Swedish University of Agricultural Sciences
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The economic consequences of Striga *hermonthica* in maize production in Western Kenya

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Jenny Andersson and Marcus Halvarsson

Summary

Kenya is a country of 35 million people and is situated in Eastern Africa. 70% of the population works within the agricultural sector and for many of them food insecurity is a major problem. Maize and beans are today the staple food for many households. Good farming conditions enable two harvests per year and a potential maize yield of 4-5 tons per hectare.

A major problem for many farmers in this area is the increase of the weed striga. The weed causes severe yield losses, and has a major economic impact on smallholders. There are several types of maize farming systems used today and they are all more or less affected by striga. The focus of this study is the economic difference between these systems and is based on the following aim.

The aim of this study is to find the most economically beneficial maize farming system that is used today by smallholders in Western Kenya.

To reach this objective a literature review as well as an empirical study was made. The literature review revealed facts about striga its impact and methods to combat it. The empirical study is based on 30 interviews conducted during the spring of 2011 in Western Kenya. It provides general information about the farming situation today, and the type of maize farming systems. The data used to calculate the different average gross margins for the systems respectively.

The results of this study reveal that the most economically beneficial maize farming system is the one where resistant maize is intercropped with legumes. Other farming systems that according to the literature are favourable are not included in this study since they were not represented in the fields. The reason why farmers do not use these more favourable systems is a lack of information and insufficient supply of agro commodities.

Sammanfattning

Kenya ligger i östra Afrika och har 35 miljoner invånare. 70 % av dessa arbetar inom jordbrukssektorn. Tillgången på mat är ofta ett stort problem och basfödan på landsbygden består till stor del av majs och bönor. Jordbruksförutsättningarna i Kenya är mycket goda och omfattar två växtsäsonger per år, den potentiella majsavkastningen är 4-5 ton per hektar.

Ett stort problem för lantbrukarna i Kenya är den ökande påverkan av ogräset striga. Ogräset orsakar stora skördeförluster och har stor ekonomisk påverkan för den enskilde lantbrukaren. Idag tillämpas det flera olika majsodlingssystem men alla är mer eller mindre negativt påverkade av striga. Den studie fokuserar på de ekonomiska skillnaderna mellan dessa odlingssystem och utgår ifrån följande mål;

Syftet med denna studie är att finna det mest ekonomiskt lönsamma majsodlingssystemet av de som idag används bland småskaliga lantbruk i västra Kenya.

För att nå det uppsatta målet gjordes en litteraturgenomgång samt en empirisk studie. Litteraturgenomgången användes för att ge grundläggande information om striga, dess effekter och metoder att motverka det. Den empiriska studien bygger på 30 intervjuer som genomfördes under våren 2011 i västra Kenya. Studien ger generell information om hur jordbruket se ut idag, vilka odlingssystem som tillämpas, dessa uppgifter gjorde det möjligt att beräkna deras respektive täckningsbidrag per hektar.

Resultatet av studien är att det mest ekonomiska odlingssystemet är majs med betat utsäde odlat tillsammans med baljväxter. Andra odlingssystem med goda teoretiska referenser enligt litteraturen inkluderas inte i denna studie då de inte tillämpades hos de intervjuade lantbrukarna. Anledningarna till att dessa metoder inte användes är enlig denna studie brist på information hos lantbrukarna och bristande utbud av nödvändiga insatsvaror.

Terms

A number of interpretations of terms has been done in this study and has been used in this sense. Brief explanations are given below:

Double cropping	when a year has two seasons and the same or different crop can be harvest twice.
Farming system	only different crop systems and methods are considered by this term. It does not reflect on livestock and similar.
Gross margin per hectare	the gross margin per hectare is the sum of all incomes and variable costs generated by all crops grown at the field.
Intercropping	two or more crops are grown at a field at the same time.
Maize farming system	only cropping systems that include maize are considered.

Table of Contents

1 Introduction

This introduction describes the current situation in Kenya in general and more specific the farming systems and the problems with the parasitic weed *striga hermonthica*. The chapter ends with the aims and delimitations of this study.

1.1 Problem background

Kenya is situated in Eastern Africa with a population of 35.6 million people (www, IFAD, 2010). Approximately 70% of the population work within the agricultural sector and their households depend on the harvest. Food insecurity is a major problem and malnutrition is common. Kenya is among the world leading countries in exporting tea, coffee and horticultural products. In spite of this, the agricultural sector is experiencing reduced productivity due to climate change and inaccessible farm inputs among smallholder farmers. Further the poor infrastructure is making it hard for farmers to bring their products to the market. Kenya has very good farming conditions and farmers are normally able to harvest twice a year. The farming year is divided into two seasons, long- and short rains (Khan *et al.,* 2009). Long rains season are from March to August and the short rains are from October to January.

Maize is a common crop in eastern Africa and is the staple food for most households in Western Kenya. Today several farming systems are used and maize and beans are the main crops included in the crop rotation (pers. communication., Röing de Nowina, 2010). This is not longer possible at some sites. The weed *Striga hermonthica* has become a big problem and causes severe yield losses in the maize production. The potential maize yield in the Western Kenya is 4-5 ton/ha (Vanlauwe *et al.,* 2008).

Striga is a root parasitic plant and 35 species exist globally (Berner *et al.*, 1995). 80% of the species can be found in Africa but not all of them affect the farming conditions. Other countries that have been affected by striga is the US and Australia. In these countries methods to combat striga have been developed during the last fifty years. The reasons why these methods are not in used in Africa is that they include chemical inputs that are too expensive for the African farmers.

Traditional farming systems in Africa include grains that are more tolerant to striga, and also include more fallow in the crop rotation (Khan *et al*., 2010). These systems reduce the damage caused by striga to a lower level. Due to the increase in population the use of fallow has decreased at the same time as the use of new crops that are more affected by striga has increased. This has caused the striga problem to increase to a new level.

As striga is a major problem for farmers in Africa several methods have been developed to combat it. The problem is that the economic effect of these systems is hard to estimate and therefore it is difficult to determine which one that is the economically most favourable for the farmers.

1.2 Problem

Striga causes severe yield losses, sometimes the farmers loose 100% of their harvest (Berner *et al.*, 1995). Therefore it has a major economic impact for the smallholders as it decreases the income significant. The weed also lowers the food supply for many households as it causes major damages on the staple food and affects families whose food consumption is dependent on the harvest, so called subsistence farmers.

As several methods to combat striga have been developed, the question is which of these are used in Western Kenya today and what impact they have on the income generated by maize production for smallholder farmers.

1.3 Aim and delimitations

The aim of this study is to find the most economically beneficial maize farming system that is used today by smallholders in Western Kenya.

To reach this aim the two following research questions has been setup;

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

This study of the effects of striga is focusing on maize production. This is because maize is the main crop in this area and is heavily affected by striga. Many of the earlier and on-going studies have focused on soil fertility and biological effects. This study therefore aims to concentrate on the economic consequences on the farmer's income generated by the fields that includes maize in the crop rotation. Since few records are being kept the data will mostly be based on the memory of the interviewed person. Therefore the study will be based on the last two seasons only as to make it relevant.

2. Method

This chapter describes the methods that were used in this study. To reach the aim of this study, an empirical as well as a literature review was made. This chapter will present which method that was used on each aim and describe those. It will end with an outline description.

2.1 Choice of methods to reach aims

A theoretical study was undertaken to describe striga, its consequences and the methods to combat it. The empirical study consists of interviews. These are used to estimate which methods that are used to combat striga and the difference between them.

Below are the research questions of this study and a description how they were answered.

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

This question was answered by both a literature review and an empirical study. Knowledge about farming in Kenya from earlier studies was necessary to provide a general understanding and also to be able to ask the right detailed questions in the field. The empirical study was used to reach the second part of the question. To do this, 30 farmers in Western Kenya were interviewed and asked about striga and the methods to combat it.

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

From the empirical interviews in- and outputs quantities were collected from the farmers. Information regarding inputs costs were gathered from the local agro dealers. This data was collected to create a gross margin spread sheet for each farmer´s best and poorest field (Ax *et al.* 2006).. Each spread sheet gave a gross margin for a field. These values were then used to calculate the average gross margin per hectare for each farming system so that they could be compared.

The average gross margin per hectare for each farming system in this study was compared to determine which of these that was the most economically favourable system for maize production. The economic effect of using different preceding crops in maize production was also analysed. This was done by comparing the gross margins of maize grown with different preceding crops in the rotation.

2.2 Literature review

The fundamental facts in this study are based on the literature review. This was done to get a theoretical understanding and cover earlier studies on the subject.

The first step in the study was to find information about the problem: background about the general farming systems used in Western Kenya and the consequences of striga. This information was found in works by Kristina Röing de Nowina and her on-going project about striga and farming systems in Western Kenya. Additional information was found on well-known internet sites that were suggested by Kristina Röing de Nowina such as the UN and the CIGAR organizations.

The second step of the study was to find the relevant literature for review and to cover earlier studies in this field. To do this the library and a librarian were used to choose the most suitable databases. For this study Scopus was chosen. To limit the search and get relevant information these keywords were chosen; Striga AND farming systems AND Africa. In this search 22 articles were suggested and out of these eight were used in this study.

To decrease the risk of not covering essential sources, the reference list of articles that suited our study well were considered. Another method to decrease the risk of picking poor sources was to choose articles that were up to date.

2.3 Empirical studies Interviews

The core of this study is built on empirical data that was collected in Western Kenya during eight weeks in the spring of 2011. To reach the aim of this study, questionnaires were designed to obtain the necessary data.

The questionnaires that were used were semi-structured (Haji J., 2008). In this method the questions are somewhat flexible and above all, depending on how the farmer's answered a question, follow- up questions could be asked.

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

To make sure that as many farming systems and methods to combat striga as possible were covered, the interviews were made in two districts in Western Kenya, Bondo and Vihiga. In these two areas each farmer's best and poorest field were observed. To be able to answer this question the farmers were asked; what kind of crops they were growing, if they find striga a problem and the methods they use to combat it, the questionnaires are presented in appendix 1 and 2.

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

To be able to calculate the gross margin the contribution margin spread sheet from Agriwise was used as a model. From this model questions to the farmers were design to obtain quantity data concerning inputs and outputs of the maize production. As the farming year in Kenya has two seasons data was collected from both of them. By gathering data from two seasons the effect by the preceding crop could be examine. To make the gross margin comparable between fields the field size was measured so that the unit gross margin per hectare could be calculated. To get correct prices on inputs agro dealers in each area were interviewed. The prices for the different output crops were taken from the Kenya Ministry of Agriculture (www, Ministry Agriculture, 2011).

By summarizing the data and the average gross margins for the different farming systems the most economically beneficial system out of the observations could be determined.

2.3.1 Sites

The interviews took place in Bondo and in Vihiga located in Western Kenya, see figure no 1 and 2 below. The interviews were conducted in two areas to reduce the risk of collecting unrepresentative data and to avoid extremes. It also increased the chances of covering more methods to combat striga, since different methods are more common in different areas. The specific farmers in each area were chosen with help from the local farm organization that suggested a number of farmers.

	Bondo	Vihiga
Population	238 780	438 940
Area (km2)	987	466
Avarage maize yield (ton/ha)	1,9	1,2

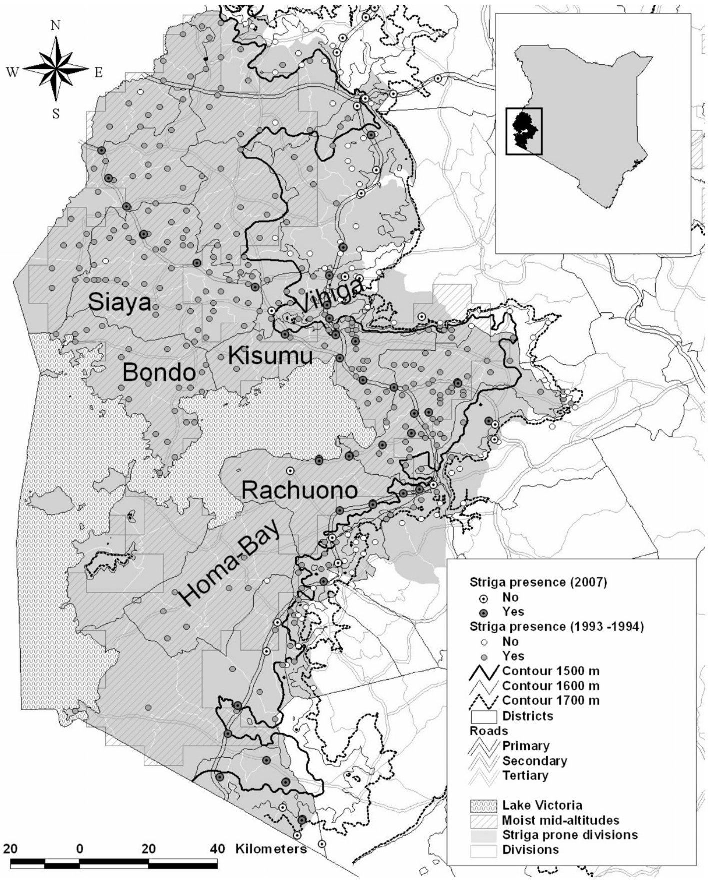


Fig 1. Facts about the areas (own creation, De Groote *et al.,* 2008)
Fig 2. Map over Kenya (De Groote *et al.,* 2008)

2.3.2 Questionnaires agro dealers

To estimate the input costs local agro dealers in both areas were visited and interviewed. These interviews were conduced after that the farmers were interviewed to make sure that all the different inputs that were used were covered, see appendix 1.

2.3.3 Questionnaires farmers

The first part of the farmers questionnaires included some general questions about the farming systems and educational background etc (Haji *et al.,* 2006). The purpose of this information was to obtain a basic understanding and to start up the interviews. The main part of the questionnaires was about the farmer's best and poorest maize field. The reason to this limitation was to save time and receive comparable and more detailed data.

For the best and poorest field input information regarding quantities for seeds, fertilizer, manure, pesticides, machinery, labour for the last two seasons were asked for. The reason why only two seasons were considered in detail is that few records exist and its hard to get correct data, as information relies only on the farmers memory. Crop type and yield were asked for four seasons, in order to examine if there was any effect of the preceding crop, see appendix 2.The last part of the questionnaires was about striga, if it was a problem, its effect, and which methods that were used to combat it.

2.3.4 Interview preparation

Prior to the interviews, preparation in terms of how to present the study and us for the farmers was undertaken. This was done to make sure that the farmers understood the purpose of the study and the questions.

2.3.5 The interviews of agro dealers

The interviews took place in shops for agricultural supplies. Shops in both Bondo and Vihiga were chosen to avoid any price and supply difference. An interpreter was used to avoid misunderstandings.

2.3.6 The interviews of farmers

The interviews took place at the farmer's household. They lasted for about an hour and during the interviews one of us asked the questions and the other wrote down the answers. An interpreter was used for most of the interviews, to enable good communication and more correct answers. To be as clear as possible the questions about the best field were asked while standing next to it. The same procedure was conducted for the poorest field. This was done to avoid misunderstandings.

In order to make the results from the different farms comparable the fields were measured, so that the gross margin could be measured in the unit SEK per hectare.

2.3.7 Contribution Spread sheet

After the interviews were conducted all data was assembled into a contribution spread sheet to calculate the gross margin for each field, for two seasons (Ax *et al.* 2006). These gross margins were then used to compare the different farming systems and make conclusions based on the empirical studies.

The gross margin (GM) was calculated from the total revenues (TRV) subtracting the total variable cost (TVC) (Ax *et al.* 2006):

GM = TRV – TVC

The total revenue was calculated by summarizing Xi which is the amount of money generated by the field outputs (i) such as maize, beans and soybeans.

$$\mathbf{TRV} = \sum_{i=1}^{K} \text{Xi}$$

The total variable cost was calculated by summarizing Yi, which is the amount of money used to buy non-farm input (i) such as seeds and fertilizer.

$$\text{TVC} = \sum_{i=1}^{k} y_i$$

While creating the contribution spread sheets all input and output quantities were converted into units used in Sweden such as SEK and kilo. The exchange rate used in this study was;
1 SEK = 11 Kshs.

2.3.8 Statistical analysis

To assure that the different average gross margin values for each maize farming system were statistic significant t-tests were made. This procedure was done for comparisons of the most common farming systems and the gross margin for maize with different preceding crops. The different steps for the t-test are presented below (Körner S, 1985);

1. The first step was to formulate null hypothesises based on the literature review so that the statistic significance could be tested.

2. Second step was to calculate the average gross margin (GM) for maize using different farming system and different preceding crop.

$$\overline{\text{GM}} = \frac{\sum_{j=1}^{n} \text{GMj}}{\text{n}}$$

n = number of units
GMj =gross margin/ha observed for unit j
(j=1….n farmers,

3. The third step was to determine the standard deviation (s) for the average maize gross margins using different farming system and different preceding crop.

$$s = \sqrt{\frac{\sum_{i=1}^{n} (GMj - \overline{GM})^2}{n-1}}$$

n=number of units
GMj = gross margin/ha observed for unit j
GM = average gross margin

4. The forth step was to calculate the variance (S^2) for the average maize gross margin using different farming systems and different preceding crops.

$$s^2 = \frac{\sum_{i=1}^{n} (GMj - \overline{GM})^2}{n-1}$$

n=number of units
GMj= gross margin/ha observed for unit j
GM= average gross margin

5. The fifth step was to calculate the t-value (t) for each Null hypothesis.

$$t = \frac{(\overline{GM} - \overline{GM}) - D}{\sqrt{s_1^2 / n_1 + s_2^2 / n_2}}$$

n=number of units
D= difference
GM= average gross margin
S^2 =variance

6. The last step was to calculate the degrees of freedom (df) for each null hypothesis. This value was needed to find the table-value that was compared with the t-value. If the t-value exceeded the table value, the null hypothesis could be rejected. The null hypothesis was tested for a 90% confidence interval due to that relatively few samples was included.

$$df = \frac{(s_1^2 / n_1 + s_2^2 / n_2)^2}{(s_1^2 / n_1)^2 / (n_1 - 1) + (s_2^2 / n_2)^2 / (n_2 - 1)}$$

n=number of units
S^2 =Variance

2.3.9 Feedback

After the summary of the interviews was completed the farmers were visited once again to give information about the results of the study and to show appreciation for their participation.

2.4 Outline

Figure no 3 illustrates the outline of this paper. Chapter 1 will provide the reader with an introduction to the problem and the problem background. In chapter 2 the method of this study will be described. Chapter 3 contains the literature review and provides the reader an understanding of the weed striga and its consequences Chapter 4 gives our interpretation of the empirical study. Chapter 5 contains an analysis and a discussion where the empirical study is reflected on with a literature perspective. The last chapter contains our conclusion.

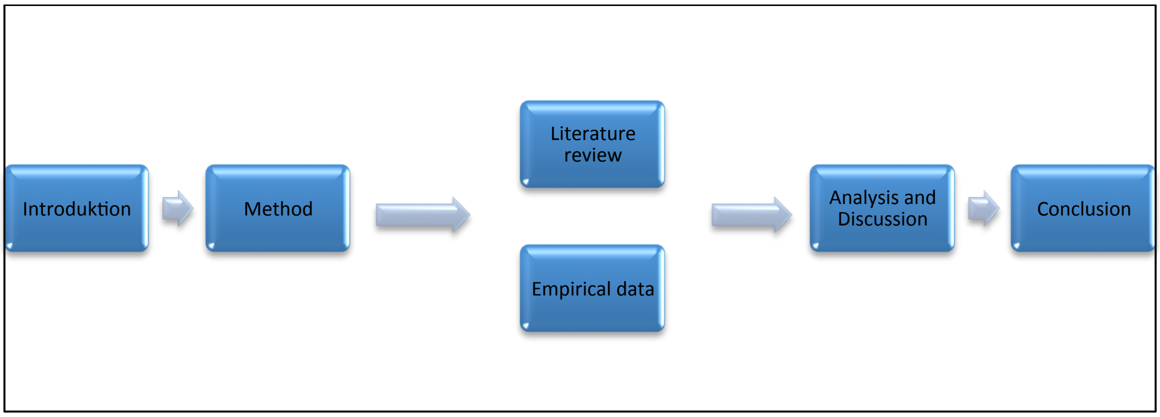


Fig 3. Study outline (own creation).

3 Literature review

In this chapter relevant information from earlier studies of striga have been summarized. This has later been used to analyse and discuss the empirical data.

3.1 Striga

Striga is a parasitic weed, it is mainly found in sub-Saharan Africa and causes yield losses of cereal crop such as maize (De Groote *et al*., 2007). As striga is a root- parasitic weed it needs a host to survive (www, cimmyt, 2010). The striga flower produces about 50 000-500 000 seeds per flower (Berner *et al.*, 1995). The seeds are triggered to germinate when there is a potential host, such as maize, close to them. When the seedlings germinate they need to attach to a host´s roots within 3-7 days, otherwise they die. If the seedlings do not germinate they can stay dormant in the soil for over 20 years (De Groote *et al.*, 2007).

Striga normally emerges about 4-7 weeks after planting (Berner *et al.,* 1995). After another 4 weeks it appears as a purple flower. It causes most damage to its host before it emerges and therefore, the use of post-emergent herbicides is not of great value (De Groote *et al.,* 2007).

Today all food crops in Africa are more or less affected by Striga (Berner *et al.,* 1995). Earlier the striga problem was not as big as it has become lately. This is because the traditional crops, such as sorghum, have evolved together with striga during a long time and build up a natural resistance. Today farmers choose crops with more focus on high yield and modern food consumption such as maize (Khan *et al*., 2010). These crops have not developed the same level of natural protection against Striga since they have not evolved with it. The traditional crops such as sorghum and millet are also more tolerant against droughts.

According to Berner *et al.,* 1995 a major cause of the big spread of striga is the market of seeds. Seeds from a large area are normally sold at the market and striga seeds are often mixed with the crops seeds. Consequently farmers in areas with no striga can get the weed from seed purchases.

3.1.1.Effects

The damage striga causes is major and the harvest losses are obvious (De Groote *et al.,* 2007). Striga slows down the growth of the host in two ways: it damages its photosynthesis and uses its nutrients, causing a deficit (Khan *et al.,* 2006). The cereal yield therefore decreases with 1,2 million tons annually in east Africa alone (www, cimmyt, 2010). In Kenya the annual economic loss is estimated to be US$46 millions.

The damage striga causes varies between fields and areas. Some fields may experience just a small yield loss while others suffer a yield loss up to 100% (Berner *et al.,* 1995). After striga has spread to a field the damage it causes increases every season if nothing is done to combat it (Khan *et al.,* 2006). Farmers who have too much striga in their fields find it easier to abandon them and start cropping somewhere else. This is one reason to why striga is increasing so rapidly.

3.1.2. Methods to combat striga

Today several methods to combat striga exist (De Groote *et al.,* 2007). In this section the following methods are described: resistant maize, intercropping with legumes, fallow, suicidal germination, pesticides. See figure no 4 below.

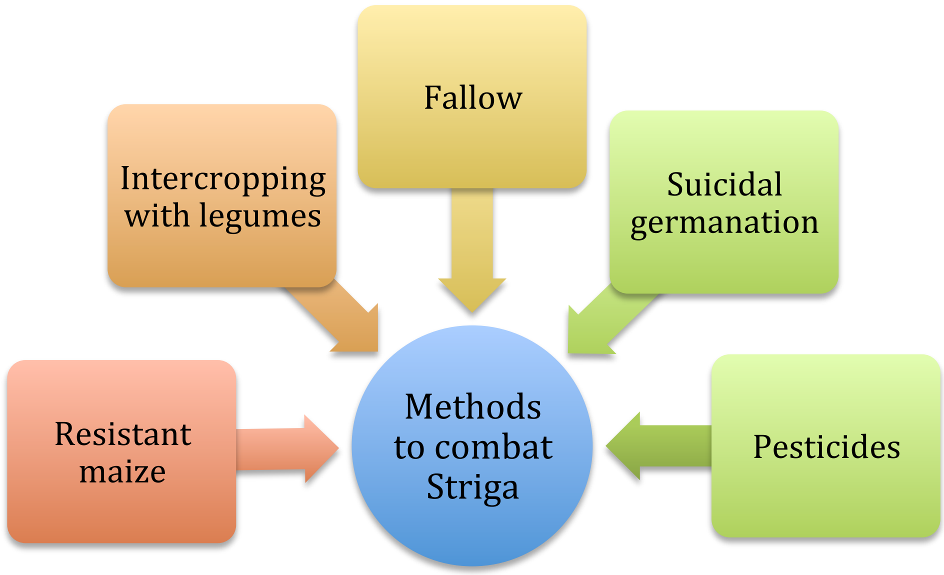


Fig 4. Illustration of methods to combat striga (own creation)

The adaption of new methods is often slow; one reason for this is that the farmers doubt them (Khan *et al.,* 2009). They say that they hear rumours about how these new methods do not work and are therefore unwilling to test them. Another reason is that the return of the new methods in terms of higher yield do not appear immediately but the cost do (Khan *et al.,* 2008*)*.

3.1.2.1 Striga resistant maize

One way to treat Striga is to use maize seeds that are dressed with certain herbicides. This herbicide gives the seeds imidazolinone resistance (IR)(De Groote *et al.*, 2007). This protects the seed from Striga infestation and improves germination. An advantage of using resistant maize is that unlike herbicide spraying with the same effect it allows intercropping with legumes. The reason to this is that when the spray is used the crop planted together with the maize is damaged. The IR maize seed has a good protection against striga up till several weeks after it has emerged.

A disadvantage with this method is that the dressed seeds are expensive and cannot be recycled (Khan *et al.,* 2006*)* The herbicide will only protect the seed for a certain time and seeds that are recycled from harvest will not have this striga protection. Therefore new seeds need to be bought every year. Another problem is that in some rural areas the seeds are not sold at the local market, which sometimes makes it impossible for the farmer to purchase them. To get this method to work properly and enable the supply of seeds at the right time the infrastructure in Kenya needs to be improved and also the delivery system (De Groote *et al.*,2008).

3.1.2.2 Intercropping with legumes

Intercropping, where two or more crops are grown at a field during the same time, has an advantage as the risk of harvest losses decreases as several crops are grown at the same time (Khan *et al.,* 2009). Another advantage when beans are grown together with mazie, is that the food supply is distributedover an extended period as the bean harvest is earlier than the maize harvest. Similarly if the grains are sold the farmers recieve a more even cash flow. It has also been proven that maize grown in monocropping is more affected by striga than maize in intercropping (Khan *et al.,* 2006).

To intercrop legumes also increases the soil fertility and provides shade that gives Striga a disadvantage (Khan *et al.,* 2006). Striga is less common in areas with high soil fertility as the crops are stronger and have a higher striga tolerance.

The reason why many farmers use the same kind of crop every season and never other alternatives is that there is a limited market for their products where not all of them can be traded and therefore they choose crops that they know can be sold (Khan *et al.,* 2009). The advantage with legumes is that a market already exists for this crop. A disadvantage with intercropping is that it is more time consuming compared to monocropping (Khan *et al.,* 2009). As two crops needs to be planted and harvested during different time periods.

3.1.2.3 Fallow

By including fallow in the crop rotation two positive effects occur (De Groote *et al.*, 2007). The first one is that the soil fertility increases which makes the conditions less favourable for striga. The second effect is that the striga seed bank in the soil decreases which leads to a smaller effect of striga during the next season. Due to an increase in population the use of fallow has decreased (Berner *et al.,* 1995). As more people needs to be fed the farmers have not been able to put land aside for a season.

3.1.2.4 Suicidal germination

Suicidal germination is also a method to combat striga (Khan *et al.,* 2010). When using this process a plant, normally desmodium is planted in the field. Desmodium stimulates the striga seedlings to germinate but cannot work as a host as the striga seedlings are unable to attach to it. Without attaching to a host the seedlings cannot survive and therefore die. Use of desmodium generates other advantages as well; it increases the soil fertility, supplies the farm with cheap and good animal fodder and is inexpensive. It can also be intercropped with most crops. Desmodium also provides ground cover that lowers the soil temperature, which makes the environment more unfavourable for striga. It has been concluded that the striga seed bank in the soil decreases significantly when desmodium is used as a intercrop with maize compared to when maize is intercropped with beans (Vanlauwe *et al.,* 2008).

A disadvantage with this method is that desmodium is a grass for animal fodder and occupies land where other crops could have been grown for food consumption. Lately it has been found that soybeans have similar effects as desmodium on striga, with the big advantage that soybeans are used for human consumption (Odhiambo *et al.,* 2009). Soybeans are a very good protein source and also have great nitrogen-fixation properties, which increases the soil fertility and decrease the need of fertilizer. Another advantage is that it already exist a market for soybeans and the surplus can easily be sold.

3.1.2.5 Pesticides

Striga can be controlled by usage of spray herbicides (De Groote *et al*.,2008). The problem is that striga causes most damage to its host before it emerges and therefore post- emergent herbicide has little effect. The biggest issue for African farmers is that this spray is too expensive. Another issue in Africa is that these pesticides are not available at the market and cannot be purchased (Berner *et al*., 1995).

3.1.2.6 Earlier economic results

The gross margins generated by different maize farming systems have been compared earlier. According to a research made 2004 the following trends was observed (Khan *et al.,* 2008). Maize intercropped with desmodium generated the highest gross margin, next best was maize intercropped with legumes and the lowest gross margin was generated by maize in mono cropping, see figure no 5 below. This research was made in six different areas in Western Kenya and did not include resistant maize.

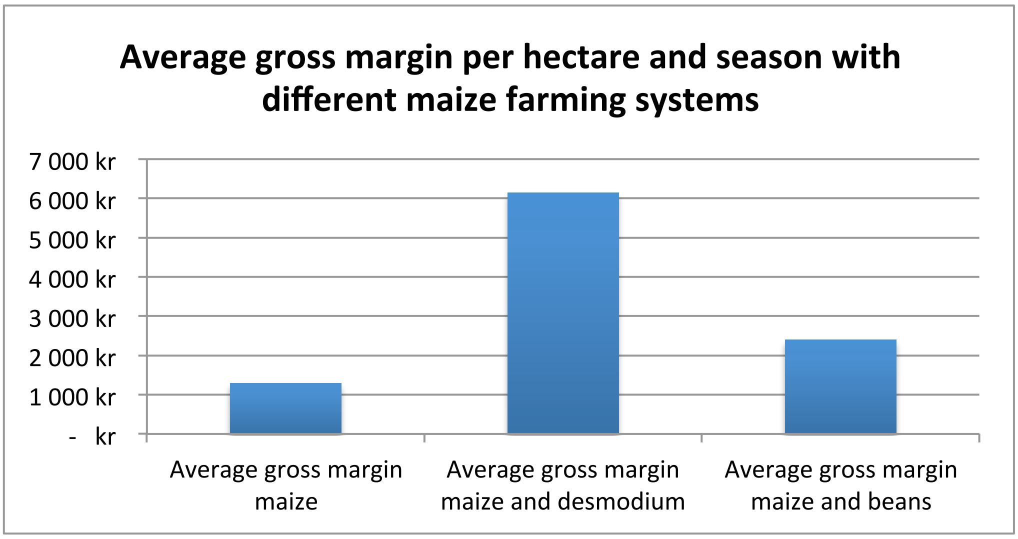


Fig 5. Comparison between different maize farming systems own creation (Khan *et al.,* 2008).

Another research was made in 2007. This research separated long and short rains and presented the same trends, see figure no 6 below. This research was done in four different areas; two of these were also represented in the research mentioned above. This research didn't either included resistant maize but our study does. It can therefore be useful for future comparisons.

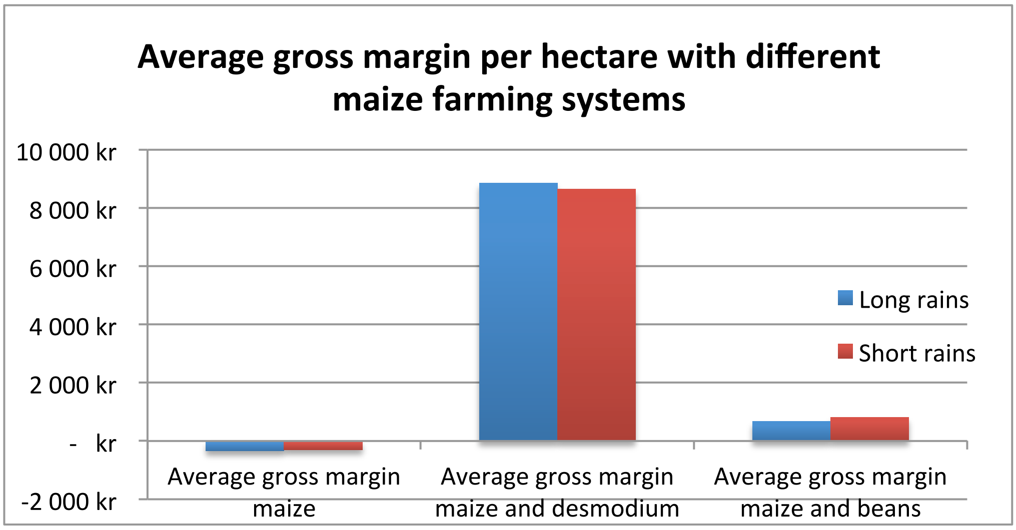


Fig 6. Comparison between different maize farming systems own creation (Khan *et al.,* 2009).

3.2 Hypothesis

In this study hypothesis were set up according to the literature review. These were later used to test if the empirical data was statistic significant. Seven null hypothesis were tested;

1. H0; Non-resistant maize generates the same average gross margin as resistant maize.

2. H0; Non-resistant maize intercropped with legumes generates the same average gross margin as resistant maize intercropped with legumes.

3. H0; Non-resistant maize generates the same average gross margin as non-resistant maize intercropped with legumes

4. H0; Resistant maize generates the same average gross margin as resistant maize intercropped with legumes

5. H0; There is no difference in using fallow or maize as a preceding crop in terms of average maize gross margin

6. H0; There is no difference in using maize or maize intercropped with legumes as a preceding crop in terms of average maize gross margin

7. H0; There is no difference in using maize intercropped with legumes or fallow as a preceding crop in terms of average maize gross margin

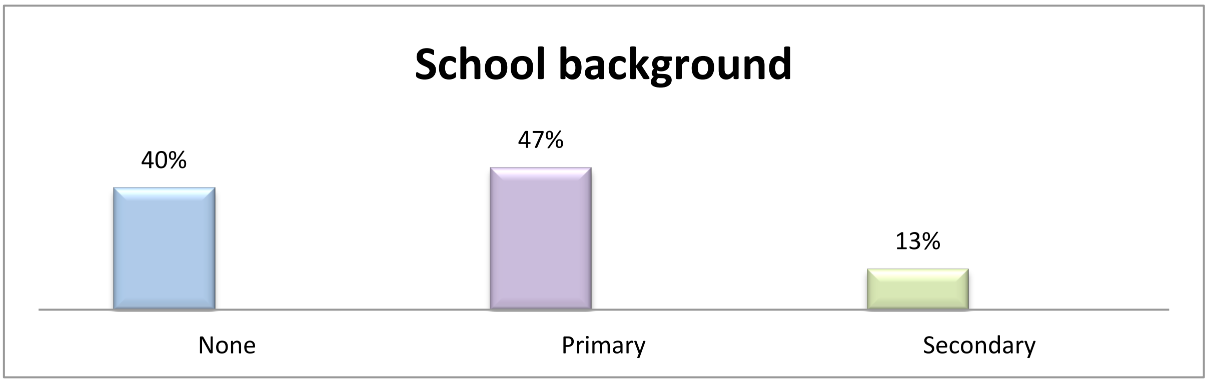
4. Empirical data

The following chapter is based on the interviews with farmers and agro dealers in Western Kenya. The empirical data from the farmers will be presented according to the research questions of this study.

4.1 General findings from the empirical studies

During the interviews basic information about the farms was collected to obtain a general understanding. The farms that were visited in Vihiga were relative small. Most of them were about one acre, that is approximately 0,4 hectares. In Bondo the farms were slightly larger around 1,5acers (0,6 ha) on average. The number of fields on each farm was on average five and was similar in the two areas, so the average field size was twice as large in Bondo.

Out of the interviewed farmers 40% had no school background, 47% had gone through primary school, which means 8 years of school. Only 13% had gone to secondary school that is an additional 4 years, see figure no 7 below. None of the 30 farmers had received any education or professional background in agriculture except one who had participated in practical training. This means that most of them acquired their farming knowledge by imitating parents and neighbours. District agriculture officers were present in both Bondo and Vihiga but only one of the 30 interviewed farmers answered that he had contact with them. The general opinion was that these officers had little or no interest in helping farmers.



On the visited farms the family consumed a large share of the harvest. The yield could therefore in some cases be hard to estimate, as the crops were consumed continuously and not only at harvest.

Traditional farming methods were used on the farms. Most work was done by hand. Only a few farms used cattle for land preparation. No machinery or tractors were used and only few farms had electricity. The different crops that were found on the farms were maize, beans, soybeans, sorghum, millet, tea, coffee, bananas, sweet potato, cassava, naiper grass, and different vegetables.

Fig 7. Illustration of the farmers school background (own creation)

4.2 Agro dealers

During the interviews with the agro dealers prices on agro commodities that the farmers used were collected. The prices were similar between the two areas and the supply was more or less the same. According to the agro dealers the supply of agro commodities that they could buy fluctuated very much so their supply to the market differed a lot. At the moment the interviews took place no soybean, desmodium or IR maize seeds could be bought in the shops. None of the shops that we visited sold pesticides for striga or had done so before. The data is presented in the figure no 8 below:

Pricelist agrodealer Vihiga				**Pricelist agrodealer Bondo**			
Seeds		ksh/kg	kr/kg	Seeds		ksh/kg	kr/kg
Maize	IR	160	14,5	Maize	IR	160	14,5
	Pioneer pan	215	19,5		Ukayoungo	180	16,4
	Pioneer phb	225	20,5		WS 505	175	15,9
	KH 500	150	13,6		Duma 043	225	20,5
	KSTP 94	125	11,4		DH 04	150	13,6
	WS 505	132,5	12,0	Cassawa	One bundle	20	1,80
	WS 909	180	16,4	Groundnuts		200	18,2
Soybenans		150	13,6	Soybenans		150	13,6
				Millet		150	13,6
				Sorghum		150	13,6
Local beans	GLP 1127	135	12,3	Local beans	GLP 1127	100	9,1
Fertilizer				Fertilizer			
	DAP	82,5	7,5		DAP	76	6,9
	CNL	62,5	5,7		CAN	56	5,1
Pesticides	-			Pesticides	-		

Fig 8. Pricelist of agro commodities in Vihiga and Bondo (own creation)

4.3 Methods to combat striga

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

During the interviews several maize systems were observed. The systems were categorized into six different types. These six types were; resistant maize grown by itself, resistant maize grown with legumes, non-resistant maize grown by itself, non-resistant maize grown with legumes, non-resistant maize grown with other intercrops and fallow, see figure no 9 below.

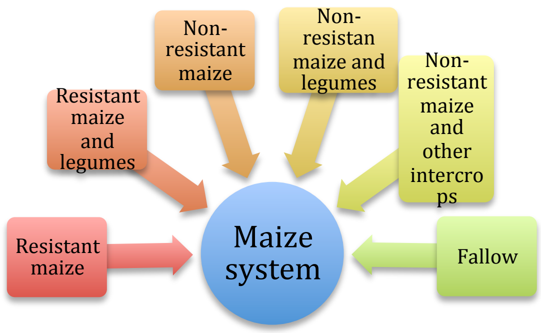


Fig 9. Illustration of different maize system (own creation)

None of the 30 farmers who were interviewed used desmodium and only one was growing soybeans. Hence the legume that most farmers cultivated was beans.

The most common system was non-resistant maize intercropped with legumes; it represented 54% of the observed fields. The second largest system was non-resistant maize grown by itself, it represented 18% of the observed fields. The other systems were represented in smaller portions, see figure no 10 below.

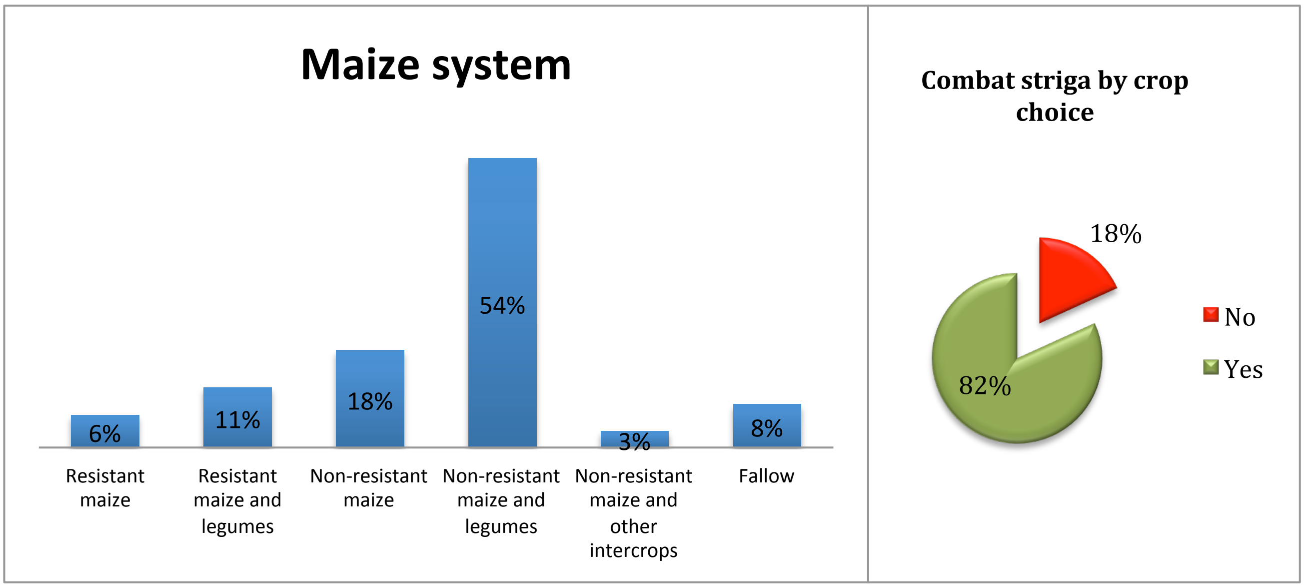


Fig 10. Illustration of the different maize systems in the study (own creation)

All these systems apart from non-resistant maize are known methods to combat striga. It can therefore be concluded that 82% of the fields were combating striga by crop choice or by including fallow, see figure no 10 above. One reason why relatively few farmers used resistant maize seeds was according to several of them that they had heard or experienced that these seed sometimes did not germinate. The farmers stated that they preferred to use their own seeds and get a smaller but more secure harvest. Another reason for using their own seeds was that the resistant seeds were too expensive. The resistant maize can also still be affected by other complications such as droughts and according to other studies give a low crop yield with higher input costs (Khan *et al*., 2006).

During the interviews all the farmers said that the amount of striga has increased and that it has become a bigger problem during the last years.

The use of fields differed between the two areas Bondo and Vihiga, se figure no 11 below. The main differences were the use of mono- and intercropping. In Bondo maize in mono-cropping and fallow was used more frequently. In Vihiga maize intercropped with legumes were more common and the usage of fallow was unusual, see figure no 11 below. Only 2% of the fields in Vihiga and Bondo grew traditional crops as sorghum, millet and cassava. None of the farmers had dismodium at their fields.

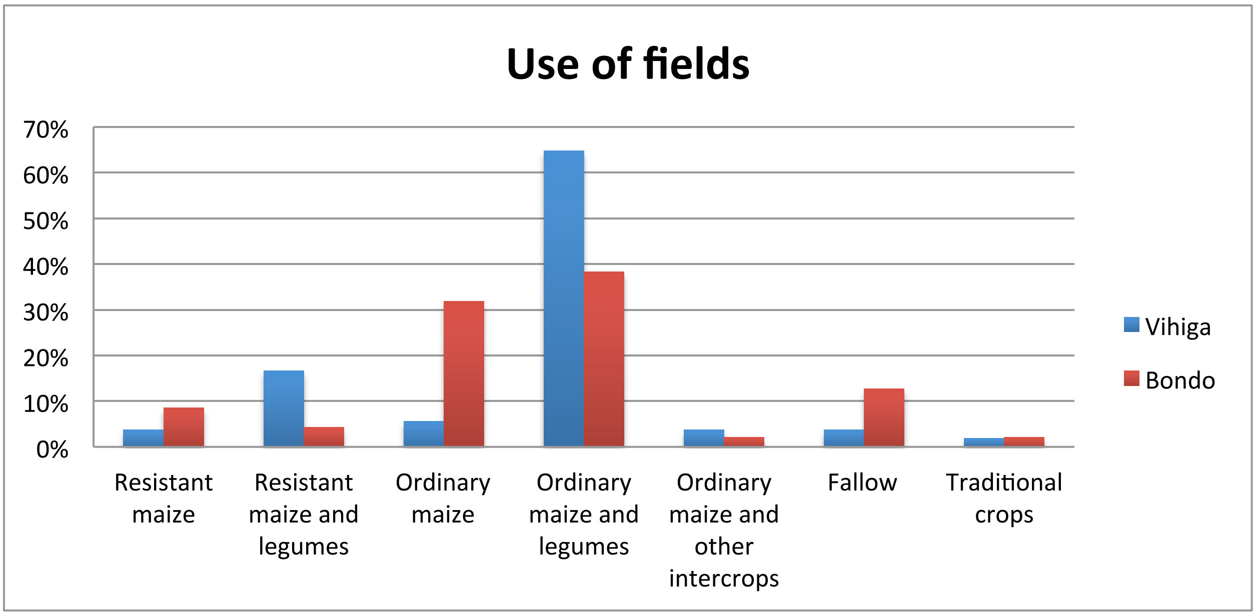


Fig 11. Illustration of use of fields in Vihiga and Bondo (own creation)

Apart from crop choice, manure and fertilizer were used as methods to combat striga. Fertilizer was spread on 35% of the fields. Manure was used on 42% of the fields and only on farms that had their own livestock, see figure no 12 below. The manure and fertilizer were used as it increased the soil fertility. The manure was often, due to practical reasons, spread on the field closest to the homestead. Because of this practice, that field was often the best one in terms of yield. None of the farmers used any kind of pesticides and all of them were weeding by hand.

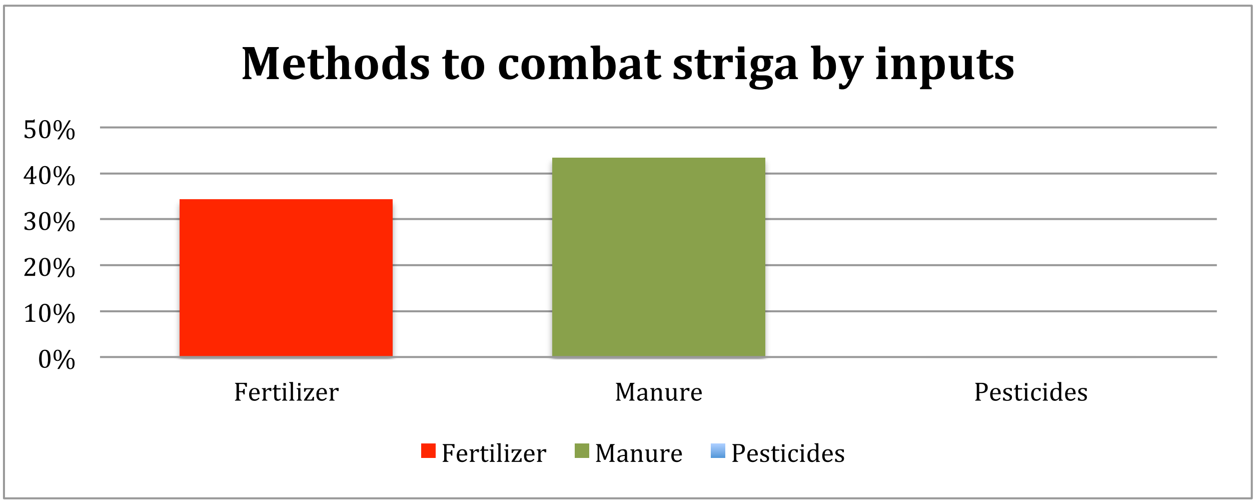


Fig 12. Illustration of the percentage usage of inputs that combat striga, none of the farmers used pesticides (own creation)

4.4 Economic difference between maize farming systems

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

Out of the data collected during the interviews the average gross margin was calculated for the most common maize systems. A division of fields was done according to seed type and season. This division enables us to compare mono-cropping maize with non-resistant and striga resistant seeds, but also to evaluate inter-cropping maize and legumes with non-resistant and striga resistant maize seeds.

In the diagrams below the gross margin for maize grown by itself has been calculated for non-resistant respective striga resistant seeds. The same has been conducted for maize intercropped with legumes. The gross margins have been calculated for the both long and short rain seasons.

The gross margin for maize with striga resistant seeds is higher than maize with non-resistant seeds in both systems and seasons. The diagram also reveals the difference in gross margin for maize intercropped with legumes and maize grown by it self. During both seasons maize intercropped with legumes yields a higher average gross margin than maize in mono cropping, see figure no 13 below.

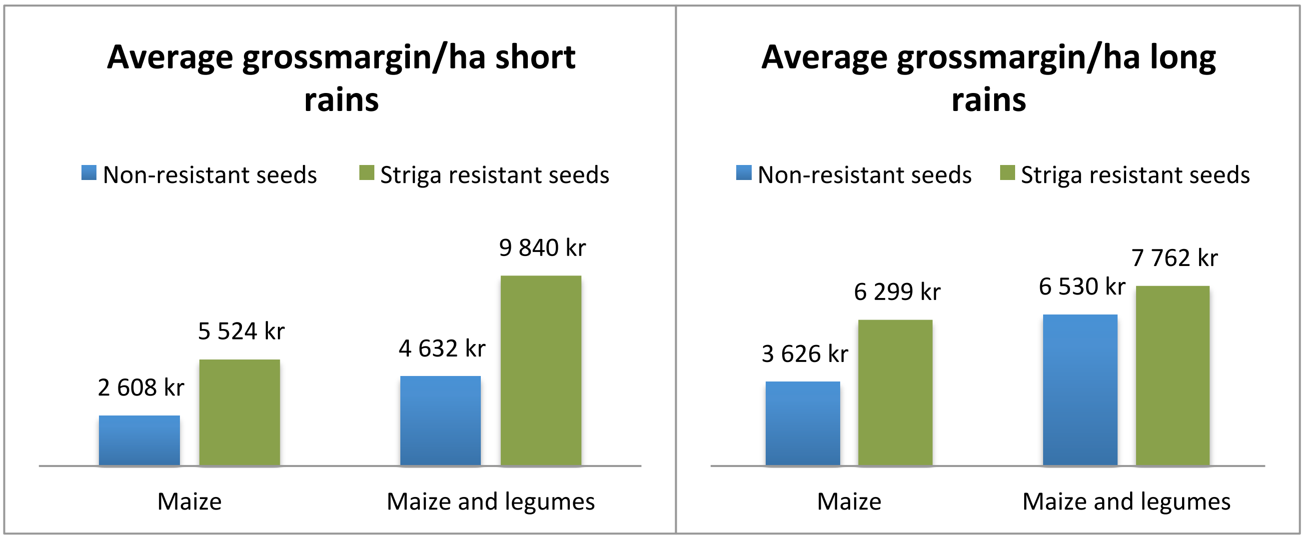


Fig 13. Illustration of the average gross margin per hectare with different maize farming systems, during long- and short rains (own creation)

In order to conduct a statistical test of the different hypotheses (1-7) the differences in average gross margin were tested. Seven null hypotheses were tested for statistical significance, see table no 14 and 16 below. The t-test was conducted with 90% confidence interval, as the number of samples was relatively small. The statistical tests revealed that the resistant maize yielded a statistically significant higher average gross margin per hectare than the non-resistant maize. It was also found that non-resistant maize intercropped with legumes generated a statistically significantly higher average gross margin per hectare than non-resistant maize. This level of statistic significance was not found for the other five null hypothesis.

Statistic significance	Df	T-value	Table-value	Reject H0
1. H0; Non-resistant maize = resistant maize	12	-1,6434	-1,3562	Yes
2. H0; Non- resistant maize+ legumes = resistant maize+ legumes	6	-1,1446	-1,4398	No, not statistic significant
3. H0; Non-resistant maize = Non resistant maize +legumes	23	-1,5490	-1,3195	Yes
4. H0; Resistant maize = resistant maze +legumes	7	-0,9173	-1,4149	No, not statistic significant
Confidence interval of 90%				

Table 14. Results from the t-test (own creation)

In order to examine if the preceding crops planted at the field the season before had any effect on the yield and the average gross margin per hectare, a comparison between the average maize gross margins with different preceding crops was carried through. In this comparison all kinds of maize seeds were included and compared. From the collected data a difference in average gross margin could be observed, see figure no 15 below. Maize after maize and legumes had a higher average gross margin than maize after maize or fallow.

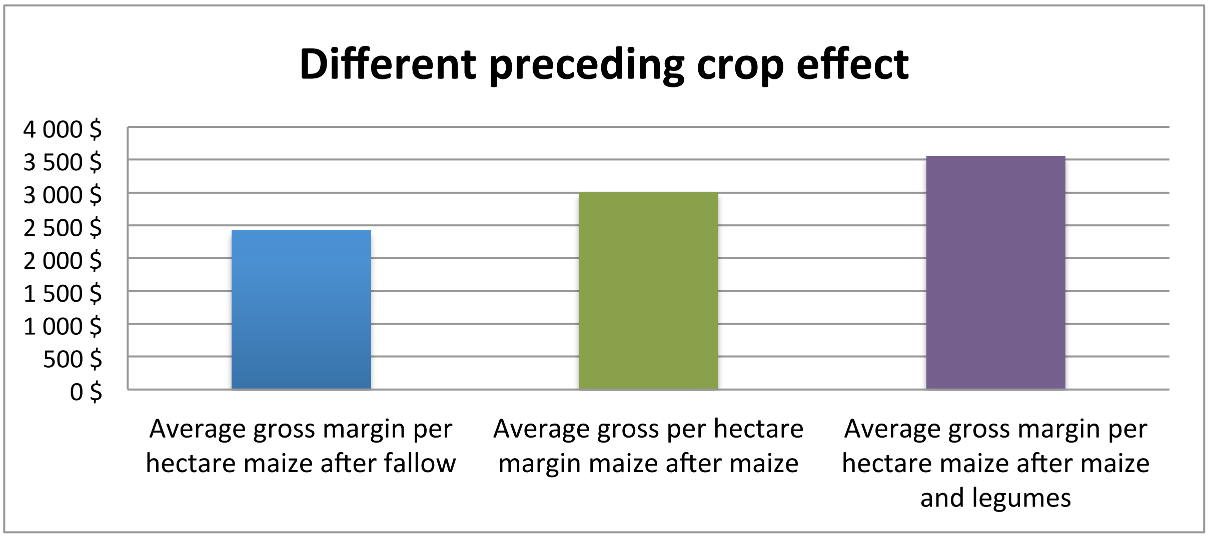


Fig 15. Different farm systems average gross margin/ha depending on the preceding crop (own creation)

According to the t-tests no statistically significance differences could be confirmed between the different preceding crops in terms of average gross margin per hectare, se table no 16 below. Even in this test a 90% confidence interval was used due to the small number of samples.

Statistic significance	Df	T-Value	Table-Value	Reject H0
5. H0; Fallow = Maize	14	-0,569	-1,3450	No, not statistic significant
6. H0; Maize = Maize + legumes	4	-0,310	-1,5332	No, not statistic significant
7. H0; Maize + legumes = Fallow	8	-0,672	-1,3968	No, not statistic significant
Confidence interval of 90%				

Table 16. Results from the t-test (own creation)

When all systems had been evaluated the system with the highest average gross margin per hectare could be determined. Maize intercropped with legumes and with striga resistant seeds was the system with the highest gross margin and is therefore the most economically beneficial farming system according to this study. The result also reveals that the maize and legumes was the best preceding crop for maize.

4.5 Sources of error

The empirical study contains a number of possible sources of error. These must be considered in the study as they can affect the result. The most obviously one was the translator. Mistakes could have been made while translating from one language to another. The translator could also have made his own interpretation and not translating the exact words of the interviewed person. Another problem during the interviews was also that the person who was interviewed adjusted the answers after what he thought was expected or sounded good. A more specific problem in this study was that the harvest could be difficult to determine as the family sometimes consumed the grains during the season.

5 Analysis and discussion

In this chapter the questions of the study are analysed and discussed based on the material from the empirical data and the literature review. The chapter is structured according to the two research questions.

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

The literature review claimed that the striga problem had increased (Berner *et al.,* 1995). This was confirmed by the empirical studies as all farmers said that the amount of striga had increased on their farms during the last years. According to the literature one reason for this is that more high yieldig crops such as maize and beans are grown more frequently than the traditional crops like sorghum, cassava and millet (Khan *et al.,* 2010). This was also confirmed during the interviews, traditional crops were only grown on 2% of the fields.

According to the literature soybeans would be a good crop choice at fields were striga is a problem (Odhiambo *et al.,* 2009). Because of its potential suicidal germination effects and its positive effecys on soil fertility qualities. Nevertheless only two farmers grew soybeans on their field. One of the reasons for this practice could be the limited supply of soybeans seeds. This was found in the empirical studies during the interviews of the agro-dealers. None of the sellers who were interviewed sold soybeans seeds at the moment the interview took place. The literature presents desmodium as a crop with similar qualities as soybeans (Khan *et al.,* 2010). The agro-dealers we visited did not sell desmodium seeds either, which could be a reason to why no farmers had it on their fields. Another reason could be that only a few farmers who were interviewed had animals and since desmodium only can be used as animal fodder many of the farmers had no use of it. For larger farms with more livestock, desmodium could be a better alternative.

Another explanation for why soybeans and desmodium are not used as methods to combat striga could be a lack of information. Very few of the farmers stated that they have any contact with the district officer and that they learn their agricultural skills by imitating neighbours and parents. This may be one explanation to why little information reaches the farmers and why these relatively new methods are not being used.

Resistant maize seeds are according to the literature a good method of combat striga (De Groote *et al.*, 2007). These seeds were used by the farmers but only by a small portion (18%). The literature explanation for this is that they are too expensive and cannot always be bought at the local market in some areas (Khan *et al.,* 2006). The empirical data confirm this supply problem and also that the price difference between the resistant seeds and the non-resistant ones is evident. It is stated in the literature review that one of the reasons for the rapid spread of striga is that farmers receive it through seeds that they buy at the market (Berner *et al*., 1995). But according to the empirical data in our study only a few of the farmers buy their seeds at the market. The majority use their own seeds. Therefore the spread of striga in the study areas cannot be explained by this reason alone.

As mentioned above there are many reasons to why these relatively new methods of combating striga: resistant seeds, soybeans and desmodium, are not used. Another reason that appears in both the empirical search as well as the literature is that the farmers are risk averse and feel that these methods are insecure and that they prefer a smaller but more stable harvest yield (Khan *et al.,* 2009). This negative attitude against the new methods seems to origin from both own experience and rumours.

Even though the literature claims that the use of pesticides to combat striga provides good results in terms of harvest they are not used by any of the farmers in this study (De Groote *et al*.,2008). This could be explained by the fact that no pesticides are provided by any of the agro dealers who were visited.

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

The main finding from the empirical data is that resistant maize has a higher average gross margin than maize grown by non-resistant seeds. This result is statistically significant according to the t-test and agrees well with the literature (De Groote *et al*.,2008). All the t-test was conducted with a 90 % confidence interval as this study included relatively few samples, to get higher statistic significance a larger number of samples would be necessary.

The empirical study also reveals that maize intercropped with legumes gave a higher average gross margin than maize in mono-cropping. This result is statistically significant with 90% confidence interval according to the t-test. This economic trend has also been found in earlier research of Khan *et al* (2008, 2009). The literature also explains this fact with the argument that legumes have good soil fertility qualities and also have big leaves that provide shade, which gives striga a disadvantage (Khan *et al.,* 2006). Apart from having a higher gross margin maize (both non-resistant and resistant) intercropped with legumes also acts as a good protein source for the households. Another positive effect with intercropping according to the literature it that it decreases the risk of harvest losses as several crops are grown at the same time (Khan *et al*., 2009***).***

The positive soil fertility effect claimed in the literature with maize and legumes in intercropping can be seen in the empirical data as well (Khan *et al.,* 2006). The average gross margin is higher for maize grown after maize and legumes compared to when maize is planted after maize. This indicates that legumes are a good crop in the rotation. This trend could be observed in our empirical data but it is not statistically significant according to the t-test.

The literature review presents maize farming systems with be better methods to combat striga in terms of average gross margin per hectare. These are maize intercropped with soybeans and maize intercropped with desmodium (Odhiambo *et al.,* 2009 and Khan *et al.,*2008,2009). These farming systems are not examined in the empirical study since too few of the interviewed farmers actually use these systems. Consequently this empirical study can not confirm, nor disconfirm, the literature findings about these farming systems.
In addition the method of using pesticides is not examined in this study since none of the interviewed farmers spray their crops.

6 Conclusions

This chapter starts with the aim of this study to enable to clarify the link between it and the results. The second part provides the answers to the two research questions based on the empirical data and the literature review.

The aim of this study is to find the most economically beneficial maize farming system that is used today by smallholders in Western Kenya.

I) What different types of maize farming systems are currently in use in Western Kenya, and what methods are used to combat striga?

Six different types of maize farming systems were determined in this study, those were;

- Resistant maize grown in mono-crop
- Resistant maize intercropped with legumes
- Non-resistant maize in mono-crop
- Non-resistant maize intercropped with legumes
- Non-resistant maize with other intercrops
- Fallow.

The different methods to combat striga that the farmers who participated in this study used were;

- Use of striga resistant maize seeds
- Use of legumes as an intercrop
- Fallow included in the crop rotation
- Use of fertilizer and manure
- Weeding by hand

II) What is the economic difference between the different maize farming systems in terms of gross margin per hectare?

The most economically beneficial farming system according to this study is resistant maize intercropped with legumes. The higher input cost of resistant seeds is compensated by the increase in yield. This fact, in combination with the use of two different crops, also provides improved food security for the smallholder farmers.

The economically most beneficial system according to this study does not consider the biological effects in the long run, but since maize and legumes have a good rotational effect it seems to be a good choice even in this aspect.

Even though the result of this study reveal that resistant maize intercropped with legumes displays the highest average gross margin it is not possible to exclude other farming systems that have good references in the literature, like maize intercropped with soybeans or desmodium. They could achieve an even higher average gross margin. However the empirical data shows that these relatively new systems are not used today due to reasons such as lack of supply from agro dealers and information from district officers.

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Personal messages

Röing de Nowing, Kristina, PhD SLU, researcher (meeting, 2010-09-09)

Personal interviews farmers

Tom Luhazo	2011-04-05	Vihiga
Alouise Oloo Odipo	2011-04-05	Bondo
Evans Ochiel	2011-04-05	Bondo
Dick Morga	2011-04-06	Vihiga
Amos Adego	2011-04-06	Vihiga
Sussan Minayo	2011-04-06	Vihiga
Felistus Musembi	2011-04-06	Vihiga
Judith Makungu	2011-04-06	Vihiga
John Ishuga	2011-04-06	Vihiga
David Mweresi	2011-04-06	Vihiga
Agness Amenti	2011-04-07	Vihiga
Peter Atsiaya	2011-04-07	Vihiga
Sahra Mandu	2011-04-07	Vihiga
Anthony Esewier	2011-04-07	Vihiga
Salome Mwboga	2011-04-07	Vihiga
Miriam Inyangu	2011-04-07	Vihiga
Norah Analo	2011-04-07	Vihiga
Veronica Muthoni	2011-04-08	Bondo
John Omulo Okumu	2011-04-08	Bondo
Jane Anyango	2011-04-08	Bondo
Peter Unduru	2011-04-08	Bondo
Agneta Oberi	2011-04-08	Bondo
Peter Oketch	2011-04-08	Bondo
Roselyne Ochigyg	2011-04-08	Bondo
Peresiah Odilla	2011-04-11	Bondo
Margret Agot	2011-04-11	Bondo
Priscah Adhambo Okumn	2011-04-11	Bondo
Agneta Ogolla	2011-04-11	Bondo
Danita Ateno	2011-04-11	Bondo
Dinah Ogula	2011-04-11	Bondo

Personal interviews agro dealers

Miriam Adego	2011-04-11	Bondo
John Amani	2011-04-06	Vihiga
Peter Obrie	2011-04-06	Vihiga

Appendix 1: Agro dealer questionnaires

Questions agrodealers

Name: Date:

Area:

A1). What kind of maize seeds do you sell and what are your prices?

A2). What kind of soybeans seeds do you sell and what are your prices?

A3). What kind of local beans seeds do you sell and what are your prices?

A4). What kind of desmodium seeds do you sell and what are your prices?

A5). What different kind of fertilizer do you sell, and what are the prices?

A6). Is there a market for manure? Different sorts to what price?

A7). What different kind of pesticides for striga do you sell, and what are the prices?

A7). What kind of other common seeds do you sell and what are the prices?

Appendix 2: Farmers questionnaires

Questions

Farmer´s name: **Area:**

Date:

N/S	E/W

GPS coordinates:

Map of the farm					
Field Nr	Crop + size		Field Nr	Crop + size	

A) Household Characteristic

A1. How many live in this household?

A2. How many people work at the farm?

A3. For how long have you farmed the farm?

A4. What is your school background?

A5. Any previous education and/or professional background in agricultural work prior to farming.

A6: Do you work in off-farm employment?? If yes.- how many hours per week??

A7 How is labour at the farm shared within the family?

B) The farm

B1. How big area do you farm?

B2. How many fields do you have?

B3. What kind of crops do you grow on the different fields?

B4. Do you have a extensive officer? (DAO)

B5. How often do you have contact with him?

C) Best maize field last season (short rains)

C1. Which maize field was the best last season and what did you grow there, double cropping?

C2. How big was it and what was the average yield?

Crop	Size	Yield

C3. What did you grow on this field last season/two seasons ago/three seasons ago? What were the yields?

Earlier crop	Crop	Yield
Last season (short rains) 2010		
Last season (long rains) 2010		
Season (short rains) 2009		
Season (long rains) 2009		

C4. What was the cost for the seeds, how much did you use on this field?

C5. What was the cost for Fertiliser, how much did you use on this field and what kind?

C6. What was the cost for Manure, how much did you use on this field and what kind?

C7. What was the cost for Pesticides, how much did you use on this field and what kind?

C8. Did you use any machinery on this field?

Inputs (short rain)	Type	Cost	Quantity
Seeds for planting			
Fertiliser			
Manure			
Pesticides			
Machinery			

Inputs (long rain)	Type	Cost	Quantity
Seeds for planting			
Fertiliser			
Manure			
Pesticides			
Machinery			

C8. Is Striga a big problem for this field?

C9. What method do you use to combat Striga here, if any?

C10. For how long have you used that method?

C11. Have you used any other method?

Method to combat Striga		Maize type	Method	Time
Maize (striga resistant)	IR maize			
Maize (striga resistant)	KSTP 94			
Maize (striga resistant)	WS 909			
Maize and legumes	KSTP 95			
Maize and legumes	WS 910			
Soyabeans				
Desmodium				
Fallow				
None				

D) Lowest yield maize field last season (short rains)

D1. Which maize field had the lowest yield last season and what did you grow there, double cropping?

D2. How big is it and what is the average yield?

Crop	Size	Yield

D3. What did you grow on this field last season/two seasons ago/three seasons ago? What were the yields?

Earlier crop	Crop	Yield
Last season (short rains) 2010		
Last season (long rains) 2010		
Season (short rains) 2009		
Season (long rains) 2009		

D3. What was the cost for the seeds, how much did you use on this field?

D4. What was the cost for Fertiliser, how much did you use on this field and what kind?

D5. What was the cost for Manure, how much did you use on this field and what kind?

D6. What was the cost for Pesticides, how much did you use on this field and what kind?

D7. Did you use any machinery on this field?

Inputs (short rain)	Type	Cost	Quantity
Seeds for planting			
Fertiliser			
Manure			
Pesticides			
Machinery			

Inputs (long rain)	Type	Cost	Quantity
Seeds for planting			

Fertiliser			
Manure			
Pesticides			
Machinery			

D8. Is Striga a big problem for this field?

D9. What method do you use to combat Striga here, if any?

D10. For how long have you used that method?

D11. Have you used any other method?

Method to combat Striga		Maize type	Method	Time
Maize (striga resistant)	IR maize			
Maize (striga resistant)	KSTP 94			
Maize (striga resistant)	WS 909			
Maize and legumes	KSTP 95			
Maize and legumes	WS 910			
Soyabeans				
Desmodium				
Fallow				
None				

E) Farming year

E1. Can you make a timeline over a typical year/?

	Jan	Feb	Mar	Apr	Maj	Jun	Jul	Aug	Sep	Okt	Nov	Dec
Land preparation												
Planting												
Weeding												
Harvest												
Pesticides												

E2. How much labour is needed for:
*The best field
*The worst field
*The farm

Activites for the best maize field	Total time	Number of people
Land preparation		
Planting		
Weeding		
Harvesting		
Pesticides		
Other		

Activites for the the worst maize field	Total time	Number of people
Land preparation		
Planting		
Weeding		
Harvesting		
Pesticides		
Other		

Activites for the the farm	Total time	Number of people
Land preparation		
Planting		
Weeding		
Harvesting		
Pesticides		