmers, didn't' cause the farmers to use more fertilizer as it was intended. Consequently, the huge supply of fertilizer ended up with a huge volume of carry overs, (Rashid, et al., 2013).Therefore, alternative polices and directions need to be developed.

According to the results of this study, the recommended quantity of fertilizer is far beyond the profit maximizing level. Therefore, this study recommends zonal level experiments designed to find more realistic recommendations of fertilizer applications based on the following points.

- Examining the yield response to fertilizer by using at least three different quantities of fertilizer in each location. The tests should be replicated. Response functions should be estimated by statistical analysis.

- Experiments should be repeated by varying other inputs such as common varieties, improved varieties, soil type and pesticides.

Based on these experiments more precise yield response functions can be estimated to make local adjusted and profit maximizing recommendations. Conceptually, increasing the use of fertilizer intending an increase yield needs to consider the farmers profit with risk and without risk. It is worth examining the actual operating environment of the small holder farmers' in developing policies to increase the food supply. New varieties that better respond to fertilizer may be part of the package.

However, the farmer is the ultimate decision maker on his farm; the farmer's decision about which crop to plant, which varieties to choose, and how much fertilizer to use depends on:

- the current input prices, the expected future crop prices,
- the expectation of rainfall,
- Weather induced risk
- Future output price risks.

In this study results, only maintaining price stability may not add more than about 5% to the total production, but this needs further more sub regional cost benefit analysis. However, an integrated policy measure to stabilize the output market price and to increase fertilizer adoption seems necessary option. Integrated strategy to address stability of prices and increase adoption of fertilizer on unfertilized land with conventional technology was estimated to add about 10 percent for the supply of food.

For example the stability of price and an increase of 15% more fertilized land estimated to rise about 5% to 8 % for teff, and 4% to 11% for wheat production.

The main limitations concerning the data were, the data available in CSA database were only fourteen years farm management and production survey data, price data in regional and zonal levels couldn't be found in any official data bases. This study recommends further study focusing on zonal level data including other variables like improved seed, farmers education level, extension access, and credit services.

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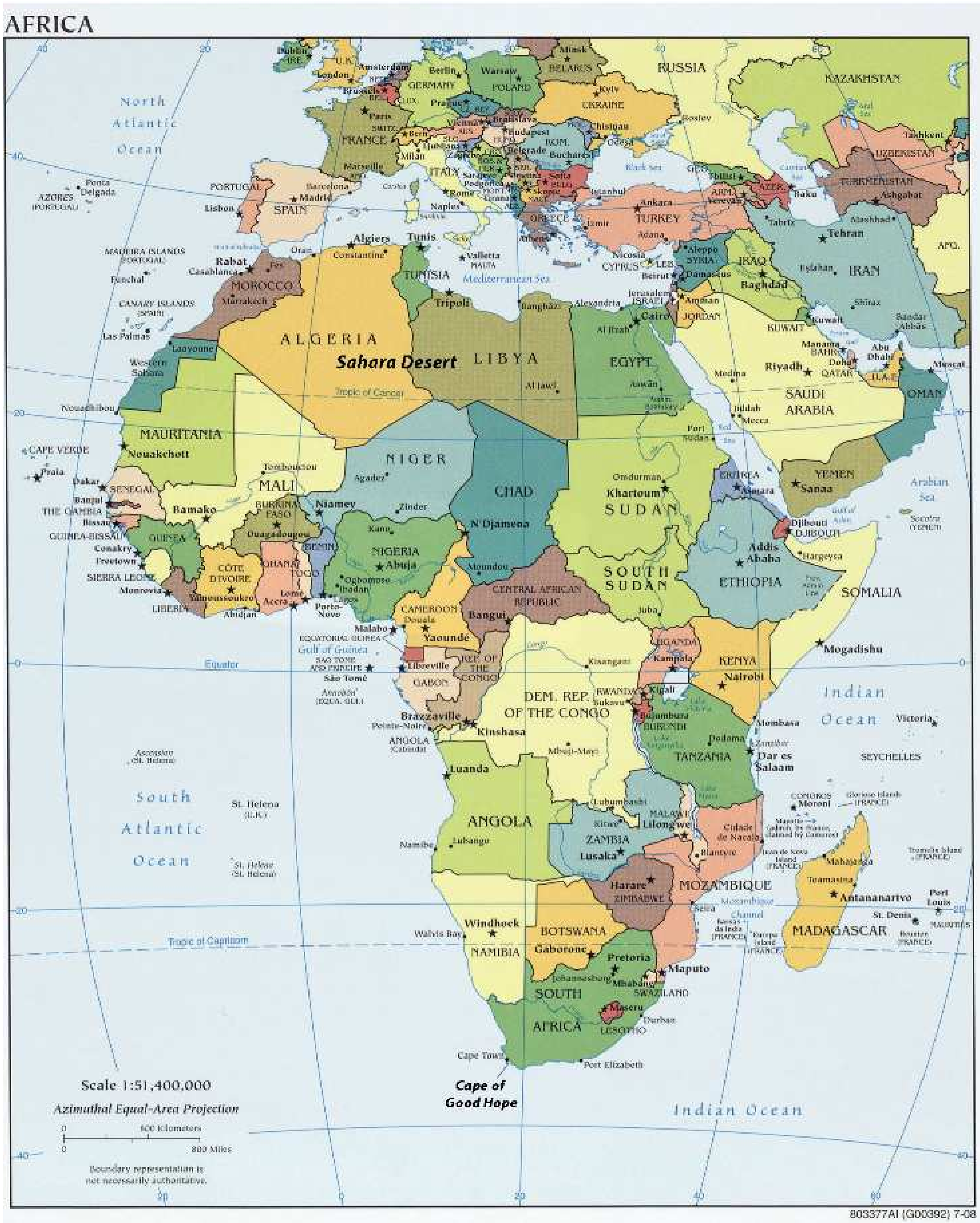
APPENDICES

Appendix .1. The regression model set up for *SAS* input

The regression analysis arranged in the following way. The unit of quantities of fertilizer and yield is measured in quintal per hectare, total area and fertilized areas are in hectares, and rainfall is by monthly average millimeter for the crop growing five months. This table describes the regression data for the base region, Tigray, all other regions data arranged on the same way

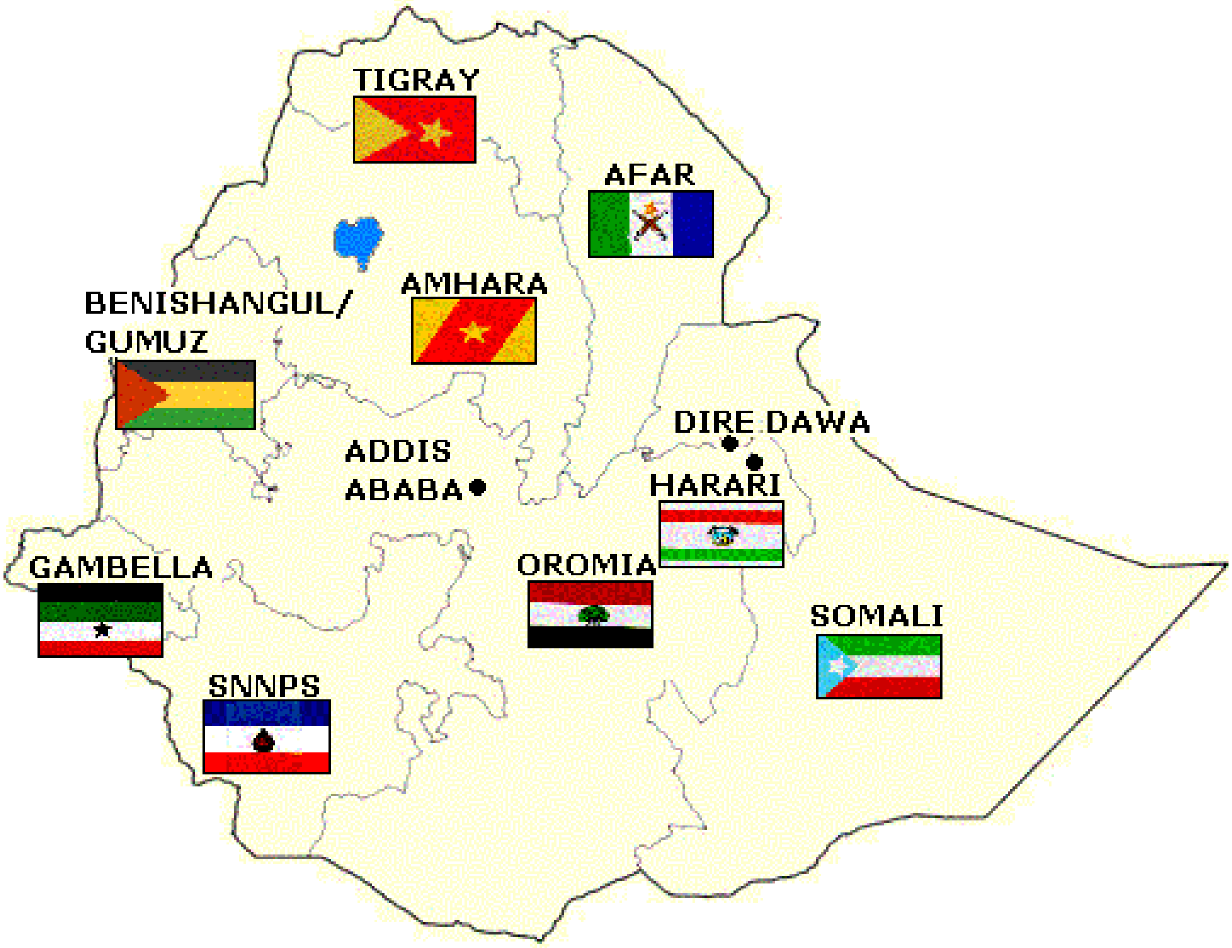
Regions	R-No	year	Crop type	Tot al area	Fertilized hectare	Qty of fertilizer	Proportion of qty of Fertilized	Fertilized prop of area	Fertilized proportion	yield	Rain fall –June -Oct	Dummy Regions from R1 to R11	Dummy to test Regional fertilizer is different from region to region	Dummy Regional fertilizer to test if quadratic term is different from each region
TIGRAY	1	1995	Teff	87880	18520	16510	0.21	0.89	0.80	6.92	29.90	1.00	0.89	0.80
TIGRAY	1	1996	Teff	99500	29730	33080	0.30	1.11	1.24	7.81	32.24	1.00	1.11	1.24
TIGRAY	1	1997	Teff	119340	50450	57060	0.42	1.13	1.28	5.86	30.76	1.00	1.13	1.28
TIGRAY	1	1998	Teff	140830	58550	58060	0.42	0.99	0.98	8.02	38.63	1.00	0.99	0.98
TIGRAY	1	1999	Teff	126440	54160	45510	0.43	0.84	0.71	9.13	26.86	1.00	0.84	0.71
TIGRAY	1	2000	Teff	141010	70660	57600	0.50	0.82	0.67	7.43	19.32	1.00	0.82	0.67
TIGRAY	1	2003	Teff	136740	65337	42546	0.48	0.65	0.42	7.66	23.05	1.00	0.65	0.42
TIGRAY	1	2004	Teff	137360	64724	32673	0.47	0.51	0.26	6.42	18.58	1.00	0.51	0.26
TIGRAY	1	2005	Teff	138346	81008	44917	0.59	0.55	0.31	8.99	21.42	1.00	0.55	0.31
TIGRAY	1	2006	Teff	160741	83126	45304	0.52	0.55	0.30	9.79	24.10	1.00	0.55	0.30
TIGRAY	1	2007	Teff	178742	101188	52329	0.57	0.52	0.27	12.77	30.14	1.00	0.52	0.27
TIGRAY	1	2008	Teff	183376	96448	57804	0.53	0.60	0.36	12.69	20.59	1.00	0.60	0.36
TIGRAY	1	2009	Teff	187859	115081	65571	0.61	0.57	0.33	10.86	22.84	1.00	0.57	0.33
TIGRAY	1	2010	Teff	165803.8	121438	66897	0.73	0.55	0.30	12.64	34.40	1.00	0.55	0.30

Appendix.4 African countries Map



Source: http://2012books.lardbucket.org/books/regional-geography-of-the-world-globalization-people-and-places/section_10/5485909ace543738fd873ced8e09550b.jpg

Appendix 5 Ethiopian regions boundaries



Source: http://upload.wikimedia.org/wikipedia/om/a/a6/Regional_map_of_FDRE.gif

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