# An Ex-Ante Impact Assessment of *Striga* Control Technology for Sorghum Production in Ethiopia

by

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# Abstract

Sorghum (*Sorghum bicolor* L. Moench) is an important food security cereal crop in Sub-Saharan Africa (SSA). It is produced under adverse conditions such as low rainfall, arid and semi-arid environments which makes it the important food security crop in East Africa where agriculture and environmental conditions are unfavorable to produce other cereals. In Ethiopia, sorghum is the third most important staple crop next to teff and maize. The production of sorghum in Ethiopia is hampered by biotic and abiotic factors. Drought is the most important abiotic factor for sorghum production in Ethiopia. The parasitic weed, S*triga spp.*, is a major biotic factor affecting the production of sorghum where the impact sometimes is reported a total crop damage.

The objective of this study was to undertake an ex-ante impact assessment of S*triga* control technology for sorghum production in Ethiopia. Based on the economic surplus method, we have estimated the economic contribution of a sorghum supply shock as a result of the S*triga* control technology. We used the World Bank LSMS-ISA 2013/14 data as a base year to simulate the welfare effect of different scenarios on yield, adoption cost, adoption rate and probability of success. Sorghum, being a non-traded crop, the increase in supply as a result of the *Striga* control technology reduces the producer's surplus and increases the consumer's surplus. We have shown the impact of S*triga* control technology on farmer's welfare in ten different scenarios. In all the ten scenarios, producers will have a negative surplus even though the S*triga* control technology is assumed to increase sorghum production by 65%. However, the consumer surplus is positive. Since sorghum producers are also consumers, the net benefit of adopting the new technology is positive.

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# Dedication

This thesis is dedicated to my most beloved wife Asegedech Yilak, to my children Wuhibt Mariam, Nahom, Amen, and my dad Gebru Kassie. A special dedication is to my late mom Zimam Nega whom I lost her when I was on the study leave and my late mother in law Mulu Mariye.

# Acronyms

| | |
|---|---|
| AATF | African Agricultural Transformation Foundation |
| Br | Birr (Ethiopian Currency) |
| CSA | Central Statistics Agency |
| CS | Consumer Surplus |
| DEA | Data Envelopment Analysis |
| EIAR | Ethiopian Institute of Agricultural Research |
| ESS | Ethiopian Socio-economic Survey |
| FAO | Food and Agriculture Organization |
| Ha | Hectare |
| HOPE | Health Opportunities for People Everywhere |
| HR | Herbicide resistant |
| ISC | Integrated Striga Control |
| ISM | Integrated Striga Management |
| KG | Kilogram |
| LSMS-ISA | Living Standard Measurement Survey-Integrated Survey on Agriculture |
| SNNP | Southern Nations and Nationalities People |
| SSA | Sub-Saharan Africa |
| USA | United States of America |

# Chapter 1 - Introduction

## 1.1. Motivation

Sorghum (*Sorghum bicolor L. Moench*) remains an important food security crop in Sub-Saharan Africa (SSA). Globally it is the fifth most important cereal and the dietary staple of around 500 million people (Worthmann et al.,2006). It is a staple crop for millions of people in Africa, South Asia and Central America and the second most important cereal in Africa(AATF,2011). Sorghum is produced under adverse condition such as low-rain fall, arid and semi-arid environments. These drought tolerance and adaptive attributes make sorghum an important food security crop in East Africa where agriculture and environmental conditions are unfavorable for the production of other cereals.

Sorghum is the third most produced cereal crop in Ethiopia following teff and maize. In some production years (2010/11-2011/12), sorghum was the second crop next to maize. Annually, Ethiopia produces at least 3 to 4 million tons of sorghum (Table 1.1).

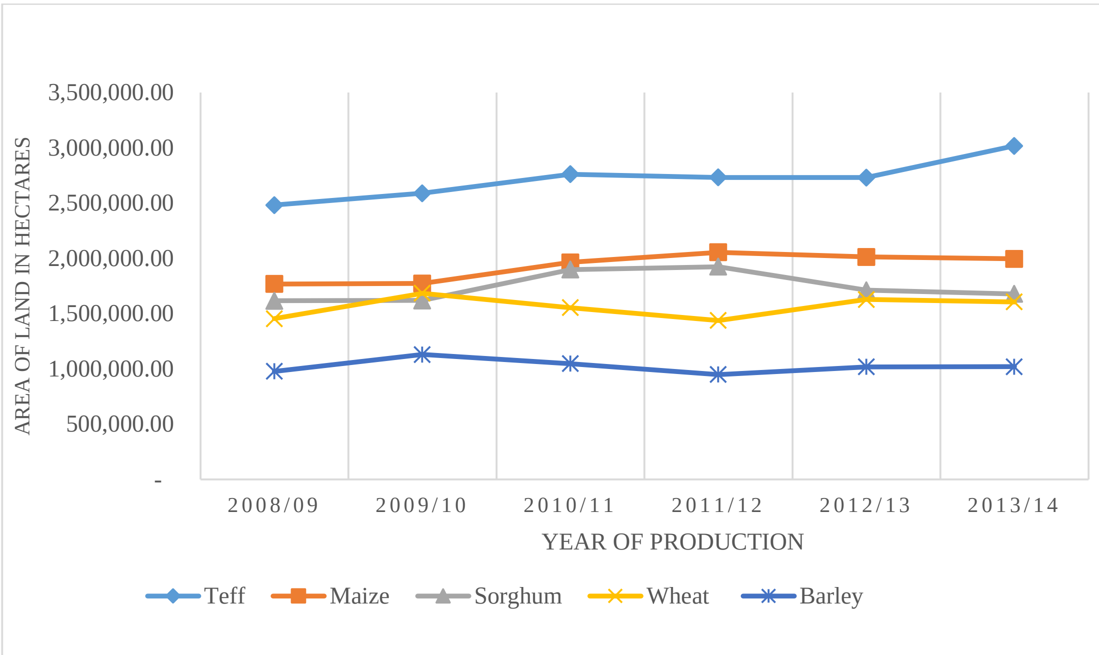
**Table 1.1: Trends of cereal production in Ethiopia from 2008/09-2013/14(tons)**

| Crop Name | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 3,337,936 | 3,504,783 | 3,840,017 | 3,855,678 | 4,150,614 | 4,870,890 |
| Maize | 4,335,015 | 4,296,037 | 5,496,455 | 6,690,617 | 6,788,621 | 7,155,949 |
| Sorghum | 3,091,376 | 3,275,374 | 4,365,193 | 4,355,709 | 3,973,158 | 4,220,755 |
| Wheat | 2,797,367 | 3,390,435 | 3,147,961 | 3,214,820 | 3,786,248 | 4,326,916 |
| Barley | 1,674,915 | 1,929,601 | 1,877,684 | 1,747,541 | 1,964,004 | 2,103,573 |

Source: CSA main season reports (2008/09-2013/14)

Teff production occupies the largest share of farm land followed by maize and sorghum farm lands measured in hectares (Figure 1.1). Table 1.1 and figure 1.1 shows the trends of land allocated to Ethiopian staple crop production and sorghum is the third

**Figure 1.1 : Total hectare of land allocated to the five cereal crops in Ethiopia (2008/09-2009/10)**




Source: CSA main season reports (2008/09-2013/14)

Maize has the highest yield (tons/ha) among the Ethiopian cereal crops. Whereas teff has the lowest yield (tons/ha) among the five staple cereal crops in Ethiopia (Table 1.2). The average sorghum yield was 2.22 tons/ha, maize 2.98 tons/ha and that of teff is 1.44 tons/ha (Table 1.2).

**Table 1.2: Trends of cereal crop yield (tons/ha)**

| Crop Name | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 1.35 | 1.35 | 1.39 | 1.41 | 1.52 | 1.61 |
| Maize | 2.45 | 2.42 | 2.80 | 3.26 | 3.37 | 3.58 |
| Sorghum | 1.91 | 2.02 | 2.30 | 2.26 | 2.32 | 2.52 |
| wheat | 1.92 | 2.01 | 2.03 | 2.24 | 2.33 | 2.69 |
| Barley | 1.71 | 1.71 | 1.79 | 1.84 | 1.93 | 2.06 |

Source: own computation based on CSA data (2008/09-2013/14)

Sorghum is a staple crop of particularly subsistence farmers in Ethiopia. It is the second most important crop for preparing injera next to teff (EIAR, 2014). It is the most consumable crop by the rural households (91%) compared to (9%) urban populations.

**Table 1.3: Percentage of one-week cereal consumption among rural and urban households in Ethiopia**

| Cereal crop | Rural | Urban |
|---|---|---|
| Teff | 46 | 54 |
| Wheat | 78 | 22 |
| Barley | 85 | 15 |
| Maize | 87 | 13 |
| Sorghum | 91 | 9 |

Source: World Bank LSMS-ISA, 2013/14

Sorghum is grown in all regions of Ethiopia between 400m and 2500m altitude. Since it provides more than one third of the cereal diet and almost entirely grown by subsistence farmers to meet the needs of food, income, feed, brewing, and construction purpose, increasing productivity and production is considered as a means of improving income and food security of the poor sorghum growing farmers (EIAR, 2014; McGuire,2005).

As evidenced in table (1.3), sorghum is one of the crucial food security crop in Ethiopia. However, the national average sorghum production of about 2 tons/ha (table 1.1) is far below the global average of 3.2 tons/ha(FAO,2005). According to the national survey data collected in collaboration by the World Bank and the Central Statistics Agency of Ethiopia, the average sorghum yield is 1 ton per hectare (World Bank LSMS-ISA, 2013/14). Different factors account for the low productivity per hectare. The major constraints that hinder sorghum productivity in the nation include drought, *Striga spp*., insect pests (stalk borer, midge, and shoot fly), disease (grain mold, anthracnose and smut), limited soil fertility, inadequate adoption of the existing improved seed varieties, lack of high yielding and good quality sorghum varieties, and post-harvest management.

In Ethiopia one of the major constraint to staple crop production is drought. Drought usually occurs in most marginal parts of the nation and at times leaves the country dependent on food aid. Over 80% of sorghum in Ethiopia is produced under severe to moderate drought stress conditions (EIRA, 2014). There are no studies that clearly estimate the total production loss of sorghum due to drought. However, the Ethiopian Institute of Agricultural Research reports that a total loss was observed in the regional state of Tigray, Mehoni area (EIRA, 2014).

The other major sorghum production constraint in Ethiopia is the witchweed (*Striga spp*.). *Striga* is the major biotic constraint in most sorghum growing areas where soil fertility and moisture stress are limiting factors (EIAR, 2014). *Striga* is a parasitic plant that affects the production of crops throughout Africa, India, South East Asia and Australia. The important food staple cereal crops of maize, sorghum, millet and rice as well as grain legumes are the primary hosts of *Striga*. Even though the genus *Striga* are described by 50-60 species, the most studied species due to their greatest economic importance are *S. hermonthica*, *S. asiatica, and S. gesrneioides* (Musselman, 1980). The genus *S. hermonthica* and *S. asiatica* affetcs cereal crops and they are originally from east Africa, specifically Sudan and Ethiopia, and S. *gesrneioides*, its origin thought in West Africa, affects legumes (Ejeta et al. 2007).

*Striga* infestation is high in sorghum producing areas of Ethiopia and the impact is estimated form 65-70% to total loss (Ejeta et al.,2007). Even though Striga is found in all over the world including in California, Florida and Carolinas of USA (Musselman L., 1980), the intensity of infestation, the impact on production, the area coverage increases from time to time in the African lands (Parker C., 2012). This parasitic weed can be controlled as evidenced by its near eradication in the United States (Parker C., 2012). Scientists consider the *Striga* problem in Ethiopia is more important in when compared to other Sub-Saharan countries due to low soil fertility and elevations (AATF, 2011).

Sorghum is a strategic crop for Ethiopian food security program. However, the parasitic weed *Striga* hampers the production and productivity of sorghum. Since it is one of the most consumed crop in the rural areas of the nation, increasing sorghum production and productivity by decreasing the impact of *Striga* needs to be a priority. Hence, in this paper we will undertake an ex-ante impact assessment of the impact of *Striga* controlling technology for sorghum production in the four major production areas of sorghum in Ethiopia: Tigray, Amhara, Oromia, and SNNP.

## 1.2. Statement of the problem

*Striga* is a major constraint for sorghum producing areas of Ethiopia and a threat to food security. The incidence of *Striga* and its impact on food security is known to the Ethiopian Agricultural Research Institute, which is the responsible institution to lead agriculture research in the country. Research to control *Striga* has been undertaken for more than two decades. But the adoption of the new technologies by farmers is very low. On the other hand, the weed continues to devastate sorghum farming communities (AATF, 2011).

Previous *Striga* research in Ethiopia was unable to address three main issues that may be considered as the main reason for poor adoption of the technology by farmers. First, there was no feasibility analysis. The recommended technology should be affordable by the sorghum producing households. Moreover, households are rational and need to maximize profit. Households will invest on the new technology if they can expect a positive profit. Most *Striga* research includes very little economic analysis, and limited information that can be used for basic comparison of benefits and costs. When it is included the net benefits overstated by ignoring transaction costs and underestimating labor costs and cost of land (De Groote H., 2007). Hence, there needs to be a thorough economic analysis on the impact of the new technology from multi-disciplinary professionals including but not limited to agronomists and socio-economic professionals, government officials, agricultural extension workers and farmers.

Second, previous research and funding allocation did not consider regional heterogeneity on the intensity of *Striga* infestation. The distribution and impact of the biotic constraint differs from region to region (Dalton.T, and Wakjira, A., 2013). Hence, the population of *Striga* in the four major sorghum producing regions Oromia, Amhara, Tigray and SNNP should be identified separately and policy makers need to look for differentiated strategies to combat the problem. The ex-ante impact assessment should also be undertaken at a regional level.

The third and most important problem that were not addressed in previous studies is that there was no national or regional level data that could quantify the intensity of *Striga* infestation and its economic impact. This problem will restrict the decision capacity of the government and international development agents who are the potential source of resource.

In this paper, we will undertake an ex-ante impact assessment of *Striga* controlling technologies for the four major sorghum producing regions of Ethiopia: Oromia, Amhara, Tigray and SNNP. Unfortunately, there is limited data at the national, regional, zonal or woreda levels that quantify the degree of infestation as well as the amount of economic loss. This is the most challenging aspect of this research. We extracted data from the World Bank Living Standard Measurement Survey-Integrated Survey on Agriculture (LSMS-ISA) and used data to develop different scenarios to show the impact of new technology on household welfare. Ex-ante analysis data is elicited from scientists, experts, extension workers and previous studies. In order to develop the scenarios, we used secondary data as the time and cost did not allow us to collect primary data.

This study will contribute to the literature in two ways. Previous studies focused entirely on agronomic solutions only and disregard the importance of multidisciplinary solutions to control *Striga*. The second contribution we tried to assess the impact of the striga control technology at regional level.

## 1.3. Organization of the paper

This study has five chapters. The first chapter discusses the rational of undertaking an ex ante impact assessment for *Striga* controlling technologies in Ethiopia and defines the problems. In the second chapter reviews of previous studies are discussed. The literature review is presented from general over view of *Striga,* followed by studies in Africa and finally *Striga* research in Ethiopia is presented. The third chapter presents the state of agriculture in Ethiopia, specifically, the state of cereal production and consumption is discussed based on data from the World Bank LSMS-ISA and Central Statistics Authority (CSA) of Ethiopia data. The fourth chapter discusses the economic surplus method and the source of data. Chapter five presents the data, results discussion and conclusion of the paper.

# Chapter 2 - Review of Related Literature

## 2.1. Origin and Incidence of *Striga*

*Striga* is a root parasitic plant more than 40 species in its genus (Ejeta G., 2007). The literature identified *S. hermonthica, S. asiatica, and S. gesnerioides* are the greatest threat to agriculture (Mohamed et al, 2007). Witchweeds (*Striga spp.*), an endemic parasitic weed of Africa, is recognized as the greatest food production constraint for Africa as it affects nearly 100 million hectares of land (Ejeta, G., 2007). Low soil fertility, light sandy soils, low rainfall areas and temperature ranges of 18-40 degrees Celsius are the most conducive conditions that help witchweeds to flourish (Mgonja et al., 2011). Striga seeds can hibernate in the soil for up to 20 years and are able to germinate shortly with moist conditions and a stimulus produced by the host plant (Mgonia et al., 2011).

## 2.2. *Striga* controlling methods

Different researchers summarized the various types of *Striga* controlling methods. Mgonja et al. (2011) summarizes the following *Striga* management practices in the Health Opportunities for People Everywhere (HOPE) project manual to increase the sorghum productivity in eastern Africa: *Striga* resistant sorghum varieties, improved soil fertility and soil moisture conservation practices, crop rotation, timely and effective weeding of sorghum fields in combination with hand pulling of *Striga* prior to flowering, and avoidance of the physical spread of Striga through animals, fodder, manure, and contaminated soil on tillage tools.

In an ex-ante impact assessment of a striga control in three East African countries, Tanzania, Uganda and Kenya, MacOpiyo et al. (2004) summarizes nine of the striga control technologies; manual weeding, fallow, crop rotation, intercropping, push-pull, soil fertility, genetic resistance, chemical control and seed dressing.

Oswald A. (2004) classified the striga control methods as direct and indirect control methods. If the striga control method attacks the parasite directly and has immediate effect on the striga density in the field but not on the crop yield, they are categorized as direct methods. Those methods that directly attack the parasitic includes resistant host crop varieties, chemicals (herbicides and ethylene), biological control agents, transplanting of host-crops, catch-cropping, and seed-dressing. Indirect methods that control striga through cropping systems and soil fertility management create a less favorable growing environment for striga. This includes crop rotations, inter-cropping, and soil fertility management.

## 2.3. Review of *Striga* management literatures in Africa

*Striga* attacks staple crops of maize, sorghum, pearl millet, upland rice, and cowpeas. It covers nearly 100 million hectares of the African Savanna and is recognized as the greatest biological constraint to food production in Africa (Ejeta, G. 2007). Striga infests a total area of 887,700 ha of land and causes annual production loss of 293,000 tons of milled rice in ten rain fed producing countries of Sub-Saharan Africa (SSA) (Rodenburg et al.,2016). According to Rodenburg et al., (2016), the estimated annual financial loss is $200,000 million with annual increase of US $30 million.

The African Agricultural Technology Foundation (AATF) undertook a feasibility study to develop, test and deploy herbicide resistant (HR) sorghum varieties for *Striga* control for selected countries of Sub-Saharan African (SSA) (AATF, 2011). The study estimates applying herbicide technology increases sorghum yield by 17.5% in Ethiopia and 36% for Mali and potentially generating income increase of US$10.96 million and US$ 83.3 million in Ethiopia and Mali respectively. Integrated Striga Management (ISM) is helpful to control striga if all the recommended methods are implemented in an integrated manner. The African Agricultural

Transformation Foundation reported an estimated loss of US $7 billion in SSA due to striga. Integrating biotechnology, breeding and agronomy to control striga in three African countries; (Ethiopia, Eritrea, and Tanzania), increases sorghum grain yield by 5.5 tons per hectare (Ejeta G.,2005). Mgonia et al. (2011) argue that Integrated Striga Management (ISM) practices require the knowledge of striga species popular in the region; monitoring and mapping of striga spread and damage; control decisions based on damage, cost of control methods and effectiveness; evaluation of effectiveness of the available control method; and importance of combining control methods to reduce striga population and damage.

In Kenya, intercropping maize with *Desmodium spp.*, that is, the fodder legumes silver leaf (*Desmodium uncinatum*) and Greenleaf (*Desmodium intortum*), or push-pull technology, dramatically reduces the infestation of maize by *Striga hermonthica* (Khan et al 2002, Khan et al 2017). Midega et al. (2015) also wrote on the impact of the climate- adapted companion cropping, the push-pull technology, reduces striga infestation, stem borers and improves soil fertility as well as forage grass benefits to smallholder farmers. Oswald A. (2004) discusses various types of striga control methods that could be adopted by smallholder farmers, the specific constraints facing farmers in adopting the improved farming technique, and striga control programs in western Kenya.

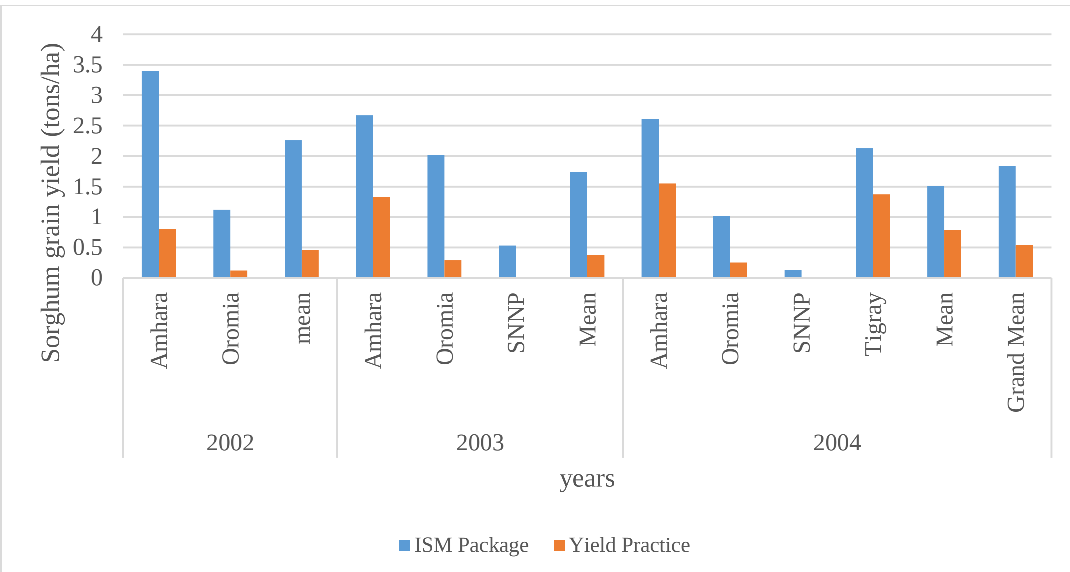
Parasitic weeds including striga cause the rice productivity losses ranging from 21% to 50%. Weeding labor inefficiency was estimated using the Data Envelopment Analysis(DEA) and the result shows farmers can save 58% - 69% weeding labor without reducing rice production (N'cho, 2014). Anderson J. and Halvarsson M. (2011) reports intercropping striga resistant maize with legumes as the most economically beneficial farming system in combating striga compared to five other controlling practices in western Kenya, namely, resistant maize grown in monocrops, intercropping non-resistant maize with legumes, non-resistant mon-crop, non-resistant maize with other intercrops, and fallow.

A study in northern Nigeria involving 33 state and local government extension agents and commercial seed companies working 42 communities involved to promote integrated striga control(ISC) showed that ISC improved crop productivity on average by 88% (Franke et al 2005). Franke et al. (2005) tested seed varieties, plant spacing, seed per hectare (seed rate), NPK fertilizer) integrated striga control technologies with 240 farmers in the Guinea savanna of northern Nigeria (Franke et al.,2005). Participatory approaches to striga management was practiced and assessed in northern Nigeria and north eastern Nigeria (Kamara et al., 2007; Douthwaite et al.,2006). Marley et al (2004) tested Fusarium oxysporum(isolte PSM 97)-based mycoherbicide in combination with selected sorghum varieties as an integrated striga management strategy in field trials in the Sudano-Sahelian savanna of Nigeria and found that integrated striga management significantly lowered striga infestation and improved crop stands. Striga emergence was reduced by about 95% and sorghum yields were increased by 49.6%. Eltayb et al. (2013), indicates Acacia seyal seeds as an effective biological control method to reduce *Striga hermonthica* and increase sorghum productivity in Sudan.

## 2.4. Review of Striga research in Ethiopia

Tesso et al. (2007) found Integrated Striga Management (ISM) reduces the emergence of striga and increases sorghum yield. The study has undertaken in the four regional states of Ethiopia, namely, Amhara, Oromia, SNNP, and Tigray between 2002 and 2004 (Figure 2.1).

**Figure 2.1: Impact of Integrated Striga Management (ISM) on sorghum yield for the four regional states in Ethiopia**




Source: Tesso et al., (2007)

Based on a survey collected from 315 households in two administrative zones in Amhara regional state and one administrative zone in Benishangul Gumuz regional state, farmers rated striga the highest constraint to production (Rebeka et al., 2014). The three administrative zones are north Shewa and north Wollo from Amhara regional state and Metekel from Benishangul Gumuz regional state. The farmers' response about the proportion of striga on sorghum is presented in table 2.2.

**Table 2.1:Farmer's response on the proportion of striga infestation for three zones**

| Zone | Proportion of Striga infestation on sorghum | | |
|---|---|---|---|
| | High Infestation (%) | Medium infestation(%) | Low infestation(%) |
| North Shewa | 88.1 | 6.9 | 5.0 |
| North Wollo | 92.7 | 5.5 | 1.8 |
| Metekel | 83.7 | 6.7 | 6.9 |

Source: Rebeka et al., (2016)

Sarmiso, Z. (2016) reported that the use of nitrogen fertilizer reduces striga counts. Sarmiso applied five fertilizer rates of 0 kg N per ha, 23 kg N per ha, 46 kg N per ha, 69 kg N per ha and 92 kg N per ha at Kile research center, eastern Ethiopia, Oromia regional state. The count of striga decreased from 7.44 per m2 when there is no nitrogen application to 2.62 per m2 when 92 Kg N per ha has applied. The lowest sorghum yield gain is 2,777 kg per ha without the application of nitrogen fertilizer and the highest yield 5,675 kg per ha with 92 kg N per ha application.

In a survey conducted to determine the abundance and distribution of *Striga hermonthica* in twelve selected districts of the Tigray regional state, on average highest level of striga infestation was 321 plants per meter squared and the lowest infestation level was 79 per meter squared. The survey also identifies the highest density of striga per plant of sorghum. Accordingly, on average the highest density of striga per sorghum plant is 25 in seven districts and the lowest is 7 in the remaining seven districts (Gebreslasie et al., 2015).

There is no single method to control striga (Ejeta,2007; Sibhatu, 2016). The push-pull technology used to control striga increases sorghum and maize yield and reduces striga (Araya et al., 2015). Araya et al., (2015) undertake farm level test on six sorghum growing farmers of south Wollo. While the national average sorghum production is 2.4 ton per hectare, the sorghum growing farmers produced a minimum of 4.8 ton per hectare and the maximum yield is 6.8 ton per hectare using the pull-push technology. The incidence of striga also reduces from 27(control plots) to three counts.

Many studies report on the role of intercropping sorghum with legumes to control striga. Dereje et al., (2016) conducted on-farm experiments to identify the influence of intercropping sorghum with legumes in three locations with eleven treatments for three years in the Asosa administrative zone, Benishangul Gumuz regional state (Table 2.3). The test includes intercropping groundnut with sorghum, intercropping soybeans with sorghum, and simultaneous planting. Intercropping groundnut with sorghum produces the highest sorghum yield compared to the yield obtained from inter cropping of soybeans with sorghum (simultaneous). Dereje et al., (2016) reported striga emergence of 777 per 24 m2 and a sorghum yield of 747 kg per ha with treatment. But intercropping with legumes, the lowest emergence of striga count was 231.2$m^2$ with relay cropping of sorghum with groundnut to 754.10 with relay cropping of sorghum with soybeans. The sorghum yield has also increased from 1155 kg per ha in sorghum-soybean intercropping to 1433 kg per ha in the sorghum ground nut relay cropping.

**Table 2.2: Impact of Intercropping technology on sorghum yield and striga emergence**

| year | Striga emergence on sorghum | Striga emergence after intercropping | Sorghum yield before intercropping | Sorghum yield after intercropping |
|---|---|---|---|---|
| 2012 | 777 | 499 | 747 | 1005 |
| 2013 | 575.3 | 214 | 1864 | 2380 |
| 2014 | 480 | 122 | 1352 | 2064 |

Source: Dereje et al (2016)

Merkeb et al (2016) studied the impact of intercropping sorghum with ground nut and soybeans in Metekel zone-Pawe, Benshangual Gumuz regional state. Intercropping of sorghum with soybean reduces striga count by 29.5% during the vegetative growth stage and by 19.7% at heading stage. As a result, sorghum yield is increased by 1.9 tons per hectare or by 29.1% over the sole crop.

Relay cropping with *Sesbania* and *Cajanus* significantly increased sorghum yield and reduce striga population (Reda et al., 2005). Reda et al., (2005) conducted experiment in three seasons (1998-2000) at two sites of Tigray regional state. The first experiment site was in Adibakel woreda, at 2080 m above sea level, that represents the cool and dry highlands with 579mm annual rainfall and erratic in nature. The second woreda is Shiraro at 970 m above sea level that represents low land plains and receives 1000 mm of rain fall with fair distribution. In the third season *Cajanus*/sorghum relay cropping increases sorghum yield by 63% and *Sesbania*/sorghum relay cropping increases sorghum yield by 130%.

# Chapter 3 - The State of Agriculture in Ethiopia

## 3.1. General information

Ethiopia is Africa's second most populous nation after Nigeria with a population of more than 105 million. The country has seven regional states and two administrative cities. Based on a nationally representative survey by the World Bank in collaboration with Ethiopian Central Statistical Authority (CSA) data, Oromia region is the most populous region that accounts for more than 40% population followed by Amhara region with 24%, the Southern Nations, Nationalities and Peoples (SNNP) as the third most populous region with 21% of the population, and the fourth is Tigray with about 6% (World Bank LSMS-ISA, 2013/14). The other three regional states Afar, Benishangul Gumuz, Somalia and Gambella with the two administrative cities Addis Ababa and Dire Dawa accounts for 9% of the population.

Agriculture is the major job creating industry followed by small business. The employment trend follows the same pattern when we disaggregate the data into the regions.

## 3.2. The State of Cereal Economy in Ethiopia

### 3.2.1. Land use and production of crop

Ethiopia has above 20 million hectares of land that is used to cultivate crops. Crop are classified into grain crops, vegetables, root crops and fruit crops. Cereals, pulses and oils & seeds are categorized under grain crops. Nationally, grain crops account for 84% of the total cultivated land. Among the grain crops, 62% of the land is devoted to cereal crops, 15% to pulses, and 7% to oils and seeds (Table 3.1).

**Table 3.1:Percentage of land used among the different crops at national level and for the four regions of Ethiopia (%)**

| Crop Type | National | Tigray | Amhara | Oromia | SNNP |
|---|---|---|---|---|---|
| Grain crops | 84 | 98 | 95 | 85 | 52 |
| Cereals | 62 | 78 | 68 | 62 | 42 |
| Pulses | 15 | 5 | 14 | 18 | 10 |
| Oils & Seeds | 7 | 15 | 13 | 5 | 1 |
| Vegetables | 2 | 0.5 | 2 | 2 | 3 |
| Root Crops | 1 | 0.5 | 1 | 1 | 5 |
| Fruit crops | 12 | 1 | 2 | 12 | 40 |

Source: World Bank LSMS-ISA 2013/14

Tigray, Amhara and Oromia regional states allocate more area of land than the national level to grain production, that is, 98%, 95%, and 85% respectively while SNNP allocates 52% of the land to grain crops and the 40% to fruit crops. Grain crops in general and cereal crops in particular are the main agricultural products for the Ethiopian small holder farmers.

Land allocated to cereal crops occupies 62% of the national cultivated land. Barley, maize, Finger millet, oats, rice, sorghum, teff, and wheat are the major cereals produced by Ethiopian farmers. Maize occupies 29% of land that is used to grow cereals followed by teff 26%, sorghum 19%, and wheat 12% (Table 3.2).

**Table 3.2: Percentage of land used to grow staple cereal crops**

| Crop type | National data | Tigray | Amhara | Oromia | SNNP |
|---|---|---|---|---|---|
| Barley | 8 | 8 | 9 | 8 | 6 |
| Maize | 29 | 8 | 17 | 36 | 31 |
| Sorghum | 19 | 44 | 22 | 15 | 16 |
| Teff | 26 | 21 | 31 | 25 | 29 |
| Wheat | 12 | 9 | 12 | 13 | 18 |
| Total | 100 | 6 | 27 | 56 | 8 |

Source: World Bank LSMS-ISA 2013/14

### 3.2.2. The state of cereal production in Ethiopia

According to the nationally representative survey data collected by the World Bank and the Central Statistics Agency (CSA), annual production of the major staple cereal crops are maize 5157.2 thousand metric tons, wheat 3018.02 thousand metric tons, teff 2667.10 thousand metric tons, sorghum 2472 thousand metric tons, and barley 1030.1 thousand metric tons (World Bank LSMS-ISA, 2013/14; Table 3.3). Maize is the first crop and sorghum is the fourth in terms of production.

**Table 3.3: Cereal Production in Ethiopia by region ('000s of metric tons).**

| Crop Name | Tigray | Amhara | Oromia | SNNP | Others | Total |
|---|---|---|---|---|---|---|
| Barley | 79 | 257 | 584 | 110 | 1 | 1,030 |
| Maize | 71 | 1,050 | 3,300 | 548 | 189 | 5,158 |
| Sorghum | 296 | 1,030 | 897 | 147 | 102 | 2,472 |
| Teff | 92 | 848 | 1,490 | 218 | 20 | 2,667 |
| Wheat | 87 | 456 | 2,280 | 195 | 0 | 3,018 |

Source: World Bank LSMS-ISA, 2013/14

### 3.2.3. The state of cereal consumption in Ethiopia

Nationally, maize is the most consumed cereal crop that accounts 26% followed by teff 24% and sorghum and wheat 18% each. The state of consumption across the regions and between the rural and urban areas does not follow similar trend with the national data. Sorghum is the most consumed cereal in Tigray (30%) and Amhara (26%) region, and the fourth (15%) consumed cereal in Oromia. Maize and teff are the first and second consumed cereals in Oromia region which follows a similar trend with the national consumption data.

**Table 3.4: Percentage of households consuming cereals nationally and in the four regions**

| Crop Type | Ethiopia | Tigray | Amhara | Oromia | SNNP |
|---|---|---|---|---|---|
| Teff | 24 | 27 | 25 | 23 | 15 |
| Wheat | 18 | 20 | 13 | 21 | 16 |
| Barley | 10 | 10 | 9 | 12 | 9 |
| Maize | 26 | 9 | 17 | 27 | 48 |
| Sorghum | 18 | 30 | 26 | 15 | 12 |

Source: World Bank LSMS-ISA 2013/14

### 3.2.4. The state of technology application in cereal production

Table 3.5 presents the application of the two types fertilizers: Urea and DAP in the four regional states for 2013/14 main production season. In all regions sorghum receives the lowest amount of fertilizer compared to other cereal crops. Fertilizer application on sorghum is higher in SNNP followed by Tigray regions. Farmers in Amhara and Oromia regional states apply almost no fertilizer. In general, there is a limited fertilizer application for the staple crops (Table 3.5).

**Table 3.5: Fertilizer application in the five major cereal crops by region**

| Region | Input (kg/ha) | Cereal Crop Name | | | | |
|---|---|---|---|---|---|---|
| | | Barley | Maize | Sorghum | Teff | Wheat |
| Tigray | Urea | 3.20 | 11.26 | 0.64 | 7.90 | 8.99 |
| | Dap | 7.80 | 13.07 | 1.26 | 9.90 | 17.50 |
| Amhara | Urea | 0.06 | 0.56 | 0.43 | 0.15 | 0.50 |
| | Dap | 0.19 | 1.70 | 0.26 | 0.45 | 0.62 |
| Oromia | Urea | 0.13 | 0.28 | 0.07 | 0.18 | 0.13 |
| | Dap | 0.52 | 0.32 | 0.10 | 0.28 | 0.24 |
| SNNP | Urea | 0.55 | 0.77 | 0.26 | 1.00 | 6.37 |
| | Dap | 2.34 | 1.26 | 1.90 | 1.39 | 5.63 |

Source: World Bank LSMS-ISA 2013/14

## 3.3. Cereal crop production, cultivated land and yield per hectare by Region

In section 3.2., the data we presented are generated from the World Bank LSMS-ISA 2013/2014 data set. The data is nationally representative data and has the power to explain the state of the cereal economy for the survey year, i.e., for 2013/2014 agriculture season. Following we will present the trends of the staple cereal crops in terms of quantity of production, area cultivated, and the yield per hectare for the four major sorghum producing regional states of Ethiopia. We use the Central Statistics Agency (CSA) of Ethiopia from the year 2008/2009 to 2013/2014.

### 3.3.1. Production, area and yield for Tigray region

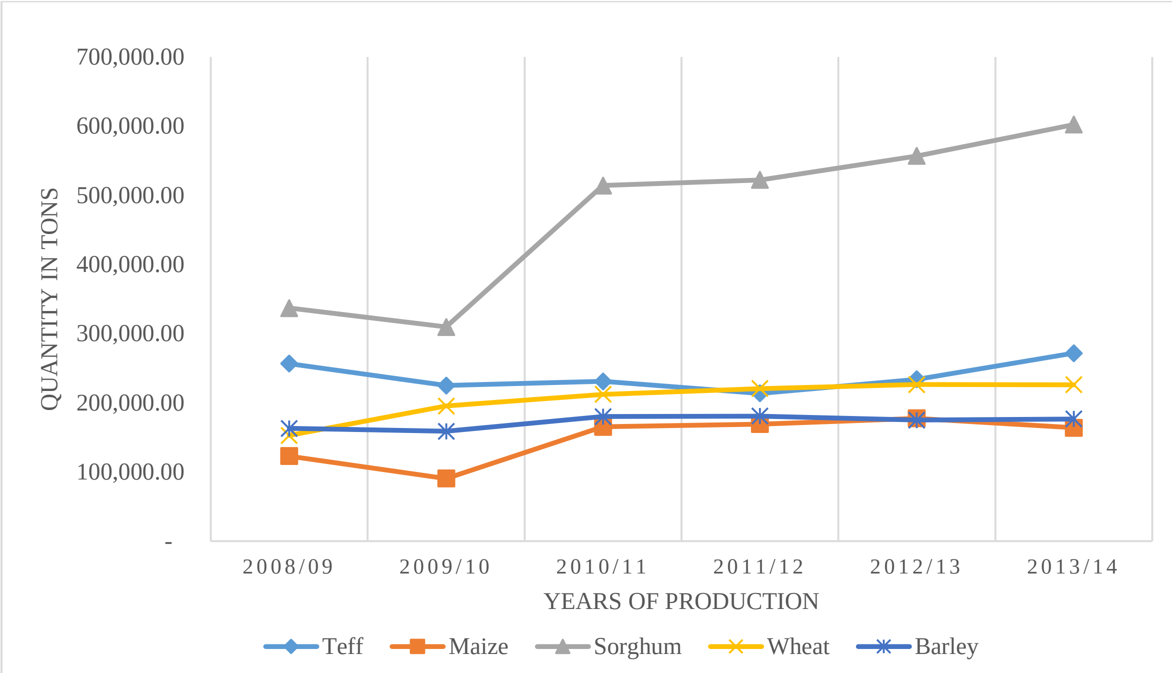
**Table 3.6: Staple crop yield trend for Tigray region (tons/ha)**

| Cereal Crop | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 1.19 | 1.31 | 1.23 | 1.26 | 1.37 | 1.39 |
| Maize | 2.08 | 2.13 | 2.58 | 3.05 | 3.15 | 3.44 |
| Sorghum | 1.72 | 2.20 | 1.79 | 1.77 | 1.88 | 2.05 |
| Wheat | 2.10 | 2.19 | 2.06 | 2.27 | 2.41 | 2.62 |
| Barley | 1.52 | 1.61 | 1.96 | 1.52 | 1.77 | 1.90 |

Source: CSA main season report 2008/2009-2013-14

Cereal yields (ton/ha) uniformly increases for teff and maize. The trend for sorghum production is not uniform. Even though the total production quantity (in tons) increases (figure 3.1), the yield in tons per hectare decreases for the years 2010/11 and 2011/12. Maize yield is higher followed by sorghum yield. Teff has the lowest compared to other cereals in the region.

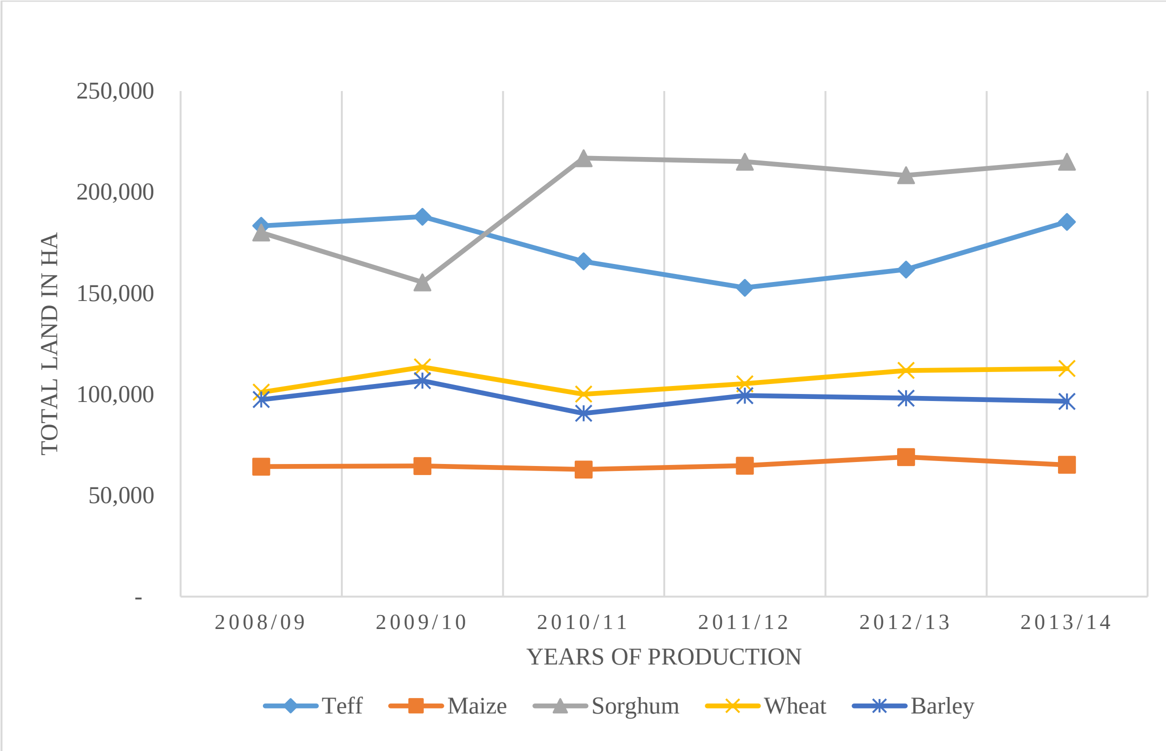
**Figure 3.1: Cereal production trends for Tigray region from 2008/09-2013/14**




Source: CSA main season report 2008/09-2013/14

Cereal production was decreased in the year 2009/10 and showed increased trend from 2010/11 to 2013/14. However, the increase in sorghum production much greater than the other cereal crops.

**Figure 3.2: Trends of land allocation to cereal production in Tigray region (ha)**




Source: CSA main season report 2008/09-2013/14

In Tigray regional state, the largest share of land is used for sorghum production from 2010/11 - 2013/14. For the production seasons 2008/09 and 2009/10 the land allocated teff exceeds the land allocated for sorghum. It seems reasonable to conclude that the increase in production (figure 3.1) and yield per ton (table 3.6) is not due to production efficiency rather new land is used by farmers for the production of cereals.

### 3.3.2. Production, area and yield for Amhara region

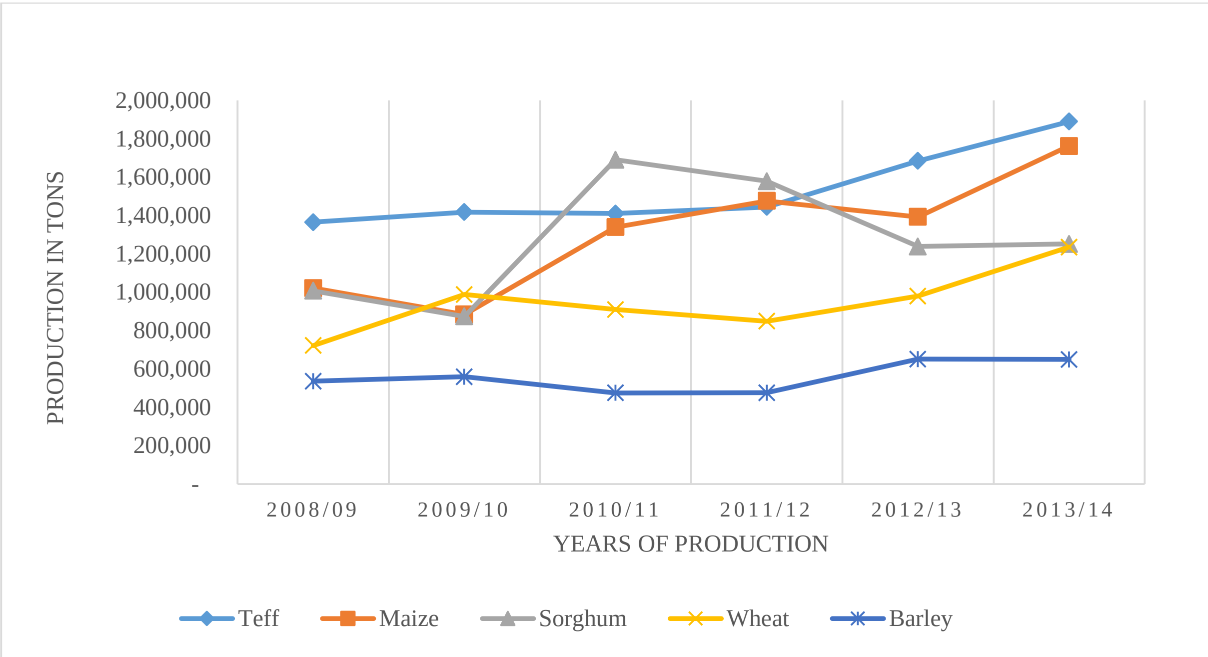
**Table 3.7: Staple crop yield trend for Amhara region (tons/ha)**

| Cereal Name | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 1.36 | 1.42 | 1.39 | 1.44 | 1.55 | 1.65 |
| Maize | 2.57 | 2.48 | 2.84 | 2.98 | 3.20 | 3.72 |
| Sorghum | 1.84 | 1.80 | 2.38 | 2.15 | 2.14 | 2.24 |
| Wheat | 1.66 | 1.80 | 1.82 | 1.84 | 1.97 | 2.33 |
| Barley | 1.54 | 1.44 | 1.45 | 1.57 | 1.68 | 1.74 |

Source: CSA main season report 2008/09-2013/14

In Amhara region, the yield for all teff and wheat uniformly increase for the reported year. The other cereals showed a fluctuating growth trend. Maize gives the highest yield (tons/ha) followed by sorghum and for one production year wheat.

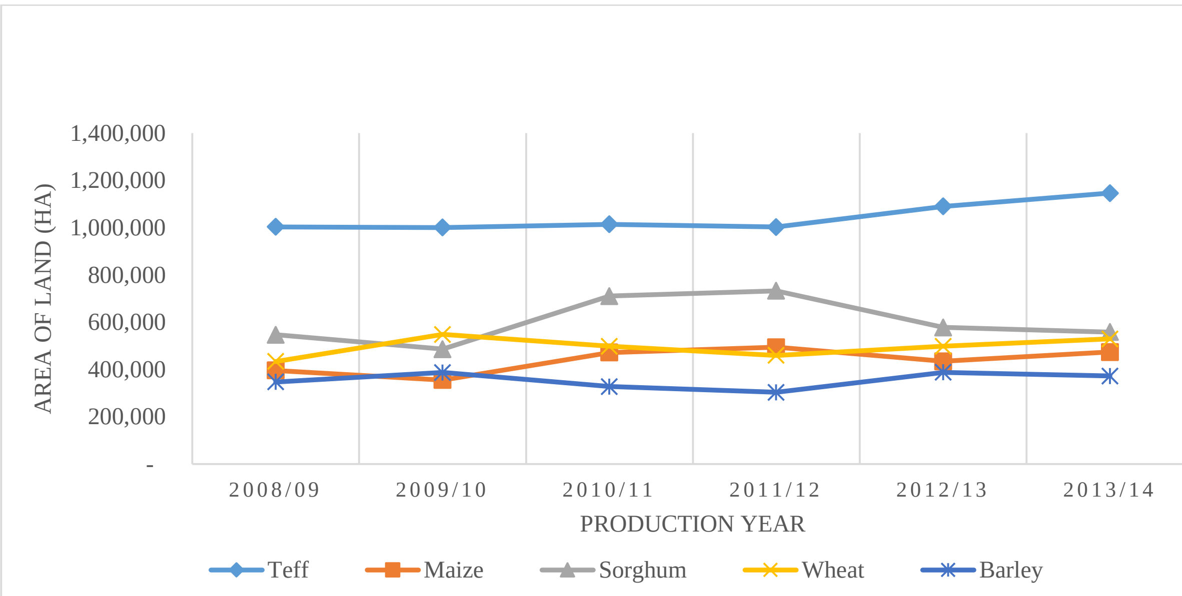
**Figure 3.3: Cereal production trend for Amhara region from 2008/09-2013/14 (tons)**




Source: CSA main season report 2008/09-2013/14

Production of teff steadily increases for the reported periods. The production of sorghum showed the most unpredictable trend. In 2009/10 season, there is a dramatic shock in sorghum production and in the next production year sorghum becomes the first followed by teff and maize and then start a sharp decline from 2011/12 to 2013/14. It seems that farmers in Amhara region switched the land previously used to produce wheat and barley for the production sorghum (figure 3.4).

**Figure 3.4: Trends of land allocation to cereal production in Amhara region (ha)**




Source: CSA main season report 2008/09-2013/14

In the Amhara region, the largest percentage of land is allocated to the production of teff (figure 3.4) compared to sorghum in Tigray region (figure 3.3). The land allocated to sorghum (figure 3.4) follows the same trend as the production of sorghum (figure 3.3) in the region.

### 3.3.3. Production, area and yield for Oromia region

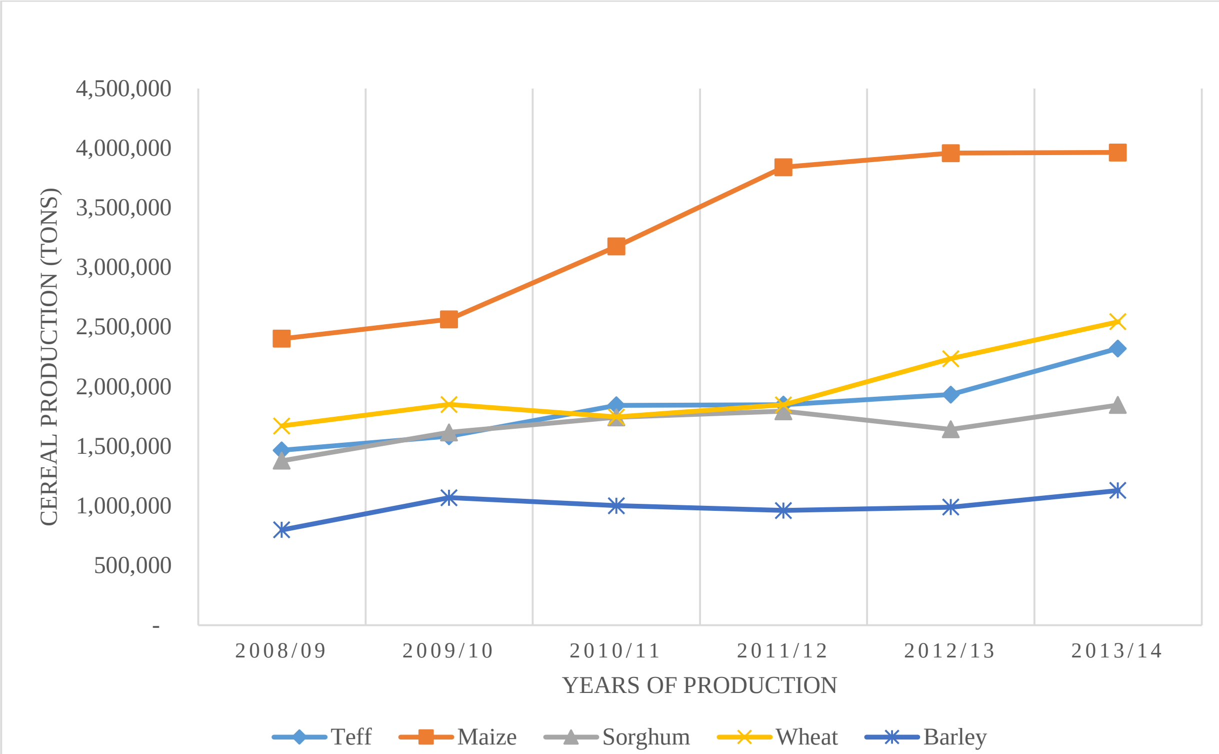
**Table 3.8: Staple crop yield trend for Oromia region (tons/ha)**

| Yield(ton/ha) | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 1.35 | 1.34 | 1.43 | 1.43 | 1.54 | 1.66 |
| Maize | 2.57 | 2.56 | 2.86 | 3.48 | 3.55 | 3.66 |
| Sorghum | 2.04 | 2.14 | 2.36 | 2.41 | 2.43 | 2.76 |
| Wheat | 2.10 | 2.16 | 2.14 | 2.49 | 2.56 | 3.04 |
| Barley | 1.77 | 1.97 | 1.95 | 2.09 | 2.21 | 2.40 |

Source: CSA main season report 2008/09-2013/14

In Oromia region sorghum yield (tons/ha) shows a regular trend of growth from 2008/09-2013/14. Maize yield is higher followed by wheat and sorghum places third.

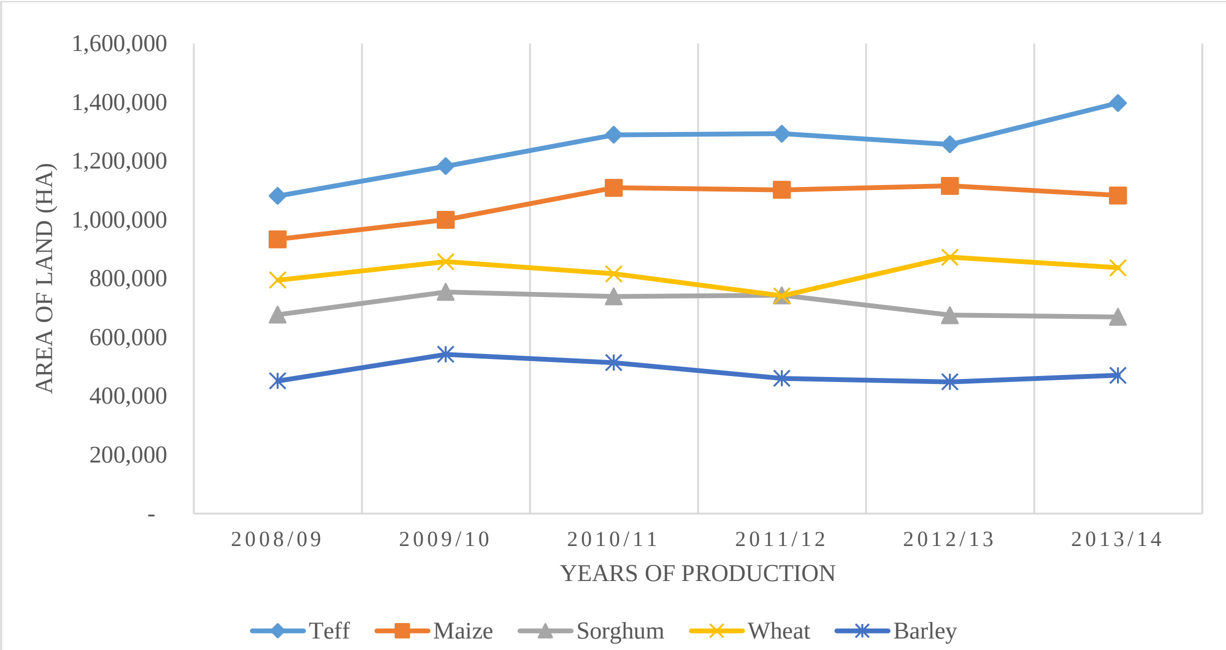
**Figure 3.5: Cereal production trend for Oromia region from 2008/09-2013/14 (tons)**




Source: CSA main season report 2008/09-2013/14

Maize is the highest produced cereal crop in the region (Figure 3.5). Sorghum ranks fourth in the region. However, the region is consistently the number one producer of sorghum in the country.

**Figure 3.6: Trends of land allocation to cereal production in Oromia region (ha)**




Source: CSA main season report 2008/09-2013/14

Teff is the third most produced crop but the highest share of land is allocated to produce it. Maize is second in terms of the area of land used to cultivate with cereals and sorghum third.

### 3.3.4. Production, area and yield for SNNP region

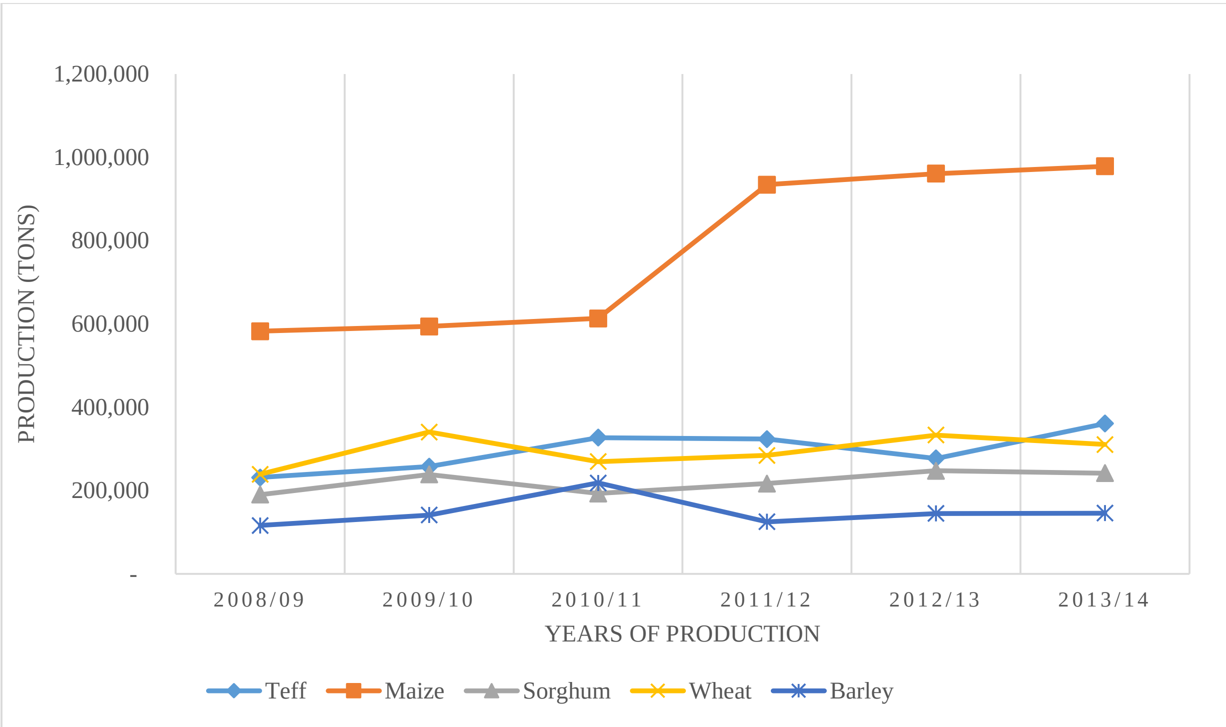
**Table 3.9: Staple crop yield trend for SNNP region (tons/ha)**

| Yield(ton/ha) | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Teff | 1.19 | 1.31 | 1.23 | 1.26 | 1.37 | 1.39 |
| Maize | 2.08 | 2.13 | 2.58 | 3.05 | 3.15 | 3.44 |
| Sorghum | 1.72 | 2.20 | 1.79 | 1.77 | 1.88 | 2.05 |
| Wheat | 2.10 | 2.19 | 2.06 | 2.27 | 2.41 | 2.62 |
| Barley | 1.52 | 1.61 | 1.96 | 1.52 | 1.77 | 1.90 |

Source: CSA main season report 2008/09-2013/14

In SNNP, maize is the only crop that showed a steady yield (tons/ha) increase from 2008/09-2013/14. Sorghum yield (tons/ha) is third following maize and wheat (Table 3.9).

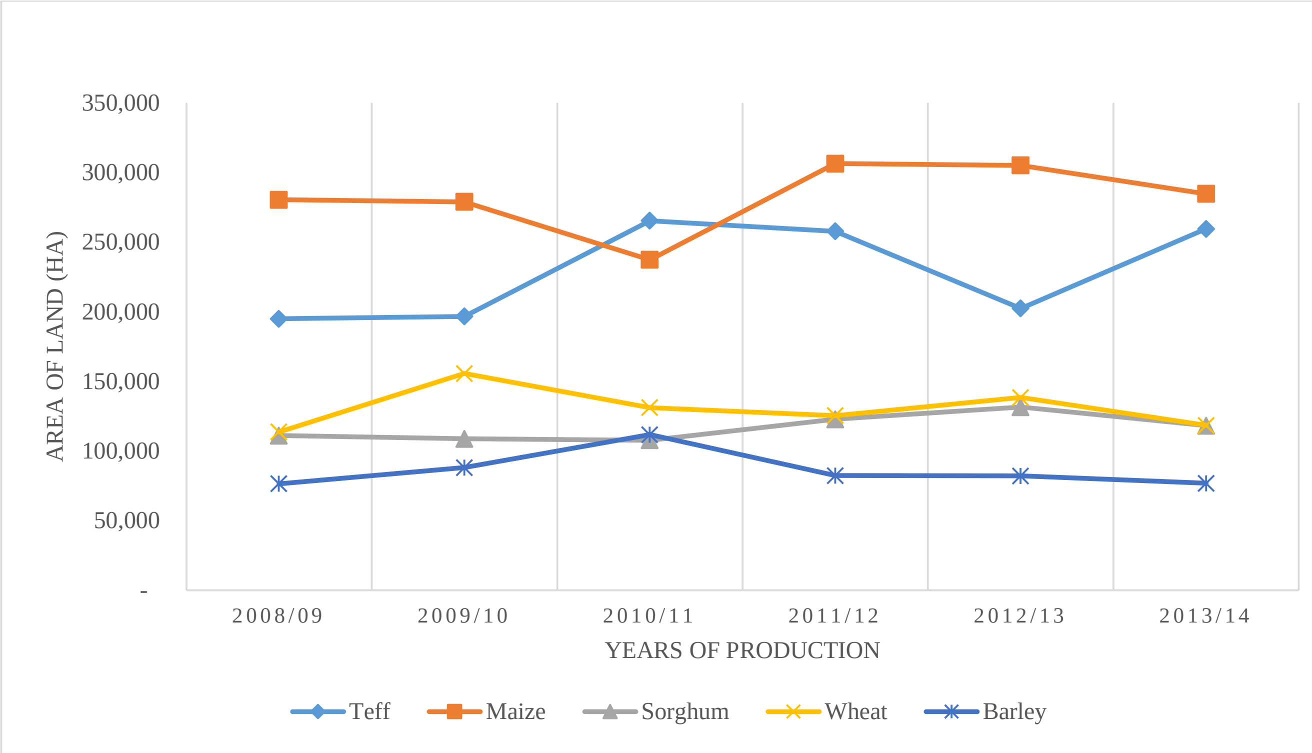
**Figure 3.7: Cereal production trend for SNNP region from 2008/09-2013/14 (tons)**




Source: CSA main season report 2008/09-2013/14

Maize is by far the most dominant crop produced by SNNP farmers. Teff and wheat switches second and third rank next to maize and sorghum is consistently the fourth highest produced cereal crop.

**Figure 3.8: Trends of land allocation to cereal production in SNNP region (ha)**




Source: CSA main season report 2008/09-2013/14

In SNNP there is regular increase or decrease in the allocation of land for cereal crop production. However, maize and teff tops the first two followed by wheat and sorghum in the third and fourth place respectively. The region allocates 40% of the land for production of root crops (World Bank LSMS-ISA,2013/14; Table 3.1).

## 3.4. Trends of sorghum production, area of land and yield in the four regions (Tigray, Amhara, Oromia, SNNP)

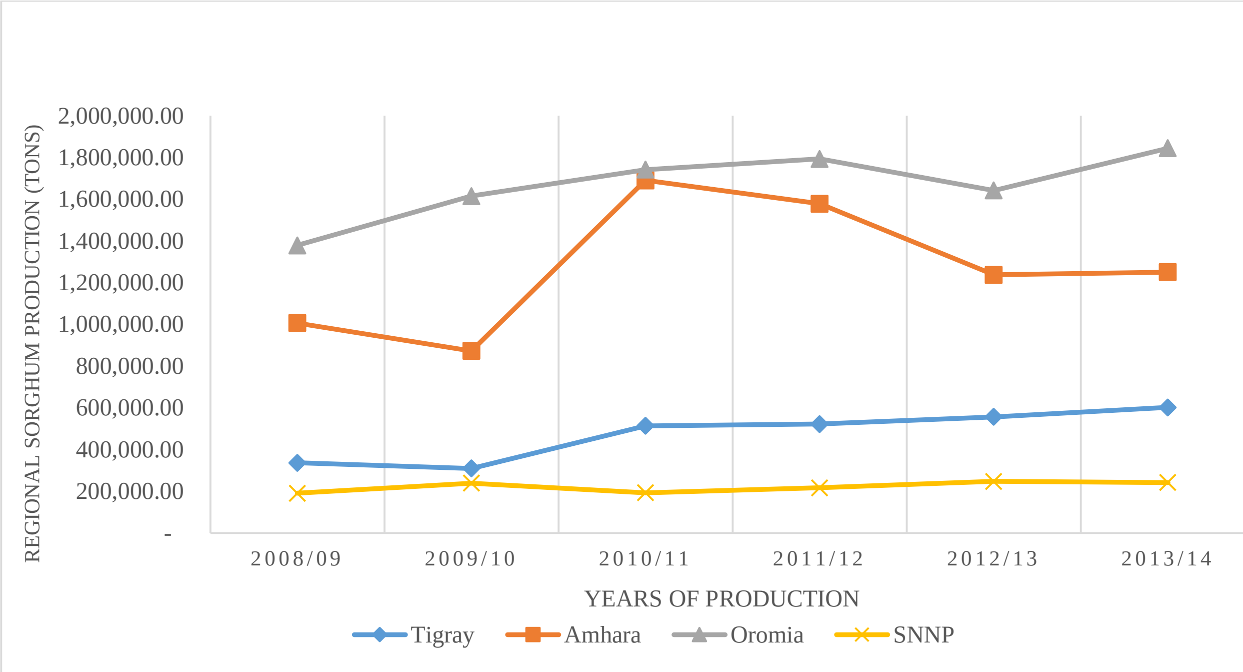
**Table 3.10: Trends of sorghum yield for the four regions(tons/ha)**

| Regions | 2008/09 | 2009/10 | 2010/11 | 2011/12 | 2012/13 | 2013/14 |
|---|---|---|---|---|---|---|
| Tigray | 1.72 | 2.20 | 1.79 | 1.77 | 1.88 | 2.05 |
| Amhara | 1.84 | 1.80 | 2.38 | 2.15 | 2.14 | 2.24 |
| Oromia | 2.04 | 2.14 | 2.36 | 2.41 | 2.43 | 2.76 |
| SNNP | 1.72 | 2.20 | 1.79 | 1.77 | 1.88 | 2.05 |

Source: CSA main season report 2008/09-2013/14

Sorghum yield regularly increases in Oromia region (from 5% to 14%) from 2008/09-2013/14. In the other three regions there is no regular trend. In some years there is an increase in yield and in other years there is a decrease in yield. In Tigray region, 62% increase is shown for farming years 2008/09-2009/10 and a 19% decrease in yield from 2009/10-2010/11. In Amhara region, the highest yield increase is 32% (2010/11) and a 2% yield decrease in 2009/10. In SNNP, there was a 28% increase in yield for the period 2008/09-2009/10 and a 19% decrease in sorghum yield for the periods 2009/10-2010/11.

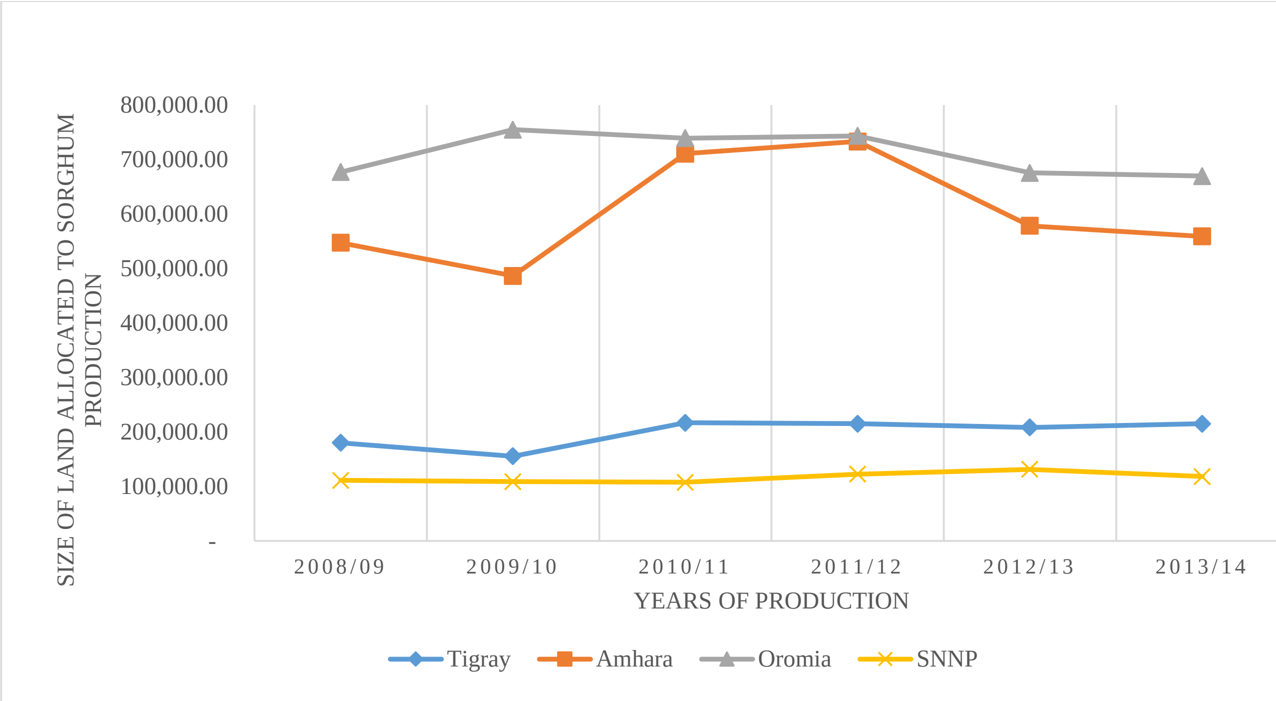
**Figure 3.9: Trends of sorghum production for the four regions (tons)**




Source: CSA main season report 2008/09-2013/14

As it is clearly shown in figure 3.9, Oromia is the largest sorghum producer, followed by Amhara region in second place, Tigray region in third place and SNNP in fourth place. The growth trend looks consistent for Oromia, Tigray and SNNP while irregular increase and decrease trends is shown in Amhara region.

**Figure 3.10: Size of land allocated to sorghum production for the years 2008/09-2013/14 by the four major sorghum producing regions (tons)**




Source: CSA main season report 2008/09-2013/14

Oromia region plants about 700,000 hectares of land to sorghum, Amhara region about 600,000 hectares, Tigray about 200,000 hectares and SNNP about 100,000 hectares of land. The land allocated to sorghum shows a decrease trend for Oromia and Amhara, an increasing trend for Tigray and similar trend for SNNP.

# Chapter 4 - Methodology and Data Source

## 4.1. The economic surplus method

The fourth chapter discusses the methods used to undertake ex ante impact assessment for adopting *striga* control technology in the four major sorghum producing regional states in Ethiopia: Oromia, Amhara, Tigray and SNNP. Economic impact assessment of new technologies provides researchers, scientists, and decision makers information and knowledge on the potential benefits and costs of the research involved. Information on the expected benefits and costs of alternative research strategies can be used to set priorities, to design research, and to evaluate research. There are two types of impact assessment methods: an ex-ante impact assessment method provides a basis for allocation of resources among competing research demands and ex-post impact analysis method provides estimates of realized economic values of an already implemented research agenda. Hence, ex-ante economic analysis is based on information obtained through workshops, group discussion or interview from researchers, extension workers, social scientists regarding the yield, probability of success rate, and adoption of the new technology.

There are three common methods used to assess the impact of agricultural research in the literature: the econometrics method, the programming method and the economic surplus method (Masters et al., 1996). The economic surplus method is more popular for ex ante impact assessment methods because it requires minimum data compared to the other two methods. The econometric method is often used for ex-post impact assessment as it requires historical data for complete analysis, while the programming method is used to identify one or more optimal technologies or research activities from a set of options. The third method, the economic surplus method, is used to measure the social benefit of a particular project or investment. Both the econometric method and the programming method require historical data to undertake the analysis. The benefit of the economic surplus method is the possibility of producing an economic analysis based on limited data without requiring past organized data set.

The economic surplus method is often used for ex-ante impact assessment of agricultural research. The framework considers per unit cost reduction and price responses for research induced quantity shifts and assess the level and distribution of research benefits. The model shows to what extent the research induced reduction in per unit cost of production may reduce market prices (Norton and Dey, 1993).

The economic surplus method measures the changes due to the adoption of the new technology in terms of producer surplus (PS) and consumer surplus (CS). Producer surplus is the return to factors of production from selling the good at the equilibrium price, while Consumer surplus reflects the consumer willingness to pay for a good in excess of the market price (Marshall, 1980; Mishan,1981). Economic surplus analysis considers the nature of the market for the commodity and the fact that prices may fall as production changes and supply increases. For our analysis, the closed economy condition is used as sorghum is not an extensively traded crop. The economic surplus method measures the changes in producer and consumer surplus, and the sum of the two changes is the total social welfare.

Harberger's (1971) "three postulates" are invoked to use the standard surplus measures for measuring the welfare change. These three assumptions are; "(1) the competitive demand price for a given unit measures the value of that unit to the demander; (2) the competitive supply price for a given unit measures the value of that unit to the supplier; and (3) when evaluating the net benefits or costs of a given action, the costs and benefits accruing to each member of the relevant group (i.e. family, city, state, nation, world) should be added without regard to the individuals to whom they accrue."

The size and nature of the shift in the supply curve influence the distribution and total benefits. Masters et al. (1996) and Norton et al. (1992) suggests using vertically parallel shift in supply curve for simplicity and consistency in evaluating research impact assessment in agriculture. One of the most important parameters in the economic surplus analysis is the research induced proportionate shift in supply (the K factor).

Following Masters et al. (1996), the impact of striga controlling technology on sorghum supply can be represented graphically as described in Figure 4.1. Figure 4.1. presents the impact of successful research on the supply curve, the equilibrium price and equilibrium quantity and economic surplus. $S_1$ is the supply curve without research, $P_1$ is the equilibrium price and $Q_1$ the equilibrium quantity without research. When new technology is applied, it reduces the impact of striga on sorghum production and output increases from $Q_1$ to $Q_3$. The increase in sorghum production shifts the supply curve to the right from $S_1$ to $S_3$. Hence, the horizontal shift of the supply curve is indicated by J. The parameter J could be found by multiplying the yield gain per hectare (tons/ha) by the area planted after the new technology is applied. The net supply curve shift $S_3$ could be achieved if the new technology adopted with zero or no cost. However, farmers need to invest in order to get the new technology. Hence, the vertical distance $I$ represents the adoption cost. The adoption cost for the new technology is the adoption cost per hectare divided by the average yield over all hectares in total production. The net shift in supply curve is from $S_1$ to $S_2$ after accounting for J and I parameters. The vertical distance K represents the net gain in terms of decrease in production costs- called the K factor.

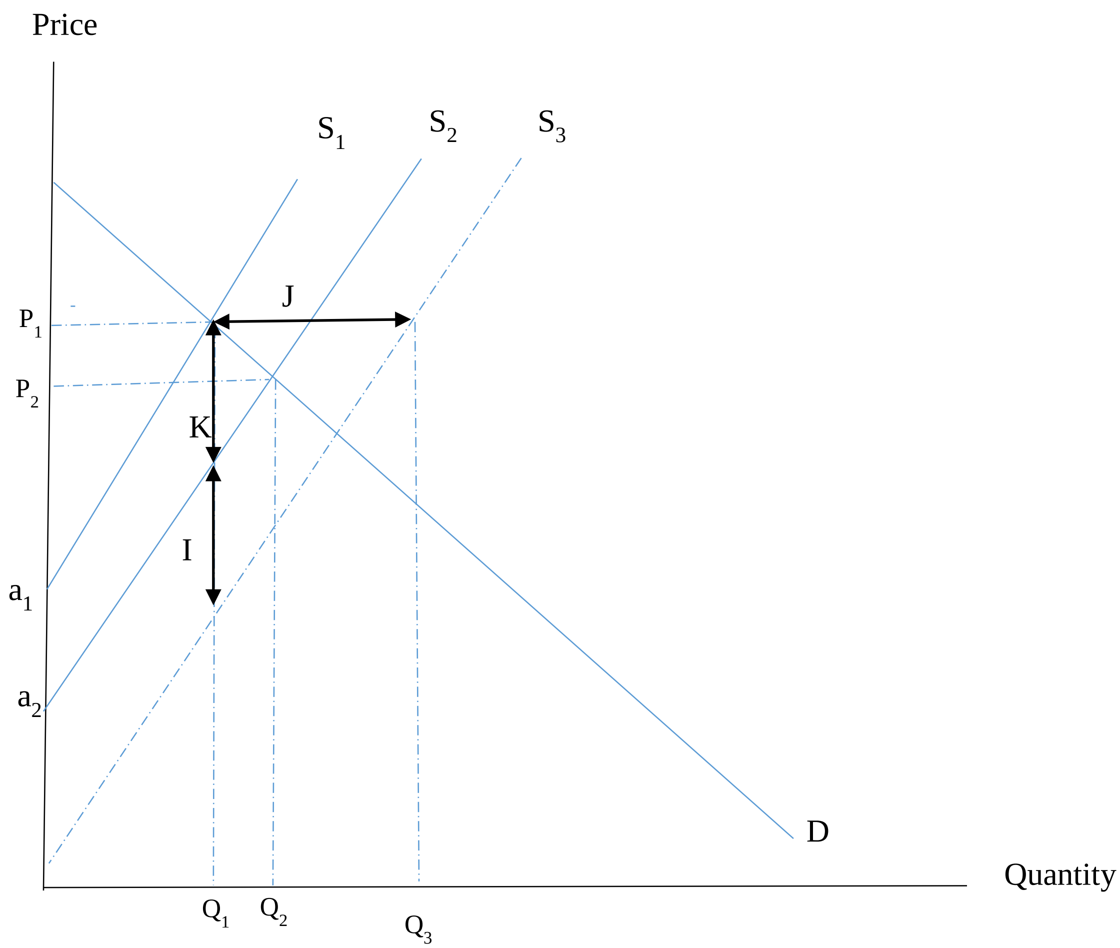



**Figure 4.1:: Graphical presentation of a parallel researched induced supply curve shift when striga control technology increases production of sorghum**

The general economic surplus model in a closed economy with a parallel research induced supply shift; the change in total surplus (TS), the change in producer surplus and the change on consumer surplus is given by (Alston et al., 1995):

$$\Delta TS = P_1 1K(1 + 0.5Z\eta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\Delta CS = P_1 Q_1 Z(1 + 0.5Z\eta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\Delta PS = P_1 Q_1 (K - Z)(1 + 0.5Z\eta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where: $P_1$ and $Q_1$ are initial equilibrium price and quantity, respectively

$Z = \frac{K\varepsilon}{\varepsilon + \eta}$ relative reduction in price due to supply shift

$\varepsilon =$ supply elasticity

$\eta =$ demand elasticity (absolute value)

$K =$ shift of the supply curve as a proportion of the initial price

According to Alston et al.(1995), the proportionate shift of the supply curve $K$ can be calculated as:

$$K = \left(\frac{E(Y)}{\varepsilon} - \frac{E(C)}{1+E(Y)}\right) pA_t(1-d_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Where:

$E(Y) =$ expected proportionate yield change (per hectare) from adoption

$E(C) =$ expected proportionate change in variable input costs (per hectare) from adoption

$p =$ probability of success of achieving the expected yield change from adoption

$A_t =$ adoption rate of technology in time t

$d_t =$ rate of depreciation of the new technology

Equations (1) – (3) are the systems of equations used to estimate the social welfare. Equation (1) estimates the total gain to the society as a result of implementing the new striga control technology that reduces the damage of the weed on sorghum. Equation (2) is the surplus to consumers. Consumers receive whatever is lost by producers due to lower prices and due to the fact that the demand for staple food crops is relatively inelastic. Equation (3) is used to measure the producer's surplus. New technology shifts the supply curve down and the shift moves the equilibrium to a lower level of price ($P_1$) and higher quantity of supply ($Q_2$). All the three equations need the value of K (equation 4). In ex-ante analysis, the parameters used to compute K usually found through group discussion with scientists and experts, extension workers and previous study results. For this paper, we created different scenarios and compute the society gain based on what-if assumption that helped us to estimate equations (1) to (3). We generated the base year data from the World Bank LSMS-ISA 2013/14 data set.

## 4.2. Data source

For this study we used the Ethiopian Socioeconomic Survey (ESS), a collaborative project between the Central Statistics Agency (CSA) and the World Bank Living Standards Study-Integrated Surveys on Agriculture (LSMS-ISA). The objective of LSMS-ISA is to collect multi-topic panel household level data with a special focus on improving agriculture statistics and the link between agriculture and other sectors of the economy. The data is collected in three waves. The first wave was implemented in 2011-2012, the second wave in 2013-2014 and the third wave in 2015-2016. The first wave covered only rural and small town areas. The second wave covered all parts of the country: rural, small towns, and large towns. The third wave was collected during the year of severe drought incidence in the country and millions of farmers lands stay uncultivated. Therefore, for completeness we used the second wave data as it covers all parts of the nation and relatively representative data. This national representative survey includes 5,262 households living in rural and urban areas.

The survey was unable to capture any data related to striga infestation, amount of production loss due to this weed as well as controlling methods. As a result, we used the 2013/2014 production and consumption data as a base and create scenario. We also reviewed the impact of some striga controlling technologies on previous studies in Ethiopia and in Africa too. Hence, we benefit from the reported data in order to build the scenarios.

Striga is the pandemic to food security in Ethiopia in particular and for Africa in general (Ejeta et al., 2007). It will be misleading to formulate food security and growth intervention policy without including the impact of striga on Ethiopia staple crop production. We extract household level data about area of land used to grow sorghum, quantity of sorghum production, sorghum consumption, agricultural input costs, and price from the World Bank LSMS-ISA 2013/2014 data set.

# Chapter 5 - Result, Discussion, and Conclusion

## 5.1. Result and Discussion

The discussion has two parts. In the first part of the discussion presents a short run profit analysis for ten yield scenarios for the four regions under study. The second steps from the first part by assuming the maximum yield gained and presents the welfare change based on the system of equations (1), (2), (3), and (4) we defined in the fourth chapter. The two sections clearly show how producers are losing to consumers due to the increase in output and the decrease in price in a closed economy.

### 5.1.1. Farmer's profitability Analysis

The first section of the discussion focuses on comparing the benefits (revenue) and the costs from investing in striga controlling technology for a representative farmer in the four major sorghum producing regions in Ethiopia, namely, Tigray, Amhara, Oromia, and SNNP. We generated the quantity of production, price, and input cost from the World Bank LSMS-ISA 2013/14 survey data set. This second method helps us to understand that the decrease in price due to the increase in sorghum yield after the technology is induced makes producers to run at a loss. The consumer surplus is positive and the net benefit is also positive that makes farmers net beneficial from adopting the new technology since sorghum producers are also consumers. The benefit cost method did not consider the decrease in price and households get a positive margin that could mislead policy makers.

**Table 5.1: Sorghum Producer Households short run profit**

| *Region* | *Qty* | *Price* | *Revenue* | *Labor* | *Fertilzer* | *Seed* | *Total cost* | *Profit* |
|---|---|---|---|---|---|---|---|---|
| Tigray | 513 | 6 | 3,078 | 1,496 | 32 | 6 | 1,534 | 1,544 |
| Amhara | 397 | 8 | 3,176 | 983 | 34 | 10 | 1,027 | 2,149 |
| Oromia | 345 | 5 | 1,725 | 990 | 31 | 6 | 1,027 | 698 |
| SNNP | 133 | 6 | 798 | 1,090 | 28 | 16 | 1,134 | -336 |

Source: World Bank LSMS-ISA, 2013/14

In the short run, except in the SNNP where labor cost is reported higher than the other regions, households have a positive net profit in the short run because the cost section does not include the indirect value of land as well as the implicit cost of the traditional farming instrument including the value of animal traction. Therefore, the costs are short term variable costs. Profit is higher in Amhara regional state that may be due to a relatively higher selling price followed by Tigray region as the production per each household is higher than the other regions.

Sorghum demand is far higher than sorghum supply. Despite the profitability of farming sorghum, this does not guarantee that they are food secure. In all four regional states there is a deficit in sorghum supply relative to demand. Most households in the sorghum producing areas are food insecure.

According to the literatures reviewed on striga control methods in Ethiopia, the impact of striga control methods increases sorghum yield from 17.5% to 130%. Herbicide technology increases sorghum by 17.5% (AATF,2011); Intercropping sorghum with legumes increases sorghum yield from 27.7% -34.4% (Dereje et al. 2016); Integrated Striga Management increases more than 100% compared with local striga controlling practices in the four major sorghum producing regions, Tigray, Amhara, Oromia, and SNNP (Tesso et al., 2007) ; relay cropping in Tigray region increases sorghum yield by 130% (Reda et al., 2005); intercropping Benishangul

Gumuz increases sorghum yield by 29.1%(Merkeb et al., 2016). For our profit analysis, we assumed the minimum yield to be 20% and the maximum yield 65%.

**Table 5.2: Households profit analysis for Tigray region**

| Scenarios | base year | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Change in Yield | 0 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.65 |
| Quantity(Kg/ha) | 513 | 616 | 667 | 718 | 770 | 821 | 846 |
| Price(Br/kg) | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Revenue (Br) | 3,078 | 3,694 | 4,001 | 4,309 | 4,617 | 4,925 | 5,079 |
| Labor cost (Br) | 1,496 | 1,496 | 1,496 | 1,496 | 1,496 | 1,496 | 1,496 |
| Fertilizer cost(Br) | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| Seed cost(Br) | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Total Cost(Br) | 1,534 | 1,534 | 1,534 | 1,534 | 1,534 | 1,534 | 1,534 |
| Profit(Br) | 1,544 | 2,159 | 2,467 | 2,775 | 3,083 | 3,390 | 3,544 |

Source: World Bank LSMS-ISA,2013/14 and Own Computation, 2019

Tigray region has the highest quantity of production (kg/ha) compared to other regions. Householders in the region the receive gross profit that ranges from Br.2,159 (in the first scenario) to Br.3,544 (in the sixth scenario) (table 5.2). The annual sorghum demand at household level is 770 kg and striga control technology that increases the yield 50% and above. This analysis has two drawbacks. The first one is we used the short run cost. And the second problem is this analysis does not consider the change in price as a result of the increase in supply.

**Table 5.3: Households profit analysis for Amhara region**

| | Base year | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Yield Increase | 0 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.65 |
| Quantity(Kg/ha) | 397 | 476.4 | 516.1 | 555.8 | 595.5 | 635.2 | 655.05 |
| Price(Br/kg) | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Revenue (Br) | 3,178 | 3,811.2 | 4,128.8 | 4,446.4 | 4,764 | 5,081.6 | 5,240.4 |
| Labor cost (Br) | 983 | 983 | 983 | 983 | 983 | 983 | 983 |
| Fertilizer cost(Br) | 34 | 34 | 34 | 34 | 34 | 34 | 34 |
| Seed cost(Br) | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Total Cost(Br) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Profit(Br) | 2,149 | 2,784.2 | 3,101.8 | 3,419.4 | 3,737 | 4,054.6 | 4,213.4 |

Source: World Bank LSMS-ISA, 2013/14 and Own Computation,2019

Amhara region is the second in sorghum yield (kg/ha) following Tigray region. The region is the second in terms of total area of land allocated to sorghum production and total production next to Oromia (CSA, 2008/09-2013/14). The data from the World Bank LSMS-ISA data contradicts this making the region the first producer of sorghum (World Bank LSMS-ISA, 2013/14). At house hold level the current production of sorghum 394 kg and the annual demand is 490 kg (World Bank LSMS-ISA, 2013/14). Striga control technology that could increase the yield by 30% and above is enough to feed the household at current consumption level. The profit is very small even in the short run when the cost of land is excluded. This may be the very reason for farmer’s reluctance of adopting new technology.

**Table 5.4: Households profit analysis for Oromia region**

| | Base Year | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| yield Increase | 0 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.65 |
| Quantity(Kg/ha) | 345 | 414 | 448.5 | 483 | 517.5 | 552 | 569.25 |
| Price(Br/kg) | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Revenue (Br) | 1,725 | 2,070 | 2,242.5 | 2,415 | 2,587.5 | 2,760 | 2,846.25 |
| Labor cost (Br) | 990 | 990 | 990 | 990 | 990 | 990 | 990 |
| Fertilizer cost(Br) | 31 | 31 | 31 | 31 | 31 | 31 | 31 |
| Seed cost(Br) | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Total Cost(Br) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Profit(Br) | 698 | 1,043 | 1,215.5 | 1,388 | 1,560.5 | 1,733 | 1,819.25 |

Source: World Bank LSMS-ISA,2013/14 and Own Computation, 2019

Oromia region is the largest producer of sorghum according the central statistics data (CSA, 2008/09-2013/14) and the second with World Bank LSMS-ISA data (World Bank LSMS-ISA, 2013/2014). When we consider the household level sorghum production and profitability, the region is at third place with Tigray region's farmers produce highest and Amhara region farmers the second highest (World Bank LSMS-ISA, 2013/14; Table, 5.2; Table 5.3; Table 5.4). Household level sorghum consumption in Oromia region is 373 kg and production is 373 kg per year (World bank LSMS-ISA,2013/2014). A 20% increase in sorghum yield to satisfy the annual consumption deficit at household level. However, the profit is very small and may be one reason for farmers to lose adoption of the new technology.

**Table 5.5: Households profit analysis for SNNP region**

| | Base year | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| yield Increase | 0 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.65 |
| Quantity(Kg/ha) | 133 | 159.6 | 172.9 | 186.2 | 199.5 | 212.8 | 219.45 |
| Price(Br/kg) | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Revenue (Br) | 798 | 957.6 | 1,037.4 | 1,117.2 | 1,197 | 1,276.8 | 1,316.7 |
| Labor cost (Br) | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 | 1,090 |
| Fertilizer cost(Br) | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| Seed cost(Br) | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| Total Cost(Br) | 1,134 | 1,134 | 1,134 | 1,134 | 1,134 | 1,134 | 1,134 |
| Profit(Br) | -336 | -176.4 | -96.6 | -16.8 | 63 | 142.8 | 182.7 |

Source: World Bank LSMS-ISA,2013/14 and Own Computation, 2019

The Southern Nations, Nationalities and Peoples (SNNP) is the third populous region in Ethiopia following Oromia and Amhara regions. The region is the fourth major sorghum producer (CSA, 2008/09-2013/14; World Bank LSMS-ISA,2013/2014). The highest labor cost hurts the region's farmers net loss for the base year and the first three scenarios. The *striga* control technology need to increase the yield by 50% and above for a positive profit in the short run (Table 5.5).

### 5.1.2. Producers' surplus, consumer's surplus and total surplus

The standard procedure to undertake an ex ante impact assessment includes collecting data from scientists and extension workers about the adoption rate, yield gain as well as the expected costs that can be used as a base data. Based on the adoption rate of the new technologies, the change in yield due to the application of the new technology as well as the change in total cost of investment to get the new technology, we can determine the net benefit or the net loss. Because when we are employing a new technology, the new technology will increase the yield as a result the producers will have more production per hectare. In addition, the new technology is not without additional cost. The increase in productivity is depicted as a horizontal shift of the supply curve and an increase in cost is a vertical shift. The difference between the horizontal and vertical shift in the supply curve is the net benefit, usually termed as 'K'. In order to determine the net supply shifter, we can use the adoption rate, the change in yield, the change cost and the coefficient of the supply equation or the own elasticity of sorghum supply.

The main interest of the economic surplus method is to determine the surplus to producers, consumers and the total social gain. For a complete analysis of the economic surplus method we need the change in price and the own price elasticity of sorghum demand. A base data is collected through group discussion, interview with the experts in the area or by undertaking national as well as regional workshops.

The economic surplus method is based on the net supply shifter (K), change in price, change in quantity of production, own price elasticity of demand and own price elasticity of supply. The beauty of the economic surplus method for ex-ante impact assessment is it allows to undertake the analysis based on limited data from relevant literatures and forecast the impact for the future feasible year. Therefore, we used the findings of different scholarly published studies data as a base and make our own judgment and assumption to develop the scenarios for adoption rate, yield change, change of cost investment cost. Suleiman (2003) estimated the price elasticity of sorghum supply is 1.0 and the price elasticity of sorghum demand -0.66 is obtained from a study by Tafere et al. (2010). Pre-research sorghum price, quantity demanded and quantity supplied is obtained from the World Bank LSMA-ISA (2013/14) Ethiopia data.

**Table 5.6: Values of the parameters**

| Parameters | Region | | | |
|---|---|---|---|---|
| | Tigray | Amhara | Oromia | SNNP |
| Own Price Elasticity of sorghum supply[1] | 1 | 1 | 1 | 1 |
| Own Price elasticity sorghum demand [2] | -0.66 | -0.66 | -0.66 | -0.66 |
| Price (Birr per kg)[3] | 6 | 8 | 5.5 | 6 |
| Pre-research sorghum quantity of demanded(ton)[3] | 344,000 | 874,000 | 1,050,000 | 270,000 |
| Pre-research sorghum quantity supplied(ton)[3] | 296,000 | 1,030,000 | 897,000 | 147,000 |
| Deficit /surplus | -48,000 | 156,000 | -153,000 | -123,000 |

Source: World Bank LSMS-ISA (2013/14)[3] ; Tafere et al. (2010)[2]; Suleiman (2003)[1]

Since we cannot observe the value of the parameters in order to estimate the supply shifter, K, we developed different scenarios and simulate the effects on consumer surplus, producer surplus and total surplus. Gierend et al. (2014) reports current and future new sorghum variety adoption rate by farmers based on Ethiopian Institute of Agricultural Research scientist's expert opinion. Accordingly, currently, it is at 5% and in the future their optimistic view is to reach 50% in the drylands, 10% in the intermediate altitudes and the national adoption at around 30% in 15 years. We take this as a base and simulate for ten years. In addition, Geirend et al. (2014) also reported adoption cost of new sorghum variety would cost 10-25% higher than the local varieties. In Ethiopia herbicide technology increases sorghum by 17.5% (AATF,2011), Intercropping sorghum with legumes increases sorghum yield from 27.7% to 34.4% (Dereje et al. 2016); Integrated Striga Management increases more than 100% compared with local striga controlling practices. We used an average of a 65% increase in sorghum yield. We also take advantage of previous studies for the value of the probability of success of achieving the expected yield change from adoption. Embaye et al (2017) use 50% probability of success on for an ex ante impact assessment sorghum research and poverty reduction in Ethiopia. Rudi et al (2008) reports scientist opinion of 90% and 67% and used the 67% for a study conducted to analyze the impact of developing low cost technologies for pyramiding useful genes from wild relatives into elite progenitors of cassava in Nigeria, Ghana and Uganda. Since the study is in Ethiopia and it is recommendable to use estimates that could not exaggerate, we directly took the assumption used by Embaye et al. (2017), that is, 50%.

**Table 5.7: The value of the supply shifter K for the ten scenarios**

| Scenario | $E(Y)$ | $E(C)$ | $\varepsilon$ | $p$ | $A_t$ | $K$ |
|---|---|---|---|---|---|---|
| 1 | 0.65 | 0.2 | 1 | 0.5 | 0.05 | 0.01 |
| 2 | 0.65 | 0.2 | 1 | 0.5 | 0.10 | 0.03 |
| 3 | 0.65 | 0.2 | 1 | 0.5 | 0.15 | 0.04 |
| 4 | 0.65 | 0.2 | 1 | 0.5 | 0.20 | 0.05 |
| 5 | 0.65 | 0.2 | 1 | 0.5 | 0.25 | 0.07 |
| 6 | 0.65 | 0.15 | 1 | 0.5 | 0.30 | 0.08 |
| 7 | 0.65 | 0.15 | 1 | 0.5 | 0.35 | 0.10 |
| 8 | 0.65 | 0.15 | 1 | 0.5 | 0.40 | 0.11 |
| 9 | 0.65 | 0.15 | 1 | 0.5 | 0.45 | 0.13 |
| 10 | 0.65 | 0.15 | 1 | 0.5 | 0.50 | 0.14 |

Source: Own Computation, 2019

### 5.1.3. Estimation of welfare for the four regions

**Table 5.8: Welfare analysis for Tigray region under the ten scenarios (in Birr)**

| Scenario | $P1$ | $Qd$ | $Qs$ | $K$ | $\varepsilon$ | $n$ | Z | CS | PS | TS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 344,000 | 296,000 | 0.01 | 1 | -0.66 | 0.03 | 60,117 | -34,141 | 25,976 |
| 2 | 6 | 344,000 | 296,000 | 0.03 | 1 | -0.66 | 0.09 | 176,815 | -100,414 | 76,400 |
| 3 | 6 | 344,000 | 296,000 | 0.04 | 1 | -0.66 | 0.12 | 233,396 | -132,547 | 100,849 |
| 4 | 6 | 344,000 | 296,000 | 0.05 | 1 | -0.66 | 0.15 | 288,799 | -164,011 | 124,788 |
| 5 | 6 | 344,000 | 296,000 | 0.07 | 1 | -0.66 | 0.21 | 396,070 | -224,931 | 171,139 |
| 6 | 6 | 344,000 | 296,000 | 0.08 | 1 | -0.66 | 0.24 | 447,938 | -254,387 | 193,551 |
| 7 | 6 | 344,000 | 296,000 | 0.10 | 1 | -0.66 | 0.29 | 548,138 | -311,292 | 236,847 |
| 8 | 6 | 344,000 | 296,000 | 0.11 | 1 | -0.66 | 0.32 | 596,471 | -338,740 | 257,731 |
| 9 | 6 | 344,000 | 296,000 | 0.13 | 1 | -0.66 | 0.38 | 689,601 | -391,629 | 297,972 |
| 10 | 6 | 344,000 | 296,000 | 0.14 | 1 | -0.66 | 0.41 | 734,398 | -417,070 | 317,328 |

Source: Own Computation, 2019 and World Bank LSMS-ISA, 2013/14

For all the ten scenarios, consumer surplus and total surplus is positive and increasing when the adoption rate increases. In Tigray region, households have the highest gross profit in the short run. The short run profit analysis does not consider the effect of price decrease due to increase in output. Producers have a negative surplus that alarms farmers are disadvantaged in a closed economy even though the striga control technology increases the sorghum yield.

**Table 5.9: Welfare analysis for Amhara region under the ten scenarios (in Birr)**

| Scenario | $P1$ | $Qd$ | $Qs$ | $K$ | $\varepsilon$ | $n$ | Z | CS | PS | TS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 874,000 | 1,030,000 | 0.01 | 1 | -0.66 | 0.03 | 203,651 | -158,400 | 45,251 |
| 2 | 8 | 874,000 | 1,030,000 | 0.03 | 1 | -0.66 | 0.09 | 598,977 | -465,886 | 133,091 |
| 3 | 8 | 874,000 | 1,030,000 | 0.04 | 1 | -0.66 | 0.12 | 790,652 | -614,972 | 175,680 |
| 4 | 8 | 874,000 | 1,030,000 | 0.05 | 1 | -0.66 | 0.15 | 978,336 | -760,953 | 217,383 |
| 5 | 8 | 874,000 | 1,030,000 | 0.07 | 1 | -0.66 | 0.21 | 1,341,726 | -1,043,599 | 298,127 |
| 6 | 8 | 874,000 | 1,030,000 | 0.08 | 1 | -0.66 | 0.24 | 1,517,433 | -1,180,265 | 337,169 |
| 7 | 8 | 874,000 | 1,030,000 | 0.10 | 1 | -0.66 | 0.29 | 1,856,872 | -1,444,281 | 412,591 |
| 8 | 8 | 874,000 | 1,030,000 | 0.11 | 1 | -0.66 | 0.32 | 2,020,603 | -1,571,632 | 448,972 |
| 9 | 8 | 874,000 | 1,030,000 | 0.13 | 1 | -0.66 | 0.38 | 2,336,090 | -1,817,018 | 519,072 |
| 10 | 8 | 874,000 | 1,030,000 | 0.14 | 1 | -0.66 | 0.41 | 2,487,846 | -1,935,054 | 552,791 |

Source: Own Computation, 2019 and World Bank LSMS-ISA, 2013/14

Amhara region is the second sorghum producer. Based on a seven-day recall consumption survey, sorghum is the most consumed crop by rural households. Sorghum price is higher compared to the other three regions (Tigray, Oromia, and SNNP). However, the increase in sorghum production due to the striga control technology do not benefit the producers.

**Table 5.10: Welfare analysis for Oromia region under the ten scenarios (in Birr)**

| Scenario | $P1$ | $Qd$ | $Qs$ | $K$ | $\varepsilon$ | $n$ | Z | CS | PS | TS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.5 | 1,050,000 | 897,000 | 0.01 | 1 | -0.66 | 0.03 | 168,204 | -94,838 | 73,366 |
| 2 | 5.5 | 1,050,000 | 897000 | 0.03 | 1 | -0.66 | 0.09 | 494,722 | -278,938 | 215,783 |
| 3 | 5.5 | 1,050,000 | 897000 | 0.04 | 1 | -0.66 | 0.12 | 653,035 | -368,200 | 284,835 |
| 4 | 5.5 | 1,050,000 | 897000 | 0.05 | 1 | -0.66 | 0.15 | 808,050 | -455,602 | 352,448 |
| 5 | 5.5 | 1,050,000 | 897000 | 0.07 | 1 | -0.66 | 0.21 | 1,108,191 | -624,829 | 483,361 |
| 6 | 5.5 | 1,050,000 | 897000 | 0.08 | 1 | -0.66 | 0.24 | 1,253,315 | -706,655 | 546,660 |
| 7 | 5.5 | 1,050,000 | 897000 | 0.10 | 1 | -0.66 | 0.29 | 1,533,672 | -864,728 | 668,944 |
| 8 | 5.5 | 1,050,000 | 897000 | 0.11 | 1 | -0.66 | 0.32 | 1,668,905 | -940,976 | 727,929 |
| 9 | 5.5 | 1,050,000 | 897000 | 0.13 | 1 | -0.66 | 0.38 | 1,929,479 | -1,087,896 | 841,584 |
| 10 | 5.5 | 1,050,000 | 897000 | 0.14 | 1 | -0.66 | 0.41 | 2,054,821 | -1,158,567 | 896,254 |

Source: Own Computation, 2019 and World Bank LSMS-ISA, 2013/14

Adoption of striga control technology decreases producers surplus and increases consumers surplus (table 5.10). Oromia region is the first producer of sorghum in Ethiopia followed by the Amhara region. However, sorghum producing households does not have a positive welfare from adopting striga controlling technology.

**Table 5.11: Welfare analysis for SNNP region under the ten scenarios (in Birr)**

| Scenario | $Po$ | $Qd$ | $Qs$ | $K$ | $\varepsilon$ | $n$ | Z | CS | PS | TS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 270,000 | 147,000 | 0.01 | 1 | -0.66 | 0.03 | 47,185 | -16,955 | 30,230 |
| 2 | 6 | 270,000 | 147,000 | 0.03 | 1 | -0.66 | 0.09 | 138,779 | -49,868 | 88,911 |
| 3 | 6 | 270,000 | 147,000 | 0.04 | 1 | -0.66 | 0.12 | 183,189 | -65,826 | 117,363 |
| 4 | 6 | 270,000 | 147,000 | 0.05 | 1 | -0.66 | 0.15 | 226,674 | -81,451 | 145,222 |
| 5 | 6 | 270,000 | 147,000 | 0.07 | 1 | -0.66 | 0.21 | 310,869 | -111,706 | 199,163 |
| 6 | 6 | 270,000 | 147,000 | 0.08 | 1 | -0.66 | 0.24 | 351,579 | -126,334 | 225,245 |
| 7 | 6 | 270,000 | 147,000 | 0.10 | 1 | -0.66 | 0.29 | 430,225 | -154,594 | 275,631 |
| 8 | 6 | 270,000 | 147,000 | 0.11 | 1 | -0.66 | 0.32 | 468,160 | -168,226 | 299,935 |
| 9 | 6 | 270,000 | 147,000 | 0.13 | 1 | -0.66 | 0.38 | 541,257 | -194,492 | 346,765 |
| 10 | 6 | 270,000 | 147,000 | 0.14 | 1 | -0.66 | 0.41 | 576,417 | -207,126 | 369,291 |

Source: Own Computation, 2019 and World Bank LSMS-ISA, 2013/14

Introducing striga control technology in SNNP has similar effect on sorghum producers of the other three regions, Tigray, Amhara and Oromia (Tables, 5.8;5.9;5.10). Producers have negative surplus and consumers have a positive surplus. The total societal welfare is positive and increasing.

### 5.1.4. Summary of the welfare analysis

In all the regional states, producers will not benefit from adopting striga controlling technologies. In the base year as well as for the consecutive ten scenarios, the effect on the producer's surplus is negative and increasing while the consumers benefit increases from period to period. The negative surplus is higher in Amhara and Tigray regional states where sorghum is the most consumable cereal crop. In all scenarios the net benefit is positive. Since sorghum producers are also consumers, farmers will be benefited from adopting the new technology. The size of the net benefit may be an important factor to increase the number of adopters. Open economy policy with neighboring countries could increase the producers surplus and the net surplus so that can attract more numbers of households to use the new technology.

In this study we benefit from previous studies of national level sorghum supply and demand elasticities. We have seen that unit price differs across regions (Table 5.6). Therefore, the producer surplus may have a different result for regional demand elasticity and we suggest any citation and future work need to consider this limitation.

**Figure 5.1: Consumer surplus of striga control technology for sorghum production**

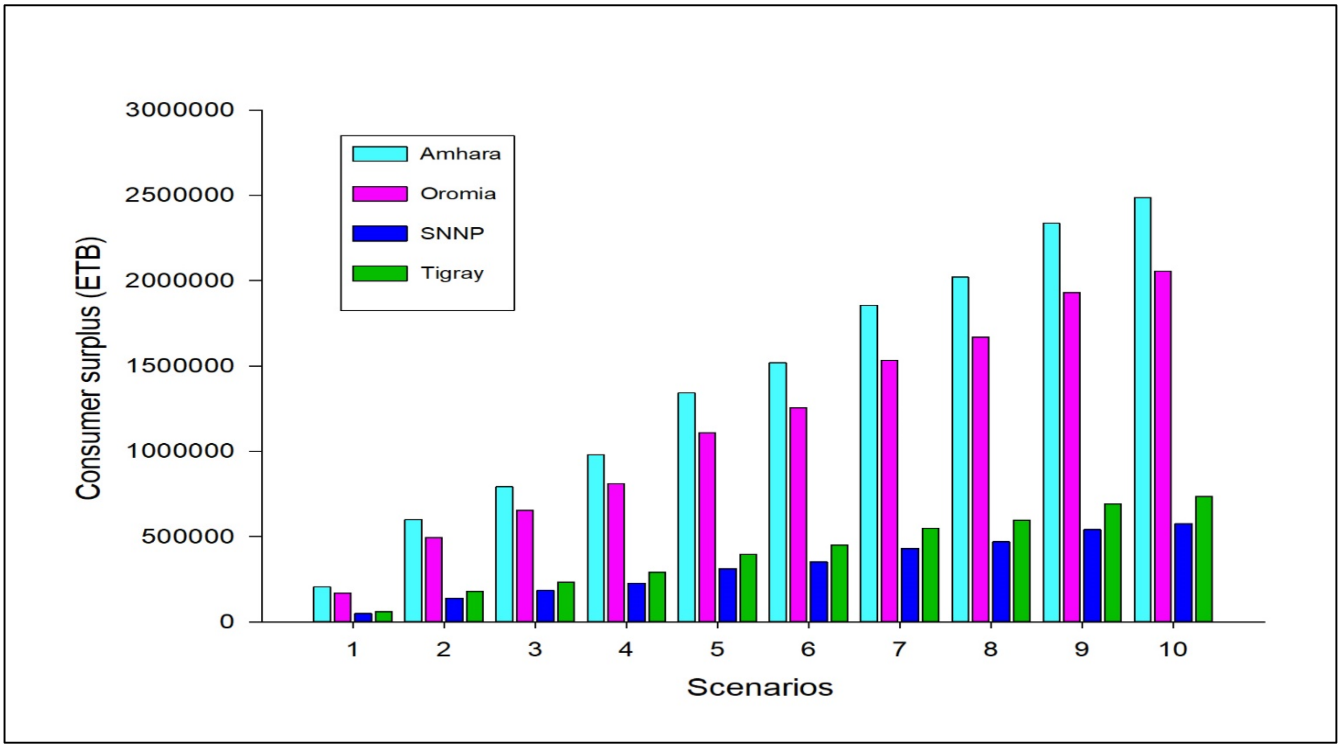


**Figure 5.2: Producer surplus of striga control technology for sorghum production**

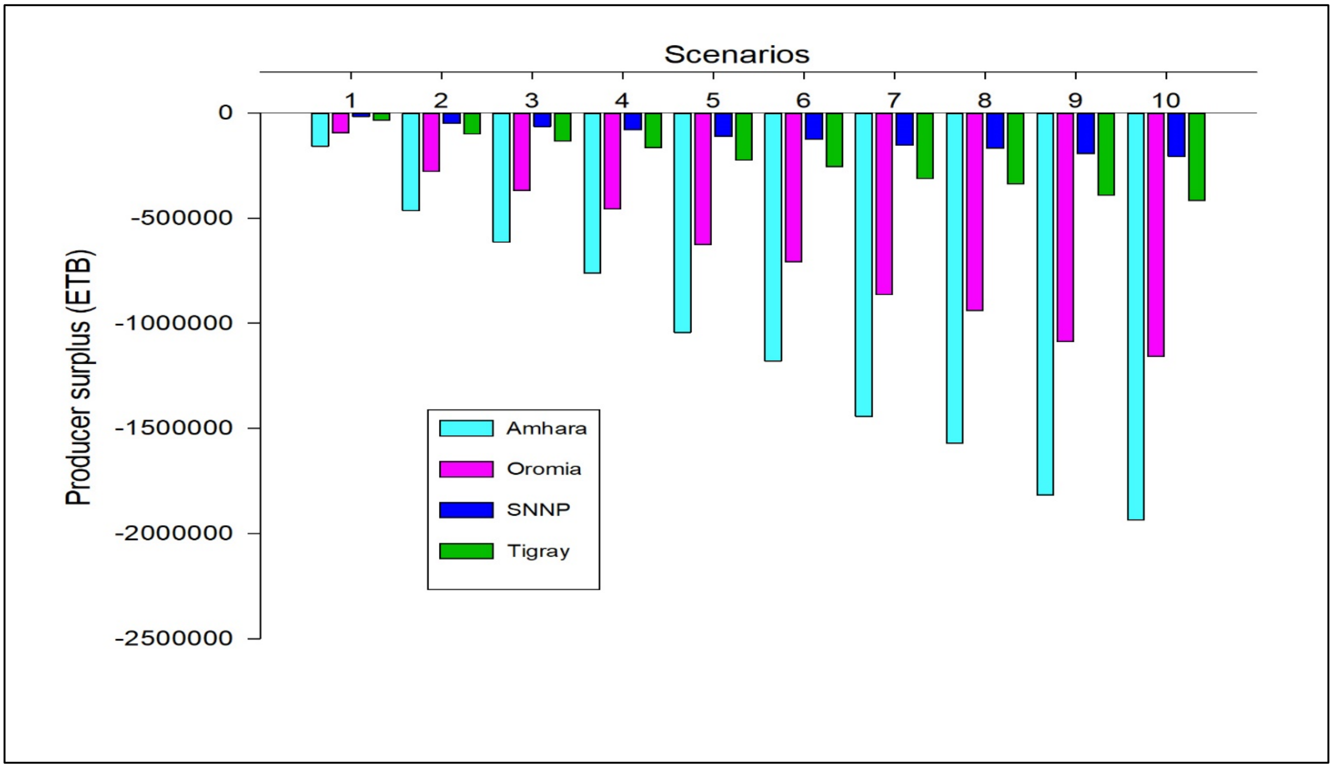
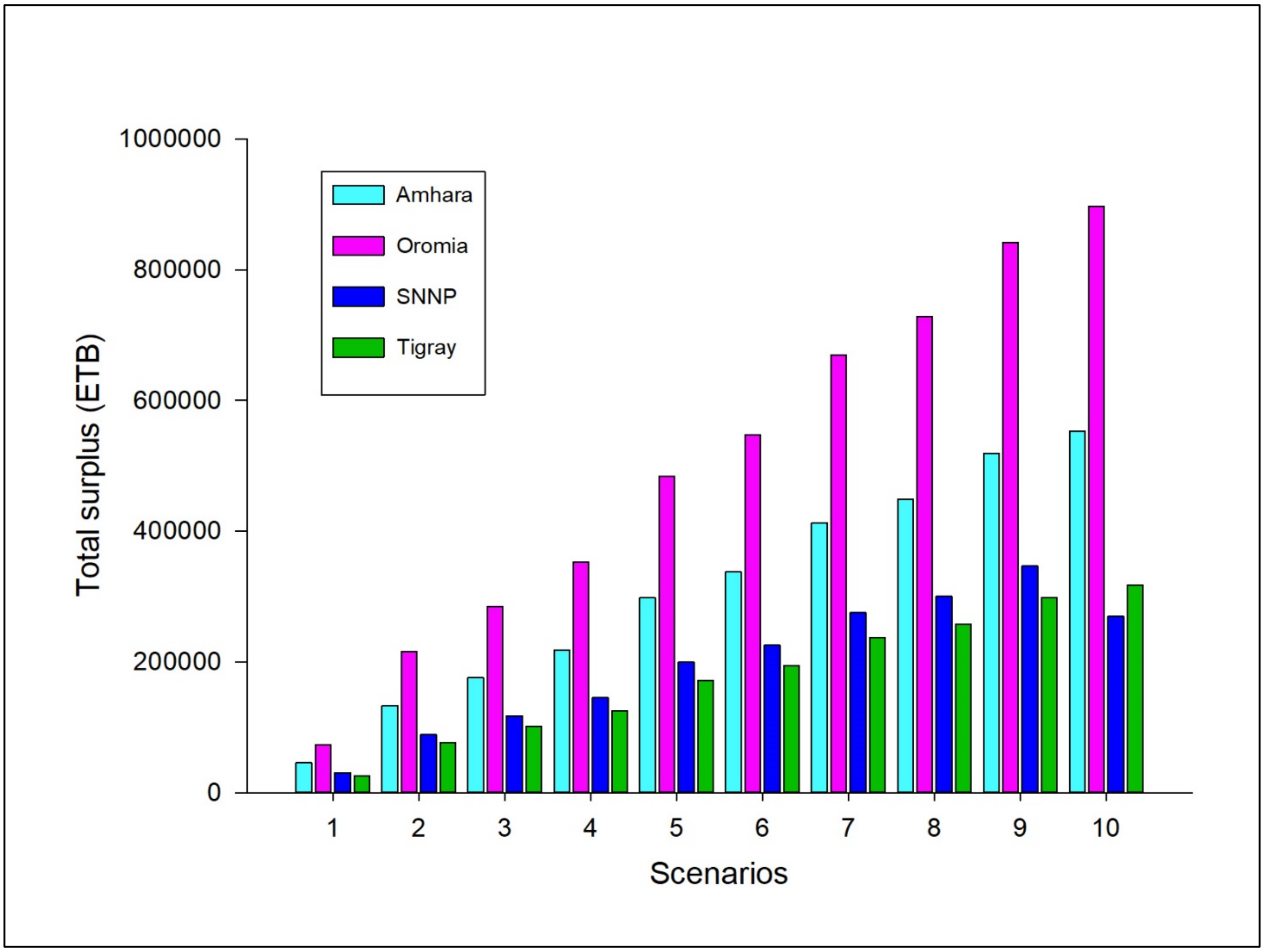


**Figure 5.3: Total surplus of adopting striga control technology for sorghum production**



## 5.2. Conclusion

An ex ante analysis on the impact of striga control technology for sorghum producing households of Ethiopia is undertaken. The study emphasis on the four major sorghum producing regions: Tigray, Amhara, Oromia and SNNP. Sorghum producing households in the three regions, namely, Tigray, Amhara, and Oromia has a positive short run profit but the SNNP has negative return due to high labor cost. Since the profit analysis does not consider the decrease in the sorghum price due to the increase in sorghum production, it may be misleading for policy makers to evaluate the performance of any newly technology on a standalone basis.

Our economic surplus model shows that producer surplus is negative, consumer surplus is positive and the total surplus is positive. Since Ethiopian households are both consumers and producers, the net benefit of adopting the stirga controlling technology is positive. Hence, farmers are still benefiting from adopting the new technology.

Producer surplus of adopting new striga control technology is negative due to the decrease in the market price of sorghum as the result of the sorghum supply shock. This will discourage the number of the new technology adopters. The market price of sorghum could be improved through the enactment of new policy by the government of Ethiopia that allows sorghum producers to trade with neighboring nations. Hence, we believe that open economy is the one and most important factor that determines the adoption of new striga control technology by farmers. There will other important factors but they are subsidiary to the trade policy.

Previous striga control technology studies did not consider regional heterogeneity of the distribution of striga and its impact on sorghum production on regional basis. All the studies consider agronomic research as the stand alone solution and the contribution of interdisciplinary research is nowhere proposed. Specifically, the contribution of socio economic research was totally overlooked. As a rational decision maker consumer, farmers will not adopt any technology if they assume the cost exceeds the benefit of adopting the new technology.

One of the limitation of this study is that we cannot extract region specific data. For example, the consumer’s response for the increase sorghum production may differ in the four regions. Hence, future studies need to consider a thorough assessment using region specific attributes and organized data for a better policy intervention and priority setting in allocating the limited resource to striga control technology research.

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