Aquaponics and the potential of BSFL farming in Ethiopia




Comparing the use of water and land of aquaponics and conventional agriculture in the context of Ethiopia and assessing the potential contribution of Black Soldier Fly Larvae (Hermetia illucens) in small-scale aquaponic farmers in Ethiopia

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Final bachelor thesis

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Pictures front page: Fishers at the shore of lake Awassa; Aquaponic farmer preparing coffee during group discussions; Aquaponic farmers restocking lettuce plants; Checking nutrient balance of aquaponic systems. Source: (Matthijs Koop)

Key words: Aquaponics, Awassa, Shoa Robit, TGS, Development, Conservation

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Abstract

The natural resources in Ethiopia are under intense pressure as a result of population growth and inappropriate farm practices. Introducing alternatives could be a step forward in reducing the impact of farming on natural resources. In Ethiopia, the pressure on water bodies and land is high which results into water shortages and land degradation. Aquaponics is an interesting alternative compared to conventional agriculture, as aquaponics has the ability to reduce pressure on water and land. Therefore, aquaponics could help to secure food production in meeting the demands for its rising population. Therefore in the last two years, aquaponic projects have been starting up in Ethiopia (Slingerland, 2015). However, one of the current difficulties of aquaponic systems in Ethiopia, is the lack of quality fish-feed as an input for the aquaponic systems. The Black Soldier Fly Larvae (BSFL) could be a sustainable alternative for fish feed. BSFL have high nutrient values and can be locally produced. Therefore, BSFL seems a suitable option for producing quality feed for aquaponic systems. For these reasons, the focus of this thesis research is conducted in twofold: The first focus is to compare the water and land use of aquaponics with conventional agriculture by analysing five literature cases of aquaponics in the same context of Ethiopia. The second focus is to identify the potential opportunities and barriers of BSFL farming within aquaponic systems in Ethiopia. This was done by a combination of single-semi structured interviews and focus-group discussions with farmers and key-informants of aquaponic systems. Also, to be certain if BSFL have potential to be used as fish feed in Ethiopia, it was important to conduct experiments in order to confirm if BSFL naturally occurred in Ethiopia. The results of the literature review on the five case studies show that aquaponic systems reduce the water and land use compared to conventional agriculture. The results on the main opportunities of implementation of BSFL farming show that reduction of costs, independency and waste reduction are seen as the main opportunities. The main barriers seen of BSFL farming is the difficulty of the breeding process, insufficient breeding quantity, fear for diseases and the amount of labour. Another important barrier for implementing BSFL farming for aquaponics systems in Ethiopia is that the BSF is seen as an unknown species according to Ethiopian law. Based on national law, the government should first conduct an proper ecological assessment in order to acknowledge natural occurrence of BSF.

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Acronyms and Abbreviations

FAO	Food and Agriculture Organization of the United Nations
UN	United Nations
NGO	Non-Governmental Organization
BSF	Black Soldier Fly
BSFL	Black Soldier Fly Larvae
NWO	Netherlands Organization for Scientific Research
SNNPR	Southern Nations, Nationalities, and Peoples Region
ASL	Above Sea Level
SD	Standard Deviation
ha	Hectare
km2	Square kilometer
m2	Square meter
m	Meter
m3	Cubic meter
VHL	Van Hall Larenstein

1 Introduction

The natural resources base (land, water and forest) is fundamental to the survival and livelihood of the majority of people in rural Ethiopia (FAO, 2003). These resources are under intense pressure from population growth and inappropriate farming and management practices (Dessie & Kleman, 2007). Small-scale farmers, who depend on these resources, face several constraints related to intensive cultivation, overgrazing and deforestation, soil erosion and soil fertility decline, water scarcity, livestock feed and fuel wood crisis (FAO, 2003). These factors often interact and create a downward spiral of declining crop and livestock productivity, food insecurity, high population growth and environmental degradation, also known as 'the nexus problem' (Cleaver & Schreiber, 1994). At this moment, the population of Ethiopia counts 101 million inhabitants of whom 32% are chronically undernourished and lack adequate food for a healthy and active life (FAO, 2015). As these numbers are expected to increase, the Ethiopian government together with the United Nations (UN) and numerous international Non-Governmental Organizations (NGOs) are trying to reduce the pressure on natural resources while improving agricultural yields by introducing alternative ways of reduced impact farming (FAO, 2014) (FAO, 2015)(Pender, Place, & Ehui, 2006). In achieving this, alternative ways of reduced impact farming like crop diversification, conservation tillage, agroforestry, hydroponics and aquaponics are explored in meeting the demands for its rising population. (Tyson, Treadwell, & Simonne, 2011) (Adugna, 2014) (CIMMYT, 2014) (Abebe, 2005).

1.1 Water and land use in Ethiopia

Agriculture is by far the largest water and land consumer in Ethiopia. This is not a surprise considering the fact that the majority of the population is directly supported by the agricultural economy. It is estimated that 93% of all water withdrawals are for agricultural purposes and 30,7% of the total land surface is used for agriculture (Headey & Dereje, 2014).Therefore, agriculture depends fundamentally on natural resources and has an impact on land deterioration and water depletion in Ethiopia. This creates an ever-increasing ecological imbalance in the ecosystem causing droughts and famine. Therefore, it is important to find alternative sustainable farming techniques that could reduce pressure on water and land in Ethiopia. In other words, sustainable agriculture plays an central role, in which aquaponics could be a vital solution.

1.2 Introduction to Aquaponics

Aquaponics is the integration of recirculating aquaculture and hydroponics into one production system. The system is based on the principle where two ecosystems are synergizing to produce products that are not independently obtainable. The fish in the aquaponics system provide the plants nutrients to grow. Whereas the plants act as bio-filter to clean the water that is necessary for the fish to survive (Tyson, Treadwell, & Simonne, 2011).

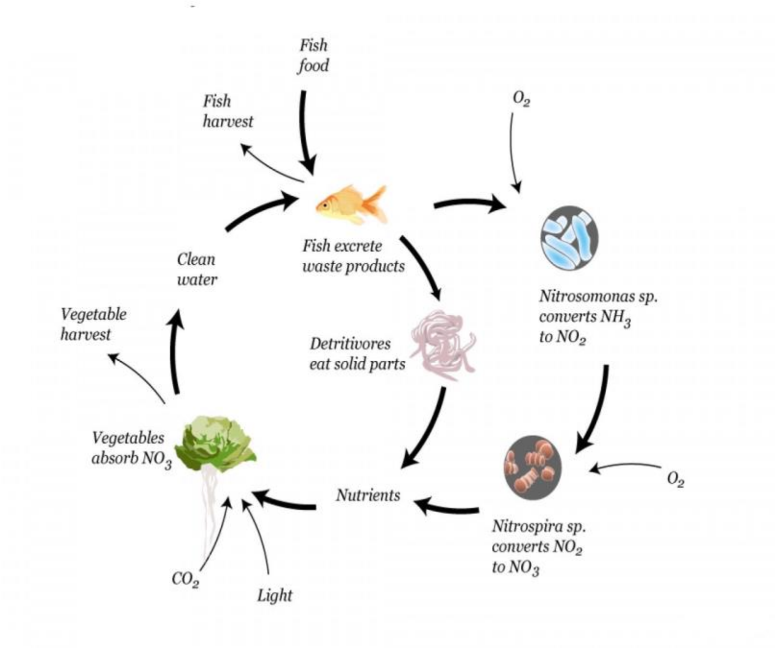


FIGURE 1.1: AQUAPONIC NITROGEN CYCLE. SOURCE: (ELS ENGEL 2013)

In order to clean the water from solid and dissolved particles, the filters needed to be placed to clean the water effectively. At first, the water is led through a mechanical filter to remove the solid particles from the water. After this, the water is led through a bio filter that processes the dissolved waste. The bio filter provides a location for bacteria to convert ammonia (excreted by fish) - which is toxic for fish into nitrate a more accessible nutrient for plants. This process called nitrification and it is inevitable for plant growth.

As the water flows through the grow beds - containing nitrate and other nutrients - the plants take up the nutrients through their roots and filter the water clean, leaving it ready to go back to the fish tank. This process allows the fish, the plants and the bacteria to thrive symbiotically and to create a healthy growing environment.

Aquaponics uses 90% less water than conventional crop farming and has the ability to increase yield eight to ten times compared to conventional agriculture (Javins, 2014). Therefore, aquaponics has a lot of potential to help reduce impact on natural resources by using substantial less land, less water, no artificial fertilizers and a higher productivity compared to conventional agriculture. For this reason, aquaponics systems is seen promising for implementation in arid and semi-arid areas that lack adequate water and land for conventional agriculture (Miles,2011)(FAO,2014). However, the disadvantage of aquaponics is that the system is complicated as it needs to be proper balanced regarding nutrient input and output. Also, start-up costs are high compared to conventional agriculture and quality feed is needed to let the system run effective.

1.3 Low cost feed supplement

High quality fish feed is needed for aquaponic systems in order to run effective. However, quality fish feed is expensive and not available in many developing countries. Especially in Africa, where fish feed is difficult to get for small-scale farmers due to underdeveloped infrastructure and industry (FAO, 2014) (FAO, 2015). For example in Malawi, several aquaculture farmers stopped farming due to insufficient quantity and high price of fish feed. There were other similar cases in Ethiopia, Madagascar, Zambia and Nigeria. Therefore, research is needed for alternative sources of low-cost feed supplements that can be produced local in order to let aquaponics become long term sustainable in developing countries. Addressing these problems requires alternatives and the use of insects can play a significant role in sustainable feed production for aquaponic systems (FAO, 2014). One of these insects is the black soldier fly [Hermetia illucens (Diptera:Stratiomyidae)](BSF) and this insect is at the moment the object of considerable world-wide interest for producing bulk agricultural commodities, i.e. industrial-scale insect farming. The BSF has potential to become an important source of protein for fish feeds. The larvae of the BSF have several desirable characteristics for this purpose: saprophagy, communal feeding habit, rapid growth rate, non-pest status, efficient digestion, high protein and lipid content, and low incidence of disease and other mortality (Schneider & Llecha, 2015). BSF are present throughout the tropics worldwide but has technical requirements to breed in captivity. The temperature and elevation are important for successful breeding of BSFL as temperatures should not get below 14 degrees during the days and elevation should not exceed 1850m in order to let the flies breed naturally (Schneider & Llecha, 2015). In addition, the BSFL is a good source of for animal feed, and has the potential of improving organic waste into a rich fertilizer.

There has been pilot-projects in West & Sub-Sahara Africa on BSFL farming for fishfeed. And so far, several projects seem successful (Baker, 2015) (Pelusio, 2014). The costs of fish feed are high, therefore BSFL farming could be more interesting for farmers if the feed costs will be reduced. At the same time, the BSF could help aquaponics farmers to be more self-sufficient and less dependent of other external sources. The climate conditions for breeding BSFL seem to be suitable in several parts of Ethiopia (UNC Institute For The Environment, 2013).

However, while the demand for quality fish feed and alternative farming methods like aquaponics are on the rise, possibilities for aquaponic farmers in Ethiopia are limited by inadequate amounts of resources and support. This is partly due to rapid population growth, waste streams are not properly managed and valuable resources are lost while food shortages are a major problem in large parts of Ethiopia. Altough BSFL production seems promising; unfortunately there are no official reports that show the occurrence of BSF. This means that the BSF is seen as an official unknown species in Ethiopia.

1.4 Problem Statement

Ethiopia's natural resources and population are under severe pressure due to population growth. Aquaponics could solve part of the problem by reducing the use of water and land. However, limited research is done on the use of water and land comparing aquaponics with conventional agriculture. Also, due to unavailability of good quality fish-feed and high costs of feed, farmers have difficulties to let their aquaponics systems run constant (FAO, 2014). One of the most promising alternatives for fish feed production seems to be the production of BSFL (FAO, 2014). The following two questions arise:

1. To what extent can aquaponics reduce the use of water and land compared to conventional agriculture in the context of Ethiopia?
2. What is the potential of Black Soldier Fly Larvae (Hermetia illucens) farming to contribute to small-scale aquaponic farmers in Ethiopia?

This study was commissioned by the company TGS-Business & Development services. TGS is involved in a relevant project[1] funded by the Dutch Organization for Scientific Research (NWO) that includes the construction of 27 aquaponic units. An example of an aquaponic unit is shown in **Appendix 8.1**.

[1]Aquaponics Ethiopia:Developing a business model for sustainable implementation of small scale aquaponics systems improving food and nutrition security of rural and peri-urban households in Ethiopia.

1.5 Study area

For this study, Awassa and Shoa Robit were chosen to conduct this research in order to compare the use for water and land of aquaponics with conventional agriculture and to better understand the potential implementation of BSFL farming in small-scale aquaponic systems in Ethiopia.

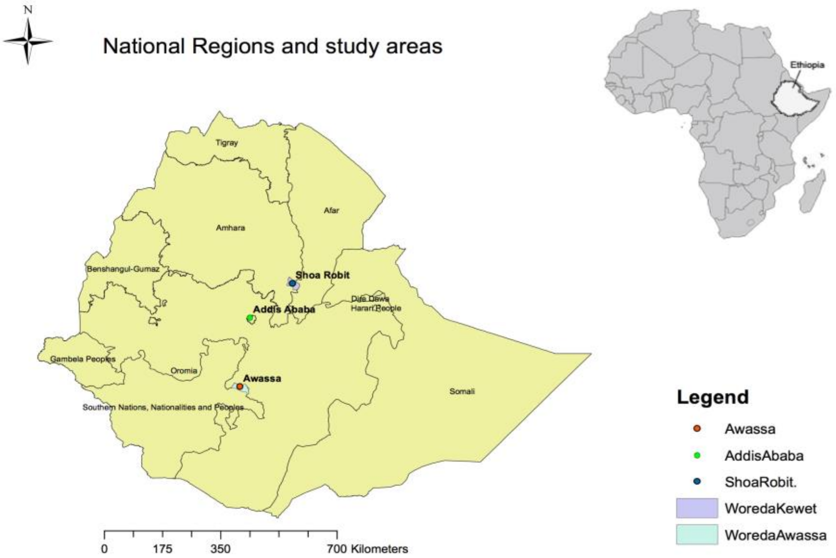


Figure 1.1: Study locations and national regions of Ethiopia (Koop,2016)

1.5.1 Awassa

Awassa is the capital of the Southern Nations, Nationalities and Peoples Region (SNNPR) and lies on the Trans-African Highway 4, Cairo-Cape Town. The city Awassa lays on the shores of Lake Awassa in the Great Rift Valley and is located 285 km south of Addis Ababa by Debre Zeit. It has a latitude and longitude of 7° 03' 43.38'' 38° 28' 34.86'' E. The elevation of Awassa is 1680 meters above sea level (ASL) and has a relative plain topography. The Awassa zone has a total population of 258,808 inhabitants of which 61% lives in the city of Awassa. The remaining 101,000(39%) are living in the surrounding kebeles. The ratio of male/female is 51% male and 49% female. A total of 85% of the population in Awassa finishes primary school, 44% secondairy school and 8% starts with University (Central Statistical Agency, 2007). The most common farming systems used in the Awassa zone is the urban based farming system; other farming systems include agro-pastoral millet/sorghum farming system and highland perennial farming systems. Farm sizes range from 0.3 to 3.5ha with an average farm size of 0.55ha per household (Central Statistical Agency, 2007). The average family size in Awassa is 6.9 (International Livestock Research Institute, 2007) Farm experience ranges from 0 to 40 year with an average of 16 years (Central Statistical Agency, 2007)

FIGURE 1.2 OUTSKIRTS OF AWASSA WITH HOUSEHOLD FARMS (KOOP, 2016)

The climate in Awassa is tropical, and is classified as (Aw) by Köppen and Geiger. The mean annual rainfall in Awassa (airport weather station 7.07°N 38.5°E) ranges between 800mm and 1300mm. The mean annual temperature is 19.2 °C with a daily average minimum and a daily average maximum of 17 °C and 27 °C (MeteoBlue, 2016). The mean relative humidity is 58%. The dominant soil in the Awassa zone is classified as eutric fluvisol (Ali & Hagos, 2016).

1.5.2 Shoa Robit

Shoa Robit is a medium size city located in the Amhara region. The town is located at 225 Km northeast of Addis Ababa. The elevation of Shoa Robit is 1,280 meters above sea level (ASL) and is situated in a mountainous area. The town lies at a longitude of 10° 06′N 39° 59′E and a latitude of 10.1° N39 983°E, respectively. Due to the fact that little specific data is available on Shoa Robit itself, further data is used from the woreda Kewet of which Shoa Robit is the main city. The woreda Kewet has a total population of 118,381 of whom 17,8% are urban inhabitants. A total of 29,058 were counted resulting in an average family size of 5,05 (Central Statistical Agency, 2007). (Central Statistical Agency, 2007) states that the sex ratio is 53% men and 47% women. The average farm size in Shoa Robit is 0.7 Ha per household and farm experience is on average 22 years (Central Statistical Agency, 1996). The most common farming system used in Kewet is agro-pastoral Teff/barley farming sytem, other farming systems include the pastoral farming system and subsistence farming.

The climate in Shoa Robit is semi-arid and is classified as Bs by Köppen and Geiger. The mean annual rainfall in Shoa Robit (9.99°N 39.9°E) is 120 mm. Usually, the maximum rainfall occurs in the months July and August.

FIGURE 1.3 OUTSKIRTS WITH HOUSEHOLD FARMS IN SHOA ROBIT (KOOP, 2016)

The mean annual temperature is 32 °C with a daily average minimum and a daily average maximum of 14 °C and 36 °C. The mean relative humidity in Shoa Robit is 21%. (MeteoBlue, 2016). The soils in the lowlands of Kewet consist of sandy clay and sandy loam moderate fertility and are classified as Ustalfs and Haplic vertisols (USDA, 2014) (FAO, 2015)

1.6 Research objective

First, this study aimes to investigate the comparison between water and land use of aquaponics and conventional agriculture in the context of Ethiopia. Secondly, the study looks at the potential of Black Soldier Fly Larvae (BSFL) and the contribution towards to small-scale aquaponic farmers in Ethiopia.

It is vital to know if aquaponics reduces water and land use compared to conventional agriculture in Ethiopia. This can help to demand for more aquaponic implementation for the reduction of water and land use in Ethiopia. Otherwise, this could show that it is better to leave aquaponics aside and look for other alternatives to reduce the pressure on water and land. Next to this, knowledge on the potential of BSFL farming within aquaponic systems in Ethiopia is of crucial importance as new technologies like BSFL farming could help to make aquaponics a success.

1.7 Research questions

The reseach questions for this thesis are the following:

1. "To what extent can aquaponics reduce the use of water and land compared to conventional agriculture in the context of Ethiopia?"

This research question is answered by the following sub questions,

- To what extent can aquaponics reduce the use of land compared to conventional agriculture in the context of Ethiopia? (literature review)
- To what extent can aquaponics reduce the use of water compared to conventional agriculture in the context of Ethiopia? (literature review)

2. "What is the potential contribution of Black Soldier Fly Larvae (Hermetia illucens) farming to small-scale aquaponic farmers in Ethiopia?''

This research question is answered by the following sub-questions.

- What are descriptive characteristics of aquaponic farmers?
- What are the main opportunities and barriers for the introduction of BSFL farming in aquaponic systems in Ethiopia?
- How do aquaponic farmers perceive BSFL-technology?
- Are BSF (Hermetia illucens) naturally occurring in Awassa or Shoa Robit?

This study can be used as a feasibility study for future implementation of BSFL farming in aquaponic farming systems in Ethiopia. Furthermore, this study can also be used for future projects and scientific articles related to sustainable agriculture, aquaculture, nature conservation, reduced impact farming, aquaponics and BSFL farming in general.

1.8 Content of this report

In the first part of this thesis report, the reader is introduced with topics regarding water and land use, aquaponics, and BSFL farming. Also, a description of the locations Awassa and Shoa Robit has been made in order to gain an understanding on the study sites where this thesis research is conducted. The second part of this thesis report contains the applied methods for data gathering with a detailed explanation on the data analysis. Finally, the conclusions are presented with the clarification on the contribution of aquaponics on the use of water and land reduction in the context of Ethiopia. Conclusions have also been made on the contribution of BSFL farming for small-scale aquaponics farmers in Ethiopia. The recommendations are based on these conclusions with the aim of finding the best course of actions that will help to make BSFL farming successful.

2 Methods

Qualitative and quantitative research methods were applied in order to achieve the objectives of this research. Several types of data collection were used for this thesis. The following section outlines the methods in chronological order.

2.1 Water and land use versus conventional agriculture

2.1.1 Literature

A literature study is conducted to understand how aquaponics could reduce the use of water and land resources compared to conventional agriculture in the context of Ethiopia. Five aquaponic cases with trustable data were reviewed and compared with conventional agriculture including the cases of Ethiopia. The specifications of the aquaponic cases needed are Nutrient Film Techniques (NFT), extensive or semi-intensive systems, production of lettuce and tilapia and with a tropical or semi-arid climate. This is done in order to compare the cases with aquaponic systems in Ethiopia. Next to this, conventional agriculture in the area needed to be extensive or semi-intensive in order to compare the aquaponic cases with the aquaponic systems in Ethiopia. Furthermore, relevant information about Ethiopia was used to understand the current setting in which the aquaponic projects are now. Next to this, the University of Addis Ababa and TGS were contacted who could provide trustable calculated predictions for the inputs and outputs of the aquaponic systems.

2.1.2 Semi-structured-interviews

Semi structured interviews have been done before focus-group discussions and key informant interviews. Before semi structured interviews started, aquaponic farmers were briefly introduced into BSFL farming by showing a case out of Ghana. During the introduction,the farmers have not been made aware of the opportunities and barriers of the BSFL project in Ghana (ProteinInsect, 2014).

For this thesis research, the main opportunities and main barriers in BSFL farming was shown by semi-structured interviews of a total of 18 aquaponic farmers who were enrolled into the aquaponics program in Awassa and Shoa Robit. Interview tools from the Food & Agriculture Organisation (FAO) and Quebec's guide to organizing semi-structured interviews were used to strcture the interviews (Stoop & Farrington, 1988) (Lafort, 2009).

By trial and error with conventional farmers, interviews have been adjusted in order to make sure aquaponic farmers could understand the questions.

During the semi-structured interviews, when respondents gave multiple answers on opportunities and barriers regarding BSFL farming. The multiple answers were categorized based on the relevancy and these are named opportunities or barriers (Appendix 3). After this, aquaponic farmers had to indicate the most important opportunity or barrier. These are called the main opportunity and main barrier. Next to this, aquaponic farmers were asked to give their perception on BSFL technology choosing between positive, neutral or negative. After the interviews, categories were made together with the translator too make the answers representable. It is shown in **Appendix 8.2** how the categorization was done.

All the interviews were recorded with approval from the respondents in order to later review the interviews. Trained translators have been used in order to reduce bias in translation of answers from respondents. The translators used a cross check of the recordings to make sure translations were accurate and questions were received right by the respondents. Furthermore, descriptive characteristics of the aquaponic farmers were documented as well.

During the interviews, aquaponic farmers were asked about their perception and opinion on BSFL farming. The questions started simple to obtain descriptive data and to let the respondent feel comfortable. Towards the end of the interview, the interviewee's became more open in response to the questions. There have been situations when the respondents gave multiple answers to some questions. For an adequate result, the respondents were asked which answers were seen as main opportunity. Transcript of a semi-structured interview can be found back in **Appendix 8.2.** The answers of aquaponic farmers were categorized by relevancy.

2.1.3 Focus-Group Discussions

The focus-group discussions were held after the semi-structured interviews. The objective of the focus-group discussions was to create dialog between farmers and formulate more concrete answers than during semi-structured interviews. An example of a focus-group interview set-up can be found in **Appendix 8.3**. In Awassa and Shoa Robit, the focus-group discussions were done with 8 farmers per location. The objective of these focus-group discussions was to gather additional data that could not be achieved during semi-structured interviews. The focus-group discussions, were structured by using the guidelines of the Bureau for Program and Policy Coordination (AID) (Kumar, 1987).

Interviews were scheduled at an informal facilitation to let respondents feel more at ease. Interviews were conducted on the basis of a flexible interview guide. A total of five topics were discussed in the flexible interview guide:

- BSFL farming
- Cooperation between aquaponic farmers
- Descriptive characteristics of aquaponic farmers
- Opportunities and Barriers of BSFL farming
- Perception on BSFL farming

At the end of the focus-group discussions, respondents were asked again individually about their opinion on the main opportunity and main barrier of BSFL farming.

2.1.4 Key-informant interviews

In addition to aquaponics farmers, interviews were held with key informants. The objective of the key informant interviews was to get a better overview on the context of BSFL farming in Ethiopia from experts, local businesses and government. In total, 6 key informants were interviewed: one professor from the University of Awassa with expertise in Zoology (fish) and one Professor in Entomology(insects) in Shoa Robit. Also, on every study site, a local feed producer was interviewed. At last, in each study site an official from the Bureau of agriculture was interviewed. The data from the key-informant interviews were used to obtain a better understanding in potential implementation of BSFL farming. The interviews were structured by using the guidelines of Quebec's guide for key-informant interviews (Lafort, 2009). The interviews were adjusted on the expertise of the key informant in order to make sure the questions asked have been properly understood.The interviews were recorded and external translators were used for translation. Examples of a key-informant set-up can be found in **Appendix (8.4)**.

2.1.5 BSFL occurrence-experiment

In Awassa and in Shoa Robit experiments on the occurrence of BSF were conducted. The method used for luring BSF into the buckets is copied from a BSF expert from the international forum of BSFL farming, shown in Figure 2.1 (Drake, 2008). Awassa and Shoa Robit had both three study sites in different locations were three bait buckets were strategically positioned.

FIGURE 2.1 BSFL OCCURRENCE EXPERIMENT(KOOP,2016)

Locations for the site locations were based on the following criteria (UNC Institute For The Environment, 2013);

- Active aquaponic project
- Accessibility,
- Urbanized area
- Elevation below 1850m
- Temperatures above 14 degrees during daytime

On every location, three buckets were placed and filled with different types of bait: coffee grounds, fermented barley and a combination of coffee grounds and fermented barley. In every bucket, 6 square holes of 2 cm by 2 cm were drilled to let BSFL go inside and pieces of cardboard were positioned inside the buckets to let BSFL lay eggs in. In each location, buckets stayed for at least 20 days before removal, this is due to the fact that BSFL larvae become visible after 14 days. In addition, bait was added every 5 days to each bucket in order to ensure that the odor of the bait continuously spread. After 20 days, buckets were emptied and larvae were compared with the pictures of BSFL. The identification was done by visually comparing larvae with pictures characterizing identifiable parts of BSFL **(Appendix 8.5)** After this, larvae from the family of *Stratiomyidae* were posted on a blog for experts (Jerry, 2011). When experts confirmed the larvae were from BSF (Hermetia Illucens), specimens were send to the University of Addis Ababa for final determination by the department of Entomology.

2.2 Data Analysis

For this research, data was analysed using the following steps:

2.2.1 Literature review

A literature study was conducted comparing water and land use of aquaponics and conventional agriculture. Different types of sources were used. These were; google scholar, greeni and wur-library. Predicted data on the water and land use of the aquaponic systems in Ethiopia are based on the University of Addis Ababa and NWO. The calculations that have been used regarding water and and land use, nutrient use and balance and on the average yield per year for tilapia and lettuce. The differences between water and land use of aquaponic farming and conventional farming are shown in table schemes created in Microsoft Excel. For this literature review, the sources used different type of variables and parameters to express the water and land use. In order to convert this, the following conversion formulas have been used;

1m3= 1000L   L=1.00m3*1000/1m3   1ha=10000M2   M2=1ha*10000/1ha

2.2.2 Semi-structured interviews with aquaponic farmers

The objective of the semi-structured interviews with aquaponic farmers is to find the main opportunities and main barriers regarding BSFL farming. During the semi-structured interviews, the respondents gave multiple answers on opportunities and barriers regarding BSFL farming. The multiple answers were categorized based on the relevancy and these are named opportunities or barriers (Appendix 3). After this, aquaponic farmers had to indicate the most important opportunity or barrier. These are called the main opportunity and main barrier.

Henceforth, the number of times opportunities and barriers were mentioned by farmers (No/b) were divided by the total amount of farmers (N) and multiplied by 100 what resulted in the percentage per categorized opinion. This resulted in the following formula; (No/b)/N*100. These percentages are presented in column graphs created with Microsoft Word. The column graphs were used to show the difference between the main opportunities and barriers by the aquaponic farmers. A chi-square analysis was used to understand if the main opportunities or main barriers given by aquaponic farmers were equally divided. The formula used for the calculations can be seen in figure 2.1. For the perception of aquaponic farmers on BSFL technology, the aquaponic farmers were asked to express their opinion on BSFL technology by voting positive, neutral or negative. After this, each opinion was calculated in the same formula as mentioned above; (Nop)/N*100. This also resulted in the percentage per categorized opinion on the perception on BSFL farming by aquaponic farmers. The results were shown in circle diagrams created in Microsoft Excel. The perception of aquaponic farmers were presented in a table made by Microsoft Word.

$$X^2 = \sum \frac{(O-E)^2}{E}$$

FIGURE 2.2 CHI SQUARE FORMULA

2.2.3 Focus-group discussions with aquaponic farmers

Focus-group discussions were done after semi-structured interviews. The objective of the focus-group discussions was to create a dialogue between farmers and to formulate more concrete answers than the semi-structured interviews. During the focus-group interviews, aquaponic farmers discussed the opportunities and barriers of BSFL farming. All of the opportunities and barriers were categorized as is shown in **Appendix 8. 3.** The categorization is based on the relevance of the given responses. After the focus-group interviews, every aquaponic farmer was taken separately from the group in order to express their main opportunity and main barrier regarding BSFL farming. The number of times main opportunities and main barriers were mentioned by farmers (No/b) was divided by the total amount of farmers (N) and multiplied by 100 what resulted in the percentage per categorized opinion. These percentages are presented in a circle diagram. A chi-square analysis was used to understand if the main opportunities or main barriers given by aquaponic farmers were equally divided.

2.2.4 Key-informant interviews

The objective of the key informant interviews was to gain a better overview on the opportunities and barriers regarding the implementation of BSFL farming within aquaponic systems in Ethiopia. This was done by interviewing experts, local business and (local) governmental bodies. After the interviews, a summary was made of the opportunities and barriers of each interview. Based on the summary, key-informant had to indicate the most important opportunity or barrier. These so called main opportunities and main barriers were divided in three categorisation based on relevancy. The main opportunities and main barriers were presented in a table created by Microsoft Word.

3 Results

The results are based on data collection of qualitative and quantitative research methods. The first purpose of this thesis research is to compare the water and land use of aquaponics with conventional agriculture. This is done by analysing five literature cases of aquaponics with the same specifications as the aquaponic systems in Ethiopia. The second purpose is to identify the potential contribution of BSFL farming for aquaponic systems in Awassa and Shoa Robit. This was done by a combination of single-semi structured interviews and group discussions with farmers and key-informants of aquaponic systems. Also a BSFL occurrence-experiment was conducted in order to measure if BSF naturally exists in Ethiopia.

3.1 Literature review

More and more aquaponic projects start in developing countries as a way to increase food security and to reduce pressure of natural resources. However due to the fact that aquaponics systems are a relative new field of expertise, it is difficult to state if aquaponics reduces water and land use in practice compared to conventional agriculture. For this literature review the focus will be on water and land use of aquaponics systems as these are the major areas where potential improvement is expected and trustable data can be compared of reliable sources. Therefore, this literature review evaluates existing literature on water and land use of aquaponic systems for lettuce and tilapia and compare available data of water and land use with conventional agriculture. This is evaluated by using five similar cases with similar specifications as the aquaponic systems in Ethiopia. The specifications were similar in:

- Type of aquaponic system
- Climate type
- Intensity of aquaponic system
- Intensity of conventional farming with what systems is compared
- Type of crop (lettuce)
- Type of fish species (tilapia)

After reviewing each case, the same method is applied to the now existing aquaponic systems in Ethiopia to see if there is a reduction of water and land use comparing aquaponics with data of conventional agriculture.

3.1.1 Water use

Agriculture accounts for 93% of the total fresh water used in Ethiopia, making it the main user of fresh water (Hoekstra, 2010). Increasing demand for food is caused by rapid population growth, which in turn increases demand for fresh water for crop production and further presses on global fresh water stocks (Norden, 2015). It is vital to conserve this important resource and increasing human population need water as a primair source to survive (Hancock, 2015). According to the study of (Diver S. R., 2010) , there is a reduction of water use using aquaponic systems. Although, many aquaponic projects have been starting up in developing countries, e.g. in Kenya and Ethiopia. However, it seems that there is no scientific literature with a review on the reduction of water and land use of several aquaponics systems (Slingerland, 2015). (Amsha Foundation, 2014) This is shown in table 3.1.

TABEL 3.1: SPECIFICATIONS PER CASE

Location	Type System	Climate	Intensity of aquaponic system	intensity of conventional farming	Conventional farm sources	Aquaponic Sources
Baltimore	NFT	Sub-tropical	Extensive	extensive	USGS,2000	Love,Uhl & Genello,2015
South Arabia	NFT	Semi-Arid	semi-intensive	semi-intensive	Chowdhury & Zahrani,2014	Al Hafedh, Alam, & Beltagi,2008
Virgin Islands	NFT	Tropical	Extensive	extensive	Diver S.R,2010	Diver S.R., 2010
Awassa	NFT	Tropical	Extensive	extensive	Arjo Rothuis,2012	Tgs and Department of zoology, Addis
Shoa Robit	NFT	Semi-arid	Extensive	extensive	Arjo Rothuis,2012	Tgs and Department of zoology, Addis

The first case is an experimental study on a small-scale aquaponic NFT- system reviewed in Baltimore in US (Love, Uhl, & Genello, 2015). This system was built to understand optimal balance for the production of basil, tomato and lettuce into one system. It was shown that only 104 liter of water was needed to produce 1 kg of lettuce and 292 liter of water to produce 1 kg of tilapia (Oreochromis niloticus) (Love, Uhl, & Genello, 2015). When this numbers were compared with averages of conventional farming of lettuce and tilapia in the region of Baltimore, it was seen that the water use of lettuce and tilapia was lower than the water use of lettuce and tilapia of extensive conventional farming (USGS, 2000). This is shown in table 3.2.

(Al Hafedh & Beltagi, 2008) did experiments on a semi-intensive NFT aquaponic system located in South Arabia. The main purpose of this system was to reduce the water use compared to conventional agriculture as the majority of South Arabia does not have sufficient water stocks for sustainable agriculture (Chowdhury & Zahrani, 2014). When comparing the results of this study, it was seen that also here the production of vegetables and fish required significant less water and land than intensive agriculture production systems in South Arabia on lettuce and Nile Tilapia to produce the same amount of fish and vegetables as can be seen in table 3.2 (Al Hafedh & Beltagi, 2008).

(Rackocy, Shultz, Bailey, & Thoman, 1993) (Diver S. R., 2010) showed an reduction of water and land use compared to conventional agriculture in the Virgin Islands, US. This is done by doing multiple tests on an extensive small-scale aquaponic system build for commercial purposes in the tropics.

The University of Addis Ababa had calculated yields from the aquaponic systems of Awassa and Shoa Robit by the incorporating feed conversion rate, the average daily feed input, optimum feeding ratio and water usage. Furthermore, it is possible that similar results are used for conventional farming due to the fact that only one source could be found for aquaculture and conventional farming in Ethiopia. The University of Addis Ababa has calculated predicted values (*) of aquaponic systems for Tilapia and Lettuce. In table 3.2 are shown the predicted values made by the University of Addis Ababa and TGS.

TABEL 3.2: WATER USE PER CASE AND FARM SYSTEM

	Aquaponics Tilapia	Conventional Tilapia	Aquaponics lettuce	Conventional production
Location	**Water use in L per kg(year)**	**Water use in L per kg(year)**	**Water use in L per kg(year)**	**Water use in L per kg(year)**
Baltimore	292	3000	104	285
Saudi Arabia	340	1200	118	225
Virgin Islands	316	1800	110	340
Awassa*	370	3300	180	380
Shoa Robit*	370	3300	180	380

3.1.2 Land use

Land is currently becoming a scarce resource as more and more people need to be fed with the same natural resources. Due to increased pressure on land for agriculture, other vital resources like forests and wetlands are under threat (Stoop & Farrington, 1988) (FAO, 2014).

New technologies like aquaponics need to be applied in order to reduce pressure while increasing the food production (Diver S. a., 2011). Sustainable intensification of agriculture leaves the opportunity to leave other fragile areas untouched. As it was seen in the five cases, the land use on yields of aquaponics was less comparing with conventional agriculture of each case. In table 3.3 can be seen that in all cases, aquaponic production yield is per square meter higher than with conventional farming.

TABEL 3.3: COMPARISON AQUAPONIC AND CONVENTIONAL PRODUCTION

	Aquaponics Tilapia	Conventional Tilapia	Aquaponics lettuce	Conventional production
Location	**Kg per m2 per year**	**Kg per m2 per year**	**Kg per m2 per year**	**Kg per m2 per year**
Baltimore	1,1	0,7	32	4
Saudi Arabia	5,8	0,8	54	3
Virgin Islands	6	0,8	16	4
Awassa*	4,8	1,5	10	3
Shoa Robit*	4,8	1,5	10	3

3.2 Semi-structured interviews

This section shows the results of the semi-structured interviews by aquaponics farmers. The first results are the ‘descriptive characteristics of aquaponic farmers for the locations Awassa and Shoa Robit. This result shows an overview of the 6 characteristics used directly within this research.

3.2.1 Descriptive Characteristics of Aquaponic farmers

During the semi-structured interviews, a total of 14 characteristics were obtained during the interviews in Awassa and Shoa Robit **(Appendix 8.6)**. Only 6 characteristics are directly used within this research. The table 3.4 below shows the descriptive characteristics of aquaponic farmers per location. The descriptive characterstics are used to see if their are relations with the data of the semi-structured and focus-group interviews. This is further discussed in chapter 4.

TABEL 3.4: CHARACTERISTICS OF AQUAPONIC FARMERS

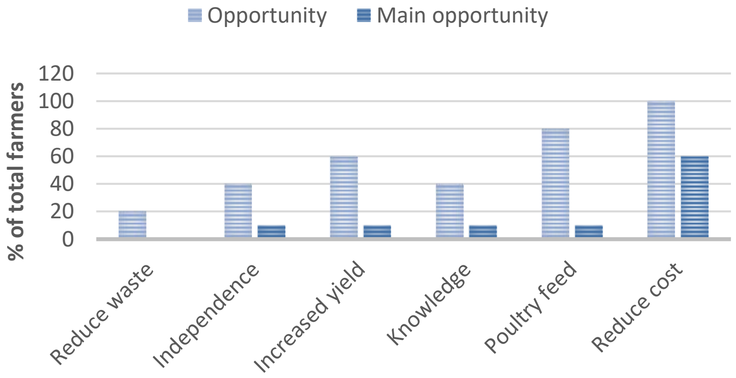
Variables	**Awassa**		**Shoa Robit**	
	Mean	SD	Mean	SD
Male(N)	6		0	
Female(N)	4		8	
Age in %				
<30	11,11		37,5	
30-40	0		37,5	
41-50	67,66		25	
51-60	11,11		0	
>60	11,11		0	
Household size(N)	5,78	1,64	5,38	1,85
Primary school (5 year) in %	60		50	
Secondary school (8 year) in %	30		50	
University degree (8+ year) in %	10		0	
Landsize in Ha	0,44	0,35	0,33	0,28
Farm-Experience (years)	14	7,1	4,5	2,51

According to the findings, the aquaponic farmers in Awassa are 60% male and 40% are female. In Shoa Robit all aquaponic farmers (100%) are woman. The age average in Awassa shows that 67,7% of aquaponic farmers are in the age range of 41-50. This is high in comparison with Shoa Robit as the majority of aquaponic farmers are below the age of 40 (75%). The household sizes are similar in both case locations. Only 60% of aquaponic farmers in Awassa went to primary school. This is a bit more that Shoa Robit as only 50% had primary education. In terms of secondary school, only 30% of the farmers in Awassa and 50% of farmers in Shoa Robit went to school. There is only one farmer in Awassa that went to University.

The size of land property of aquaponic farmers is less than 0.5 Ha. This makes it difficult for aquaponic farmers to be self-sufficient. As aquaponic farming in Ethiopia is still in its infancy, it is interesting to know the average farm experience of aquaponic farmers in Awassa and Shoa Robit. The farm experience in Awassa is higher with an average of 14 years' experience compared to Shoa Robit. These farmers only have an average of 4.5 year experience.

3.2.2 Results of semi structured interview in Awassa

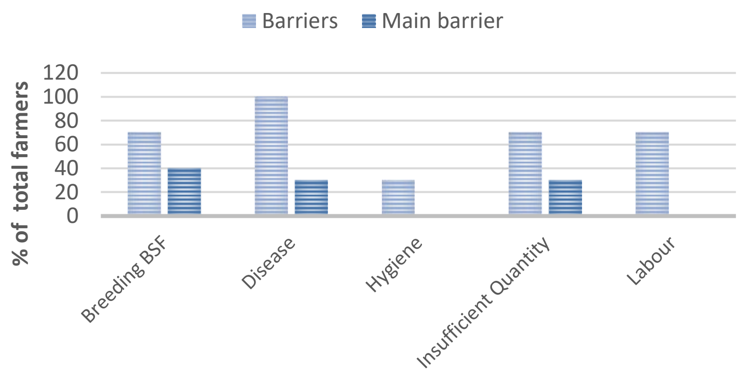
During the semi-structured interviews, the respondents gave multiple opportunities regarding BSFL farming. After this, aquaponic farmers had to indicate the most important opportunity. This is indicated as the main opportunity as it is shown in graph 3.1. In Awassa, 60% of the aquaponic farmers mentioned reduction of feed costs as a main opportunity of BSFL farming. Other main opportunities included independence on external food sources (10%), increased yield (10%), gaining knowledge (10%), and poultry feed (10%) **(Appendix 8.2).**



GRAPH 3.1: MAIN OPPORTUNITY OF BSFL FARMING IN AWASSA (N=10)

According to the chi-square test, the main opportunities are not equally divided($p<0.01$). The main opportunity 'Reduce cost' contributed most to the chi-square value. This is an indication on the importance of this main opportunity in the sample. The exact calculations can be found back in **Appendix 8.7.**

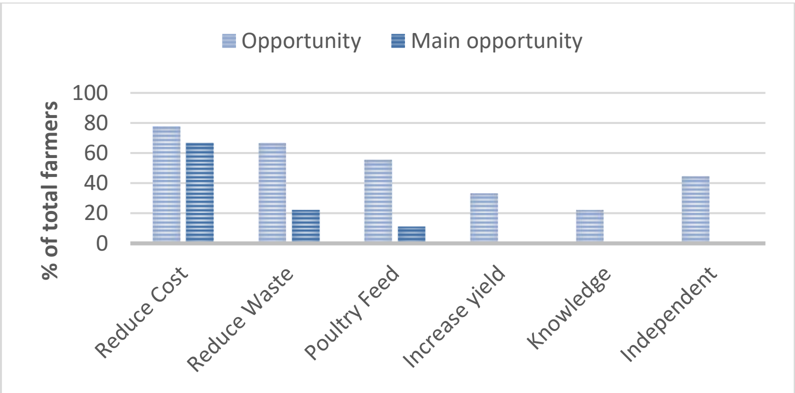
During the semi-structured interviews, the respondents gave multiple barriers regarding BSFL farming. The aquaponic farmers had to indicate the most important barrier. This is indicated as the main barrier as it is shown in graph 3.2. In Awassa, the most important main barrier is the difficulity of the breeding process of BSFL (40%). Other main barriers included were concerns on the potential diseases carried by the fly (30%) and producing insufficient quantity for fish feed by BSFL farming (30%)



GRAPH 3.2: MAIN BARRIES OF BSFL FARMING IN AWASSA (N=10)

According to the chi-square test, the main barriers are not equally divided($p<0.01$). The main barrier ‘Breeding BSF’ contributed most to the chi-square value. This is an indication on the importance of this main barrier in this sample.

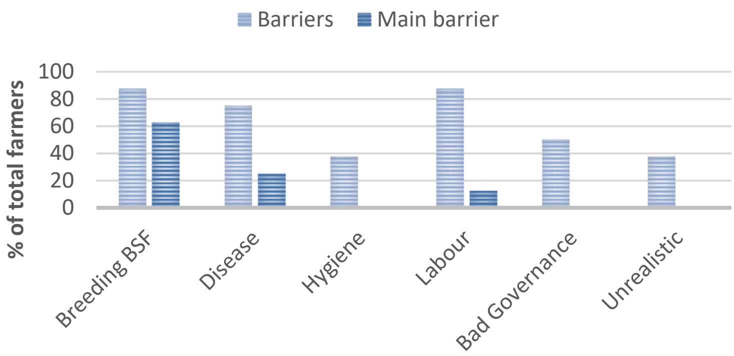
The aquaponic farmers in Shoa Robit, gave multiple opportunities regarding BSFL farming. After this, the aquaponic farmers had to indicate the most important opportunity. This is indicated as the main opportunity and is shown in graph 3.3. A total of 66,7% of the respondents saw reduction of feed cost as main opportunity. Other main opportunities included reduction of waste (22,2%). Also here BSFL is mentioned as a potential option for poultry feed (11,1%) **(Appendix 8.2).**



GRAPH 3.3: OPPORTUNITIES OF BSFL FARMING IN SHOA ROBIT (N=8)

According to the chi-square test, the main opportunities are not equally divided($P<0.01$). The main opportunity ‘Reduce cost’ contributed most to the chi-square value. This is an indication on the importance of this main opportunity. The exact calculations can be found back in **Appendix 8.7.**

The aquaponic farmers in Shoa Robit, gave multiple barriers regarding BSFL farming. The aquaponic farmers had to indicate the most important barrier. This is indicated as the main barrier as is shown in graph 3.4. According to the aquaponic farmers, the most important main barrier is the breeding process of BSF (62,5%). Other main barriers included fly disease carriers (25%) and BSFL farming seem to be labour intensive (12,5%).



GRAPH 3.4: MAIN BARRIERS OF BSFL FARMING IN SHOA ROBIT

According to the chi-square test, the main barriers are not equally divided($p<0.01$). The main barrier 'Breeding BSF' contributed most to the chi-square value. This is an indication on the importance of this main barrier.

3.3 Focus-Group Discussions

The focus-group discussions with aquaponic farmers was done after semi-structured interviews. The objective of the focus-group discussions was to gather more data by creating a dialogue among the farmers on the opportunities and barriers of BSFL farming. After the focus-group interviews, all aquaponic farmer indicated their main opportunity and main barrier regarding BSFL farming. **(Appendix 8.3)**

3.3.1 Awassa

There is a total of 10 aquaponic farmers in Awassa. A number of 8 aquaponic farmers were present during the focus-group interviews. After the focus-group, the reduction on costs for external fish feed is indicated as the most important main opportunity (50%) Other main opportunities on BSFL farming included less dependent on third parties for fish feed (37,5%) and an increasing on yield per rotation (12,5%).

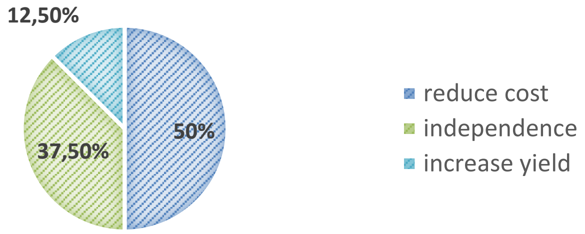


DIAGRAM 3.1: MAIN OPPORTUNITIES FOCUS-GROUP IN AWASSA (N=8)

According to the chi-square test, the main opportunities are not equally divided($p<0.01$). The main opportunity 'Reduce cost' contributed most to the chi-square value. This is an indication on the importance of this main opportunity within the sample. The exact calculations can be found back in **Appendix 8.8.**

Below shows the diagram 3.2. on the main barriers indicated after the focus-group interviews. The difficulty on the breeding process of BSF is indicated as the most important main barrier (50%). Other main barriers included, the fear for diseases of flies (37,5%) and disbelieve in sufficient quantity for fish feed produced by BSF (12,5%).

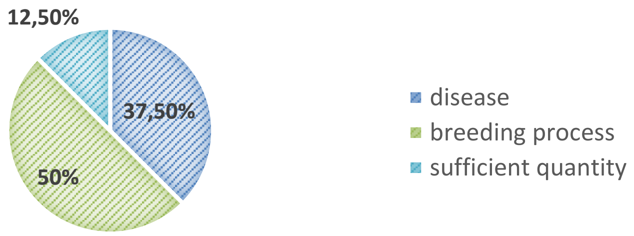


DIAGRAM 3.2: MAIN BARRIERS FOCUS-GROUP IN AWASSA (N=8)

According to the chi-square test, the main barriers are not equally divided($p<0.01$). The main barrier 'Breeding process' contributed most to the chi-square value. This is an indication on the importance of this main barrier within the sample.

3.3.2 Shoa Robit

There is a total of 8 aquaponic farmers in Shoa Robit. All aquaponic farmers were present during the focus-group interviews. After the focus-group, the reduction of fish feed cost (37,5%) and less dependence on third parties for fish feed (37,5%) are indicated as the important main opportunities of BSFL farming. Other main opportunities included, BSFL for poultry feed (25%).

DIAGRAM 3.3: MAIN OPPORTUNITIES FOCUSED GROUP IN SHOA ROBIT (N=8

According to the chi-square test, the main opportunities are equally divided(p<0.01). The main opportunities contributed relative similar to the chi-square value within the sample. The exact calculations can be found back in **Appendix 8.8**

Below shows the diagram 3.4. on the main barriers indicated after the focus-group interviews. The difficulty on the breeding process of BSF is indicated as the most important main barrier (57,2%). Other main barriers included, the fear for diseases of flies (29%) and disbelieve in sufficient quantity for fish feed produced by BSF (14,3%).

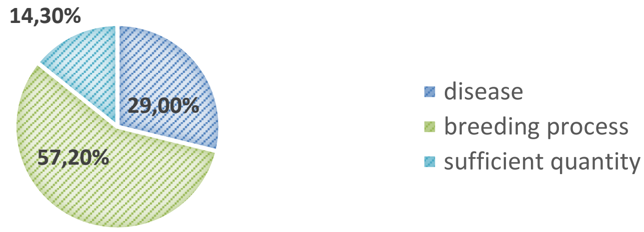


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DIAGRAM 3.4: MAIN BARRIERS FOCUSED GROUP IN SHOA ROBIT(N=8)

According to the chi-square test, the main barriers are not equally divided(p<0.01). The main barrier 'Breeding process' contributed most to the chi-square value. This is an indication on the importance of this main barrier within the sample.

3.4 Perception on BSFL technology

The majority of the aquaponic farmers are positive towards implementation of BSFL farming in both Awassa and Shoa Robit. In Awassa, 65% of the farmers are positive towards implementation of BSFL technology. While 25% perceive BSFL technology as neutral and only 10% is negative towards implementation of the technology. The diagrams, shows that there are no major differences in the perception towards implementation of BSFL farming between Awassa and Shoa Robit.

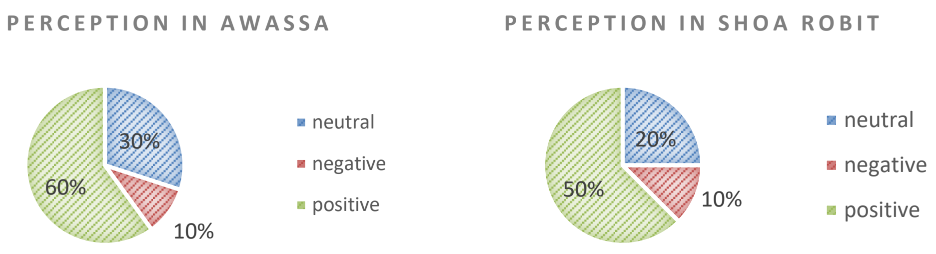


DIAGRAM 3.5: PERCEPTION BSFL IN AWASSA (N=10) AND SHOA ROBIT (N=8)

The aquaponic farmers with a positive perception on BSFL farming, have perceived the technology as not difficult to build as the building materials are available in Awassa. Also, aquaponic farmers indicate BSFL farming technology as impressive, as the technology is unknown to the farmers and breeding fish feed by BSFL farming seems like a low cost solution. The increase of fish growth by BSFL as a high nutrient rich fish feed is also perceived as a positive reason as fish growth will increase their yields. At last, farmers indicated BSFL technology positive, as the technology is seen as a way to become less independent from external fish feed sources. Some of the farmers perceive BSFL as neutral. On the one hand, farmers indicated BSFL farming reduces their dependence on fish feed sources. On the other hand, the farmers have concerns on their lack of knowledge in BSFL farming. Besides, aquaponic farmers perceive the potential of quality fish feed as a positive aspect but farmers seem to have doubts in the implementation due to governance restrictions. Aquaponic farmers that voted negative, due not believe that the flies could be bred in captivity. The reasons on perceptions are summarised in table 3.5.

POSITIVE	NEUTRAL	NEGATIVE
Not difficult to build BSFL farm	Likes the independency but lacks knowledge of BSF farming	Unrealistic idea as flies cannot be bred in captivity
BSFL farming seemes impressive for production of fish feed		
Increased growth of fish	Good quality fish feed increases fish growth. Doubts if it is realistic due to bad governance	Disbelief, as it seems impossible as flies are born from dirt
Increased independence		

TABEL 3.5: REASONS OF PERCEPTIONS IN AWASSA

The majority of aquaponic farmers in Shoa Robit perceived BSFL technology positive as the technology seems simple to implement, requires little maintenance, has low investment cost and less labour intensive. Also, farmers indicate BSFL technology positive as the technology is seen as a way to become less dependent from external feed sources. Some farmers perceived BSFL as neutral. On the one hand, farmers have indicated that BSFL farming reduces their dependence on external feed sources. on the other hand, they are concerned for their lack of knowledge in BSFL farming.Besides, aquaponic farmers perceive the potential of quality fish feed as positive but have doubts in the actual implementation due to governance restrictions. The aquaponic farmers with a negative perception, argue that BSFL is an unrealistic idea and flies could not be bred in captivity. The table 3.6 shows the summary of the reasons on the perceptions by the aquaponic farmers in Shoa Robit.

POSITIVE	NEUTRAL	NEGATIVE
Simple technology with low maintenance cost	Likes to be more independent but lacks knowledge about BSF farming	Unrealistic idea, flies cannot be bred in captivity
Low invest cost for farmer, little labour		
High potential to become more independent as a farmer, not labour intensive		
Can be grown local with own resources and simple technology	Not sure if it will work due to bad governance, but seems like a good quality feed that can increase growth of fish.	
Low investment for farmer, low risk		
Low risk and new technology that seems easy to implement		

TABEL 3.6: REASONS OF PERCEPTIONS IN SHOA ROBIT

3.5 Key Informant interviews

In addition to aquaponics farmers, interviews were held with key informants. The objective of the key informant interviews was to gain a better understanding in the opportunities and barriers of BSFL farming in Ethiopia. In total, 6 key informants were interviewed, from experts, local businesses and government. The views of key informants that are given during the interviews are shown in **Appendix 8.9**.

3.5.1 Awassa

In the table 3.7 shows the main opportunities given as response by key-informants. A total of 3 respondents have been interviewed: a feed producer in Awassa, head officer from the Bureau of Agriculture and a professor from the University of Awassa. The data given by the key-informants are divided into three categories called BSF farming, policy and law.

MAIN OPPORTUNITIES ON BSFL FARMING		
BSF FARMING	POLICY	LAW
Increased availability of protein rich feed. (Feed producer)	New recent policy (2014) of Ethiopian government is to fund new technologies like aquaponics and BSF on contract base (University of Awassa)	Exceptions are made more frequent for permits for farmers involving in new farming technologies. (Bureau of Agriculture) Feed production from animal sourced ingredients is accepted as long as the species used are native to Ethiopia. (feed producer, Bureau of agriculture)

TABEL 3.7: MAIN OPPORTUNITIES BY KEY-INFORMANTS IN AWASSA (N=3)

In the table 3.8 shows the main barriers given by key-informants. The barriers are also subdivided into the same three categories.

MAIN BARRIERS ON BSFL FARMING		
BSF FARMING	POLICY	LAW
A lot of preparation is needed to make the implementation successful (University of Awassa) The difficulty to breed BSF in the most optimal conditions (University of Awassa)	BSF is seen as an unknown species in Ethiopia. A proper ecological assessment needs to be conducted in order to acknowledge the BSF occurrence in Ethiopia. (Bureau of Agriculture) Complicated procedures is needed to make the implementation possible (feed producer)	By law, it is not allowed to introduce unknown species. The exception procedures are done by national government (University of Awassa & Bureau of Agri) The fish feed production based on insects is an unknown technology in Ethiopia. It is possible that, restrictions are in place (Bureau of Agriculture)

TABEL 3.8: MAIN BARRIERS BY KEY-INFORMANTS IN AWASSA(N=3)

3.5.2 Shoa Robit

The main opportunities given by the key informants in Shoa Robit are shown in table 3.9. A total of 3 respondents have been interviewed: a small-scale feed producer, a professor of the University of Shoa Robit and the head officer of the Bureau of Agriculture in Shoa Robit.

MAIN OPPORTUNITIES ON BSFL FARMING		
BSF FARMING	POLICY	LAW
It increase the availability in protein rich fish feed. Reduction on organic waste around urban areas	New policy (2014) is implemented in order to stimulate new farm technologies.	Exceptions are made on giving licences in new farming technologies. Feed production from animal sourced ingredients is accepted as long as the species used are native to Ethiopia.

TABEL 3.9: MAIN OPPORTUNITIES BY KEY-INFORMANTS IN SHOA ROBIT(N=3)

In table 3.10 shows the barriers of the key-informant interviews on BSFL farming. The barriers are also divided into the same three categories.

MAIN BARRIERS ON BSFL FARMING		
BSF FARMING	POLICY	LAW
It looks difficult to implement BSF farming Insect breeding is an unknown technology	BSF is seen as an unknown species in Ethiopia. It is not allowed to introduce unknown species. A proper ecological assessment needs to be conducted in order to acknowledge the BSF occurrence in Ethiopia. Difficult logistical procedures are needed before the actual implementation is possible.	It is not allowed to introduce unknown species unless, the exception procedures are done by national government The fish feed production based on insects is an unknown technology in Ethiopia. It is unclear what will happen when it is introduced, likely restrictions or ban of ingredient in place.

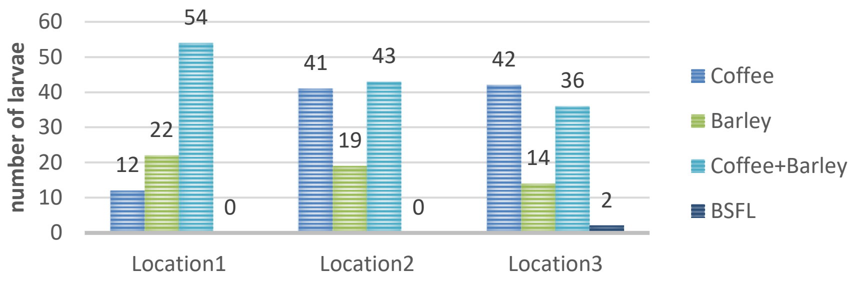
TABEL 3.10: MAIN BARRIERS BY KEY-INFORMANTS IN SHOA ROBIT (N=3)

3.6 Black Soldier Fly occurrence-experiment

The Black Soldier Fly occurrence-experiment was conducted in order to measure if the BSF has a natural existence in Ethiopia. The data below shows the amount of larvae found in each bucket per type of bait per location.

3.6.1 Awassa

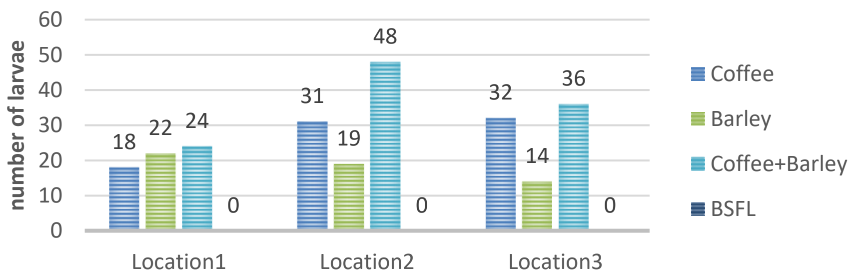
In Awassa, a total of 288 larvae were found in bait traps. Only 2 larvae were determined as BSF (Hermetia Illucens). BSF was found on location 3, in a bucket with bait type ‘Coffee & Barley’. These larvae had a length of 4-6 mm. This means that the larvae were still in the stadium of prepupae and they were maximum 14 days old. The largest number of larvae were found in location 2 with a total of 103 larvae. The ‘Coffee & Barley’ bait had the most amount of number of larvae with a total of 133 larvae. The majority of other larvae were housefly or undetermined species. Description of the location and the GPS -coordinates are shown in **Appendix 8.10**.



GRAPH 3.5: NUMBER OF LARVAE FOUND PER LOCATION IN AWASSA

3.6.2 Shoa Robit

In Shoa Robit, a total of 244 larvae were found in the bait traps. No BSFL were determined in Shoa Robit. Location 2 had the most amount of the larvae with a total of 98 larvae. The bait buckets with ‘Coffee & Barley’ had the largest number of larvae with a total of 108 larvae. The description of each location and the GPS coordinates are shown in **Appendix 8.10.**



GRAPH 3.6: NUMBER OF LARVAE FOUND PER LOCATION IN SHOA ROBIT

4 Discussion

The purpose of this research is to first compare the use of water and land between aquaponics and conventional agriculture. This is done by conducting a literature review on five case studies. The second purpose is to gain knowledge in the possibilities of BSFL farming in aquaponic systems in Ethiopia.

4.1 Reduced use of water and land

According to the findings of the literature review, it was shown that the use of water and land is lower with aquaponics compared to conventional agriculture. These findings were shown in all five cases including Awassa and Shoa Robit. This gives a strong suggestion that aquaponics can reduce the use of water and land resources in Ethiopia, meaning that aquaponics could be a viable solution to tackle the severe degradation and water shortages in the country.

However, it has to be noted that each investigated case used different parameters to present the results. Therefore, it was sometimes necessary to use simple conversion calculations in order to compare water and land use properly. Due to the fact that each case has used different formulas in their calculations, a test of significance cannot be applied to the water and land values. According to the results, it is shown that aquaponic systems have a considerably lower usage of water in liter per kg of Tilapia. Also, a lower usage in square meters per kg of lettuce were reviewed by literature.

It has to be taking into account that although aquaponics does reduce water and land use, the start-up costs for aquaponics are higher compared to the costs for conventional agriculture. This could be a bottleneck for farmers in starting their business in aquaponics (FAO, 2014).

Considering the fact that aquaponics reduces the use of water and land, aquaponics can give a new potential opportunity in having aquaponics as an indirect conservation tool for water and land resources. However, this does not guarantee that farmers will use less water and land resources. As aquaponics reduce the water and land use, it is possible that more water and land resources become available. This ‘extra’ water and land availability can be used for expansion of farms in conventional agriculture instead of conserving these natural resources. In theory it is possible to conserve natural resources by reducing the use of land and water for similar production. In practice however, it is likely that farmers start to use the conserved water and land to further increase agricultural production. If strict regulations would be put in place, it is possible to use aquaponics as a conservation tool to protect natural resources.

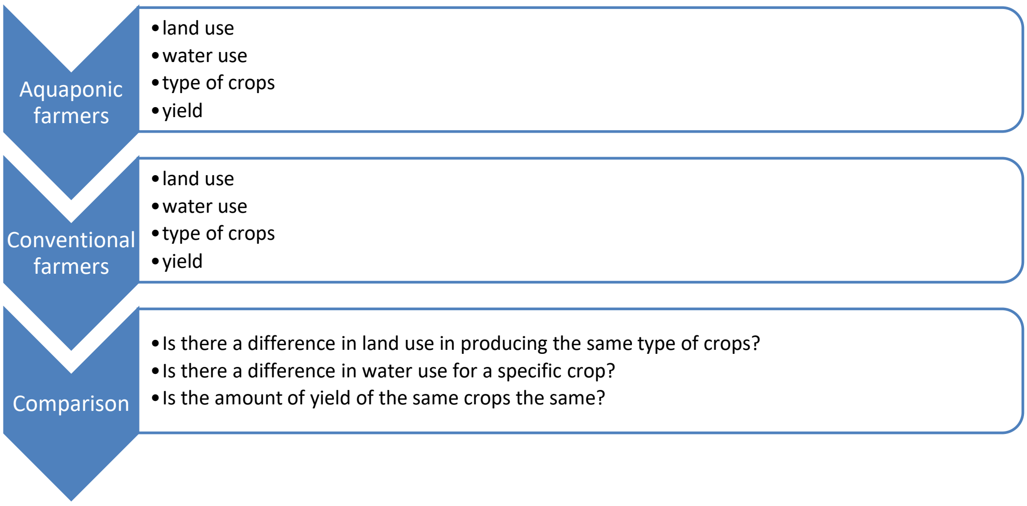
Unfortunately, it has to be noted that within the current situation in Ethiopia, it will be difficult to implement strict regulations (Plummer, 2012).

4.1.1 New research study

The literature review for this thesis research was conducted in order to compare the use of water and land between aquaponics and conventional agriculture in the context of Ethiopia. This literature study is a contribution in reaching the first research objective.

This research did not compare the water and land use between the aquaponic and conventional farmers in Awassa and Shoa Robit. This is due to the research framing, as the second focus of this thesis research is on finding the potential contribution of BSFL farming within aquaponic systems.

However, comparing the water and land use between aquaponic farmers and conventional farmers in Ethiopia could be an interesting research topic for the following research project. A new set of data is needed in order to go more in depth



in the comparison of water and land use between aquaponic farmers and conventional farmers in Ethiopia. The following research project could be a scientifically support on the beneficial effect of aquaponics on the reduction of water and land use. It will then also show that sustainable farming is needed in order reduce water and land deregation and to meet the needs for food production. This would help in paving the way for justifying national implementation of aquaponic systems in Ethiopia.

The new research design should be framed in comparing the water and land use of a specific crop. The reason why it should be focus on a specific crop type is because not all crops have the same requirements , e.g. the same amount of water input to make the yield successful. The new reseach design should then focus on the water and land use and the amount of yield of a specific crop. These variables should be compared for aquaponic- and conventional farming.

4.2 Descriptive characteristics of aquaponic farmers

During the semi-structured interview, the descriptive characterstics of the aquaponic farmers in Awassa and Shoa Robit were obtained. The results show on overview of 6 characterstics and these are used directly within this research. These descriptive characteristics of aquaponic farmers have been carried out in order to find similarities or differences in characteristics of the farmers who are practicing aquaponics. These characteristics has been compared between the aquaponic farmers in both study sites.

According to (Hughey, 2014), there is an overall trend of applied use of small-scale aquaponic set-ups in developing countries. It seems that the farmers with a small land property try to find alternative farming practices in meeting the needs for (food) production. The average size of land property of aquaponic farmers in Awassa is 0,44ha and for Shoa Robit this is 0,33ha. When this is compared with the land size of conventional farmers, it shows that the average land property of conventional farmers is larger. The average size of the land property in Awassa is 0.55ha and in Shoa Robit a landsize of 0.7ha (Central Statistical Agency, 1996) (Central Statistical Agency, 2007). This shows that aquaponic farmers have in average less land size compared to conventional farmers.

As aquaponic farming is still in its infancy in Ethiopia, it is interesting to know if the 'new' aquaponic farmers have farm experience before the farmers initiated with aquaponic farming. The reason behind this interest, is to determine the proposition that BSFL farming can successfully be applied with farmers with more farm experience. According to the findings, there is a difference in the average farm experiences between Awassa and Shoa Robit. The aquaponic farmers in Awassa have an average farm experience of 14 years as for the farmers in Shoa Robit only have 4,5 years.

There are possibly two reasons for the difference in farm experience between Awassa and Shoa Robit. One reason could be that the farm experience is related to gender difference. According to the findings, there is a clear gender difference between the aquaponic farmers in Awassa and Shoa Robit. The gender ratio of the aquaponic farmers in Awassa are 60% male and 40% female, while the aquaponic farmers in Shoa Robit are all women. The relation between farm experience and gender ratio is the work occupations of men and women. Besides farming, women are also responsible for the household and some women run small shops for additional income. As for the men, their only work occupation is farming (Tadele). Another plausible reason for the difference in farm experience between the study sites is the age difference. According to the results, the farmers in Awassa are in average older. 67,7% of the farmers are between the age of 41 and 50 years. In Shoa Robit, 75% of farmers are below 40 years old.

It is also interesting to take the educational level of the aquaponic farmers into consideration. This is with regard to their knowledge level in terms of understanding the technology of BSL farming. When it comes to the education of the aquaponic farmer, only 60% of aquaponic farmers in Awassa went to primary school. This is a bit more that Shoa Robit as only 50% had primary education. In terms of secondary school, only 30% of the farmers in Awassa and 50% of farmers in Shoa Robit went to school. There is only one farmer in Awassa that went to University. These findings are interesting in order to find possible relations with the data based on the interviews.

4.3 Main opportunities and barriers of BSFL farming

BSFL farming could be an alternative source of low-cost fishfeed supplement. Finding the main opportunities and main barriers of BSFL farming was done by using semi-structured,focus-group and key-informant interviews in Awassa and Shoa Robit, of which the findings are discussed below.

4.3.1 Main Opportunities

Most of the farmers have indicated, the reductions of costs as the main opportunity for the introduction of BSFL farming. The farmers perceive the reduction of feed costs as a reduction of maintenance cost of the aquaponic system. Therefore, the reduction of maintenance costs is seen as a preventing financial risk. According to Legesse (2003), the overall concern of the majority of farmers in all different farming systems in Ethiopia is to reduce risks by all means (Legesse, 2003). It is seen as more important compared to the other main opportunities: increase yield, reduce waste, independency or to use BSFL as poultry feed. However, this is not the case for the aquaponic farmers in Shoa Robit. According to them, the reduction of waste seemed to play an important role. It is likely that the reduction of waste is important because Shoa Robit has no garbage collection system. This is in contrast with Awassa, as they do have a type garbage collection system making the reduction of waste less necessary (Emmanuel Development Organization, 2015).

It was seen during focus-group discussions in Awassa and Shoa Robit, that the majority of the farmers saw the reduction of costs as main opportunity. However, becoming more independent of external sources for fish feed seemed to play an important role too. Surprisingly, the farmers mentioned this during focus-group discussions and not during semi structured interviews. It seems that the farmers feel more open to speak about this opportunity together in a group than by semi-structured interviews. This is in line with the findings of the research by (Kraaijvanger, 2015). According to his paper, group discussions can help to let farmers express their true opinions. There was a difference between Awassa and Shoa Robit in terms of having poultry feed as an alternative source for fish feed. The major difference between Awassa and Shoa Robit was that 25% of farmers from Shoa Robit saw poultry feed as a main opportunity, whereas in Awassa, this main opportunity was not mentioned. It could be due to the fact that farmers in Shoa Robit are more dependent on poultry farming.

According to the key-informants in Awassa and Shoa Robit, the main opportunities are to increase availability of protein rich fish feed for aquaponic farmers. Moreover, the key informants also shared that one of the benefit of BSFL farming is the reduction of organic waste in urban areas and this could result in the increase of hygiene.

The key informants also mentioned that there is a main opportunity for implementing of BSFL farming in Ethiopia. According to them, the new policies of the Ethiopian government helps to fund new innovative technologies in agriculture. (SOURCE). These new policies could help to fund BSFL farming in Ethiopia and it will increase the chance of success of new BSFL farming projects.

4.3.2 Main Barriers

One of the most important main barriers indicated by aquaponic farmers are the breeding process of BSFL in Awassa and Shoa Robit . The breeding process seems too technical for most farmers. The cause why the aquaponic farmers indicated this as main barrier is probably not related to the farm experience but to the educational level of the aquaponic farmers. This is with regard to their knowledge level in terms of understanding BSFL farming. One of the observations that has been made during the interviews, was that the farmers - and even some key informants- seemed to have difficulties to fully understand the topic on BSFL breeding. For example, the majority of the farmers and some key informants did not realize that there is a relation between fly and larvae. Another example given, the farmers strongly believed that flies are born out of organic waste. This observation shows that there is a knowledge gap. According to the findings of the descriptive characterstics, the education level of the aquaponic farmer are relatvily low. A total of 60% of aquaponic farmers in Awassa went to primary school, while in Shoa Robit, 50% had primary education. In terms of secondary school, only 30% of the farmers in Awassa and 50% of farmers in Shoa Robit went to secondary school. This knowledge gap could be a possible reason why the aquaponic farmers indicated the technicality of the BSFL breeding as a main barrier. It is likely that this knowledge gap could be a bottle-neck for the implementation of BSFL farming (Bayissa, 2015). The main concern of the aquaponic farmers regarding BSFL breeding is that the breeding process would fail and therefore they have the preference to let the breeding process be done by a BSFL breeding specialist. The farmers prefer to buy the BSFL eggs from a breeder so the farmer can let the eggs grow till its harvest size.

Another concern of the aquaponic farmers of Awassa is the insufficient breeding quantity of BSFL farming. The concern is that the quantity of BSFL will not be sufficient to feed the fish in the aquaponic system. According to the results, 30% of the aquaponic farmers in Awassa see this as one of main barriers, while in Shoa Robit this barrier has not been noticed. This could be related to the fact that there is better access of other feed alternatives for aquaponics in Awassa what would make BSFL farming seem less useful for farmers in Awasa.

Also, the minority of the farmers in Shoa Robit have mentioned that the time of labour spend on BSFL farming is seen as a main barrier. Although the farmers do see the potential of BSFL farming, 12,5% of the aquaponic farmers were concerned that the start-up of BSFL farming will cost too much time and labour.

Also, farmers in Awassa and Shoa Robit are concerned in fly diseases (or fly disease carriers). Having this concern on their minds, farmers have little interest in BSFL farming. Altough aquaponic farmers were informed that BSFL could not carry any diseases, it still did not change their minds and the majority of farmers stayed sceptical towards BSFL breeding.

During key-informant interviews, it became clear that the BSF is seen as an unknown species according to the Ethiopian law. This is a main barrier for introducing BSF farming in Ethiopia. BSF farming cannot take place as long the BSF is seen as an unknown specie to the Ethiopian government. In the current situation, the national government of Ethiopia does not acknowledge the occurrence of BSF and therefore the government will not give permission to start BSFL breeding. According to the national law and policy handbook, it is not allowed to introduce unknown species in feed production (Federal Democratic Republic Of Ethiopia, 2013). In order to accept the occurrence of BSF, the Ethiopian government should first conduct an proper ecological assessment. When the BSF is found through a proper environmental assessment, experiments can start with BSFL farming.

Next to this, the key informants have seen another barrier on the actual implementation of BSFL production. According to the key informants, feed production based on insects is unknown territory in Ethiopian law. Therefore, it is possible that there can be restrictions to produce fish feeds from insects. However, it is not possible to check the legislations by source on new developments on farming technologies as the latest updated law proclamations are from 2013 (Federal Democratic Republic Of Ethiopia, 2013).

Another main barrier that is mentioned by the key informants is that the BSFL farming techniques need to have optimal conditions -temperature and light intensity- in order to let the BSF breed successful done by the farmers. In other words, the key informants have concerns that the BSFL farming techniques are too technical for aquaponic farmers to apply.

4.4 Perception on BSFL technology

It has to be noted that the method used by letting farmers only choose positive, neutral or negative is susceptible for a polarised view and using more steps could have reduced this biased view. For example, by using a 5-point scale.

The results show that the majority of aquaponic farmers perceived BSFL technology as positive. The reasoning of farmers was that BSFL farming seemed like a simple technology with low investment costs and less dependence on outside sources. This result of the perception of BSFL technology contradicts with one of the main barriers. Although the aquaponic farmers have indicated the difficulty of the BSFL breeding as the main barrier, the majority perceives BSFL technology as positive.

Farmers that voted neutral towards the perception of BSFL technology, have the perception that the technology seems like an interesting opportunity to become less dependent and to reduce cost. However, these ‘neutral farmers’ were not sure if BSFL technology would work in practice as it was seen as an unrealistic idea to breed flies for feed. Farmers that voted negative were not convinced that flies could be bred. The ‘negative farmers’ perceived the project as an unrealistic idea.

4.4 Black Soldier Fly Occurrence- experiment

An experiment on the occurrence of BSF has been conducted in Awassa and in Shoa Robit. It is unknown if the BSF is naturally existing in Ethiopia and if it is possible to breed BSF in Ethiopia. Therefore for this experiment, 3 buckets were dispersed in each of 3 locations. Each bucket had an different type of bait. The reason for this experiment was to understand which type of bait was attracting BSFL and if BSFL were occurring in the study areas where aquaponic systems are present.

It was confirmed by the department of Entomology and Ecology of Addis Ababa University that a total of 2 larvae were determined as BSF. This was determined at location 3 in Awassa in a bucket of ‘coffee & barley’. This discovery helps to make it possible to breed BSF from wild populations. According to department of Entomology and Ecology of Addis Ababa University, it is no surprise that BSFL are found in Awassa as the area is tropical with relative low elevation making it suited for reproduction of wild BSF populations (ProteinInsect, 2014). In Shoa Robit, conditions are less favourable due to the fact it is a drier area. This is likely the reason why BSFL only could be found in Awassa and not in Shoa Robit. The sub-tropical and tropical regions of Ethiopia are favourable for finding BSF **(Appendix 8.11)**. However, BSFL is not recognized by Ethiopian law as an endemic species, therefore an ecological assessment needs to be conducted in order to make the production of BSF possible (Republic Of Ethiopia, 2000).

5 Conclusion

5.1 Water and land use by aquaponics farming

The conclusions made by the literature research on the comparison of water and land use between aquaponics farming and conventional agriculture are as follow:

- The literature research shows the use of water and land is lower with aquaponics systems compared to the conventional farming.
- The start-up costs for aquaponics are higher compared to the costs for conventional farming. This could be a bottleneck for farmers in starting their business in aquaponics.
- The aquaponics farming systems could be a new potential opportunity to serve as an indirect conservation tool for water and land resources.

5.2 BSFL farming within aquaponics systems

Here are the main conclusions on the potential contribution of BSFL farming to small-scale aquaponic farmers in Ethiopia. This is shown in chronical order of the research sub-questions.

5.2.1 The descriptive characteristics of aquaponics farmers

The main conclusions of the descriptive characteristics of aquaponics farmers in Awassa and Shoa Robit are as follow:

- The average land size of of aquaponic farmers is smaller compared to the conventional farmers.
- The gender ratio between the study sites are different:
  - The aquaponic farmers in Awassa are 60% male and 40% female
  - The aquaponics farmers in in Shoa Robit are all female
- The average farm experience in Awassa is higher (14 years) compared to Shoa Robit (4,5 years). The plausible reasons for this difference:
  - The gender ratio in relation with the work occupations between men en women: women are also responsible for the household and some run small shops for additional income. As for the men, their only work occupation is farming
  - The age difference: 67,7% of the farmers are between the age of 41 and 50 years. In Shoa Robit, 75% of farmers are below 40 years old.

5.2.2 The main opportunities for the contribution on BSFL farming

These are the main opportunities for the introduction of BSFL farming in aquaponic systems:

- Preventing financial risk by reducing maintenance cost of the system
- More independency on fish feed seemed to play an important role
- The reduction of waste is important in Shoa Robit because there is no garbage collection system in Shoa Robit.

5.2.3 The main barriers for the contribution of BSFL farming

These are the main barriers for the introduction of BSFL farming in aquaponic systems:

- The breeding processes seems too technical for most farmers
- There is a knowledge gap among the farmers and some key informants in terms of understanding the breeding process.
- The knowledge gap could be a possible bottle-neck for the implementation of BSFL farming.
- The farmers have the preference to let the breeding process be done by a BSFL breeding specialist.
- The farmers have a concerns that BSF can transmit diseases
- Introducing BSF farming cannot take place as long as the BSF is seen as an unknown specie by the Ethiopian law.

5.2.4 The perceptions on BSFL-technology

The main conclusion on how aquaponics farmers perceive the BSFL-technology is:

- The majority of aquaponic farmers perceived BSFL technology as positive. The BSFL farming is perceived as a simple technology with low investment costs and less dependence on the outside sources.
- The results of the perception contradict with the indicated main barriers. The aquaponic farmers have indicated the difficulty of BSFL breeding as the main barrier, nevertheless, the majority is positive about BSFL technology.

5.2.5 Black Soldier Fly Occurrence- experiment

According to the results of the BSF occurrence-experiment, it can be concluded that:

- BSF Larves are found in the experiment located in Awassa. This area has a tropical conditions with relative low elevation
- BSF larves are not found in experiment located in Shoa Robit. In this area the conditions are less favourable due to the fact it is a drier area with a relative high elevation.

6 Recommendations

6.1 Water and land use

By reviewing literature on water and land use of aquaponics it could be concluded that aquaponics use less water and land compared to conventional agriculture. This makes it justifiable that aquaponic systems could help in reducing the impact on water and land resources in Ethiopia. However, more data is needed. It is recommended to conduct a follow up research project in comparing the water and land use between the aquaponic farmers and conventional farming in Ethiopia. The production of aquaponic farmers should be compared with the data from conventional farmers. These results can be used as a scientifically support on the beneficial effect of aquaponics on the reduction of water and land use. It will then also show that sustainable farming is needed in order reduce water and land deregation and to meet the needs for food production. This could help in paving the way for justifying national implementation of aquaponic systems in Ethiopia. Therefore, it is recommended to invest in long-term study projects regarding water and land use between aquaponics farmers and conventional farmers in Ethiopia. This could be done in cooperation with local universities.

6.2 BSFL farming within aquaponic farming

It can be concluded that there is potential for the introduction of BSFL farming in aquaponic systems in Ethiopia. The main opportunities seen by farmers and key-informants are the reduction of costs, more independency from external sources, and reduce waste. In the findings of descriptive characteristics seem to be favourable for implementation of BSFL farming for the farmers who owns a small landsize. And according to perception of the farmers, the majority of aquaponic farmers seem to be positive towards BSFL technology.

Also, Ethiopia have new national policies that promote new innovative farming techniques that could be beneficial in implementing BSFL farming. However, as long as the BSFL species is not recognized as a native species by the Ethiopian law,then it will not be possible to farm BSFL on national scale. It is therefore recommended to send a proposal to the Bureau of Natural Resources and Environmental Protection in Addis Ababa, to conduct an ecological assessment regarding determination of the species BSF (*Hermetia Ilucens*). This would be the first step towards legal production of BSF and this would also help in making it possible to start testing with BSFL farming.

When the ecological assessment has been conducted and the BSF has been determined, the next recommendation is to start with a test set-up by the University of Addis Ababa to see if the breeding process is possible to copy from existing literature. This test set up could also give the opportunity to develop low-tech breeding chambers for BSFL farmers. This is needed to produce sufficient quantities and to keep aquaponic systems running with minimal costs.

However, it also needs to be addressed that farmers and key-informants also see main barriers on the actual implementation of BSF farming. The barriers that have been mentioned is that it seems too technical to effectively breed BSF on location. Besides, the farmers are concerned for transmitted diseases by BSF. Also, an observation has been made during the interviews, that there is a knowledge gap when it comes to larvae breeding process. It is recommended that there should be a simple and practical courses for the aquaponic farmers to help with the technical, social and public issues regarding the implementation of BSFL farming within aquaponics.

Aquaponic farmers have also shared their preference to let the breeding process be done by a BSFL breeding specialist. It is therefore recommended to conduct an inventory in how many aquaponic farmers are interested in buying their BSFL from a breeding specialist. If the interest is high, then the next step should be a research on the possibilities to train individuals who will be specialised in BSFL breeding. This could increase the motivation for the aquaponic farmers to use BSFL as fish feed for their aquaponic systems.

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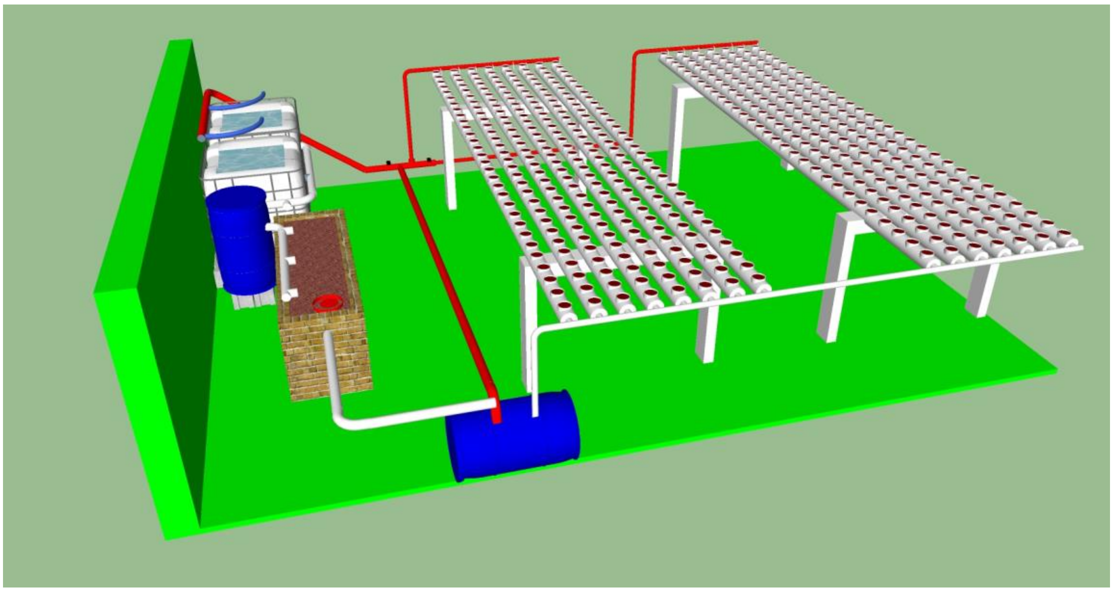
8 APPENDICES

8.1 Aquaponic set-up and design, Ethiopia



8.2 Categorization of semi structered interviews

Opportunities **Awassa**	Responses given by farmers	Barriers	Responses given by farmers
Reduce cost	Less cost for food Feed is expensive, less cost No more costs for feed , makes me happy More income for me, it is good	Breeding BSFL difficult	Seems difficult to breed Not enough knowledge Is too difficult for me
Independence	More independent from other people Less waiting on feed from producer Less dependent on others Being free from commitment to others	Disease	Afraid child get sick Flies give diseases I dont like flies in house, is bad for you Afraid it bites me I dont want to get sick, flies make you sick
Increase yield	More fish to eat More production, more income	Hygiene	Flies make it more dirty I dont want flies near my house, smells
Knowledge	Like to learn more God gave me the chance to learn more with this project	Insufficient quantity	-Larvae too small, need a lot for fish Not enough trash to give to larvae
Poultry feed	Good for chicken Chickenfood, worms make chicken strong Need good food chicken	Labour	Takes more time, I dont have time Seems lot of work Think is to much work for little
Reduce waste	No more smell Less animals in house Less waste Less diseases from aimals or bacteria Cleaner environment around house Better for surrounding water source		

Opportunities Shoa Robit	**Responses given by farmers**	**Barriers**	**Responses given by farmers**
Reduce waste	Reduces smell around house Less animals near my house Use waste effective Less waste around house	Breeding BSFL	Seems to take skill to breed well Breeding Is too difficult for me Seems to much work, someone else should do this.
Reduce cost	Less cost of food, more profit Feed is expensive, less cost Less risk, costs are low for me	Disease	Afraid child get sick Flies give diseases Flies can give you illness Poo of flies can make your skin green
Increase yield	Higher production is better for keeping customers happy More production, more income for me	Hygiene	Flies make it more dirty I am afraid larvae eat my house
Knowledge	This knowledge I can later apply in future farming It is a message of god, that we can make from waste feed again	Labour	Larvae too small, need a lot for fish, Not enough trash to give to larvae Seems labour intensive, to much work for too little.
Poultry feed	Good for chicken Chickenfood, worms make chicken strong Need good food chicken	Bad Governance	Government want to share profit in this Government will block any developement
Independence	Makes more independent , not buying anymore Financial stronger, so more independent	Unrealistic	Flies come from dirt, made by god, you cannot breed them. Inefficient, not helpful

8.3 Categorization focus-group discussions

Opportunities Awassa	Responses given by farmers	Barriers	Response given by farmers
Reduce cost	I dont want more expenses, reduction of costs is nice for , also for the chickens would be nice Reduce cost, it is expensive I want more profit, by buying less feed More profit for me	Disease	Flies make you sick, they always tell in hospital I dont like the flies, the make child sick In what way a fly nearby can be good for you? It is bad I still dont like the idea to give it to the fish
Independence	it is better to grow it myself I dont want to wait on others, always late with the feed or problem on road Seems to me like an important part of becoming selfsufficient	Breeding Fly	I think the breeding of the fly is to complicated for us. I hope it will help us , I just dont see it happen especially because it sounds complex Breeding will not be possible, raising I guess is an better idea
Increase yield	I need my fish to grow fast, A lot of mouths to feed	Quantity	This littly fly cannot help to feed the fish sufficient feed

Opportunities **Shoa Robit**	**Responses given by farmers**	**Barriers**	**Response given by farmers**
Reduction of cost	Costs are too high now reduction of feed costs. want more profit Dont really understand, but seems a cheap alternative for feed Want less financial risk, this is why I see it is a good idea	Disease	I am still afraid of the fly, I know they can bring disease Seems a bad idea, could bring diseases to our children Maby it will be better for the animals, but I am not sure if it will be for us.
Independence	-Helps to become more independent from project Wants to keep faith in own hands, with bsfl farming she does not have to rely on others. -, sometimes no feed available in town	Breeding Fly	I think the breeding of the fly is to complicated for us. I hope it will help us , I just dont see it happen especially because it sounds complex Breeding will not be possible, raising I guess is an better idea
Poultry feed	Want it for chicken feed Chicken will like this. I want to understand how this works, it seems like an good idea for my chickens.	Quantity	It just seems it will not be enough to make big fish

8.4 Interviews

8.4.1 Single Semi Structured Interview

Most questions were supplemented with a range of explaining questions, like: Why? How? How many? By whom?

Introduction of interviewer

Salaam,

Indene?

Indene,

Hello farmer, how have you been, what an lack of water these days

Farmer answers;

Have a laugh and drink some buna

Farmer is informed about Black Soldier Fly farming and how this fly relates to aquaponics. Printed poster is shown to show what BSF farming is and how it can be implemented in the aquaponics systems.

Translator starts:
1. What is your full name?
2. What is your age (estimation)?
3. What is your religion?
4. Are you married?
5. First marriage?
6. Do you have children(if yes , how many?)
7. What is your job/previous job?
8. What is your daily schedule?(how many time a day is available to do other work)
9. Do you have cattle, land, chickens or transport like motorcycle/donkey?
10. How would you describe yourself?
11. Have you been farming before?
12. If yes, what crops you produced, how much land you had, did you use fertilizers?
13. Did you produce food for yourself?(farm system)
14. Can you describe aquaponics, what advantages do you see?
15. What disadvantages do you see?
16. Would you produce with the aquaponics system for yourself or the market?
17. What crops do you want to produce?
18. What ways do you know to feed fish in an aquaponics sytem?
19. How would you feed the fish?
20. What would you prefer to feed to the fish?
21. How much do you think the feed costs are?
22. What do you do with your organic waste?
23. What advantage do you see in using fish?
24. What problems you think are going to occur?
25. What do you think of BSFL Breeding?
26. What advantages and disadvantages you see?

Questions after showing existing breeding chamber and grow place of maggots.

27. How much time you think it would take to build a bsf farm?
28. You think this is acceptable?
29. How much time you think it would take to feed ?
30. You think this is acceptable?

31. How much time you think it would take to maintain the bsf farm?
32. You think this is acceptable?
33. How would you make a breeding chamber?
34. From which material would you make it?
35. How much you think it will cost?
36. Do you think it works better to have a chamber alone or with a group? Why you think that?
37.Would it be oke for you to separate the maggots from the organic material?(why yes , why no)
38. What do you think of using maggots in the feed?
39. Do you have contact with the other aquaponic farmers?
40. Are you willing to work with other aquaponic farmers?
41. Are you in a cooperation or organization?
42. Are you interested in working together with aquaponic farmers in a cooperation or organization?

Thank you for your time! (Amesagenalum)

8.4.2 Focused Group Interview

Most questions were supplemented with a range of explaining questions, like: Why? How? How many? By whom?

Introduction of interviewer

Salaam/Indene?

Respondents are introduced to eachother and get the chance to tell a little bit about their own aquaponics set-up and what went well and what went less well. Farmers have the chance to talk a little to eachother before the Focused Group Interviews start.

Farmers are informed about Black Soldier Fly farming and how this fly relates to aquaponics. Printed posters are shown to show what BSF farming is and how it can be implemented in the aquaponics systems.

A total of 6 subtopics were chosen:
Black Soldier Fly(BSFL) farming
What does the group think of BSF farming?
How can it help? What are barriers?
Produce together BSF or seperate?
How would respondents set up a BSF farm?
Aquaponics
What is the best way to sell the aquaponics products?
What is difficult? What goes well?
Cooperation
Do respondents have contact with eachother?(how often?)(why?)
Are some of them working together in a cooperation?
Would this work for aquaponics or BSF?
Government
How is government involved in the project the group believes?(how people are chosen for the aquaponics project?)
What could be possible contraints local governance would have?(how could this be avoided?)
How could local government help aquaponics and BSF production?
Skills
Anyone has skills in farming, business , logsitics etc??(if so, what kind of skills?)
Which skills are needed but not available in the village?
Market
How should end products be sold?
Who should structure the plan of selling?
Is a plan needed to sell the product?

8.4.3 Key Informants Interview (Government)

Introduction of interviewer
Salaam,Indene?
Indene, dana na chu?
Dear Sir/Madame,
Before we start, I would like to thank you for your time and corporation in this interview.
Respondent answers;
Quick introduction on aquaponics and BSF farming.

Most questions were supplemented with a range of explaining questions, like: Why? How? How many? By whom?
1. Are you from this area or from another part of Ethiopia?
2. What kind of position you have within the government (main tasks etc.)
3. What do you think of aquaponics?
4. What do you think of BSF farming?
5. What would be difficult (regarding to policies, guidelines, laws etc?)
6. What could be possibilities (regarding subsidy help from governmental bodies etc?).
7. What would be the steps for a procedure to start a pilot project?
8. In what time frame would it be possible to finish the procedure?
9. What requirements need to be followed to obtain a license for (feed production)?
10. How realistic does this new farming system sound to you?

Thank you for your time, Amesagenalum

8.4.4 Key Informants Interview (Universities)

Introduction of interviewer
Salaam,Indene?
Indene, dana na chu?
Dear Sir/Madame,
Before we start, I would like to thank you for your time and corporation in this interview.
Respondent answers;
Quick introduction on aquaponics and BSF farming.

Most questions were supplemented with a range of explaining questions, like: Why? How? How many? By whom?

1. What kind of role do you play within the university?
2. Has their been done any research on BSF here in Ethiopia?
3. Can aquaponics reduce pressure on natural reosurces?
4. What do you think of BSF farming, could it become succesful within Ethiopia?
5. What are difficulties of both systems?
6. What are the opportunities related to BSF and aquaponics?
7. How realistic is it to say that aquaponics can become an success in Ethiopia(Same for BSF)
8. How can farmers increase production of their yields?
9. Where should we begin if we want to start a project like BSF?

10. What type of aquaponics system would be most suited for small scale projects in Ethiopia?

Thank you for your time, Amesagenalum

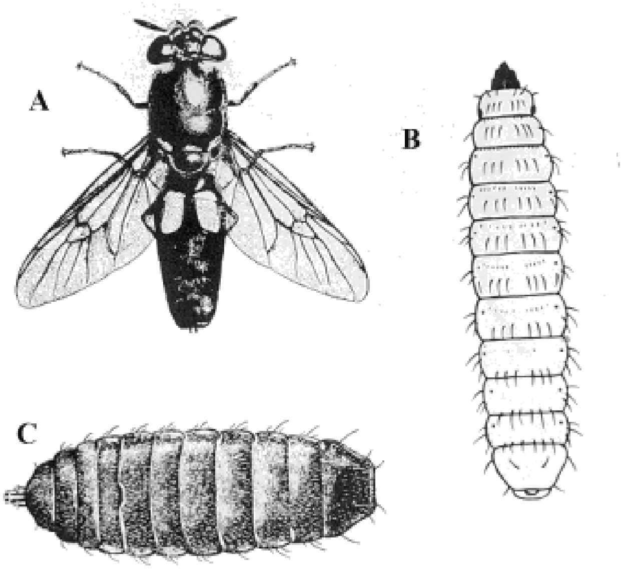
8.4.5 Key Informants Interview (Public sector)

Introduction of interviewer
Salaam,Indene?
Indene, dana na chu?
Dear Sir/Madame,
Before we start, I would like to thank you for your time and corporation regarding this interview.
Respondent answers:
Quick introduction on aquaponics and BSF farming. Quick understanding of business respondent is involved in.

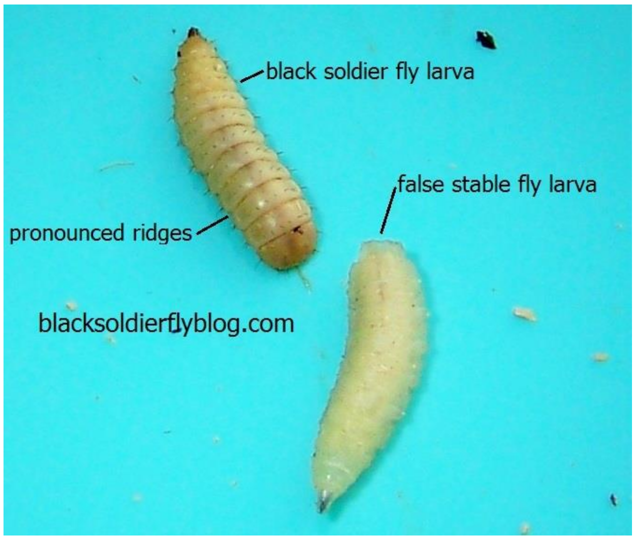
Most questions were supplemented with a range of explaining questions, like: Why? How? How many? By whom?

1. What type of business are you involved in?
2. What do you think of aquaponics, what benefits/barriers do you see?
3. What do you think of BSF, what benefits/barriers do you see?
4. In what way you think BSF/aquaponics could increase your profit or reduce costs of your business?
5. How would you start with a project like this?
6. What would be the costs to start up the process? (assesments, permits etc.)
7. Would you be interested in BSF farming (why yes/why not)
8. To what extent you think BSF production is realistic?
9. How would you start with production of BSF?
10. What would be the best way to market aquaponics products?
11. How would you sell BSFL meal?

8.5 Black Soldier determination



Black soldier fly. A, Adult female. B, Larva. C, Puparium.



Description: The larvae can reach 27 mm in length and 6 mm in width. They are a dull, whitish color with a small, projecting head containing chewing mouthparts. Larvae pass through six instars and require approximately 14 days to complete development (Hall and Gerhardt 2002). During larval development, black soldier fly larvae are insatiable feeders. As adults they do not need to feed and rely on the fats stored from the larval stage (Newton et al. 2005).

8.6 Descriptive characteristics of aquaponic farmers

	Farmer	M(1)/F(0)	Age	origine	education(y)	Religion	Household	married	marr x	children	job(1yes/2no)	job	wealth status	Time left	chicken	cattle	goat	land(ha)
Shoa Robit	1	0	30	shoa	7	orthodox	8	1	1	4	1	seller shop	2	2	10	0	0	0.15
	2	0	29	shoa	8	orthodox	6	1	2	2	1	cobbler	2	1.5	4	2	3	1
	3	0	44	shoa	4	orthodox	5	1	1	3	1	small shop	2	2	5	0	1	0.3
	4	0	28	debre-zeit	6	orthodox	3	1	1	0	1	cook	1	5	3	0	0	0.15
	5	0	32	shoa	7	orthodox	8	1	1	5	1	fix cloths	2	3	5	1	0	0.3
	6	0	40	debre han	4	protestant	5	1	1	2	1	cook	2	1	10	0	0	0.15
	7	0	27	shoa	4	orthodox	4	0	1	1	1	breakfast house	1	2	4	0	2	0.3
	8	0	33	shoa	6	orthodox	4	0	0	1	1	assitent welding	1	4	3	0	0	0.3
Awassa	1	1	44	Awassa	6	protestant	4	1	1	2	0	evangelist	2	3	4	0	1	0.25
	2	1	45	awassa	4	protestant	4	1	1	0	1	ngo	2	2	0	0	0	0.2
	3	1	48	awassa	7	orthodox	7	1	1	5	0	no job	2	2	4	3	0	0.5
	4	1	43	awassa	4	protestant	9	1	1	4	1	orphanage	1	1	0	0	0	1
	5	0	65	debre zeit	7	protestant	6	1	1	4	1	cook/seller	2	6	8	0	0	0.15
	6	0	58	awassa	4	protestant	7	1	1	3	1	seller	2	3	2	1	0	0.1
	7	1	45	awassa	5	protestant	5	1	1	2	1	farmer	3	2	20	3	0	1
	8	0	29	awassa	5	orthodox	5	0	1	2	1	cook/seller	2	2	4	0	0	0.25
	9	1	42	awassa	6	protestant	5	1	2	2	1	ngo	3	2	8		0	0.5

Shoa Robit	transport	exp farming(year)	cropsfarm	use fertilizer(y=1 or no=0)	crop prod aq	organic wa(kg)	veg garden	compost	active organisation(yes=1 or 0=no)	what coop	interest work together coop
	0	2	0	1	basil,oregano	2	1	0	1	social aid	no
	Donkey	6	maize	1	lettuce,tomato	6	1	1	1	woman assoc	yes
	0	0	0	0	lettuce,tomato	3	1	0	1	social aid	no
	0	4	maize/potato	1	basil,oregano	1	1	1	0	0	maby
	0	5	teff/maize	1	lettuce	5	1	1	1	social aid	yes
	0	8	teff	1	basil,oregano	3	1	1	0	0	maby
	0	6	teff	0	lettuce,zuckini	8	1	0	0	0	no
	family bike	5	potato,tomato	1	lettuce	3	1	0	0	0	no
Awassa	0	15	maize,teff	1	zuckini	4	1	1	1	church	yes
	motor	7	maize,teff	1	zuckini,lettuce	3	1	0	0	0	yes
	0	20	banana,cabbage	1	lettuce	8	1	1	0	0	yes
	badjadge	2	teff,quat	0	lettuce	6	0	0	1	church	no
	0	15	teff	0	zuckini,lettuce	4	0	0	1	woman associ	yes
	0	24	teff,maize	1	lettuce	6	1	0	1	woman associ	yes
	motor	15	teff,quat	1	zuckini,lettuce	20	1	1	1	farm assoc	yes
	badjadge	8	potato,maize	1	lettuce,tomatoes	4	1	0	1	woman associ	yes
	0	20	maize,teff	1	lettuce	6	1	0	1	church	yes

Variable	Variable description(n=10)	Mean	SD	Min	Max
Age of HHH	Age of household head	46,56	10,16	29	65
Gender	1 is male,0 otherwise	0,67	0,50	0	1
HHsize	Household size	5,78	1,64	4	9
Wealth	Wealth status,1poor,2medium,3rich	2,11	0,60	1	3
FerRate	Fertility rate(n of birth per woman)	2,67	1,50	0	5
MAST	Married status,1 yes,0 otherwise	0,89	0,33	0	1
EducLev	Education level(years)	5,20	2,83	3	7
Employed	1 if farmer is employed, 0 otherwise	0,78	0,44	0	1
LandSize	Land size(ha)	0,44	0,35	0,1	1
FarmExp	Farming experience(year)	14,00	7,11	2	24
CattleHH(n=8)	Cattle per Household	0,88	1,36	0	3
GoatHH	Goats per household	0,11	0,33	0	1
ChickenHH	Chickens per household	5,56	6,15	0	15
FertilizerUse	1 if farmer uses,0 no use	0,78	0,44	0	1
OrgWaHH(n=8)	Organic waste(kg) produced per day by household	6,78	5,19	3	17
ActiveCoop	1 if active in cooperation 0, otherwise	0,78	0,44	0	1
VegGard	1 if farmer has vegetable garden,0 otherwise	0,78	0,44	0	1
ComUse	1 if farmer use compost,0 otherwise	0,33	0,50	0	1

Variable	Variable description(n=8)	Mean	SD	Min	Max
Age	Age of farmer	32,88	6,06	27	44
Gender	1 is male,0 otherwise	0,00	0,00	0	1
HHsize	Household size	5,38	1,85	3	8
FerRate	Fertility rate(n of birth per woman per household)	2,25	1,67	1	5
MAST	Married status,1 yes,0 otherwise	0,75	0,46	0	1
EducLev	Education level(years)	6,38	2,72	4	12
Employed	1 if farmer has job, 0 otherwise	1,00	0,00	0	1
LandSize	Land size(ha)	0,33	0,28	0,15	1
FarmExp	Farming experience(year)	4,50	2,51	0	8
CattleHH(n=8)	Cattle per Household	0,38	0,74	0	3
GoatHH	Goats per household	0,75	1,16	0	1
ChickenHH	Chickens per household	5,50	5,50	3	10
FertilizerUse	1 if farmer uses,0 no use	0,75	0,46	0	1
OrgWaHH(n=8)	Organic waste(kg) produced per day by household	3,88	2,30	1	8
ActiveCoop	1 if active in cooperation 0, otherwise	0,57	0,53	0	0
VegGard	1 if farmer has vegetable garden,o otherwise	1,00	0,00	0	0
ComUse	1 if farmer use compost,0 otherwise	0,50	0,53	0	0

8.7 Semi-structured interviews-chi square analysis

Awassa							
Main Opportunity						critical value	
	Responses %	expected	Squared difference(x	DF	Chi Square	p<0.01	
Reduce cost	60,00	16,67	112,67	5,00	140,00	15,09	
poultry feed	10,00	16,67	2,67				
Knowledge	10,00	16,67	2,67				
Increase yield	10,00	16,67	2,67				
Independence	10,00	16,67	2,67				
Reduce waste	-	16,67	16,67				
Main Barrier							
	Responses %	expected	Squared difference(x	DF	Chi Square	p<0.01	
Breeding BSF	40,00	20,00	20,00	4,00	70,00	13,28	
Disease	30,00	20,00	5,00				
Insufficient quan	30,00	20,00	5,00				
Hygiene	-	20,00	20,00				
Labour	-	20,00	20,00				
Shoa Robit							
Main opportunity	Responses %	expected	Squared difference(x	DF	Chi Square	p<0.01	
Reduce Waste	22,20	16,67	1,84	5,00	203,90	15,09	
Reduce Cost	66,70	16,67	150,20				
Increase yield	-	16,67	16,67				
Knowledge	-	16,67	16,67				
Poultry Feed	11,10	16,67	1,86				
Independence	-	16,67	16,67				
Main Barriers	Responses %	expected	Squared difference(x	DF	Chi Square	p<0.01	
Breeding BSF	62,50	16,67	126,04	5,00	181,25	15,09	
Disease	25,00	16,67	4,17				
Hygiene	-	16,67	16,67				
Labour	12,50	16,67	1,04				
Bad governance	-	16,67	16,67				
Unrealistic	-	16,67	16,67				

8.8 The focus-group discussions- chi square analysis

Awassa

opportunities

	Responses	Expected	Squared difference(x2)	DF	Chi-square	p<0.01
Reduce cost	50	33.3333	8.333333333	2	21.875	9.21
Independence	37.5	33.3333	0.520833333			
Increase yield	12.5	33.3333	13.02083333			

Barriers

	Responses	Expected	Squared difference(x2)	DF	Chi-square	p<0.01
Disease	37.5	33.3333	0.520833333	2	21.875	9.21
Breeding fly	50	33.3333	8.333333333			
Quantity	12.5	33.3333	13.02083333			

Shoa Robit

Opportunities
Shoa Robit

	Responses	Expected	Squared difference(x2)	DF	Chi-square	p<0.01
Reduce cost	37.5	33.3333	0.520833333	2	3.125	9.21
Independence	37.5	33.3333	0.520833333			
Poultry feed	25	33.3333	2.083333333			

Barriers

	Responses	Expected	Squared difference(x2)	DF	Chi-square	p<0.01
Disease	37.5	33.3333	0.520833333	2	39.0625	9.21
Breeding fly	62.5	33.3333	25.52083333			
Quantity	12.5	33.3333	13.02083333			

8.9 Summary key informants

8.9.1 Feed producer Awassa

- Increased availability of protein rich feed

- Feed production from animal sourced ingredients is accepted as long as - the species used are native to ethiopia

We need to understand that there is simply not enough feed available in the country for the production of effcient poultry and fishfeed. I sometimes make it with dried or grinded bones in order to increase production a little but this still does not work that well. I have heard from several feed producers that it is allowed to use all different type of materials in the feed to produce the feed. Only the it is important to not use materials that do not originate from Ethiopia. However I never had anyone check m fort his. The way I see this breeding, it seems a little technical but easily manageable for me. I am sure I will be able to use it and produce. It will be difficult to get permission from the government I think, They make a lot of problems quiet easy. It is seen that difficult procedures are needed before before implementation is possible, policies by government are difficult to follow and make it hard to understand where possibilities are seen.

8.9.2 Bureau of Agriculture Awassa

I am unsure about the BSFL production as I do not fully understand the topic. However, to me it seems that reducing waste is a major improval as the city itself has issues with organic waste. Especially, the lake gets contaminated as a lot of waste is dumped near to the lake, what makes the water of very bad quality. It is good to know that the government is trying to increase production of conventional agriculture to reduce the pressure on natural resources. They are now promoting by new policies new technologies to make production more efficient and BSFL seems to be one of these technologies. Another opportunity now is that laws are more stable what makes hit more likely that a project as BSFL has success. Still it is sometimes difficult to understand the procedures but slowly on things start to change. One of the difficulties with this BSF is that i fit is not known to the ethiopian government of natural resources, it is not allowed to start producing the BSFL. The production of insects in general as far as I know is not clear tought about. It is possible that nobody started with this, and first procedures need what could result in restrictions of the production of insects.

8.9.3 University of Awassa

It seem to be a good intitiative and their is a lot of demand for the production of BSFL farming in Ethiopia. We need better quality of feed and better production procedures especially in rural areas. The main opportunity I see now for BSFL farming is that Ethiopian government is funding new farming technologies, what includes BSFL farming. This could help to make BSFL farming an succes. Barriers are the technical breeding, and implementation of BSFL farming . Another barrier is that the fly should be known by the Ethiopian government, otherwise it is not allowed to introduce the new species.

8.9.4 Feed producer Shoa Robit

I would be happy if the feed would become of better quality. As it is now, the quality is just not sufficient. I think that it also would to reduce by cost and feed my chickens, but the main opportunity I see for now is the better availability of qualitive protein rich feed. It seems not so difficult to produce the fly , it will be a challenge but definetly possible. However, The procedures that need tob e followed by official government rules is difficult, this makes the process long lasting before actual breeding can start. This is an major barrier. It is a major barrier that the technology is relatively unknown, this needs to be taken into consideration before looking further into BSFL farming.

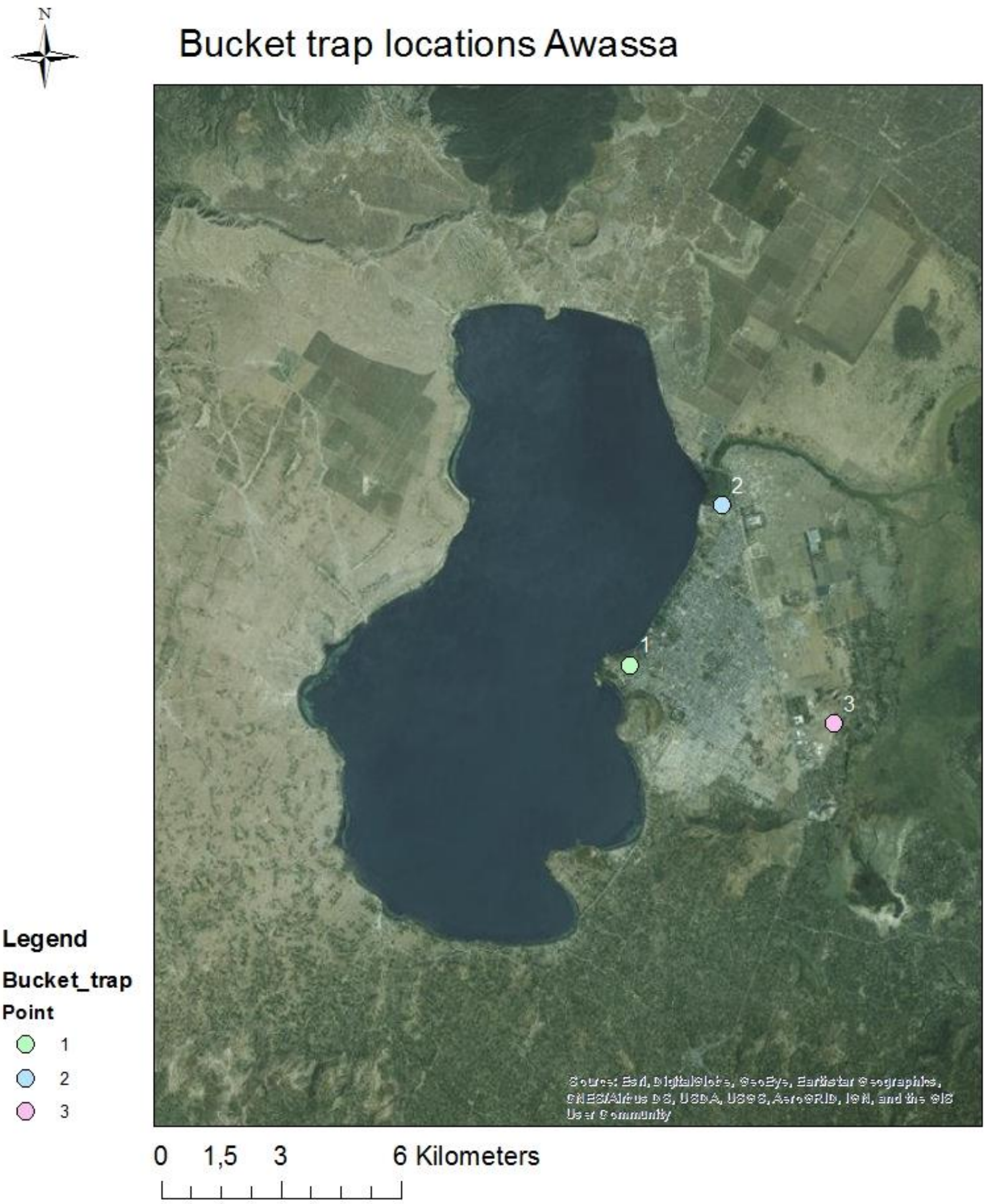
8.9.5 Bureau of agriculture Shoa Robit

One of the biggest problems we now face is Shoa Robit is the excessive amount of organic waste. The city is growing faster than can be handled with garbage collection. If this BSFL could help us to reduce this problem, I am sure that an exception is made to start production with BSFL farming. I would like to see a start up here, as their are more and more problems with hygiene/diseases in the town. I know by official law that it is not allowed to introduce new species, but I hope that they will make an exception for this, as is it is important for further development of the town. I hope that there are no restrictions regarding insect breeding for feed. I never heard from it and I am not sure if it is possible by law.

8.9.6 University of Shoa Robit

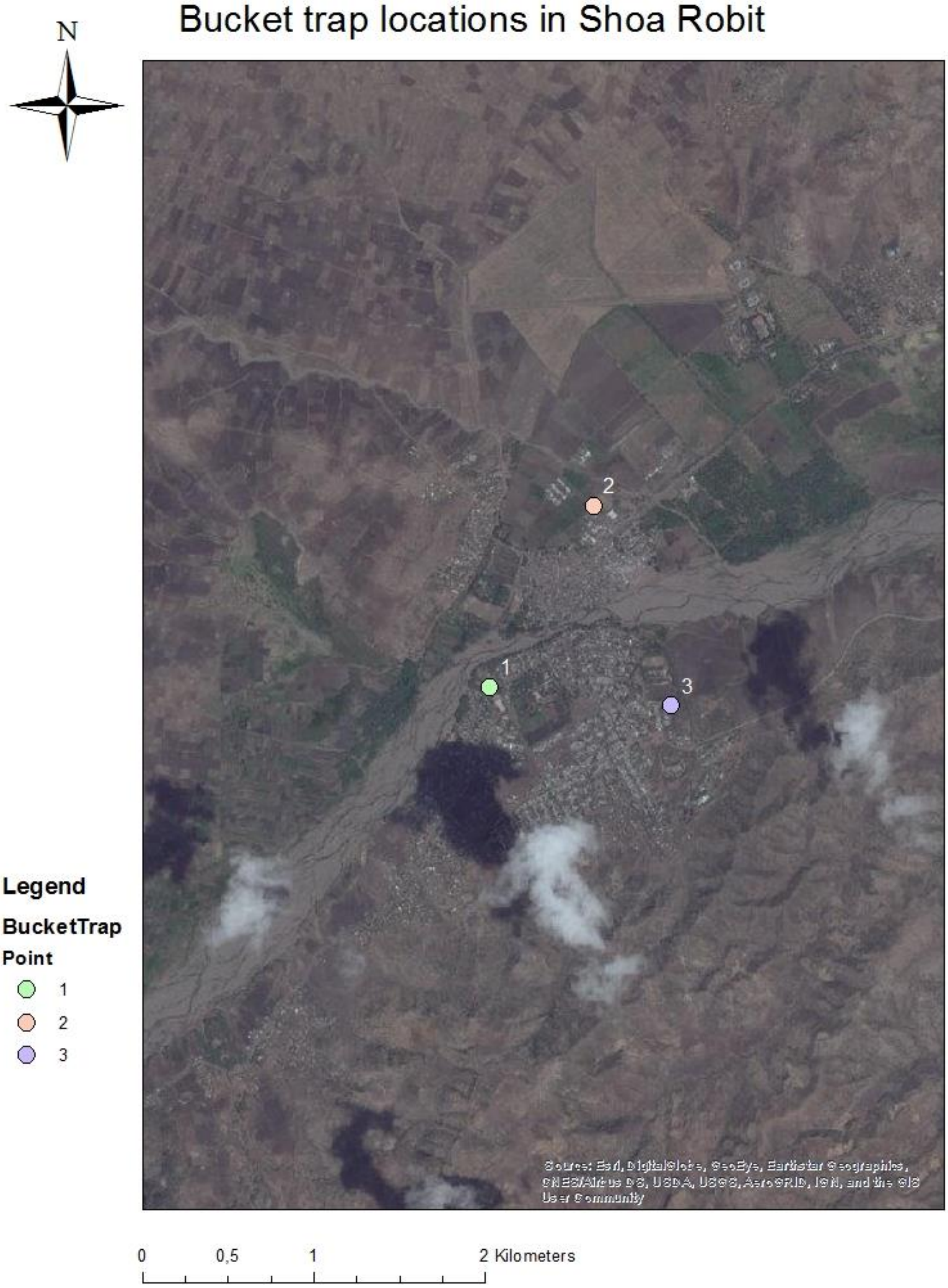
I think that this could be a step in the good direction to reduce the problems regarding food insecurity. We need to make sure that this problem is solved. The policies by Ethiopian government are favourable for the production of quality feed. One of the major barriers I see is that it is difficult to implement this in Shoa Robit. The university could produce it but I dont think the farmers can. It seems quiet a technical problem.

8.10 Bucket trap locations per study area



Awassa	UTM_Coordinates	Nr of Larvae
1	37N 4407320778975	64
2	37N 443953 0782996	98
3	37N 445824 0777517	82

Bucket trap locations in Shoa Robit



Shoa Robit	UTM_Coordinates	Nr of Larvae
1	37P 598032 1105015	88
2	37P 598629 1106062	103
3	37P 599075 1104892	92

8.11 Climate zones of Ethiopia