Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources
and Agricultural Sciences

Cooking banana farming system in rural Uganda

–A comparison between agroforestry systems and non agroforestry systems

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Bachelor Thesis • 15 hec • First cycle, G2E
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Keywords: Agroforestry farming system, non agroforestry, cooking banana, improved livelihoods and Uganda.

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Abstract

The demand for food, feed, fibre and fuel has increased in Uganda over the past 50 years due to population growth. Recurring extreme climate events such as drought and flooding, in combination with large-scale land degradation, have led to declining crop yields. Lack of equipment, money and socio-economic issues has contributed to low yields. However, the soils in Uganda have the potential to produce much higher yields than they do today.

This study, which was carried out in April-June 2013 in Kkingo District, south-east Uganda, examined the effects of agroforestry on yield of cooking bananas in small-holder farming systems. Six farms practising agroforestry and six farms with no agroforestry, which were chosen in cooperation with the NGO *Vi Agroforestry*, were compared. On each farm, semi-structured interviews and seasonal interviews were held and the crops cultivated were recorded, particularly cooking bananas in mixed cropping systems. This study was run in parallel and in cooperation with two other studies, one on soil carbon stocks and one on macrofauna, and farms and sampling sites were chosen to fit all three studies.

The results showed significantly increased yield of cooking bananas in the agroforestry systems. The farms which used organic manure (*i.e.* the agroforestry farms) also had significantly higher yields of cooking bananas. Agroforestry gave a more diverse cropping system than the non-agroforestry system, which resulted in a higher standard of living and more self-sufficient households on agroforestry farms. Agroforestry was no more time-consuming than the non-agroforestry system. In fact, in the long run agroforestry involved less heavy work. One of the most important factors for success in agroforestry was the farmer’s knowledge and dedication to managing the farm and taking advantage of all available resources.

Keywords: Agroforestry farming system, cooking bananas, mulch, use of manure, improved livelihoods, Uganda.

Sammanfattning

Efterfrågan på mat, foder och ved har ökat under de 50 senaste åren i Uganda, på grund av en snabbt växande befolkning. Samtidigt som småskaliga lantbrukare i Uganda lider av produktionsnedgång i jordbruket. Det finns studier som visar på att agroforestry ger en ökning i skörd av kokbanan samt andra grödor som majs och kaffe. Agroforestry kan även ge jorden en bättre vattenhållande kapacitet och öka mullhalten i marken vilket kan bidra till en ökning i skörd.

Syftet med denna studie var att undersöka effekten agroforestry har på skörden av kokbanan i småskaliga lantbruk i Uganda. Sex gårdar med agroforestry principer jämfördes med sex gårdar som inte praktiserade agroforestry, gårdarna valdes ut i ett samarbete med den svenska biståndsorganisationen Vi Skogen. Hypotesen var att agroforestry metoden leder till högre skörd av kokbanan än icke-agroforestry. Samt att agroforestry är mer tidskrävande och hårdare arbete och att användning av organisk gödsel skulle ge högre skörd än utan gödsel. Fältarbetet utfördes i Kkingo region, sydväst om Masaka, Uganda. På varje gård valdes sex provrutor ut for att undersöka vegetationen. På varje gård gjordes även intervjuer med varje bonde (kunde ske parvis) samt gruppintervjuer med ca 10 bönder åt gången.

Resultaten visar på signifikant högre skörd av kokbanan med agroforestry jämfört med icke-agroforestry. Användningen och användningsmetoden av organisk gödsel, hade stor betydelse och gav högre skörd av kokbanan om gödsel användes. Dock så var inte agroforestry mer tidskrävande än icke-agroforestry och långsiktigt krävde det mindre tungt jobb. Slutligen resulterade agroforestry i att ge småskaliga bönder i Uganda en högre levnadsstandard och ett mer självständigt hushåll med mer komplext odlingssystem med större mångfald.

Abbreviations

EADDP	East African Dairies Development Programme
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
ha	Hectare
ICRAF	International Centre for Research in Agroforestry
LER	Land Equivalent Ratio
N	Nitrogen
SIDA	Swedish International Development Cooperation Agency

Preface

This Bachelor’s degree project, worth 15 credits (Swedish hp), was supported by a minor field study (MFS) scholarship from the Swedish International Development Cooperation Agency (Sida). The study was the result of collaboration between the Department of Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), and the non-government organisation *Vi Agroforestry*.

Associate professor Magnus Halling and Kajsa Hallen Nyerere, chairwoman of the *Vi Agroforestry* programme in Uganda, supervised the work.

I would like to thank Magnus Halling for his help in planning and carrying out the work. I would also like to thank professor Göran Bergkvist, examiner of the project, for his support and advice in the final phase of the project. I also want to express my sincere thanks to all the staff at the *Vi Agroforestry* office in Masaka for their fantastic supervision, which made our work pleasant and possible. The office in Masaka contributed to a great experience and a wonderful time in Uganda. I would also like to thank the executive committee at Kkingo Farmers’ Organisation for their help with finding suitable farmers for the study.

Finally, special thanks to all the farmers and their families for their hospitality during our visits, for the information they shared with me and for letting me work in their fields.

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1 Introduction

Uganda is a developing country with almost 35 million people, located on the equator in East Africa. Uganda is currently experiencing the fourth fastest population growth in the world, 3.6% per year. The climate in Uganda is tropical, with two rainy seasons. However, the rainy seasons are becoming more unpredictable in recent years due to climate change (The World Factbook, 2013). Around 80% of the Ugandan population are dependent on agriculture and most of these are small-scale farmers. Agriculture contributes 23.9% to gross domestic product (GDP) (Rusoke *et al.*, 2000). The four most common cultivated crops are cassava, sweet potatoes, coffee and plantain (V. Komakech, pers. comm. 2013). However, farmers in Uganda are facing many challenges in food production, such as drought, soil erosion, land degradation, poor land management practices, low political power, lack of scientific research and lack of new techniques. These factors are resulting in a major yield shortfall (Rusoke *et al*., 2000). The soils in Uganda have the potential to produce much higher yields than they do today. There is a need for sustainable agriculture which can provide small-scale farmers with food, animal feed, fuel, soil fertility and finance (Licker *et al*., 2010). Agroforestry is a practice of intercropping trees with crops (can also include animals) which is currently being promoted by the Swedish NGO *Vi Agroforestry* (Vi-Skogen, 2012). By intercropping suitable trees with crops, it is possible to increase the yield of the main crop and also improve the quality of the soil (Van Asten *et al*., 2011).

Objectives of the study and hypothesis tested

The overall aim of this study was to determine the effects of agroforestry on the yield of cooking bananas for small-scale farmers in Uganda. An additional aim was to compare the advantages and disadvantages of different cropping systems and identify that giving the greatest improvement for households on smallholder farms.

The hypotheses tested were that:

- Agroforestry systems are more time-consuming and involve more heavy work than non-agroforestry systems.
- Agroforestry improves farmers’ livelihood and makes them more self-sufficient.
- Farming systems which use manure achieve higher yield than systems without manure.

2 Background

2.1 Agroforestry

Agroforestry is not a new science; in the past, trees grew naturally on farmland together with fallow areas and crops. With increasing population and a growing demand for food, the trees were cut down and the forested land converted into agricultural land. However, with continuing population growth, land shortage is now a common problem in Uganda. Agroforestry is a potential method to prevent soil degradation because of its intense use of land (Rusoke *et al*., 2000; Schwilch *et al*., 2012). In an agroforestry land use system, woody perennials (*e.g*. trees, shrubs or bushes) are integrated with crops or/and with livestock on the same land. The intercropped trees can be arranged in a spatial or temporal sequence (Figure 1). Landscape form (*e.g*. hilly or flat) is also a contributing factor in how the trees are planted (Rusoke *et al*., 2000). The trees have a larger root system than the crops, which means they can access water and nutrients in deeper layers in the soil, and they also increase water infiltration into the soil (Verchot *et al*., 2007). Agroforestry is a dynamic system based on natural resource management that diversifies and increases economic, social and environmental benefits (Rusoke *et al*., 2000; Lwakuba *et al*., 2003). In the following text, all agroforestry trees, shrubs and bushes, *i.e*. woody perennials, are referred to as trees.

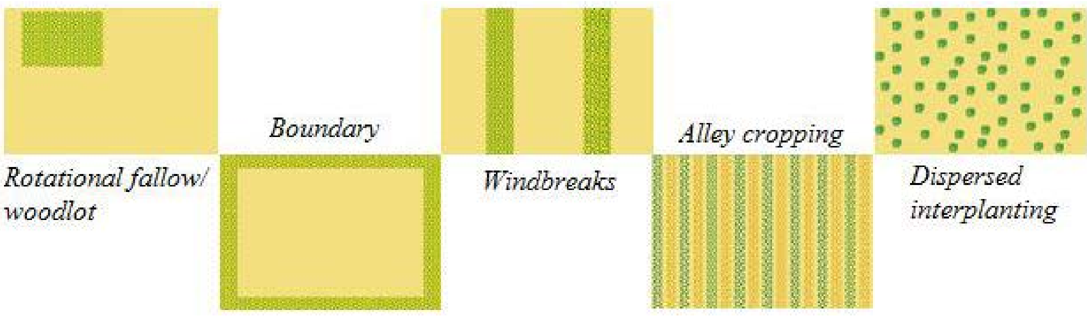

Figure 1. Example of how trees (green) can be intercropped with crops (yellow) in temporal and spatial patterns. Source: Y. Nyberg (pers. comm. 2013), reproduced with permission.

Advantages

There are both advantages and disadvantages in intercropping trees with crops. According to researchers at the World Agroforestry Centre, farmers who convert from sole cropping to an agroforestry farming system save 5-10 hectares per hectare converted (in yield) (Y. Nyberg, pers. comm. 2013). According to Verchot *et al*. (2007), farming systems with trees can withstand dry periods better. Because of the deep root system, the ability to reach water in deeper soil layers increases. Water infiltration into the soil is also improved, thereby reducing water runoff and increasing the soil porosity. The integrated crops also benefit from the leaf and root litter produced by the trees (Verchot *et al.*, 2007). Other advantages include provision of fodder and shade, which leads to lower solar radiation as the large canopy intercepts the sun's rays. Plant residues (from trees and crops) which are left on the ground form a surface mulch that decomposes over time and improves the organic matter content in the soil. This higher soil organic matter content increases soil fertility, water storage and the humidity under the tree canopy (Figure 2). Soils rich in humus and organic matter produce higher yields than soils depleted of nutrients. A high quality, healthy soil produces good yields of high quality crops (Magdoff & Van Es, 2009; Jones, 2012).

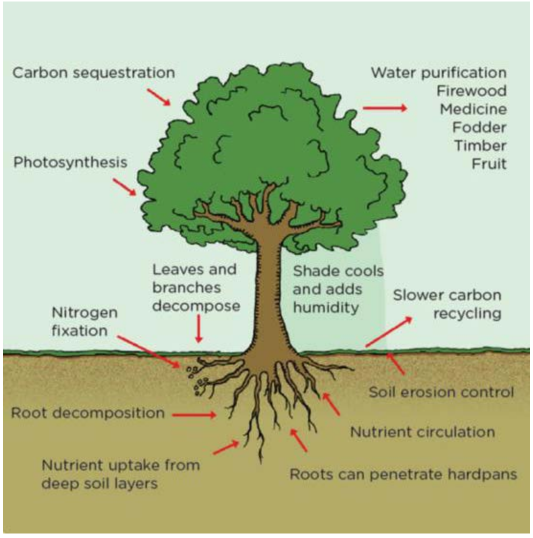

Figure 2. Example of what a tree contributes to a cropping system. Source: Y. Nyberg (pers. comm. 2013), reproduced with permission.

Agroforestry systems also involve a more diverse and intense production system, with decreased weed pressure and a more stable system compared with cropping systems without trees (Schroth *et al*., 2000). By growing trees on some of their arable land, farmers get food, animal feed, firewood and fuel, and thereby increased income through selling various products. If one crop suffers low yield, it is still possible to stabilise farm finances by obtaining high yield from another crop grown on the farm. This means that the income is spread across the year and that in times of crisis, *e.g*. pest attack, disease or drought, the household is less vulnerable (Verchot *et al*., 2007). A highly diversified cropping system such as agroforestry also increases the biodiversity of both soil flora and soil fauna. For example, it favours the presence of more species of herbivores, decomposers and carnivores (Malezieux *et al.*, 2009). A study in Uganda by Van Asten *et al.* (2011) comparing monoculture cooking bananas and intercropped bananas with coffee concluded that cooking bananas benefited from the intercropping system and that it resulted in significantly higher yields than sole cropping systems.

According to Verchot *et al.* (2007), all the benefits contributed by trees to farming systems lead to higher yields in areas such as Uganda, which has degraded soils lacking in nitrogen (Figure 3). This increase in crop yield is the result of better water-holding capacity, increased amounts of nutrients in the soil and enhanced biological properties (Verchot *et al.*, 2007).

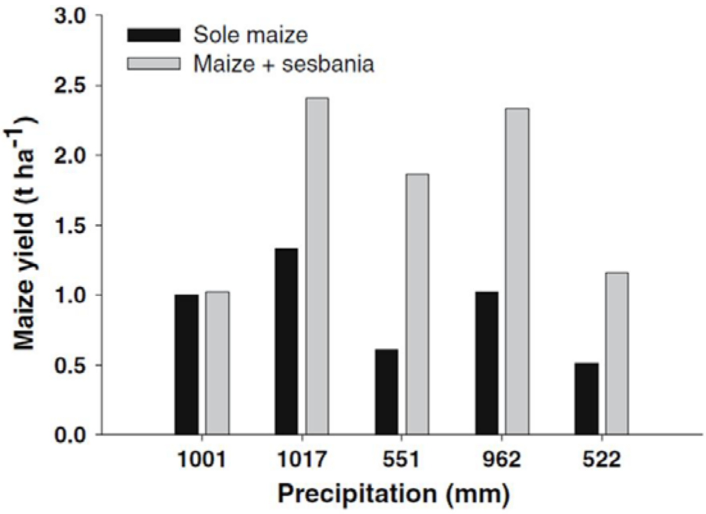

Figure 3. Differences in yield between maize cultivated in monoculture and in a mixed farming system Source: Verchot *et al*. (2007).

According to Malezieux *et al.* (2009), agroforestry systems give higher yields than sole cropping systems. A study in Central America showed that intercropping coffee shrubs with trees improved the quality of the berries. Because of the shade provided by the trees, the berries ripened more slowly and had more time to achieve better quality than those on unshaded coffee shrubs (Malezieux *et al*., 2009). Another project by Munyuli (2012) in central Uganda showed that intercropping cooking bananas with trees and coffee bushes increased the number of species and abundance of butterflies. Agroforestry achieved this increase in biodiversity by mimicking the natural landscape (Munyuli, 2012).

Disadvantages

With intercropping, there may be competition between trees and crops for the same resources in terms of water and nutrients, which will lower the yield of the crops. Some crops have restricted growth in shade, which means that large trees could have a negative impact because of shade effects from the canopy. The effects from the trees can benefit some crops, but at the same time have a negative impact on other crops. This makes the choice of species very important in achieving good intercropping and obtaining high yield. Making the wrong choice of species to intercrop and bad management can lead to reduced yields in agroforestry systems (van Noordwijk *et al*., 2011). Furthermore, non-agroforestry farmers obtain an income straight away, but agroforestry farmers need to wait some time to obtain an income from their trees.

There can be a delay of up to a few years before the farm reaches the real breakeven point with profitable products. This can be ruinous for smallholder farmers and their livelihoods. The agroforestry farmers also lose in production by planting a tree instead of a crop on a particular site, before eventually benefiting from their investment. This leads to a reluctance among farmers to invest and practise agroforestry. In addition, there has to be a market for the agroforestry products in order for farmers to achieve high incomes (Buttoud, 2013). The farmers need to be motivated and receptive to the new farming system so that they can embrace new knowledge and succeed with the new farming systems. Otherwise there is a major risk they will fail and that agroforestry will itself cost more than it benefits the farmer (Kessler, 2006).

2.2 *Vi Agroforestry* - a non-government organisation

Vi Agroforestry is a Swedish non-government organisation and has no religious or political affiliations. The organisation was founded in 1983 and the idea behind it was to improve the situation for smallholder farmers in the area around Lake Victoria (Nilsson, 2007). *Vi Agroforestry* is active in four countries: Uganda, Kenya, Tanzania and Rwanda. The organisation works through capacity building and providing advice on agroforestry. Today *Vi Agroforestry* is a well-known organisation and has planted more than 100 million trees since it started (Vi-Skogen, 2013). The first trees were planted in West Pokot District in Kenya, to stop desertification and soil erosion. *Vi Agroforestry* is funded by individual donations and by the Swedish government through the Swedish International Development Cooperation Agency (Sida) (Nilsson, 2007). *Vi Agroforestry*'s vision is: '*A sustainable environment offering good living conditions for farming families*' and its mission is: '*To make agroforestry and enterprise development engines of economic growth and poverty reduction*' (Nilsson, 2007). The organisation works with spreading knowledge to small-scale farmers and promotes a more diverse cropping system, which will make the farmers less vulnerable because of the increased production (Vi-Skogen, 2013). *Vi Agroforestry* promotes many methods to improve the standard of living of small-scale farmers in East Africa. These methods include storing manure and adding more manure to fields, using manure to produce biogas for cooking, and providing training in agriculture practices through workshops (Nilsson, 2007).

2.3 Tree species used by *Vi Agroforestry*

Vi Agroforestry promotes different tree species and bushes in practice. When choosing the right trees for a mixed cropping system, there are some important aspects that need to be kept in mind. The products from the trees need to benefit each specific farm and to fit in the cropping system with the rest of the crops (Lwakuba *et al*., 2003). There are a lot of different characteristics of trees: Nitrogen fixation, fast growth, coppicing, deep rooting, light canopy, suitable for fodder and compatibility with crops (Rusoke *et al*., 2000). Some of the tree species promoted by *Vi Agroforestry* are described in the following paragraphs (V. Komakech, pers. comm. 2013).

Bark-cloth fig (*Ficus natalensis*)

Bark-cloth fig (known as *mutuba* in Luganda) is a common tree in Uganda belonging to the family *Moraceae* (Katende *et al*., 2000). The tree grows very large and can reach up to 20 m. Bark-cloth fig improves the soil structure and is able to grow well on both dry and wet areas (Vi-Skogen, 2013). It gives good shade because of its wide canopy and is therefore good to intercrop with species such as banana, coffee and cocoa (which benefit from shade). The leaves have anti-inflammatory properties and can be used as a medicine (Katende *et al*., 2000).

Sesbania (*Sesbania sesban*)

Sesbania is a small nitrogen-fixing tree which can reach up to 6 m. It belongs to the family *Papilionoideae*. It can be used as firewood but as it is soft and has light wood, it is also good as fodder. The roots can be crushed and used as a medicine that is good for scorpion stings (Dharani, 2011).

Calliandra (*Calliandra calothyrsus*)

Calliandra is an large, ornamental multi-stemmed bush (4-6 m) with beautiful red flowers belonging to the family *Mimosaceae*. It grows fast and has a lot of spreading branches. Calliandra can be used for both fuelwood and fodder for livestock because of its high content of protein (22%). The bush can withstand drought for a long time, but grows better with intense rainfall (Katende *et al*., 2000).

Guava (*Psidium guajava*)

Guava is an almost naturalised tree belonging to the family *Myrtaceae* which can grow up to 8 m. The fruit is appealing to people and animals, especially bats and birds (Dharani, 2011).

Avocado (*Persea amiricana*)

The avocado is a fruit tree belonging to the family *Lauraceae* which is suitable for growing in moist areas. It grows one straight trunk that can reach up to 10 m in height and has a dense surface root system, which makes it very suitable for intercropping with beans. The tree can be used for firewood, charcoal and shade. The fruit is very nutritious, with a high percentage of fat, protein and vitamins. Avocado can be used for consumption as food and in cosmetics (Katende *et al*., 2000).

Mango (*Mangifera indica*)

The mango tree is an evergreen tree with a rounded canopy belonging to the family *Anacardiaceae.* It is one of the most important fruit trees and is very common in Uganda; the tasty fruit is rich in vitamins A and C. The wood can be used as fuel and the leaves as fodder, green leaf manure and mulch (Dharani, 2011).

Jackfruit (*Artocarpus heterophyllus*)

Jackfruit is a very common tree that grows naturally in Uganda. Jackfruit belongs to the family *Moraceae* and can grow from 5 m up to 20 m high. The tree gives good shade because of its great size and can be used as both timber and firewood. Jackfruit is one of the largest fruits in the world; it can weigh up to 20 kg and reach 1 m in length. Jackfruit grows right on the stem or on big brunches and is sweet and very tasty (Dharani, 2011).

Neem *(Azadirachta indica*)
The neem tree belongs to the family *Meliaceae* and can grow up to 15-20 m high. It is an evergreen tree which can withstand drought and is suitable for arid and semi-arid areas. The neem tree can be used for many purposes; firewood, timber, neem oil. The leaves can be used as medicine, for the treatment of malaria and eczema, among other ailments (Dharani, 2011).

2.4 Cooking banana (*Musa balbisiana*)

There are a total of 30 different species or subspecies of bananas in the world. Two of the most common species are cooking bananas (*Musa balbisiana*) and sweet dessert bananas (*Musa acuminata*). These differ in terms of amount of starch granules and shape. Cooking bananas have large starch granules and, after ripening, contain a higher percentage of starch than the sweet dessert bananas (Litzenberger, 2005; Gibert *et al*., 2010). Cooking banana is one of the most important food crops cultivated in Uganda. It can also be used as fodder and for making rope and baskets from the leaves (Komakech, 2006). Cooking bananas, which are also known as plantain, are a good energy source both for humans and animals, as they contain 75% water, 1.2% protein, 0.2% fat, 23% carbohydrates and 0.8% ash, plus calcium, phosphorus and iron (Litzenberger, 2005). Even though the cooking banana plant is able to reach a height of 3-6 m, it is not classified as a tree, but instead as a perennial herb (Litzenberger, 2005; Gibert *et al*., 2010; Dharani, 2011).
The optimum conditions for growing cooking bananas are around 27 ^{o}C and 25 mm rain per week. During the dry season, irrigation would be a good solution to solve problems with drought, but it is very costly for small-scale farmers (Litzenberger, 2005). Cooking bananas require large amounts of nutrients, so the infrequent use of fertilisers and manure in Uganda is a major problem (Lekasi *et al*., 1999).The leaves of the cooking banana plant are large and thin and easily tear into pieces during windy weather conditions. The productivity of the banana plant in terms of fruit decreases when the leaves are destroyed (Litzenberger, 2005). The yield of cooking bananas can be improved by intercropping the plants with trees, due to lowering in wind turbulence brought about by the tree canopy (Van Asten *et al*., 2011). The root system is shallow and forms a semi-spherical zone around the rhizome. The radius and depth of this semi-spherical zone depend on the type of soil and the drainage system operating in the field. From the rhizome, smaller roots grow out and anchor the banana plant in the soil, while the leaves start to grow from the central nodes on the rhizome (Litzenberger, 2005). Each flower contains many clusters positioned in spirals, with each cluster covered by a large, red-brown palea (Figure 4). The flower has both a pistil and a stamen, so the fruits develop without fertilisation. Only the 5-15 first clusters of flowers develop into fruit, and after three months the fruit is ripe and ready to harvest (Dharani, 2011). One individual banana fruit is called a finger, while the row of fingers on each side of the nodes is called a hand. On two sides of its stem, the banana plant grows many hands of bananas, which together form one bunch of bananas, which is in fact a five-sided berry (Litzenberger, 2005).

Figure 4. Banana fruits and the red-brown palea, surrounded by banana leaves. (Photo: M. Andersson).

Cooking bananas grow continually in a generation of three stems; mother, daughter and granddaughter. One so-called ‘button’ is placed on the middle of each rhizome node and is covered with leaf sheath. When one stem has fruiting bunches of bananas, the stem (mother) dies and a new ‘button’ starts to grow up through the soil to become a new sucker (daughter). In this system there are always three stems of different sizes very close to each other and sharing the same root system (Rusoke *et al*., 2000).

2.5 Common cultivated crops in Uganda

Apart from cooking banana, the most common crops grown in Uganda are coffee, maize, beans, cassava, yams, sweet potato and groundnut. All crops grown in Uganda are fast growing. In the following text, these main crops are explained in more detail.

Arabian coffee (*Coffee arabica*)

Arabian coffee is a large evergreen shrub that belongs to the family *Rubiceae*. It is the most commonly grown cash crop in Uganda. The berries are placed in clusters on the branches. After ripening, these berries are washed, dried and roasted and to produce coffee, a beverage that is very well known around the world (Dharani, 2011).

Maize (*Zea mays*)

Maize is an annual coarse-leaved, cross-pollinated cereal that belongs to the grass family. Maize is rich in carbohydrates (71%) and contains high concentrations of vitamins and minerals and it is used for both food and fodder, especially for pigs and poultry. Maize is one of the most important cultivated crops in the world (Langer & Hill, 1991). It grows best in hot, sunny climates where the moisture is constant during the growing season. The crop is very productive, mainly because of its large leaves, which are able to maximise photosynthesis (Litzenberger, 2005).

Beans (*Phaseolus vulgaris*)

Beans are an annual crop and are able to fix atmospheric N through bacteria on the root system. Beans are a common food source, with a high percentage of protein (20-25%) and complement the local dish *matooke* (mashed cooking banana). Beans are commonly grown together with maize during the rainy season (Litzenberger, 2005).

Cassava (*Manihot esculenta*)
Cassava is a perennial shrubby crop that can reach up to 2-3 m in height. It contains a high content of carbohydrates (33% starch) in its roots, which is twice as much as in potatoes. Cassava is cultivated in most tropical countries and is one of the most important crops in Uganda. The roots can be up to 40 cm and weigh 5 kg after a few years, but cassava can be harvested after only 9-12 months, when the roots are still fleshy. Cassava is a cheap and good crop to grow for human consumption (Litzenberger, 2005).

Yam (*Dioscorea* spp.)
Yams are a perennial and a common starch crop in Uganda. The root tubers contain 23% carbohydrates and can be harvested every season, even though they are perennial. Like cassava, yams can be harvested after a few months but can also be left for a longer time and thereby grow larger root tubers (Litzenberger, 2005).

Sweet potato (*Ipomoea batatas*)
Sweet potato is a perennial crop, but it is often cultivated as an annual crop. It belongs to the family *Convolvulaceae* and is not related to potatoes (*Solanum tuberosum*). As in yams and cassava, the main component (25-30%) in sweet potato is carbohydrate (starch and sugar). It is best harvested in the beginning of the dry season, but not too late as the insect population grows larger (Litzenberger, 2005).

Groundnut (*Arachis hypogaea*)
Groundnut is an annual legume, high in protein (26%) and a good complement to all the starch crops grown. Groundnut is often cultivated in mixed farming systems with maize. The crop is ready to be harvested when the seed pods show a mature brown colour (Litzenberger, 2005).

2.6 Small-scale farmers in Uganda

As mentioned previously, agricultural activities are very important in Uganda. Around 80% of the population live off farming and own about 1-2 hectares per household. The farms have low access to capital and do not have access to mechanised tools, so all work is done by hand, using a hoe or machete. Inputs such as irrigation and fertiliser are not usually used. Instead, rain-fed agriculture is practised. The conditions out in the field can be really tough, especially during the dry season, with lack of water and extreme heat. It is thus very common to have high harvest losses (Rusoke *et al.*, 2000). It is therefore difficult for farmers in Uganda to achieve a sustainable livelihood, which according to Van Noordwijk *et al.* (2011) is when the livelihood is able to recover from stresses and maintain its assets and enhance these for future generations. Agriculture in Uganda is very vulnerable to all hazards and needs to become more sustainable (Buttoud, 2013). In order to achieve more sustainable agriculture, a change is needed and one of the most important key factors in accomplishing the required change is the level of motivation among farmers to change their agricultural activities and their willingness to make progress. According to Kessler (2006), farmers with higher income from agriculture will be more willing to invest in new projects such as *Vi Agroforestry* than farmers with lower income. Many farmers also prefer to carry out simple practices in fields with visible problems, where short-term thinking is more likely (Kessler, 2006).

3 Materials and methods

3.1 Study area

This field study was carried out from April to June 2013 in Kkingo District, west of the village of Masaka in south-central Uganda (00˚20.307’S, 031˚37.562’E) (Figure 5). All the farms that took part in this study were small-scale farms with an average acreage of 2.2 hectares.

Figure 5. (Left) Map of Uganda, with sampling area marked with red arrow. Source: About.com (2013). (Right) Map of Africa, with Uganda marked with red square. Source: Google.se/maps (2013).

There are two rainy periods in Kkingo District, one from March to May and one from September to November (The World Factbook, 2013). All farms included in the study had a similar climate, since they all were situated in the same district (Figures 6 and 7). The study was carried out during the first rainy period. The agroforestry farms were originally part of a project carried out by *Vi Agroforestry* in the period 1995-2006.

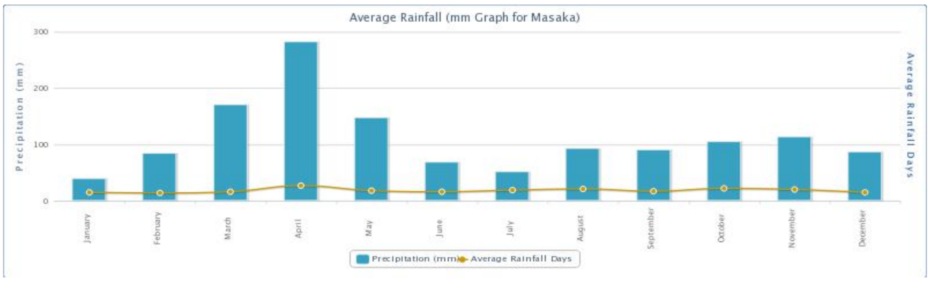

Figure 6. Mean monthly precipitation and number of rainfall days in Masaka, Uganda. Source: World Weather Online (2013).

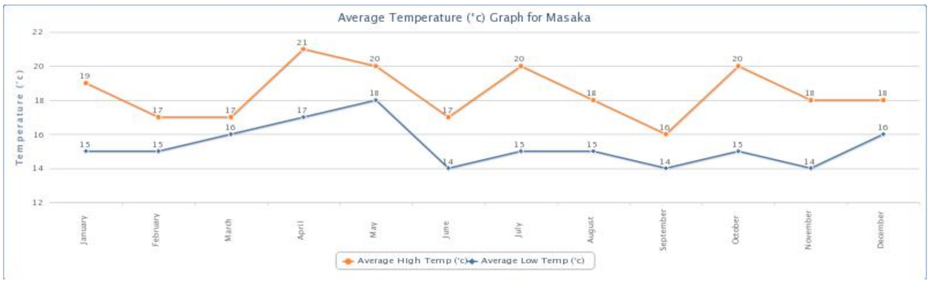

Figure 7. Mean monthly temperature in Masaka, Uganda. Source: World Weather Online (2013).

3.2 Field work

3.2.1 Crop sampling

This study was run in parallel and in cooperation with two other degree projects and the farms and sampling sites were chosen to fit all three studies. Six farms that have been practising agroforestry for 18 years and six farms that were not using agroforestry at all were selected for study after communication with *Vi Agroforestry* and Kkingo Farmers' Cooperative and the farmers, as well as observation for certain characteristics. In order to determine the effect of the agroforestry system, three criteria needed to be fulfilled by all fields. The clay content had to be the same on each farm, around 25-30%, and all farms had to grow cooking bananas. The sampling sites needed to have about the same amount of solar radiation, tree density and disturbance, and to be as homogeneous as possible. Photo documentation was performed for all field activities.

The agroforestry farms were selected using the following criteria:

- The intercropped trees had to be agroforestry trees promoted by *Vi Agroforestry*.
- The trees had to be planted in a mixed pattern.
- The farm had to have practised agroforestry for at least 15 years.
- The farm had to use zero grazing for its animals.
- All farms had to be located in the same area.
- The farmer had to have applied mulch to the field.

The non-agroforestry farms were selected using the following criteria:

- The agroforestry trees promoted by *Vi Agroforestry* had to be absent from the farming system.
- The farm had to use free grazing for its animals, not zero grazing.
- All farms had to be located around the same area.
- The farmers must not have applied mulch to their fields.

Every farm visit started with a transect walk to measure the size of the fields and to get an overview of each farm (Y. Nyberg, pers. comm. 2013). Cooking banana crops and other crops (vegetation) were sampled. On each farm, six sites in one field were selected and measured out with a yardstick to survey the vegetation. Each site had an area of 2 m x 2 m = 4 m^2. The first site was 5 m from the house and the remaining sites were set out at equal spacing in the rest of the field, so they covered the entire field (see Figure 8). To get useful values, the sampling process had to be carried out in detail.

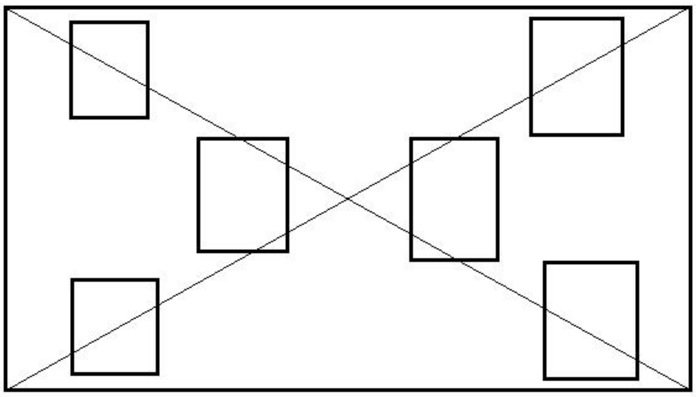

Figure 8. Example of a field with six sampling sites.

All the crops in each site were defined by visual scoring, with the aid of different floras, the staff at *Vi Agroforestry* and the local farmers. The weight of cooking bananas was determined through interviews and by weighing bunches using a portable balance. A form for recording the crops (only cultivated plants not weeds) growing on each plot was filled out (see Appendix III). The biomass of each crop and of trees was estimated by visual scoring. For statistical analysis of the data collected, the two-sample test in the statistics programme Minitab (2013) was used, with significance level set at $P<0.05$.

3.2.2 Interviews

Data were collected in two different types of interviews (Figure 9). The first type aimed to collect information about the farmer's life in general and to compare farming activities before and after the introduction of agroforestry and between the agroforestry and non-agroforestry systems. A semi-structured interview technique was used and all 12 farmers were interviewed about their farm and farming systems with the help of an interpreter from *Vi Agroforestry* (see Appendix I).

Figure 9. Interviewing a farmer with the help of an interpreter,. Photo: M. Andersson.

The second type of interview aimed to create a seasonal calendar and approximately five chosen farmers were interviewed at a time (see Appendix II). This method was more detailed than the semi-structured interview technique. The seasonal calendar interviews were held on four occasions, so in total 20 farmers took part. The seasonal calendar illustrated the relationship between activities on the farm and the seasonal changes on a monthly basis during the year. Information on abiotic parameters such weather conditions, rain, cold/hot season was included. In addition, information on biotic parameters such as season when planting, weeding, harvesting, fertiliser application *etc*. was collected for the most important crops in the study area (cooking banana, coffee, maize and beans) (Geilfus, 2008). The results were discussed and the best and worst times for growing were identified. The seasonal calendars created on the five different occasions were then compared with each other to provide a broader understanding about the small-holder farming systems in Uganda (Seebauer & Tennigkeit, 2012). Open-ended questions were asked and the form was made as easily understandable as possible (Y. Nyberg, pers. comm. 2013).

4 Results

In the following text, farms using *Vi Agroforestry*'s methods are referred to as 'agroforestry farms' and farms not using these methods as 'non-agroforestry farms', although the latter had a few trees in their fields.

4.1 Interviews

The average size of each household was six people, in general comprising one husband, one wife, a few children and some grandchildren. The farms often consisted of a small house made of bricks and mud (clay) and a small timber barn for the livestock (cattle, chickens, pigs, goats). The farmers worked on average 4.4 h out in the field during the dry season and 6.7 h/day during the rainy season. The agroforestry farmers worked slightly more in the field, but the difference was small. Almost all agroforestry farms had higher yields of cooking bananas than the non-agroforestry farms (Tables 1 and 2). Agroforestry farms thereby had more surplus yield to sell. Products from cattle, such as milk, meat and manure, were also sold. The chickens produced meat and eggs, pigs and goats only meat for household consumption. Most of the farmers did not have any other off-farm income apart from selling surplus crops and products from their livestock. The non-agroforestry farms did not sell as many products because of lack of surpluses (lower yields and less livestock).

Table 1. *Characteristics of the agroforestry farms included in the study (* = participated in interviews)*

Agroforestry farm	**Area of farm, ha**	**Interviews performed**	**Weight (kg) per bunch of cooking bananas**	**Bunches of bananas ha^{-1}**	**Seasonal calendar**
Farm 1	4.9	*	15	12	*
Farm 2	2.4	*	20	30	*
Farm 3	0.8	*	20	20	
Farm 4	2.4	*	20	80	*
Farm 5	2.2	*	20	30	
Farm 6	2.4	*	20	10	*
Mean	2.52		19.2	30.3	

Table 2. *Characteristics of the non-agroforestry farms included in the study (* = participated in interviews)*

Agroforestry farm	**Area of farm, ha**	**Interviews performed**	**Weight (kg) per bunch of cooking bananas**	**Bunches of bananas ha^{-1}**	**Seasonal calendar**
Farm 7	1.6	*	15	10	*
Farm 8	0.4	*	12	10	
Farm 9	2.2	*	20	40	
Farm 10	2.4	*	15	10	
Farm 11	2.4	*	15	8	*
Farm 12	1.2	*	40	40	
Mean	1.8		15.4	14.7	

On average, the agroforestry farms owned more animals than the non-agroforestry farms (Tables 3 and 4). All the animals lived in simple houses except the chickens, which were free range. This means that the agroforestry farms had greater access to nutrient-rich manure, especially from cattle, which they used on their fields.

Table 3. *Geographical location and number of animals on the agroforestry farms*

Agroforestry farm	**Coordinates**	**Number of cattle**	**Number of chickens**	**Number of pigs**	**Number of goats**
Farm 1	00˚20.77’S, 31˚37.18’E	1	8	1	1
Farm 2	00˚20.52’S, 031˚37.74’E	4	45	0	6
Farm 3	00˚20.65’S, 031˚37.70’E	2	25	0	0
Farm 4	00˚20.25’S, 031˚37.58’E	3	150	10	10
Farm 5	00˚20.68’S 031˚37.27’E	3	7	17	0
Farm 6	00˚20.92’S, 031˚37.06’E	2	10	0	10
Mean		2.5	40.8	4.7	4.5

Table 4. *Geographical location and number of animals on the non-agroforestry farms*

Non-agroforestry farm	Coordinates	Number of cows	Number of chickens	Number of pigs	Number of goats
Farm 7	00˚20.68'S, 031˚37.05'E	0	8	4	0
Farm 8	00˚20.65'S, 031˚37.68'E	0	4	0	0
Farm 9	00˚20.64'S, 031˚37.78'E	0	0	0	2
Farm 10	00˚20.09'S, 031˚37.76'E	0	4	4	0
Farm 11	00˚20.92'S, 031˚37.11'E	0	0	0	1
Farm 12	00˚20.77'S, 031˚37.18'E	17	0	0	0
Mean		2.8	2.7	1.3	0.5

The non-agroforestry farms practised mixed farming, with maize, common beans, cassava, sweet potatoes, cooking bananas, groundnuts, avocado tree and fig trees (Tables 5 and 6). Two of the agroforestry farms had one part of the fields cropped with maize grown alone. The non-agroforestry farms grew the same crops, but had smaller fields (only one farm grew maize in a sole cropping system).

Table 5. *Crops and trees grown on the agroforestry farms*

Agroforestry farm	Crops grown	Trees grown
Farm 1	Cassava, sweet potatoes, cassava, maize, beans, groundnut	Fig, sesbania, avocado, jackfruit
Farm 2	Maize, beans, cassava, yams, sweet potatoes, cooking bananas	Sesbania, calliandra, graveria, avocado, neem, mango, orange, jackfruit,
Farm 3	Maize, beans, coffee, cooking bananas, yams, pumpkin, cassava	Calliandra, avocado, guava, albizia, jackfruit tree, mango, sesbania

Farm 4	Maize, beans, coffee, cooking bananas, yams, pumpkin, cassava, sugarcane	Fig, avocado, jackfruit, mango, guava, papaya, calliandra, ginger
Farm 5	Maize, beans, coffee, cooking bananas, yams, pumpkins, cassava, sweet potatoes, groundnut, sugarcane	Fig tree, avocado tree, jackfruit tree, mango tree, eucalyptus tree, calliandra, pine tree
Farm 6	Maize, beans, coffee, cooking bananas, yams, pumpkins, cassava, sweet potatoes, groundnut, sugarcane	Fig, avocado, jackfruit, mango, eucalyptus, calliandra, pine, papaya, guava, grevaria, passionfruit, sesbania

Table 6. *Crops and trees grown on the non-agroforestry farms*

Non-agroforestry farm	**Crops grown**	**Trees grown**
Farm 7	Maize, beans, coffee, cooking bananas, cassava, sweet potatoes, yams, eggplants, sugarcane	Fig
Farm 8	Maize, beans, cassava, yams, coffee, cooking bananas	Fig
Farm 9	Maize, beans, coffee, cooking bananas, yams, cassava, sugarcane	Jackfruit, fig
Farm 10	Cooking bananas, coffee	Fig, jackfruit, avocado
Farm 11	Maize, beans, coffee, cooking bananas, yams, cassava, groundnuts	Fig, jackfruit, mango, guava, neem, passionfruit
Farm 12	Maize, cooking bananas	-

None of the farmers used mechanised tillage. All the agroforestry farms applied mulch to their fields. The non-agroforestry farms did not apply mulch, but were sometimes able to leave crop residues in the fields. However, in those cases they still obtained lower yields than the agroforestry systems. All the farmers bought herbicides and pesticides if they could afford it, which was not often. Organic fertiliser (manure) was applied by all the agroforestry farmers, but not by the non-agroforestry farmers. Two of the non-agroforestry farmers bought fertiliser outside the farm and applied it.

4.2 Yield of cooking bananas

The weight of cooking bananas (bunches per month & hectare) was higher on agroforestry than non-agroforestry farms (Tables 1, 2, 7 and 8). The two-sample test comparing agroforestry and non-agroforestry farms revealed almost statistically significant differences in weight of cooking bananas between the farming systems (P-value for zero difference = 0.053, *i.e.* ~ P<0.05). The two-sample test comparing agroforestry and non-agroforestry in terms of number of bunches of cooking bananas per month and hectare revealed clear statistically significant differences (P = 0.010). Thus the hypothesis tested was correct, *i.e.* the agroforestry farms had significantly higher yield of cooking bananas and a larger number of bunches of cooking bananas per month and hectare than the non-agroforestry system.

Access to manure had a significant effect and resulted in one of the greatest differences between the farms. The farms which used organic manure obtained higher yields (Tables 7 and 8). Yield of cooking bananas is measured in yield per month & hectare because this is a perennial crop and different varieties provide yield in every month of the year.

Table 7. *Yield of cooking bananas on the agroforestry farms*

Agroforestry farm	**Yield, kg ha^{-1}**
1	180
2	600
3	400
4	1600
5	600
6	200
Mean	596.7

Table 8. Yield of cooking bananas on the non-agroforestry farms

Non-agroforestry farm	**Yield kg ha^{-1}**
7	150
8	120
9	800
10	150
11	120
12	1600
Mean	490

5 Discussion

5.1 Fieldwork

The main hypothesis was confirmed in this study, *i.e*. the agroforestry farms obtained higher yield of cooking bananas than the non-agroforestry farms in terms of kg/ha, number of bunches/ha and weight of bunches. All these variables were statistically significant, which made the results trustworthy. These results are not unexpected; other studies have also shown increased yield of cooking bananas in mixed cropping systems where manure is added (Malezieux *et al*., 2009; Van Asten *et al*., 2011; Munyuli, 2012). A mixed cropping system such as agroforestry also reduces the amount of weeds, as shown by *e.g*. Schroth *et al*. (2000). Choosing suitable trees to plant with cooking bananas is very important in obtaining the maximum benefit from the mixed cropping system. A large tree species such as bark-cloth fig can reduce wind damage to banana leaves because of less wind turbulence owing to the large canopy and trunk. Inclusion of large trees, *e.g*. bark-cloth fig, can therefore improve banana yield. The large canopy also provides the cooking banana plants with shade, which results in slower ripening of the bananas (Litzenberger, 2005). Some previous studies have shown that the leaf litter mulch generated in agroforestry systems protects the migratory root system (rhizome) of cooking banana plants. This reduces water runoff, increases soil fertility and improves yields through lowering the weed pressure (Schroth *et al*., 2000; Litzenberger, 2005; Van Asten *et al*., 2011; van Noordwijk *et al*., 2011). A study in Kenya, which has a similar climate to Uganda, showed increased water infiltration, below-canopy humidity and soil moisture content following use of mulch on the fields. This confirms the claim that cropping systems such as agroforestry which use mulch can increase crop yields (Othieno, 1980).

The Kkingo Farmers' Cooperative helped to select the farms, which made the work easier, but also contributed to a slightly skewed selection of farms. All the farms studied had animals (which was one of the criteria), but only the agroforestry farms had cattle (which gave the most manure) (Tables 3 and 4). This made it difficult to separate the impact of the trees and that of the manure between the two systems, since the results were confounded by manure addition. In fact, the comparison probably showed more of the impact from the manure. In addition, the complexity of the non-agroforestry farms was underestimated. All these farms had trees on their fields and a lot of intercropping, often the same as the agroforestry farms (compare Tables 5 and 6). The main characteristic that distinguished the agroforestry farms from the non-agroforestry farms was that the former had more trees and a greater number of different species. After a few interviews, it became clear that all farmers in the study had started practising agroforestry 18 years previously. Some farms had continued (the six agroforestry farms), while the others had stopped agroforestry (the six non-agroforestry farms). The fact that the non-agroforestry farms had kept their trees made it easier for us to identify the obvious importance of the usage of manure (Y. Nyberg, pers. comm. 2013). If the study were to be repeated, it would be better to spend more time choosing farms and to ensure that the farms met all the criteria for the study. It would also be better to determine the yield of an annual crop, *e.g*. maize, instead of a perennial crop such as cooking bananas, since maize ripens in one growing season and only gives one harvest per season, whereas cooking bananas give more than two harvests per season. Another improvement in future studies would be to use methods such as land equivalent ratio (LER) to compare the two different farming systems more exactly. LER is very efficient in showing which crops give the greatest yield and most advantages. It might also be easier to compare two farming systems that clearly differ from each other for better results, as this would reduce the uncertainty about the effects of different factors contributing to the results (Mead & Willey, 1980).

5.2 Socio-economic aspects

The agroforestry farmers considered that agroforestry was a good farming system, since it had improved the fertility and soil quality in their fields. They had become more independent because of increased yield of cooking bananas. This led to increased income and less household expenditure (because they already had all the products needed on the farm). When the farmers received higher income, they were able to hire employees for the heavier work and thereby had time for activities other than working on the farm. All the farmers reported that after starting with agroforestry, they had acquired much more knowledge about agriculture and how to manage the work on the farm and maximise the yield. The non-agroforestry farmers thought it was too time-consuming to practise agroforestry and did not see how it would benefit them. Almost all of the non-agroforestry farmers wanted to acquire more knowledge about farming and agroforestry. As long as small-scale farmers in Uganda have the standard of living seen today, this study shows that they would benefit more from agroforestry systems than monoculture systems (Malezieux *et al*., 2009; Van Asten *et al*., 2011; Munyuli, 2012). A specific monoculture farming system might be good if sufficient capital is available to invest in pesticides and fertilisers. In that case, the farmers would no longer be as vulnerable and could buy what they needed to maximise the yield. However, monoculture is still not sustainable in the long run due to land degradation.

Agroforestry farms could at first sight be regarded as more time-consuming than non-agroforestry farms because of the work involved with trees. In fact, many of the non-agroforestry farmers interviewed did not see how agroforestry could benefit them. At the same time, these non-agroforestry farmers were complaining about low yields, long distances to travel looking for fireweed and poor soil fertility. Lack of knowledge and non-sustainable long-term thinking led to ignorance about the benefits of agroforestry, making it difficult to implement the agroforestry system on these farms. This in turn led to decreasing yields. According to Buttoud (2013), lack of knowledge and limited knowledge are two of the main reasons for poor management on non-agroforestry farms. Some farmers only think in a short-term way, which is not always best for the development of their farm (Kessler, 2006). That study concluded that low-income farmers have a more short-term way of thinking and are not always willing to implement new systems because they think it would cost too much, without any immediate profit. This was confirmed in the interviews in the present study.

All agroforestry farmers interviewed reported increased fertility where manure had been applied in their fields. Some of these farmers grew crops all year round, but still obtained good yields. Most of the farmers agreed that there was more hard work during the implementation period for agroforestry, but then after implementation, agroforestry was less labour-demanding than non-agroforestry. The non-agroforestry farmers had to travel long distances looking for firewood, which is even harder work (never-ending task). The agroforestry farmers saw the benefits with planting trees in a long-term way (Rusoke *et al*., 2000). Agroforestry seemed to improve farmers' livelihoods and their lives, through more diversified agriculture production and provision of income (Van Asten *et al*., 2011). With increased biodiversity in the cropping system, farmers can obtain more products throughout the year and become more self-sufficient, securing nutritional food sources (Buttoud, 2013). Increased yield leads to higher household income, which makes it possible to buy materials that improve the household's standard of living, *e.g.* more animals, a biogas stove, a bicycle, a radio, clothes *etc*. The agroforestry farmers interviewed here seemed unafraid to try new things and to develop their farming systems, with many of them also collaborating with other organisations than *Vi Agroforestry*, such as the East African Dairies Development Programme (EADDP) and local authorities. These farmers were more open-minded than the non-agroforestry farmers, which was to their benefit (Tamale, 2010). They reported that the most time-consuming crops were maize and beans because they were sensitive to weeds. Most of the non-agroforestry farmers considered the perennial cooking bananas and coffee as the most time-consuming crops because they needed a lot of care all year round.

During the interviews, the division of labour and ownership were discussed. The most common form of ownership was for a man to own the farm. The farm work was often divided between men and women on the farm. The men usually took care of the coffee bushes, the business and the income. The women worked with the cooking bananas, maize, beans and the rest of the crops, including sowing, weeding, adding manure *etc*. A few of the farming couples did not divide the work between the sexes. These were older couples and had one or two employees for the 'harder' work on the farm, *e.g*. their children/grandchildren were able to help them during weekends, when they did not go to school.

Two agroforestry farms had access to biogas and two were going to gain access in the coming year. These farmers reported that biogas had really improved their standard of living by making everyday tasks so much easier. The only drawback with biogas seemed to be the high investment cost, but the agroforestry farmers seemed able to afford it after a few years of practising agroforestry. However, many years of tradition and culture determine what to grow rather than what gives the highest income, which is why farmers do not always plants the most suitable crop, such as cooking bananas.

According to Rusoke *et al.* (2000), the consequences of land degradation affect crop yield because of the reduction in natural fertility in the soil and the water-holding capacity. Planting trees to reduce land degradation and adding manure to increase soil fertility would result in higher yield for the small-scale farmers in Uganda (Rusoke *et al*., 2000). In a similar study in Indonesia on an *azolla*, duck and fish system, the increased complexity of this agro-ecosystem resulted in increased yield, sustainable soil fertility and improved management (Khumairoh *et al*., 2012).

5.3 Sources of error

There are many sources of probable error in this study. During the interviews, there were a lot of questions that the farmers could not answer and they provided approximate answers to many of the numerical questions, *e.g*. area of the fields and yield, because they did not keep crop journals. Having an interpreter translating from Luganda to English was also complicated and sometimes caused misunderstandings. In addition, the farmers sometimes gave what they thought was the 'right' answer rather than an accurate answer. My lack of experience of interviewing might also have affected the answers. However, the more accustomed I became to interviewing the farmers, the better results I obtained and I revised some of the questions after the first visit. If this study were be performed again using the same methods, I would recommend practising interviewing in advance and conducting a few test interviews with farmers before starting on the real farmers, to see how they responded to the questions.

6 Conclusions

The volume of data collected was relatively small, so it is difficult to draw general conclusions from this study. However, the results indicated that small-scale agroforestry farms in Uganda obtained significantly higher yield of cooking bananas and a more sustainable livelihood through higher farm income than non-agroforestry farms. One of the most important factors in success was the knowledge and dedication of farmers and their willingness to adapt and learn new farming techniques. If farmers have the driving force and knowledge, sustainable farming is possible. Overall:

- Agroforestry farms obtained significantly higher yield of cooking bananas.
- Agroforestry farms generally had more livestock, and thereby more manure. Farming systems which used manure had significantly higher yield of cooking bananas than farming systems without manure.
- *Vi Agroforestry* methods seem to improve the life of small-scale farmers in Uganda. Those farmers had better knowledge of agriculture and diversified farming systems, making them more self-sufficient and less vulnerable to crisis.
- Non-agroforestry farms required more time and involved more heavy work than agroforestry farms. The non-agroforestry farmers have to travel long distances looking for firewood and carry it back on their shoulders every week, while the trees grown on the agroforestry farms allowed the farmers to focus on other chores.
- To benefit as much as possible from the agroforestry system, all the resources produced, *e.g*. firewood, animal feed, food and fuel, should either be useful on the farm or sellable on the market.
- More wealthy farmers could afford to buy fertilisers, organic manure, good seeds *etc*. and benefitted less from *Vi Agroforestry* methods than poorer farmers because they already had a better standard of living.

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7.1 Personal communications

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8 Appendix

8.1 Appendix I. Semi-structured interview topics

Social and human capital
How many people live on the farm? (members in the family) Age?
How many people work full-time and part-time on the farm?
What kind of education do the people on the farm have?
Is there some off-farm income?
How many hours of work on the farm/day during rainy seasons?
How many hours of work on the farm/day during dry periods?
Is the work on the farm divided between women and men?

Natural and physical capital
What is the ownership of the farm? Does the family (or the man) own or lease the land? Is it inherited or owned as in having title deeds for it?
How much land is there on the farm? Is there other land somewhere else?
What kind of land? (arable land, grassland, settlement or other?)
How many fields? (very often Ugandan farmers do not divide their land clearly into fields, but rather decide every season which portion of the land should have which crop)
Crop seasons per year? (if bananas are present, they will grow throughout the year, maize may be 1-3 seasons but vegetables can be many seasons)
What crops are grown this year and this period? (may change from year to year; a period of time was chosen and all questions asked for that period)
Which is the most time-consuming crop to grow? Does it change during the year or per season? (also important to think about the time taken during a whole season or a year, since some crops may need a lot of work to plant during some weeks, while others need a little time every day over a long period).
Are the fields similar? Or are there large differences in fertility, weeds, management, and are different grown crops in the fields?
What do you think about your soil, compared with that on neighbouring farms?
Are there any differences between the soil today compared with 5 or 10 years ago?

Are there animals on the farm? What kind?
Is there grazing, zero grazing or a mixed system?
What fodder sources are there on the farm? Do the animals get fodder from outside the farm?
Which is the main source of fodder?
Do you use manure from livestock as fertiliser on the farm? Do you store the manure?
Are there other organic matter inputs, *e.g.* compost or crop residues left on soil, or is a mulch added?
Is there access to irrigation?
Water harvest management? Is water collected from a well? Or some other way?
In the last 12 months, has firewood been collected on farm or off farm?
Are there problems with pollution in the water used for irrigation?

Before/after agroforestry

How long has agroforestry been practised on the farm?
What type of agroforestry and what is the specific method used, *e.g.* alley cropping?
Is information and training obtained from Vi Agroforestry? How often?
What are the most important changes since the farm started planting trees in *e.g.* an alley cropping system?
Are there any differences in yield between before and after implementation of agroforestry?
Are there any differences in labour input before and after implementation of agroforestry?
Are there any differences in income throughout the year after implementation of agroforestry?
Is there other income compared with before (added income from the trees)?
Is there more off-farm income (value of firewood, fodder, fruits)?
What investment was needed when the farm introduced agroforestry? What did it cost?
Is it more time-consuming with agroforestry than before?
What quantity of maize was harvested last year (farmer's recall)? Amount/area/size of the field.
What quantity of maize yield was expected (farmer's prediction)? Amount/area/size of the field.
Is management different now than before implementation of agroforestry?
What is your general opinion of agroforestry?

8.2 Appendix II. Form used to create seasonal calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry periods												
Rainy seasons												
Tillage												
Planting												
Pesticide												
Weeding												
Harvesting												
Sale												
Income												
Expenditure												
Storage												

8.3 Appendix III. Form used for recording crops grown in the field

Farm (size of field): 2.4
Name:
Location:
Date:

Crops	**Development stage**	**Quantity (plants)**	**Biomass, degree of coverage (%)**	**Amount of banana bunches (a piece)**	**Density, tightness (m)**	**Yield (kg/crop)**
Cooking banana	Fruit is one month	1 * 3 generations	25	1	40 to coffee	20

8.4 Appendix IV. Results of statistical analyses

Results of statistical analysis using Minitab (2013):

Two-sample T test for amount of banana bunches in Agroforestry vs. non-agroforestry.

	N	Mean	St Dev	SE Mean
Agroforestry, amount bunches of bananas	6.0	30.3	25.8	11.0
Non-agroforestry amount bunches of bananas	6.0	9.7	0.8	0.3

Difference = mu (A-bunches of bananas) - mu (Non-A- buncges of bananas)
Estimate for difference: 20.7
95% lower boundary for difference: -0.6
T-Test of difference = 0 (vs >): T = 1.96, P = 0.053*, DF = 5
Non-significant, null hypothesis cannot be rejected at P<0.05.

Two-sample T test for weight (kg) of one bunch of cooking bananas in Agroforestry vs. non-agroforestry.

	N	Mean	St Dev	SE Mean
Agroforestry, kg	6.0	19.17	2.04	0.83
Non-agroforestry, kg	6.0	15.33.	2.58	.11

Difference = mu (A-kg) - mu (Non-A- Kg)
Estimate for difference: 3.83
95% lower bound for difference: 1.37
T-Test of difference = 0 (vs >): T = 2.85, P = 0.010*, DF = 9

*Statistically significant, null hypothesis can be rejected at P<0.05.