University of Gastronomic Sciences

LSG18

SMALLHOLDER FARMERS' PERCEPTION OF PEST MANAGEMENT AND THE AGROECOLOGICAL APPROACH ON BANANA WEEVIL, *COSMOPOLITES SORDIDUS,* IN MUKONO DISTRICT, UGANDA

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Enrollment Number: 18SG076

Academic Year 2021/2022

Acknowledgements

This work came to be with the help of many others. First and foremost, I'd like to thank my thesis advisor Paola Migliorini. Paola has believed in this work and supported me from the start. She has allowed me to pursue my ideas for this study in total freedom, while giving the right guidance and support at the right time. At the same time, co-advisor Edie Mukiibi has helped me along the way, and shared his critical opinion and many years of experience in the field. Then, I'd like to thank Gabriele Volpato, whose help in preparing me for the field work and interviews proved to be incredibly useful.

I had not been able to do this field work, had I not been welcomed with the incredible hospitality that the Ugandan people have showed me. The team of Slow Food Uganda have welcomed me into their city, their homes, and provided me with all necessary contacts to successfully visit the farms and conduct the interviews.

John Wanyu and Christopher Wali Alwana deserve my deepest thanks, as they tirelessly drove me around Mukono district, helping with site selection, as well as staying with me and translating throughout all interviews.

Maud, thank you for being available at every hour of the day to listen, criticise, and give the occasional push in the right direction. Lastly, I would like to thank Els and Wilko, without whom none of this would have been possible.

Abstract

Bananas, and the East African Highland Banana (EAHB) in particular, are an essential part of Uganda's culture and economy. Unfortunately, the banana plant knows many pests, among which the banana weevil, *Cosmopolites sordidus*, a small and highly destructive insect. Most of Uganda's working population is in some way involved in agriculture, and the agricultural sector is dominated by smallholders. Research on banana weevil management is plentiful, yet the little bug is still wreaking havoc across the world's banana growing regions. In other situations, the agricultural practice of agroecology has shown to be effective as pest control. To understand the Ugandan small-scale farmers' motivations and perception of banana weevil management and agroecology, I performed farm visits and qualitative interviews with ten farmers in the Mukono district, Uganda.

Their farms are highly diverse; they were able to identify 15 different crops, and 11 different EAHB cultivars. Their farming and pest management methods are largely in line with agroecology: the farmers employ a variety of techniques including intercropping, mulching, use of organic manure, use of organic pesticides, biological pest control, and their farms have a relatively high inter- and intraspecific crop diversity. A few use synthetic pesticides, but most do not, out of fear for their own and their soil's health. They mostly showed familiarity with and positivity towards agroecology. All but one confirmed that their farm is negatively affected by the weevil. Nonetheless, the situation seems to be relatively under control. This might be due to a combination of crop diversity and the application of various management techniques. All farmers have full ownership over their land, which could ease agroecological farming. At the same time, the situation is vulnerable; as one farmer put it: "These days if you relax, those weevils will not give you some more time. They won't wait for you, they will just come immediately". If for one reason or the other the farmer is unable to be consequential in their management, weevil populations could go through the roof.

1 Introduction

With an impressive per capita consumption of close to 1 kg per day, no country consumes more bananas per person annually than Uganda (Edmeades et al., 2006). In 2018, the country produced some 4.3 million tonnes of bananas and plantains (FAOSTAT, n.d. a). It is needless to say that the banana plays an important role in Uganda, both culturally and economically. Between 65% and 69% of Uganda's working population is involved in agriculture (MAAIF, 2021; FAO, 2018b), and about 89% of Ugandan farms are small family farms. Most of these also produce for subsistence. Smallholders thus play an important role in feeding Uganda and make up a considerable part of the country's agricultural economy. The East African Highland Banana (EAHB) is by far the most important banana subgroup in Uganda (Vézina, 2018a).

Unfortunately, the banana plant knows many pests, among which the banana weevil, *Cosmopolites sordidus* (Gold & Tinzaara, 2008). The banana weevil has various destructive effects on banana plants: the insect lays eggs, from which the larvae bore into the plant, causing toppling of plants, and a dramatic reduction of yield up to 60% (Gold et al., 2004). The weevil is highly problematic, and because of that, research on weevil management is plentiful.

No method is highly effective on its own. Since there is no simple solution to this problem, a comprehensive understanding of the entire situation is needed. There is an array of research on the effect of some more common, and some more experimental methods to manage the banana weevil. However, the input of small-scale farmers in most research is limited. There is the need for an understanding of the perception of the small-scale farmers who are responsible for such a large part of Uganda's banana cultivation.

1.1 Research questions

General goals: To acquire a comprehensive understanding of the situation surrounding banana farming and weevil management in Uganda and beyond. To understand the situation of the Ugandan small-scale farmers, to grasp their motivations, and create an overview of the farming and pest-management methods they use and their perception of these methods, as well as their perception of the agroecological approach.

To achieve those goals, I use two methods: The first part of this thesis consists of literature research, to get an overview that is as broad as possible. It answers the following questions: What is the importance of the EAHB for Ugandan society and cuisine? What is the importance of the EAHB for the Ugandan economy? What is the banana plant like morphologically? What exact damage does the banana weevil do? What research on banana weevil management has been done in Uganda and

elsewhere? The last question is divided into two subgroups: agroecological and non-agroecological. Genetic improvement (including GMOs) is included in a separate section.

The second part of this thesis consists of an overview of 10 cases of small-scale farmers in the Mukono district, Uganda, and qualitative interviews with these farmers. The main goal of these interviews is to understand the situation of these farmers, and to understand their motivations to use or not use certain pest management methods, as well as their perception of agroecology.

Ultimately, with the combination of the literature research and the interviews I intend to unravel the smallholder farmers' perception of pest management and the agroecological approach on banana weevil, *Cosmopolites sordidus,* in Mukono district, Uganda.

2 Materials and methods

2.1 Literature review

The literature review serves to first create a wide overview of the situation of banana cultivation in Uganda, and to narrow it down from there. To be able to grasp the more specific literature on banana weevil management techniques, as well as to properly conduct the interviews, an understanding of the context is needed. I therefore start with looking into literature on the East African Highland Banana and its morphological properties, cultivation methods as well as cultural and economic importance for Uganda. I will then dive deeper into the banana weevil, the damage it does and to what extent. The literature review will then be continued with an explanation of what agroecology entails. I will then compare literature on various banana weevil management techniques, and their effects. This literature mainly comes from research conducted in Uganda, although some good examples of other important banana-producing countries will be included if relevant. As mentioned, this part will be divided into agroecological methods and non-agroecological methods, to make a clear distinction. Since genetic improvement could be placed under agroecological methods (crossing to make new cultivars) as well as non-agroecological methods (genetic engineering), I have decided to give it its own chapter.

2.2 10 cases: smallholder farmers in Mukono district, Uganda

With visits to 10 small-scale farmers, and in-depth interviews with them, I aim to figure out how the banana weevil affects the smallholders' farms. More importantly, I ask them whether they use any management techniques to counter banana weevil damage. And, if so, why they use the methods they use. On top of that, we discuss intercropping, crop diversity, and agroecology and the farmers' perception on these topics, as well as their perceived effects.

Given the importance of the smallholder farm in Ugandan agriculture, as described in 3.1.2, I have based the selection of the interviewees on the definition of small-scale farmers as given by the FAO (2018b). The selection criteria: Farms are family farms of about a hectare in size (this is not precise, as farm size is rather variable), the EAHB is one of their main crops, and they produce for both market sales as well as subsistence. All farmers are in the Mukono district, a district surrounding the city of Mukono, east of Kampala (Mukono District, n.d; Figure 1). As seen on Figure 1, the district (marked in light green) is in the Lake Victoria crescent. Further site selection was done together with a former Mukono district extension officer, who accompanied me on the interviews. Final selection was done on-site in the Ntenjeru and Nakisunga sub counties, in the southern part of the Mukono District (see Figure 3 in Chapter 4 for the exact locations). The area has a tropical climate (Climate-Data, n.d.). There is a dry and a wet season. The dry seasons are from January to February, and July to September. Monthly precipitation ranges from around 120 mm in July (the driest month) up to about 250 mm in April. The average annual temperature lies between 20°-25° Celsius.

Ten farmers participated in the visits and interviews. The interviews were held in Luganda and English, with the help of a local translator. They were recorded and transcribed, and consequently coded using Nvivo.

3 Results 1: Literature review

3.1 The East African Highland Banana in Uganda — Context

First and foremost, a clarification is needed. The banana is a fruit that originates in southeast Asia (Davidson, 1999). The preferred scientific name for banana is *Musa L.* (CABI, 2021a). Bananas are commonly subdivided into eating-bananas and cooking-bananas. The latter category includes plantains, and bananas in this category are also referred to as ‘green bananas’ (Davidson, 1999). The East African Highland Banana is the common name of a subgroup of cooking bananas (Vézina, 2018a). So, to be clear, the East African Highland Banana is a subgroup of the banana, just as the plantain is a subgroup of the banana (Vézina, 2018b). The focus in this thesis will be on that subgroup, henceforth referred to as ‘East African Highland Banana’, ‘EAHB’ or ‘Matooke’. In Uganda, the East African Highland Banana is known by the name ‘Matooke’, which is also the name for a dish made with the same banana (Akankwasa et al., 2020). The EAHB makes up for most of the banana production in Uganda (Vézina, 2018a).

3.1.1 Society and Cuisine

The banana, and the East African Highland Banana, ’Matooke’, in particular, undoubtedly plays an important role in Ugandan culture and cuisine. The fact that the average per capita consumption of bananas is estimated at close to 1 kg per day (Edmeades et al., 2006), underlines the banana’s

prominent position in the Ugandan's daily life. Upon visiting Uganda, the high presence of the banana was quickly confirmed. No plate lacked the fruit, neither during breakfast, nor lunch nor dinner. I've heard the locals say it numerous times: a meal without matooke is not a meal at all. The Ugandans know a variety of cooking and processing methods: from roasting to drying, from juicing to fermenting and distilling (*ibid.*). The most common way of processing the East African Highland Banana is to take the green Matooke, cut off their skin, wrap them in banana leaves and steam them in a pan. The often mashed starchy and steaming national dish usually accompanies a variety of stews and bitter herbs.

3.1.2 Agriculture, economy, and farm structure

Between 65% and 69% of Uganda's working population are in one way or the other engaged in agriculture (MAAIF, 2021; FAO, 2018b). Among females, this amount is even higher, up to 70%. The Agricultural sector is also responsible for the highest number of formal employment, at 36%. Furthermore, agricultural output was good for a staggering 25% of Uganda's GDP in 2016/2017 (UBOS 2018). In the same years, agricultural products accounted for 73% of the country's total export (MAAIF, 2021).

About 144.000 of the total 200.000 square kilometres of land area in Uganda are made up of agricultural land (FAOSTAT, n.d. b). The amount of agricultural land rose steadily from slightly less than 50% of the total land area in 1964, to almost 72% in 2018 (World Bank, n.d.).

According to the Ugandan Ministry of Agriculture, Animal Industry and Fisheries (2021), "the production of plantain banana increased from 4.530.880 tons in 2016 to 4.803.000 tons in 2017". The Ministry attributes this increase to favourable weather conditions and the use of disease resistant planting materials (MAAIF, 2021). Though, the data provided by FAOSTAT (n.d. c) puts the total production of 'plantains and others' in Uganda in 2016 and 2017 at just under 3.400.000 tons and 3.500.000 tons respectively. Now it is worth mentioning here that the FAO uses separate statistics for 'bananas' and 'plantains and others'. Still, in the case of Uganda, most of the production in the latter category is made up of East African Highland Banana (Vézina, 2013). It is unclear what the definition of 'plantain bananas' of the Ugandan Ministry precisely entails. In any case, Uganda produces more bananas and plantains than any other country in East Africa (IITA, 2021). Furthermore, more than 80 different EAHB cultivars can be found in Uganda (Vézina, 2018a).

Uganda produces a significant amount of bananas and plantains. Most farmers, however, are not engaged in industrial large-scale agriculture. In fact, "small family farmers account for 89% of all Ugandan farmers" (FAO, 2018b). Smallholders mainly produce crops such as maize, beans, and bananas. Small scale farmers in the Lake Victoria crescent are responsible for most of the country's banana production (UBOS, 2020). The Lake Victoria crescent is an area that runs from Uganda's

border with Kenya to the border with Tanzania, along the shores of Lake Victoria (Figure 1; Mulumba et al., 2012).

As defined by the FAO (2018b), small family farms have some common characteristics. Their land is on average about a hectare in size. Crops are used for own consumption as well as for commercial purposes. Family farms are usually male-headed and consist of about five people. It is very common for family farms to also have livestock, which functions as a form of security in case of poor harvest due to weather. For these smallholders, most income comes from crop production. As this is still only 54% of their total income, most farmers diversify their income with various non-agricultural activities. Most work time is however spent on-farm. Access to inputs is not great: most Ugandan farmers do not use commercial fertiliser and have no access to improved seeds. At the same time, likely due to high costs, Ugandan family farms spend a large amount of their total production value on agricultural inputs. Irrigation is not common. Agriculture in Uganda is highly dependent on rainfall.

Interestingly so, in the fact sheet on Ugandan farmers as published by FAO (2018b), pesticides (including herbicides, insecticides, fungicides and rodenticides) are not even listed as a cost factor for small scale farmers. In fact, pesticide use among agricultural households in Uganda is low: a total of 18.7% uses pesticides, and the remaining 81.3% claims to not use pesticides at all (UBOS, 2020).

Figure 1: Uganda. Lake Victoria crescent, rough drawing in light brown, and Mukono district, marked in green (NordNordWest/Wikipedia, 2009)

3.1.3 Trends

"In East African countries (Uganda, Rwanda and Burundi), where bananas are produced as a staple or for domestic consumption, productivity has fallen from 30 to 40 t/ha in the 1970s to about 15 t/ha in year 2000 due to the combined effects of pests, declining soil fertility and reduced input use" (Arias et al., 2003). Ugandan farmers have reportedly also attributed the productivity decline to moisture stress (Nyombi, 2013). Between 2002 and 2016, the total production of 'plantains and others' as described in the previous subchapter, has fallen from more than 9.888.000 tonnes to 3.400.000 tonnes (FAOSTAT, n.d. d). Latest data show

that in 2020, total production went up again to 7.401.579 tonnes (FAOSTAT, n.d. d). It is unclear what has caused this steep increase.

3.2 The EAHB and the banana weevil

3.2.1 Morphology of the banana plant and cultivation

The number of different species and cultivars of edible bananas is vast. Because of the difference within these species, "all banana taxonomists agree that no single scientific name can be given to all the edible bananas" (Robinson & Galán Saúco, 2010). The bananas that are the subject of this research, are part of the 'AAA' genomic group. The subgroup is also called 'Lujugira', and they, as explained before, are commonly referred to as 'East African Highland Cooking bananas'. Though these groups and subgroups are different, they share some basic morphological characteristics.

The banana plant is a monocot (*ibid.*). It is an evergreen perennial. The plant has adventitious roots, of which the growth depends heavily on the soil conditions. Vertical root growth is relatively little. The horizontal extension is normally about 1-2 meters, but can reach up to 5 meters. This horizontal root system is called the 'mat'. The central, vertical, visible part of the plant to which the leaves are attached, is not actually the stem, but the pseudostem (see Figure 2). The true stem of the banana plant is a rhizome, and is mostly, or entirely, underground. Some literature uses the term 'corm' interchangeably with rhizome. Robinson & Galán Saúco (2010) argue that this is incorrect, and various other sources also refer to the underground stem exclusively as rhizome (Vézina et al., 2020; NHB, n.d.). I will stick to the term 'rhizome' for the rest of this research. In some cases, the rhizome rises slightly above the soil, a phenomenon called 'high mat'. High mat causes instability and decreases yield potential (Robinson & Galán Saúco, 2010). In Uganda, the phenomenon is more common on older banana fields (Abera et al., 1999). High mat exposes the rhizome, making the plant more susceptible to weevil damage. The banana plant propagates itself with 'suckers', small sections growing vertically from the rhizome. These suckers essentially serve to replace the mother plant (Robinson & Galán Saúco, 2010). Commercial bananas only propagate in this way (NHB, n.d.). Unlike their wild relatives, they do not produce seeds.

At some point, though unclear what exactly triggers it, the banana plant starts an inflorescence from the top central part of the pseudostem (where the stalk arises on Figure 2). The female flowers develop into rows called 'hands'. Each individual fruit that comes forth out of these flowers is called a 'finger' (*ibid.*). The fruit thus hangs on a stalk, in a spiral, in a formation called 'hands'. The bunch is the entire stalk with these series of hands (see Figure 2).

In banana farming, there are two types of planting material: tissue culture and 'conventional' (suckers) (*ibid.*). Though tissue culture plantlets perform better than conventional suckers, adoption of tissue culture among Ugandan banana farmers is low (Kilwinger et al., 2020). Using suckers as

planting material is the norm. To plant, suckers or bits of sucker are extracted from the soil, and consequently planted directly into soil on a separate spot, or are concentrated in a nursery (Robinson & Galán Saúco, 2010). Interestingly so, in other countries such as South Africa and the Canary Islands, commercial banana plantations have practically abandoned the use of suckers (*ibid.*). Time of harvesting depends on the type of banana as well as the weather conditions. In general, bunch maturation is between 3 and 5 months after flowering (Kashaija et al., 2001). Harvesting is usually done by cutting the pseudostem so that it falls over, and consequently cutting off the bunch, effectively cutting down the entire plant (Robinson & Galán Saúco, 2010).

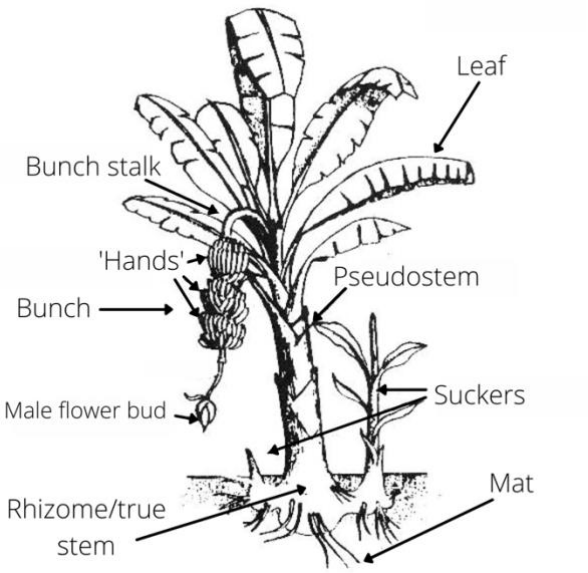

Figure 2: Banana plant morphology (Organisation for Economic Co-operation and Development, 2009; Robinson & Galán Saúco, 2010)

3.2.2 The banana weevil and the damage it does

Cosmopolites sordidus is a species of weevil, and is often considered the most important pest for bananas (Gold & Tinzaara, 2008). It is commonly referred to as the banana weevil (CABI, 2021b). It can be found in all regions of the world in which bananas are grown (Robinson & Galán Saúco, 2010). It originates in southeast Asia, where it is not usually considered a pest (Abera et al., 1999). An adult banana weevil is black and between 10 to 15 millimetres in length (Gold & Messiaen, 2000). The weevil usually resides at the base of the mat of the banana plant, in between leaves or in crop residues on the field floor. As they rarely move or fly themselves, they spread mainly through infested plant material. Oviposition (egg-placement) has been estimated at 1 egg per week. Oviposition mostly occurs in the base of the pseudostem (90%), and a small part in the rhizome and the roots (Abera et al., 1999). However, in cases where a part of the rhizome appears above the soil surface (high mat), most of the oviposition is in the rhizome. After emerging, the larvae bore into the rhizome. Hence the name ‘banana borer’ (CABI, 2021b). The larvae prefer feeding in the rhizome (Gold & Messiaen, 2000).

The weevil is strongly attracted to cut-open rhizomes. The effects on banana plants can be disastrous: “Banana weevil attack has been reported to interfere with root initiation, kill existing roots, limit nutrient uptake, reduce plant vigour, delay flowering and increase susceptibility to other pests and diseases” (*ibid.*). Two main consequences of weevil attack cause heavy yield loss: plant loss and

decreased bunch weight. Mat disappearance and plant toppling cause total plant loss. A study conducted in Namulonge, northwest of Kampala, showed that in weevil-infested plots, 36.3% of the mats disappeared over the course of 7 years (Gold et al., 2004). Although toppling is usually attributed to nematodes (Gold & Messiaen, 2000), during this trial, individual plants were lost through snapping and toppling in the absence of nematodes as well (Gold et al., 2004). Plants of weevil infested plots stunted by 5-10%. During the last 4 years of this 7-year trial, bunch weights were shown to decrease dramatically in weevil-infested plots. During these 4 years, bunch weights saw a 21%, 28%, 48% and 51% decrease respectively. In the worst year of the trial, yield losses were estimated at 60%. It is evident that a banana weevil infestation can have devastating effects on banana farms.

According to a study conducted in Kawanda and Namulonge, north and northwest of Kampala respectively, plant age is an important factor in the number of eggs laid (Abera et al., 1999). Oviposition was higher among older plants than in any other plant stage. Weevil oviposition on peepers and suckers was much lower. However, such young plants are highly affected by weevil damage.

3.2.3 Other pests

Weevils are considered the most economically important pest in banana fields of East African highland bananas. However, according to Gowen & Quénéhervé (1990), the weevil can be confused with nematodes, as the symptoms are similar. Unfortunately, the weevil is not the only pest that plagues banana cultivation. In fact, bananas and plantains are prone to a variety of serious pests and diseases (Robinson & Galán Saúco, 2010). Some important ones are the following: Black Sigatoka, or black leaf streak (BLS) is a highly problematic fungal disease caused by *M. fijiensis,* which destroys patches of the banana plant's leaves (*ibid.*). In East Africa, Xanthomonas wilt (also known as BBW, banana bacterial wilt) is an important bacterial disease (Geberewold & Yildiz, 2019). Symptoms include progressive yellowing and wilting of the leaves, uneven and premature ripening of the fruits, and poor flower development (Robinson & Galán Saúco, 2010). There are several other fungal and bacterial diseases, but the previously mentioned two are the most important in East Africa. Besides the banana weevil, another destructive pest is the burrowing nematode (*ibid.*). The nematode spreads through plant material (just like the weevil), and feeds inside the roots of banana plants, damaging the cells. Weakened roots often rot, causing toppling.

3.3 General agroecological practices

This subchapter serves as an introduction to what agroecology entails. It includes research done on banana production fields in Uganda, that does not necessarily focus on banana weevil management. Rather, the focus lies on agroecological practices, and their general effects, as well as

farmers' knowledge on the topic. First and foremost, a definition is needed. Gallardo-López et al. (2018) define agroecology as "an approach to understand the ecological principles of traditional agricultural systems". Agroecology has seen various interpretations across recent years (*ibid.*), among which three principal currents can be identified: agroecology as a science, as a social movement, and as an agricultural practice. In this research I am mainly referring to agroecology as a practice, or rather, wide range of agricultural practices. Wezel et al. (2015) identify some agroecological practices, including the use of cover crops, intercropping, agroforestry, green manure, and biological pest control. According to Wezel et al. (2015), agroecological practices have some essential characteristics. The goal is to produce a significant amount of food, in a way that includes ecological processes as fundamental parts. The practices rely on these ecological practices, and not on chemical fertilizers, synthetic pesticides, or technological fixes like genetically modified organisms. The practices seek to increase sustainability of agriculture and agroecosystems.

Agroecology has been widely regarded as a promising alternative to the currently dominant system of monoculture (no more than four crops cover almost 50% of global agricultural land (Martin et al., 2019)), particularly regarding pest and disease management (Watts & Williamson, 2015). History has shown how disastrous relying on a single or a few genetically similar or identical crops can be, such as mid-19th century Ireland (Fraser, 2003). Agricultural systems relying on monoculture have been widely regarded as more vulnerable to pests (Nicholls & Altieri, 2004). Uniform resistance of crops, as well as extensive use of pesticides inevitably leads to pests and pathogens evolving and ultimately becoming pesticide resistant (Hawkins et al., 2018).

It should be noted here that agricultural development and food production are highly variable depending on where you are in the world. Agriculture in Uganda is hardly comparable to agriculture in the United States. For comparison, pesticide use in 2018 in U.S. agriculture was about 2.5 kg per hectare of cropland (FAOSTAT, n.d. a). In Uganda, this amount was about 0.0097 kg per hectare. In Uganda, it makes little sense to see agroecology as an alternative to the current system. As I will explain further on in this chapter, many agroecological practices are still commonplace in Ugandan agriculture. It is however still of use to further investigate and evaluate the use and benefits of these practices, and this way of farming. This is particularly relevant due to the changing nature of Uganda's agricultural sector: the government is actively attracting investors for profit-oriented cash crop-based agriculture (MAAIF, 2021).

3.3.1 Traditional crop diversity

Diversifying crops both in terms of intercropping as well as genetic diversity has been part of banana farming in Uganda for a long time (Nantale et al., 2008; Mulumba et al., 2012). Though selection of banana cultivars is based mainly on their end use, and finger size, the high genetic

diversity of *Musa* in East Africa allows farmers to better manage their farm, both economically as well as ecologically (Nantale et al., 2008). Mulumba et al. (2012) argue that diversity in crop variety is "one of the few assets available to small-scale farmers in developing countries to reduce pests and diseases damage". They make an argument for traditional crop varietal diversity in Uganda, as a means to minimize the vulnerability of the farmers' fields to future pests or pathogens. Ugandan banana farmers interviewed by Mulumba et al. (2012) displayed knowledge on which banana varieties are pest and disease resistant. The farmers also specified which variety was resistant to which pest or disease, including resistance against for example 'black Sigatoka', nematodes, and the banana weevil.

Inter-specific diversity is also thought to have several benefits. Coffee is another highly important crop to Uganda, and other East African countries, where coffee-banana intercropping is common practice (van Asten et al., 2011). In a field study, intercropping banana and Arabica coffee showed a significant increase in banana yields, compared to monocropping (*ibid.*). However, the yield increase differed depending on the coffee variety. In Robusta coffee growing areas, monocropped fields had significantly higher banana yields than the intercropped ones. Yet, the study showed a clear economic benefit of intercropping compared to monocropping. Though the exact benefits of intercropping are somewhat disputed, intercropping banana and coffee is seen as beneficial for small-scale farmers among stakeholders across the coffee supply chain (Jassogne et al., 2012).

A scenario analysis in Uganda showed that crop diversity can also increase the farmers' resilience to shocks such as climate change and disease incidence (Kozicka et al., 2020). However, the study does recognize the possibility of certain trade-offs: increasing agricultural biodiversity will not maximize the farmers' income. This trade-off also depends on the variety of crops being used. Kagezi et al. (2017) make a case for agroforestry, in which trees and banana plants are intercropped, as highly beneficial agricultural system in Uganda. In simple terms, agroforestry is an agricultural system in which trees are included as an integral part of the agricultural landscape (ICRAF, n.d.). Multiple species of tree have various possible benefits for banana production, including soil fertility improvement, if managed properly. The study conducted by Kagezi et al. (2017) showed that Ugandan farmers have been integrating trees into their crop fields for a very long time, and display good knowledge of the services and functions the trees provide, one of which being extra income from timber. Based on these results they recommend different planting locations and purposes based on different kinds of trees.

3.4 Banana weevil-specific pest management: agroecological practices

Much research has been done, and many different techniques have been developed to cope with the banana weevil in Uganda (and beyond). In this chapter I will discuss some of the methods most

prominently present in the available literature and their respective results. I have listed these methods under agroecological practices. They all have the common characteristic, as defined earlier, that they rely on ecological processes, rather than on pesticides, chemical fertilisers, or technological fixes. They will be subdivided into cultural and biological pest management. This chapter serves to create an overview of (relatively) isolated methods used to manage or prevent banana weevil damage, and to briefly reflect on their effectiveness.

3.4.1 Cultural pest management

Cultural pest management includes the most long-standing control measures that humans have used to counter pests in agriculture (Hill, 1987). Cultural pest control is essentially altering and influencing the crop production system in such a way that pest prevalence and damage is minimized. This includes crossing to create new cultivars, and practices such as mulching, crop sanitation, crop rotation, site selection and more. Cultural pest control is not a lone measure, but rather a set or combination of practices (de Graaf et al., 2008)

In this subchapter I will discuss the available literature on cultural pest management to manage the banana weevil, and the effects of individual techniques. The focus will mainly be on Uganda, with some examples of similar locations elsewhere.

Plant diversity

Apart from the various possible benefits of crop diversity as mentioned in 3.3.1, crop diversity could also have a positive effect on banana weevil regulation, so argue Poeydebat et al. (2017). In an elaborate field study in Costa Rica, they showed that "plant species richness is associated with a reduction of weevil abundance and corm damage". A high variety of plants in the banana agroecosystem would increase the populations of omnivorous ants and predatory arthropods, which are likely to be responsible for controlling the banana weevil (*ibid.*). Interestingly so, the increase of plant diversity would thus contribute to biological control of the pest. I will further elaborate on biological pest management in 3.4.2.

Mulch

Mulching is a technique used in agriculture, where certain materials are used to cover the soil (Altamura et al., 2016). Materials include organic waste (leaves, plant rests), plastic, as well as green mulch (live plants). Desirable effects of the practice are conservation of soil moisture, increased biochemical activity due to optimal humidity and temperature, and weed control. Mulching is widely used on banana fields. Intercropping bananas with legumes as green mulch in Brazil showed an increase in banana yields, though this also had to do with the nitrogen fixating properties of legumes

(Espindola et al., 2006). In Uganda, van Asten & Wairegi (2010) tested the agronomic and economic benefits of fertiliser and mulch on EAHB systems. Almost all tested EAHB plots showed higher bunch weights and higher yields. The exact effect of the mulch alone is unclear because mulch and fertiliser use were tested simultaneously. However, they argue that "reduced weed pressure in demonstration plots compared with control plots could be partially explained by the fact that demonstration plots had significantly more mulch". Generally, effects of mulching are found to be positive. On the other hand, Gold et al. (2006) found that mulched sites contained up to 48% higher mean banana weevil population densities, compared to no-mulch control sites. However, mulching did have positive effects on the banana plants. The plants were greater in height and gave higher yields in the mulched sites. Based on this, Gold et al. (2006) concluded that "mulching is a critical management component for increasing highland banana yields. Mulches add nutrients, contribute to moisture conservation and suppress weeds". At the same time, mulches appear to favour the growth of banana weevil populations. Because of this, some farmers keep a mulch-free area around the plant, so that the banana mat is un-mulched. This is however unlikely to aide in banana weevil management (*ibid.*). The weevil is highly sensitive to humidity and needs a certain level of soil moisture to survive. Mulch therefore creates an optimal environment for the weevil to survive in.

Crop sanitation

Crop sanitation, or field sanitation is essentially the removal of all residues of plant material (Rannestad et al., 2013). Especially parts of the banana plants that are cut down after harvest are removed. These residues are most susceptible to banana weevil infestation. Cut-down stems are significantly more attractive to weevils, than those left standing upright (Gold & Bagabe, 1997). Crop sanitation is widely seen as an effective control measure against the banana weevil (Masanza et al., 2004). Its effect is essentially to eliminate places for the weevil to hide and breed (Robinson & Galán Saúco, 2010). Such practices include cutting up the old pseudostem into small, quickly rotting chunks, making them unattractive to the weevils. To determine preference and oviposition rate, Masanza et al. (2004) conducted laboratory experiments, in which they placed pieces of rhizome and pseudostem in plastic containers with groups of banana weevils. They found that fresh rhizome gained the least attention from the weevils. Old rhizome residues were most attractive. At the same time, difference in age did not affect attractiveness of the pseudostem. At field level, difference in weevil population related to level of field sanitation is mentionable. A multi-year study revealed little to no difference in weevil population density between three different levels of sanitation at first (Masanza et al., 2005). Later on, however, population density in fields of low sanitation increased significantly. There was no significant change in weevil population density at fields with high sanitation levels. This meant it was significantly lower than at sites with different sanitation levels. Another study in Tanzania had

similar results (Rannestad et al., 2013). They combined field sanitation with weevil trapping and saw a clear decrease of banana weevil density in the cleaned areas. At the same time, the areas in which no sanitation took place, had an increase in weevil density. Masanza et al. (2005) highlight the fact that crop sanitation is very labour-intensive, and positive effects are uncertain.

3.4.2 Biological pest management

Fungi

Some interesting research has been done to see what effects species of fungi have on the banana weevil. Several fungi have been identified that produce 'fungal volatile organic compounds' that are effective as banana weevil repellent (Lozano-Soria et al., 2020). Besides using fungi as repellent, entomopathogenic fungi (parasites of insects) such as *Beauveria bassiana* have been used in an experiment in Uganda, to reduce banana weevil populations on banana fields (Akello et al., 2008). Banana plants were inoculated with the fungus, and banana weevil were planted to see what effect the fungus has on oviposition and weevil development. Though the fungus had no significant effect on oviposition, 50% of dead weevils collected died from *B. bassiana* infection. Besides that, damage done to the banana plants by the weevils was significantly reduced. Inoculating the banana plants with the fungus had no negative effect on fruit growth.

Ant species as natural enemies

Pest populations may be kept in check by natural predators. One well-known example is the ladybug, which is a predator that feeds mainly on aphids (plant-lice), a serious plant pest (Encyclopaedia Britannica, 2021). The effectiveness of ladybugs as biological control agents is, however, subject of debate (Hemptinne & Dixon, 1997). The same idea, using a predatory species to control a pest has been applied in an experimental research project in Uganda: Two predatory ant species were released to evaluate their effect on the banana weevil (Abera et al., 2008). In a multitude of experiments, both on-field as well as confined, they aimed to evaluate how the presence of the ants affected the survival of weevil larvae. One of the experiments showed a higher mortality rate of weevil larvae. The other four experiments did however not produce similar outcomes. None of them caused any significant change in weevil larvae mortality. So, the idea of using predators as biological pest control has been experimented with, but the effectiveness of the method is unclear. In this study, the effect on plant damage was also not measured. Interestingly so, Abera et al. (2008) refer to similar research in Cuba, that showed a 74% reduction in banana weevil numbers. Over the past decades, similar research has been done in banana-growing regions globally, from Indonesia to the Caribbean, with mildly positive or unclear results (Sirjusingh et al., 1992; Hasyim & Hilman, 2011).

3.5 Pest management: non-agroecological practices

3.5.1 Insecticides (chemical and botanical)

Pesticide use in Ugandan agricultural households is very low (UBOS, 2020). As said before, 81.3% did not use any pesticides whatsoever in 2018 (UBOS, 2020). Insecticides for this application, do exist. For example, the company Bayer currently has two banana weevil-specific insecticides on the market (Bayer Australia, n.d.). In Cameroon, Mongyeh et al. (2015) evaluated the effects of a handful of insecticides, both chemical and botanical, on banana weevil populations. They tested the effects both in a laboratory, as well as in a field trial. Some of the tested insecticides were highly effective, showing a 100% mortality rate among the tested upon weevils. Several botanical insecticides and their effect on mortality and oviposition have been tested in Uganda (Tinzaara et al., 2006). They found no significant effect on mortality, though some of the insecticides appeared to decrease oviposition.

Interestingly so, Mongyeh et al. (2015) claimed that "chemical control with insecticides remains the most common and widely used method, especially in agro-plantations and some smallholder farms". At the same time, literature on the use and efficacy of chemical pesticides on the banana weevil is scarce.

3.6 Genetic improvement – Hybridization and genetic modification

Genetic improvement, and in particular genetic modification and engineering, is a complicated matter. Genetic modification and engineering have long been subject to debate. GM crops are seen both as potentially highly beneficial, as well as highly problematic, both sides of which I will further elaborate on in 3.6.2.

3.6.1 Hybrids

A promising approach in Uganda is the development and use of hybrid EAHB varieties that have a certain resistance to or tolerance for the banana weevil. One such hybrid is the 'Kiwangaazi' (Nowakunda et al., 2015), a conventionally bred EAHB hybrid, with black Sigatoka resistance as the main target. The variety was given the name 'Kiwangaazi', which translates to 'long lasting' from Luganda (one of the main local languages), because of its ability to retain vigour after 5 years, which is uncommon due to pests and diseases (*ibid.*). The hybrid was also evaluated for banana weevil damage. The evaluation was done in comparison to other cultivars and showed that "'Kiwangaazi' had considerable tolerance to the banana weevils" (*ibid.*). Their conclusion is that this hybrid can be part of the solution to the weevil-induced short plantation life.

3.6.2 Genetically modified organisms (GMOs)

CRISPR/Cas9 is a potentially highly effective tool for gene editing. Tripathi et al. (2020) argue that the banana is a good candidate for gene editing, and CRISPR/Cas9 genome editing has already been done on bananas. They furthermore argue that genetically engineered crops can "play a pivotal role in agriculture for enhancing nutrition, food safety, and security" (*ibid.*). GM bananas are also estimated to have a very high market potential (Kikulwe & Asindu, 2020). Though some sources mention the development of genetically modified bananas for weevil resistance, no such development has been completed yet (Twesigye et al., 2018; Addison & Schnurr, 2016).

The use of GM (genetically modified) crops is seen as a realistic option in Uganda, since it was already part of the Agricultural Sector Development Strategy & Investment Plan of the Ugandan Ministry of Agriculture, Animal Industry and Fishery (Republic of Uganda, 2010) since 2010. The plan mentions the need for "development of bananas genotypes" for pest and disease resistance, but there is no mention of introducing GM bananas (*ibid.*). The plan does however mention the general introduction of GM crops: A draft of the Biosafety Bill regarding the introduction and use of GM crops in Uganda was already referred to. This National Biosafety Bill was passed through parliament in 2017, enabling the testing and use of GM crops, though subject to strict regulation (Muheebwa, 2017; Kakooza, 2018). GM crops are under development in controlled field trials (Muheebwa, 2017). Earlier, 10 Ugandan civil rights organisations expressed their concerns regarding the bill, and GMOs in general (PELUM, 2015). Concerns brought up in the open letter include lack of labelling requirements for GMOs, absence of a liability clause, and the group argues that the bill "prioritizes promoting as opposed to regulating the GMOs" (*ibid.*). They also argue that the possible penalty for non-compliance with regulations is far too low. Furthermore, the group raises some general concerns about GMOs, such as destruction of local seed systems and exposure of the Ugandan food systems to corporate control. Besides that, Addison & Schnurr (2016) challenge the quite common view that introducing GM banana has positive effects on labour, and benefits women in particular. According to their analysis, "the technology is just as likely to add to their labour burdens, without necessarily enhancing their bargaining power within male headed households" (*ibid.*).

The development and introduction of disease resistant GM bananas and other GM crops is clearly a complicated matter. Going further into the possible benefits and downsides exceeds the scope of this paper.

4 Results 2: 10 cases and qualitative interviews with small-scale farmers in Mukono district

The ten farmers I visited are located in the southern part of the Mukono district, divided between two sub counties: Nakisunga and Ntenjeru (see Figure 3).

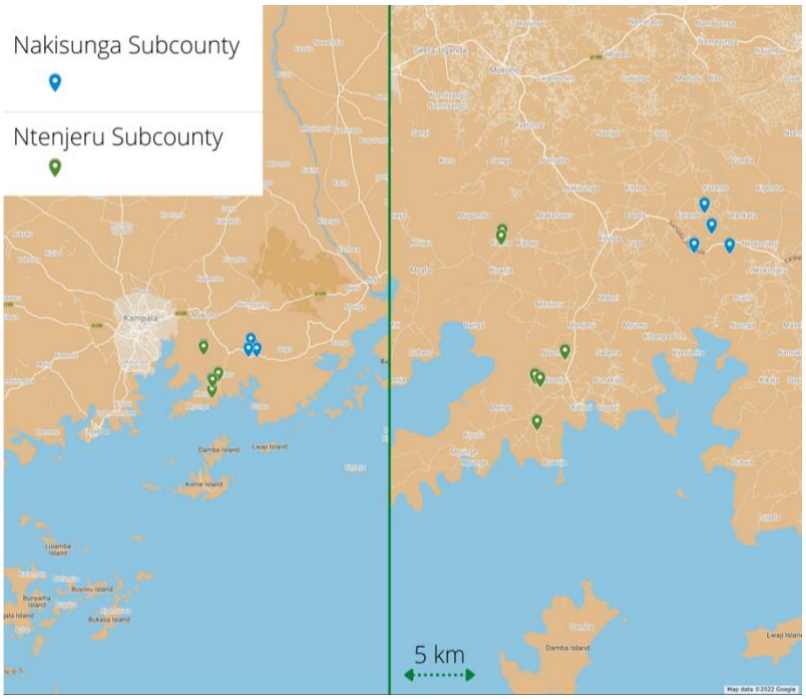

Figure 3: Interviewed farmers farm locations (Google Maps, 2022)

4.1 Farm types

4.1.1 Size, ownership, history

In general, the farms are small. The size of the interviewed farmers' land is between 1 and 6 acres, with one outlier of 32 acres (full interview transcripts can be found in Appendix A). That is between about 0.4 and 2.4 hectares, with the exception of a little less than 13 hectares. Most farmers were not able to give exact numbers, so the mentioned sizes are estimates made by them. Most of the land directly surrounds the farmers' homes, though some of them owned small pieces of land elsewhere in their village. With no exceptions, all of the farmland is owned by either the farmers themselves or their direct family. In many cases, the land has been owned by the family for decades, passed on one generation to the other. Some farmers bought new pieces of land throughout the years. Most of them have farmed their land for at least 20 years, and have been farmers for most if not all of their lives. One of them explains how long the land has been part of her family: "I was born here, by the time I started farming, my father had already farmed here for so many years". She was born in 1946. One exception is a former businesswoman, who started seriously farming her land only 4 years ago, and says to have made the switch simply for the love of farming.

4.1.2 Output

The farmers are first and foremost subsistence farmers. All of them grow crops for their own consumption. Most of them also produce commercially. For some, there is a clear distinction between what types of crops are grown for commercial purposes, and which ones are strictly for food. Usually, the East African Highland banana, local name 'matooke', is grown for home consumption, as it is

one of the most important foods. Other crops like coffee and vanilla are usually cash crops (I will go further into the different types of crops grown in the next subchapter). Reasons for desire of income vary. Some require money for farm inputs, and some use the income to pay for their children's or grandchildren's education. In any case, the farmers' economic output is small.

4.1.3 Crops and farming system

Crop selection

These small farms have a very high diversity of crops. All of the farmers were able to name at least eight different crops, most of which were either intercropped or planted closely together. Most of the farmers had a very similar selection of crops. Crops grown include different types of banana, coffee (exclusively robusta variety), cacao, avocado, cassava, maize, potatoes, beans, ground nuts, sugarcane, vanilla, sweet potato, watermelon, pumpkin, and garden eggs (a kind of eggplant). The farmers displayed good knowledge on the different types of banana they have. The types of banana include matooke (the farmers refer to it also as green cooking banana, they have never used the name East African Highland Banana), different types of plantain, Gros Michel (local name 'bogoja'), and apple bananas (a small dessert banana). Even more impressive is their knowledge of the different types of green cooking bananas, all of which looked identical to my untrained eye. Together they were able to identify 11 different cultivars within the EAHB subgroup (local names): Nakitembe, omuziba, kibuzi, muvubo, ntikka, mussakala, npologoma, mbwazirume, namunwe, nakabulu, and ngwabuzito.

The principal given reason for the specific selection of crops is the size of the farmers' land. Given the fact that they rely completely on their land for both food and income, they plant a high variety of crops together, that serve both these purposes. Coffee, cacao and vanilla are usually cash crops, grown exclusively for commercial purposes. And matooke mostly for home consumption. Some also mentioned the lack of funds as the reason for their selection of crops, and others specifically stated that "they are plants that actually cooperate. They grow together harmoniously". One of them explained that cacao is rather competitive, and for that reason they only have a few plants. Cultural believes are also a motivator. One farmer stated that they grow plantain because "in our culture, it's a male banana variety. You must mix it with other varieties to protect them from storms. That's what our ancestors believe". The former district extension officer who accompanied me explained that culturally speaking, it is strictly necessary to grow matooke (C. Wali Alwana, personal communication, January 20, 2022). The food is extremely important both in the farmers' daily life, as well as for ceremonies like weddings. In fact, "if you don't grow the matooke, people will think there's something wrong with you!".

Hybrids

Some of the farmers have hybrid banana varieties on their farm. Though, asking about hybrids did cause some confusion. Some farmers first confirmed the presence of hybrid banana varieties on their farm. After more detailed explanation of what hybrids are, it turned out they confused it with tissue culture. Interestingly so, 7 out of the 10 farmers have the same exact hybrid: 'FHIA-17'. FHIA-17 is a disease resistant hybrid developed and released in the 1980s by the Honduran Agricultural Research Foundation (FHIA, n.d.). The farmers were generally not satisfied with the hybrid in question. Their negative experience is based on several aspects. One farmer explained that "we were told in the beginning that they are resistant to the banana bacterial wilt, but still they get affected actually". Other farmers explained that the hybrid didn't last long, and some even claimed that hybrids in general negatively affected the performance of the nearby indigenous banana varieties. Three of the farmers specifically mentioned the taste of FHIA-17's fruit as a downside: "It is not the tastiest food, but at least you'll have something to eat". Most of them either stopped using the hybrid varieties, transferred them to another garden, or simply give away whatever they harvest.

Use of pesticides

Only one of the farmers currently uses synthetic pesticides to treat banana plants on a regular basis. A few use them only occasionally, and others more regularly on other crops such as watermelon, maize and beans. For example, one farmer explained she would only use herbicides when she's "feeling a little weak", so she doesn't have to weed by hand. In any case, the majority does not currently use synthetic pesticides on their bananas. The reasons for not using pesticide vary, and include concerns about personal health, concerns about soil health, lack of funds and bad experience with the effectiveness of pesticides in the past. One farmer also explained that cacao is an important cash crop, and the buyers only want it grown organically. Those who use or used pesticides in the past use 'Dudu Cyper', 'Dudu Guard' and a certain type of ant killer, which they were unable to specify. The knowledge of the negative effects of synthetic pesticides was acquired either by personal experience, or by training from the extension service of the district. For most farmers, synthetic pesticides have multiple negative connotations, and they do not use them on a regular basis. They do however use organic pesticides, which is often a mixture of various organic substances found on their own farms. The organic pesticides are used onto and around the banana plant, or directly on the trapped weevils. I will further discuss the organic pesticides and traps in 4.2.3.

Use of fertilizer

With only one exception, the farmers generally use fertilizers. Organic fertilizers are the norm, and only two of them said to sometimes use commercial NPK fertilizers. They apply a variety of organic

fertilizers, including cow, pig and chicken manure, compost, ash, urine, herbs and weeds. The farmers stressed the importance of rearing animals for a farm like theirs, and many of them use their own produced fertilizers. Application of fertilizers varies by farmer, by crop and by area. Some use fertilizers sporadically, others claim to use them extensively. One farmer explained they use commercial NPK fertilizers specifically for coffee. As some farmers said, some areas require manure, whereas on others they don't apply anything at all, due to differences of soil quality.

Soil

The farmers' perception of the performance of their soil varied. Some claim it is very fertile and has been fertile for as long as they can remember. Others have had major problems of land degradation due to overuse. They state this as the main reason for using fertilizer. As a response to the degrading land, some have started using animals, for example by adopting a 'zero-grazing cattle' system for manure production. Zero-grazing cattle is essentially a system in which the animal is kept in a closed confinement, and fed exclusively by the hand of the farmer, hence the term 'zero-grazing' (FAO, 2017). One of the interviewed farmers has an interesting view on the soil, explaining that according to them "it is the same as everywhere. You influence it by applying different practices", implying it is not the quality of the soil that influences the success of the farm, but the farmer.

Intercropping

Intercropping is standard practice on these Ugandan farms. As explained before, the farmers have a wide variety of crops, and a relatively small amount of land. None of the farmers have plots of land with one single crop; monoculture is simply not a logical choice to them. Most of the mentioned crops are planted close together, in an arrangement that appears random at first sight. However, the farmers explained that they know very well what to plant where, with what and why. It is common to plant coffee and banana together, so that the banana plants provide the coffee with its much-desired shade. Others intercrop maize and beans. Some of them explained that you cannot just plant any crop together; they should be able to live in harmony. Another reason given was that, simply because of the size of their land, they have to plant everything close together.

4.1.4 Gender roles and culture

The farmers are primarily women. Seven of the ten farmers I interviewed were female. Though in some cases either their husband or father joined and then usually led the conversation, they always acknowledged that the woman of the household is the main farmer. The former district extension officer who accompanied us, explained that gender plays various roles in traditional Ugandan farming (C. Wali Alwana, personal communication, January 20, 2022). For example, matooke is typically

seen as a female crop. As he explained, this has to do with the fact that traditionally, the woman is the provider of food for the household. And matooke is one of the most important foods. Therefore, matooke and women are closely connected. As mentioned before, one of the farmers said that according to their ancestors, plantain is considered a male banana variety. And, it should therefore be planted to protect other crops from, for example, storms.

4.2 Banana weevil

4.2.1 Familiarity

All farmers were able to identify the banana weevil. Though, some of them needed more explanation, as occasionally they confused it with banana bacterial wilt. The local name of the banana weevil is 'kayovu' which translates to 'little elephant', referring to its trunk-like snout (C. Wali Alwana, personal communication, January 20, 2022). We were able to establish familiarity of the weevil by having the farmers explain what the weevil is or what it does: "Kayovu seems to be this black insect that eats the banana from the bottom". The weevil is present on most of the farms, and most farmers explained it does great damage. Even though all of them knew about the weevil, not all of them had any problems with it. One farmer said that their farm is more affected by the banana bacterial wilt, and that the weevil is manageable. Another farmer even said that the weevil is not a problem for them at all.

4.2.2 Damage: effects, severity, and timing

Those with weevil-affected farms articulated the effect the weevil has on their banana plants in different ways. One explained that the weevil digs holes in the bottom of the banana, preventing the plant from adequate water and nutrient uptake. This would cause smaller bunch size. The most mentioned effect of the banana weevil is plant toppling. As they said, the weevil attacks from the bottom, weakening the plant and often causing it to topple. Another perceived effect of the 'drilling' of the weevil is that the plants start rotting. Some of them also blamed the weevil for yellowing of the plants' leaves. One farmer even blamed a group of monkeys for dispersing the weevil. The farmer explained that their farm had previously been almost entirely free of the weevil. At some point, a migration of monkeys took place, and after they left, the weevil was back. The farmer said that "the monkeys caused so much yellowing of the leaves".

The perceived severity of the damage the weevils do or did to the farms varied. When asked how much of their farm is affected, the farmers' estimates ranged from nothing at all to as much as 75%. Most of the estimates were between 20% and 40%. Some of these observations are however outdated, as some explained that this was the percentage before they started applying management techniques.

Some farmers estimated the affected part of their farm as low as 10% and attributed this low number specifically to the fact that they use pest management techniques.

Based on the farmers' observations, it is unclear at what time during the year the weevil is most prevalent. Three of the farmers mostly observed the weevil during the wet season, another three observed it mostly during the dry season, and the remaining farmers either didn't know or simply said it's there all the time.

4.2.3 Applied management techniques

Most of the farmers exclusively apply organic pest management techniques. There is a clear overlap between the farmers' techniques. Most farmers use a combination of different techniques. First of all, they make their own organic pesticides. The homemade concoction consists of urine (of both livestock and humans) as a liquid base, in which they mix a combination of ash, herbs and red pepper. Some were more specific on the herbs they use: two herbs locally called 'muluku' (*Tephrosia vogelii*) and 'kawunyira' (*Tagetes minuta*). The pesticide is then either applied preventatively, directly on and around the banana plant's base, or used to kill the weevils collected in a trap. The trap is another widely used technique. Whenever they harvest the bananas, the farmers cut off the top of the plant and leave the base, covered with a banana leaf. The cut-open stem attracts weevils, as the leaf-cover provides them with a suitable environment. After some days, the weevils have gathered there, and the farmer collects and kills them. They are killed either by using the organic pesticides or burning them under direct sunlight or in a fire. The ash is also used on its own, and is poured around the plant's base. Furthermore, some farmers explained it is crucial to remove the weevils' hiding places. This means mulching at some distance from the plant and removing dried fibres from the outside of the pseudostem (crop sanitation). Some also uproot the entire plant whenever they notice an infestation. The plants are heaped and consequently burned or simply dry out in the sun. Then as explained before, a few farmers also use synthetic pesticides like 'ant killer', 'Dudu Guard' and 'Dudu Cyper'.

The farmers had different sources from which they learned about the aforementioned techniques. Some of them acquired the skills through farmers groups, organised by organisations such as Slow Food Uganda, the Katosi Women Development Trust (KWDT), the Eastern and Southern African Small-scale Farmers Forum (ESAFF), and also the Ugandan National Agricultural Advisory Services (NAADS). Furthermore, the district extension service also plays an important role in spreading the knowledge on techniques. Besides that, farmers also commonly gained the knowledge from their parents, neighbours, or even the radio, particularly those who live outside of the extension service's reach.

4.2.4 Specific techniques: mulching, sanitation, biological pest management

Because of the findings in the literature (see 3.4.1), we discussed some specific techniques: mulching, crop sanitation, and biological pest management. Most of the farmers use mulch, yet emphasised the importance of keeping the mulch at a distance from the base of the banana plant. As one farmer explained: “When you prune and mulch close to the banana, then this weevil is really intense”. Crop sanitation, including cleaning off the dried fibres on the outside of the plant, is also widely practiced, though for different reasons. Some cleaned the banana plant well, to facilitate effective pesticide application. Others to remove the hiding places for the weevil. Crop sanitation around the base of the banana is also done to remove competition (weeding). The majority of the farmers had not heard of biological pest management, although with some explanation they understood what it meant. Interestingly so, two of them explained that it happens automatically on their farms, though not through ants or fungi: their chickens roam the farm and eat the weevils.

4.2.5 Familiarity with other management techniques

We discussed whether the farmers were familiar with any other weevil management techniques that they do not use themselves. Several of them named conventional pesticides. The reasons for not using synthetic pesticides vary. A few explained that the most important reason is concern for their own health, as one farmer put it: “I take my life as the first priority”. Others said that pesticides “destroy soil”, and also explained that it becomes a routine that causes the plants to lose resistance, making it difficult to quit. Another given reason is that conventional pesticides are simply too expensive for the farmers. Those who weren’t familiar with any other techniques they didn’t use themselves, explained that “neighbours would share their knowledge”.

4.2.6 Perceived effect

Though some farmers explained to always have used the mentioned management techniques, others only started some years ago. Most of them say the measures have a clearly noticeable effect, though have not reduced the amount of weevils to zero. Some that use a combination of the organic pesticides and physical traps, explain that “they work if you are consistent”. It takes a lot of effort and dedication. According to the farmers, as soon as you ‘relax’, the weevils come back. When asked which of the methods they perceive as the most effective, they usually named the combination of techniques they use themselves. Several also emphasized that it is crucial to remove the infested stems and to keep them at a distance from the healthy ones. One farmer expressed the need for “a biological method to fight the weevil”, as they didn’t find any of the currently used methods effective. This particular farmer occasionally uses pesticides, in combination with weevil trapping and sanitation of the banana plants.

4.2.7 Trends: weevil presence and plant vitality

When asked whether the farmers have seen any trends in weevil presence on their farms over the past 20 years, the response varied. Some said there has been an increase, even though they use management methods which they claim are effective. Others have noticed a decrease in weevil numbers, yet it heavily depends on management. For example, one farmer explained that there is a part of their farm that they no longer manage, because it is too old. Weevil presence instantly increased on this plot. Some farmers explained the amount has been relatively stable, also saying it depends on the effort you make: “If you care for them, it is less. If you don’t, it’s always a lot”.

General vitality of the banana plants also differed from farmer to farmer. Most farmers explained that the banana plants were stronger before. They notice this in the fact that the plants give smaller bunches, or are less resistant to diseases: “It seems they are more vulnerable now, because you need to take more care, which wasn’t the case before”. Another farmer blames too much sunshine for the deterioration of their bananas. Opposingly, one farmer explained that currently, their bananas are stronger. The farmer attributes this trend to the fact that, as a farmer, they have acquired knowledge and experience over the past 20 years. This knowledge translates to healthier and stronger banana plants.

4.3 Other pests

The farmers named several other pests that affect their farms. Most farmers mentioned the presence of banana bacterial wilt (BBW) on their farm, and some even said it is worse than the weevil: “This BBW is a little more dangerous in a way that it is very hard to detect. You can only see when the banana has already been attacked. You can’t check in the ground and see like you see the weevil”. Besides that, another farmer explained that “the most disturbing one is the wilt, which dries up the banana leaves and you can’t even use the suckers”. A third pest that several farmers mentioned is the black safari ant, which, according to some, cuts the stem of the banana plant until it topples. Lastly, one farmer named termites, which are a pest to sugarcane.

4.4 Agroecology

4.4.1 Familiarity and perception

Most farmers were not familiar with the term ‘agroecology’. However, upon giving a definition, most of them said to know what it is. Their perception and knowledge of agroecology varied. They commonly understood it as a farming method that works more harmoniously with nature. Those who were familiar were positive about it mostly because they believe the natural and organic way of farming is best: “Plants survive longer if they’re left to work with nature”. They also thought it is a

good way to protect the soil and nature, and it gives good and healthy products. Though, one farmer emphasized the importance of the role of the farmer in deciding which plants to grow together: “There are those that are actually just a disadvantage …. in this case, instead of helping, they actually just damage and repel the other plants”. They stressed that this is knowledge that a farmer is supposed to have. Other farmers were also positive about agroecology because it can decrease input costs. The farmers got their knowledge of agroecology from various sources: radio, tv, trainings, neighbours and farmer groups. Even though one them said that “very few people apply this way of farming”, only one farmer said to have never heard of it.

5 Discussion

5.1 The weevil

All but one case confirmed weevil presence on their farms and damage to their banana plants (Appendix A). The amount of damage the farms suffer varies, yet is usually considerable. Particularly given the fact that even though the farmers employ a myriad of labour-intensive management techniques, they still claim infestation amounts of up to 40% of their farm. The seriousness of the weevil’s presence is in line with the findings of Gold & Tinzaara (2008), who claimed it is often considered one of the most important pests for bananas. Interestingly so, one farmer said to have no problems with the weevil at all (Appendix A). This farm was at a stone’s throw away from another heavily infested farm. Why the farmer has no problems with the weevil is unclear, as they do not actively fight it as much as others. However, it should be noted that this farmer has only been farming their land for 4 years (the others have farmed their land for decades). So, it might be that the farmer has not had enough time to fully witness the weevil’s effect yet.

5.2 Agroecology and farmers’ knowledge

Even though they didn’t name it as such, most of the farmers use a variety of agroecological techniques. Intercropping is common practice for these small-scale Ugandan farmers. Most of them rely exclusively on organic inputs, such as homemade organic pesticides and manure from their own or their neighbour’s cattle. Their farms have a high degree of both inter-specific as well as intra-specific diversity (most of them have several different subtypes of the East African Highland Banana). The crop diversity on their farms was commonly motivated by lack of space and desire for a complete range of crops. Both in terms of diet as well as economically; they all have crops for subsistence as well as cash crops like coffee and vanilla. A few of them also emphasized that the choice of crops depends on whether those crops grow together harmoniously or not, highlighting a focus on ecology. The farmers know their farm very well, and seem able to apply a variety of techniques with high

precision (manure when and where needed, weevil traps, organic pesticides). They also frequently use techniques such as mulching and crop sanitation. As explained in 3.4.1, Gold et al. (2006) suggest that even though mulching is a critical technique in banana fields, mulched fields also show an increase in weevils. The knowledge of the interviewed farmers seems to coincide with this finding.

The farmers showed considerable positivity about agroecology. The term 'agroecology' is not widely used to describe this way of farming, but with further explanation they mostly recognized it. Though the interviews were held in Luganda, I still decided to ask whether they were familiar with the English word 'agroecology'. There is no direct translation for this word in Luganda, but English is an official language, and it is common to mix English and Luganda. The farmers expressed positivity for various reasons, such as reduced input (e.g. no pesticides). Some also perceived agriculture "that works with nature" as the most desirable form of agriculture. The majority is negative about the use of hybrid banana plants. However, they have only had experience with a single hybrid variety: FHIA-17. So, willingness for adoption of other hybrids is unclear.

Regarding pest control, only a few used synthetic pesticides. Most of the farmers use some form of integrated pest management, relying on several different management techniques. Although several farmers used synthetic pesticides, the general tendency was to view them as negative. Some considered the negative impact on the soil, but the main factor was concern for human health. Others simply stated lack of funds, highlighting their willingness to use such pesticides if available to them. The farmers generally perceived the set of measures they took as effective to fight the weevil. Almost all of them acknowledged that the weevil is present and damages their farm. However, the amount of damage they talked about is not enormous, and they did not seem deeply concerned about the weevil. I could carefully say that the situation seemed relatively under control. There might even be some confusion as to whether the weevil or BBW is the cause of some of the observed symptoms. But there are some less apparent challenges which I will further discuss in 5.5.

Sharing knowledge is a part of agroecology as a movement (Barrios et al., 2020). Since it was such a common thread in the interviews, it deserves some attention. The farmers gained much of their knowledge regarding pest control in farmers groups. These groups were usually organized by NGO's such as ESAFF and Slow Food, and provide a forum for the farmers to exchange knowledge. This exchange of knowledge between different actors is in line with the principles of agroecology (*ibid.*). Besides that, some farmers explained that sharing whatever knowledge they have with their neighbours is common practice: "neighbours would share their knowledge". Particularly those places that are out of reach of the district extension service rely on farmer-to-farmer exchange of knowledge.

5.3 Land ownership

Land ownership may not be directly linked to pest management and agroecology, but due to the unanimity of the farmers' situation, it is worth mentioning here. Particularly in regards to agroecology as a social movement, which is closely linked to food sovereignty (Wezel et al., 2020). All 10 farmers practice exclusive ownership over the land they farm. Across the world, agroecology is linked to the struggle for access to land (IDS, 2017; Rioufol et al., 2018; Nyéléni Europ & Central Asia, 2021). A common challenge can be summarized as follows: "Tenure agreements are often too short or unfavourable for the long-term investments that agroecological farmers make in the land" (IDS, 2017). Sub-Saharan Africa has seen two simultaneous trends over the past decades: a high degree of land concentration for among others large-scale agriculture, and a high degree of land fragmentation for peasant agriculture (Awumbila & Tsikata, 2010). Besides that, there has also been "a transformation of customary norms of land tenure in ways which have weakened collective interests at the expense of individual interests in land" (Awumbila & Tsikata, 2010).

The fact that all farmers exercise complete ownership over their land seems to provide them with some stability and room for long term investment. The head of biodiversity of Slow Food Uganda, who accompanied me as translator, was however not so positive about the situation: "In Uganda, the fact that you legally own the land does not necessarily guarantee ownership in the future" (J. Wanyu, personal communication, January 21, 2022).

5.4 Plant diversity & effect on reduced weevil damage

Interestingly so, the farmers seem to have the weevil population somewhat under control. Given the similar nature of the farms, there might be a link between the high degree of both inter-specific and intra-specific plant diversity and pest control. High plant diversity positively affects the arthropod community in an agroecosystem (Zhao et al., 2018). As Poeydebat et al. (2017) showed in a Costa Rican field trial: "Plant species richness is associated with a reduction of weevil abundance and corm damage". In this trial, high plant diversity indirectly stimulated the presence of predatory arthropods, which in turn kept the banana weevil in check by preying on its eggs and larvae. This principle has been studied even more directed towards other crops, such as coffee: more diverse and complex tropical (coffee-)agroecosystems tend to provide crucial ecosystem services that can aide in pest management (Vandermeer et al., 2010). Moreover, such an approach to tropical agriculture can also improve biodiversity conservation, due to reduced pesticide use (Vandermeer & Perfecto, 2008). All of the Ugandan farms I visited have a highly diversified crop selection (Appendix A). Together they were able to identify 15 different crops, and 11 different EAHB subvarieties. None of the farmers have all of these crops: The selection ranges between 3 and 8 different crops (about 6 on average),

and between 2 and 7 EAHB subvarieties. The high crop diversity on these farms might have a tempering effect on the banana weevil's presence and damage.

Crop diversification can also benefit economic security (Antonelli et al., 2022) and is associated with increased food security (Namulondo & Bashaasha, 2021); farmers that have a high diversity of crops (both for subsistence as well as cash crops) are less vulnerable to extreme climate events as well as market fluctuation.

It should be noted that the interviewed farmers have various reasons for the diversity of crops on their lands, and none of them gave pest management as a reason (Appendix A). The main reason is the fact that they rely on their land for both income as well as subsistence, and their land is small. So, they logically have to plant a high diversity of crops to meet all economic needs, as well as supply themselves with a good diet. Besides that, the farmers displayed some knowledge on which plants to grow together, and which not to.

5.5 Challenges

The high inter-specific and intra-specific crop diversity on these farms, as well as the farmers' strong knowledge on the crops and their land, could prove them resilient to future events like temperature changes and extreme weather. Moreover, many of the farmers have extensive knowledge of a myriad of weevil-specific pest management techniques. Sharing knowledge appears to happen effectively through neighbours, farmers groups and the district extension service. But not every farmer is satisfied with the effectiveness of the techniques they use. Some expressed the desire to use pesticides, but didn't due to lack of funds.

Even though at first sight I would carefully say the weevil situation seems under control, there is a serious vulnerability. This vulnerability has to do with the amount of time and effort the farmers spend on pest management. As one of the farmers put it: "These days if you relax, those weevils will not give you some more time. They won't wait for you, they will just come immediately" (Appendix A). This shows that, even though the situation seems relatively stable, the farmers are highly vulnerable to changes in fitness for work. If for one reason or the other they are unable to put in the time and effort they are currently putting in, the weevil population could explode. And, falling back on pesticides for such a situation is not always possible, due to lack of funds. This gap could be filled by family, as they all had several family members around.

6 Conclusion

The banana is an incredibly important crop for Uganda; it's nutritionally, culturally, and economically unmissable. Ugandan agriculture is characterised by small-scale family farms, that usually operate for both subsistence and commercial purposes. Different types of bananas are an

essential part of these farms, in particular the East African Highland Banana, locally called ‘matooke’. The banana plant knows a variety of pests, of which the banana weevil is arguably the most destructive one. The weevil lays eggs that consequently hatch into larvae that bore into and feed on the banana plant. If left unchallenged, weevil infestation can cause dramatic yield reduction by decreased bunch size and plant toppling. Naturally, there is plenty of research on weevil management. There is no single method that can fight off the weevil completely. Yet, 10 smallholder farmers in the Mukono district, Uganda, seem to have the weevil relatively kept in check. These 10 cases give great insights into the perception of the Ugandan small-scale farmer on banana weevil pest management in general, as well as on the agroecological approach.

First and foremost, these farms have a very high inter-specific and intra-specific crop diversity. They have up to 8 different crops, and up to 7 different varieties of matooke, all grown together in very small plots of land; between 0.4 and 2.4 hectares. Besides that, they displayed ample knowledge on this diversity as well as which crops to grow together. Together, the farmers were able to identify 11 different cultivars within the EAHB subgroup, all of which looked identical to my untrained eye.

The farmers employ a variety of techniques to manage the banana weevil. They most commonly use several different techniques at once, such as physically trapping the weevil, and applying homemade organic pesticides. A few of them also use synthetic pesticides, of which only one farmer uses them on a regular basis. Even though almost all of their farms are affected by the weevil, the situation seemed to be relatively under control. They perceived the damage as significant, but not devastating, and did not appear overly concerned about the weevil. This could be the result of the combination of applied management techniques, as well as the highly diverse agroecosystems. Highly diverse agroecosystems can be beneficial for pest management. But, behind this seemingly balanced situation, hides vulnerability. As some of the farmers explained, as soon as you stop applying the management techniques, the weevil comes back in an instant. This makes the situation vulnerable to sudden changes in the farmers’ fitness for work. This gap might be partially filled by the farmers’ families, as they usually have several family members around.

In all 10 cases, the farmers exercise complete ownership over the land they farm. Ownership over land can give farmers a form of security and make long-term investments in their farm more feasible. This can ease organic and agroecological farming. On the other hand, some say that legal land ownership in Uganda is no guarantee.

The farmers are positive about, and open to agroecology. Moreover, all of them use a variety of agroecological methods: intercropping, inter- and intra-specific crop diversity, biological pest management, use of organic pesticides and organic fertilisation. Some also employ synthetic pesticides, but most farmers deem this harmful to their own as well as their soils health. They farm this way for reasons of subsistence and commercial purposes: They rely on their small land for (a

good part of) their diet as well as a range of commercial crops for some income, effectively forcing them to plant everything together. They did however show good knowledge on which crops can be grown together and which cannot. The farmers are mostly positive about the agroecological and organic approach: "Plants survive longer if they're left to work with nature".

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Figures

Figure 1: NordNordWest/Wikipedia. (2019). Uganda location map. Supplemented with data from: UBOS, Uganda Bureau of Statistics. 2017 (Housing Census Mukono District).

Figure 2: Adapted from Organisation for Economic Co-operation and Development. (2009). Consensus Document on the Biology of Bananas and Plantains (*Musa* spp.). Supplement with data from Robinson & Galán Saúco, 2010.

Figure 3: Google Maps. (2022). *Interview locations.* Available at: https://www.google.com/maps. (Accessed March 3, 2022). Locations self-recorded in Google Maps application.

8 Appendix A: Interview transcripts

Scan QR-code for access to full transcripts
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