Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Ecology

Ants and termites in small-scale plantain farms in Uganda

– A comparison between agroforestry and non-agroforestry farms

Sara Söderlund

Agricultural programme - Soil/Plant
Bachelor thesis
Uppsala 2013

Independent project/Degree project / SLU, Department of Ecology 2013:13

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Sara Söderlund

Supervisor: Jan Lagerlöf , Swedish University of Agricultural Sciences, Department of Ecology

Examiner: Mattias Jonsson, Swedish University of Agricultural Sciences, Department of Ecology

Credits: 15 hec
Level: G2E
Course title: Independent project in Biology – bachelor project
Course code: EX0689
Programme/education: Agricultural programme - Soil/Plant

Place of publication: Uppsala
Year of publication: 2013
Cover picture: Sara Söderlund
Title of series: Independent project/Degree project / SLU, Department of Ecology
Part no: 2013:13
Online publication: http://stud.epsilon.slu.se

Keywords: Agroforestry, Small-scale farmers, Uganda, Macrofauna, Ants, Termites

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Abstract

This study was conducted in Kkingo district, west of Masaka, Uganda. It compared soil macrofauna abundance in non-agroforestry farms with that of agroforestry farms. The agroforestry farms had participated in the Vi Agroforestry´s program between 1995 and 2006, and continued on their own after 2006, when Vi Agroforestry left the area. The soil macrofauna is important for soil structure and processes that are contributing to soil organic matter decomposition and nutrient mineralization. They are also predators of potential pests. The soil macrofauna generally thrives in more complex and undisturbed systems, hence, the study hypothesis was that the abundance of the studied macrofauna groups would be larger in agroforestry systems compared to non-agroforestry systems. The sampling of macrofauna was made using monoliths (25 cm x 25 cm x 20 cm), Sampling occurred at 5 farms per farming system, totally 10 farms. At each farm, two samples were taken at each of the three sampling sites. Termites were typed to subfamilies and ants were typed to genus, with expert help at Makerere University, Kampala. Earthworms, millipedes, centipedes and woodlice were counted but not typed. An ANOVA showed that there was a significant difference in ant abundance (P-value 0.023) between the different sampling sites, with more ants at the most fertile parts of the farms compared to at the middle of the field (P-value 0.031).

Keywords: Agroforestry, Small-scale farmers, Uganda, Macrofauna, Ants, Termites

Referat

Den här studien utfördes i Kkingo distrikt, väster om staden Masaka i Uganda. Det var en jämförelse mellan förekomsten av makrofauna i marken på agroforestry- och icke-agroforestrygårdar. Agroforestrygårdarna hade deltagit i Vi Skogens projekt mellan 1995 till 2006, och därefter fortsatt på egen hand. Makrofaunan är en viktig komponent i marken och deras aktiviteter skapar markstruktur som bidrar till omsättning av markens organiska material och växtnäring. De kan även agera som naturliga fiender mot potentiella skadegörare. De trivs oftast i mer komplexa och ostörda system, därför var hypotesen i studien att det skulle finnas ett större antal individer av de studerade djurgrupperna i agroforestrysystemen. Insamlingen av makrofauna utfördes med monoliter (25 cm x 25 cm x 20 cm). Prover samlades in på totalt 10 gårdar, 5 per system. På varje gård valdes tre insamlingsplatser in och på varje plats togs två prover. Termiterna bestämdes till underfamiljer och myrorna till släkte, med hjälp av expertkunskap på Makerere University i Kampala. Daggmaskar, tusenfotingar, enkelfotingar och gråsuggor räknades men bestämdes inte till lägre systematisk nivå. En ANOVA visade att det var en signifikant skillnad (P-värde 0.023) på antal myror mellan de olika insamlingsplatserna, med fler myror där marken var som mest bördig eller gödslad jämfört med på mitten av fältet (P-värde 0.031).

Nyckelord: Agroforestry, Småskaligt jordbruk, Uganda, Makrofauna, Myror, Termiter

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Abbreviations

C	Carbon
COP	Conference of the Parties
FAO	Food and Agriculture Organization of the United Nations
ha	Hectares
ICRAF	International Centre for Research in Agroforestry
N	Nitrogen
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Plans of Action
P	Phosphorus
Sida	Swedish International Development Cooperation Agency
UNCCD	United Nations Convention to Combat Desertification

1 Introduction

Figure 1. Map over Uganda (About.com, 2013), sampling location west of Masaka is marked with a red arrow

Uganda is a landlocked country, bordering Kenya, Tanzania, Rwanda, the Democratic Republic of Congo and South Sudan. The climate is mainly tropical but semiarid in the northeast. In 2013, the population reached 34.8 million people. A big part of the population is depending on agriculture for living; it currently employs more than 80% of the labour force (Central Intelligence Agency, 2013). Agroforestry is a commonly used system for farmers throughout Africa, and it provides firewood, fodder, fruits and improved soil fertility, which is beneficial to the farmer (Place et al., 2012). The fertility of Ugandan soils has decreased and the agricultural productivity has declined, as for example from an average banana yield of 8.5 tonnes in 1970 to 5.7 tonnes in 1996 (Rusoke et al., 2000). The soil macrofauna is often beneficial in agricultural systems, since their activities contribute to plant litter decomposition and nutrient mineralisation as well as by spreading the organic material throughout different layers. Their activities are also creating soil structure and aggregates (Okwakol & Sekamatte, 2007).

The objective of this study was to observe the soil macrofauna (focusing on ants and termites) and their abundance in small-scale farms in Uganda. The study compared farms that were using the method agroforestry (recommended by Vi Agroforestry) to farms that were not using agroforestry. The study will give an idea if agroforestry systems are beneficial for the below ground macrofauna or not.

The study hypothesis was that agroforestry systems at small-scale farms in Uganda had a higher abundance of macrofauna than non-agroforestry farms in the same area. Also, that there would be a difference in the abundance of macrofauna at the different sampling sites (near tree, in the middle of the field and where they added most manure/had their most fertile part of the field).

2 Background

2.1 Agriculture in Uganda

Soils in Uganda have declined in fertility, and issues such as poor land management and soil erosion are causing the agriculture to be less productive. An average farm in Uganda is about 2 ha (Rusoke et al., 2000). Due to the high population density and growing competition over arable land, the pressure on the already overused land as well as new agricultural land is increasing. Uganda's forests are cut down to give space to other land uses, and land is overgrazed. The governments of many African countries are not prioritizing the agricultural sector, even though agriculture is a key stone in reducing poverty (Vi-Skogen, 2012).

An area of 1.2 million ha of Uganda is occupied by banana and plantain plantations. Banana is a staple food in Uganda, and it is grown both by smallholders for domestic use and commercially. Bananas are generally intercropped, often with beans and maize, but also cassava, coffee and groundnuts are common. Residues from the bananas are commonly used as mulch, which is suppressing weeds as well as preserving the moisture in the soils (Lekasi et al., 1999) and it is used as feed for the livestock (Bekunda & Woomer, 1996).

2.2 About Vi Agroforestry

Vi Agroforestry (Vi Skogen in Swedish) is a Swedish organization, working in Eastern Africa at the Lake Victoria basin. It is to a large extent financed by Sida (Swedish International Development Cooperation Agency) but also by private donors. Vi Agroforestry started as a tree planting organization in 1983 and has since then developed into nowadays, mainly focusing on teaching small-scale farmers about agroforestry. The vision of Vi Agroforestry is "A sustainable environment that makes it possible for people living in poverty to improve their lives" (Vi-Skogen, 2012). Vi Agroforestry currently has four working areas:

1. *Sustainable and climate adapted agriculture, based on agroforestry, and the right to food:* This type of agriculture is constructed to help people adapt and mitigate to climate change, to preserve biodiversity, to recycle nutrients etc. Trees are increasing the moisture in the fields and it is hindering soil erosion. Nitrogen fixing trees can be used in the agroforestry method to improve soil fertility (Vi-Skogen, 2012).
2. *Strong farmers´ organizations:* Vi Agroforestry is promoting farmers organizations, to make farmers go together and more easily make their voices heard. Cooperation may help them to get a bigger influence in political decisions and it may help the farmers to get better prices on markets. These farmers´ organizations are hopefully the ones that in the future will advise farmers, so the farmers become independent from Vi Agroforestry (Vi-Skogen, 2012).
3. *Equality:* Vi Agroforestry is working for equality. Gender inequalities are common throughout the world and women are overrepresented among the poor people in the world. Lack of influence on their own lives is a common issue for women. Vi Agroforestry is cooperating with other organizations that are specialized on gender issues. Important tasks are to work with attitudes of men, women´s right to financial services and women´s right to land (Vi-Skogen, 2012).
4. *Economic security:* Vi Agroforestry encourages the farmers to look at their farms as a business. The farmers are taught basic economics so that they will be able to negotiate their product prices and get a profit when selling them. Since banking systems in developing countries often are inefficient, methods for savings and loans are developed (Vi-Skogen, 2012).

2.3 Agroforestry

2.3.1 Positive aspects of agroforestry

Agroforestry is a method where the farmer is intercropping trees and crops in the same field. Animals are also included on the farm. When using agroforestry, the production becomes more diversified and the farmers can spread their incomes and risks (Vi-Skogen, 2012). To introduce agroforestry in countries where the percentage of people living in poverty is high, the purpose is to improve the livelihoods of the people, mainly focusing on food security and poverty (Böhringer, 2002). The farmers will directly benefit by getting firewood, fruits and fodder as well as improved fertility of their soils (Place et al., 2012). Agroforestry has been implemented by small-scale farmers in developing countries for a long time, although, it has now advanced to become a system with scientific basis. That is since ICRAF (International Centre for Research in Agroforestry), which from the beginning was an information council focusing on agroforestry, started to perform research to be able to strengthen what they were promoting with scientific knowledge (Denning, 2002).

FAO (Food and Agriculture Organization of the United Nations) is also promoting agroforestry. One reason is since it is a way to adapt to and mitigate the effects of climate change and to use resources in a sustainable way (FAO, 2013). The biodiversity seems to increase (FAO, 2013; Poch & Simonetti, 2013) and erosion is prevented when using agroforestry (FAO, 2013).

Different processes performed by trees may improve the soil. Trees can increase the soil organic matter, some trees are able to fixate N_2 (Buresh & Tian, 1998) and they are able to take up nutrients from deeper layers of the soil where plant roots are unable to reach. When trees use nutrients from deeper layers in the soil, the nutrients will later contribute to the nutrient content in the upper soil layers when falling back as tree residues (Buresh & Tian, 1998; Smith et al., 2012). Trees are also contributing to the water holding capacity as well as preventing erosion and soil degradation. When preventing erosion, leaching of nutrients is also decreased. Trees are improving soil biology and preventing acidification (Buresh & Tian, 1998), and they are working as carbon sinks (Place et al., 2012; Smith et al., 2012). In Durban, at the 2011 COP 17 (Conference of the Parties) meeting, the potential of agroforestry as a mitigating and adapting component to combat climate change was discussed, and it was suggested by both NAPA (National Adaptation Plans of Action) and NAMA (Nationally Appropriate Mitigation Actions) to be an important part in the actions of the agricultural sector. Furthermore, UNCCD (United Nations Convention to Combat Desertification) were recognizing agroforestry as a potential method to combat desertification (Buttoud, 2013).

2.3.2 Challenges and obstacles regarding agroforestry

There are some challenges met when promoting agroforestry. Land ownership and long-term rights to land are uncertainties for farmers, which might make them unwilling to make long-term investments on the land (Place et al., 2012; Buttoud, 2013). It may take a few years to get benefits from the income when investing in agroforestry, instead of getting the direct income from crop production (Buttoud, 2013; Smith et al., 2012), the initial inputs is usually higher for agroforestry systems (Smith et al., 2012). Another problem is that agroforestry is generally not included in policy-making and rural development programs and it is according to (Buttoud, 2013) due to lack of knowledge thought to be a low output system. Tax exemptions are often favourable for farmers using monoculture- and industrialized systems, and thus not for agroforestry systems (Buttoud, 2013).

Moreover, cautiousness when choosing species for an agroforestry system has to be taken, since not all species works together in a desirable way. Trees and crops that do not compete for water, sun radiation and other resources should be chosen. If the species compete, the results might not be beneficial. In addition, trees might hinder the use of mechanical equipment (Buttoud, 2013), hence, agroforestry systems might not be favourable at large-scale farming. Local and regional differences have to be taken into account when developing and managing agroforestry systems (Souza et al., 2012). However, there is not too much research regarding agroforestry, which might be due to difficulties to measure the actual effects. Most of the research is showing positive effects of agroforestry, perhaps there might not be an interest in showing negative effects.

Figure 2. Banana plantation, one of the non-agroforestry farms included in the study

2.4 Soil macrofauna

Soil macrofauna are animals that are longer than 4 mm and wider than 2 mm, thereby being easy to discover with the naked eye (Okwakol & Sekamatte, 2007). In temperate areas, earthworms are considered most important while ants and termites are more important in tropical areas (Moreira et al., 2008). Macrofauna are important for the soil structure (Moreira et al., 2008; Okwakol & Sekamatte, 2007). Their different activities are producing tunnels, they are transporting soil particles to different layers, building aggregates, decaying organic matter, and farmers might benefit from maintaining the diversity of soil fauna (Okwakol & Sekamatte, 2007). The decaying rate for organic matter to decompose to 50% in banana based systems in Uganda, is much faster when macrofauna is present than without macrofauna (Lekasi et al., 1999). The time for nutrients to be released from banana leaves is also reliant on activities by soil fauna (Lekasi et al., 1999).

Decreasing activities and abundance of soil fauna in the tropics are connected to soil degradation (Lal, 1988).

Generally, the soil macrofauna is more abundant in environments where there are fewer disturbances, for example, the earthworm and termite population has been found to be larger in fallow than in agricultural land (Ayuke et al., 2011). Annual cropping systems tend to have a lower number of macrofauna than forests and agroforestry systems (Rahman et al., 2011). Earthworms are sensitive to disturbance, such as agricultural management (Ayuke et al., 2011). There are also more macrofauna in natural ecosystems than in agro-ecosystems (Tabu et al., 2004). Mulch farming, no tillage, cover crops and agroforestry are management methods that are favouring the environment for macrofauna (Lal, 1988). Where soils are managed, compaction is often a big problem that causes losses of soil fauna (Decaëns et al., 2006), and when using tillage, the fauna is exposed to tough environments that they are not used to, as well as to predators (Ayuke et al., 2011). Land use changes in Uganda have led to disturbances in the faunal habitats. Less diversity of fauna may be part of the reason for the decreasing fertility of the soils. Although, disturbance is making some species, such as certain spiders and some other insects living on the soil surface more abundant (Okwakol & Sekamatte, 2007).

2.4.1 Ants (Formicidae)

Currently, there are more than 10 000 known ant species, and most species are living in tropical forests. Ants often live in large communities that are controlled by a queen or sometimes several queens. To communicate with each other, ants are using chemicals. Depending on species, their source of food varies. Some ants are feeding on nectar, seeds, fungi or insects while there are species that are feeding on other animals, such as reptiles, birds and small mammals (National Geographic, 2013). Ants are carrying out important services to the environment, such as decomposing organic material (Rust & Choe, 2012). They are also transporting soil to different layers and are thereby altering the soil structure. The chemical properties of an anthill tend to differ from the surrounding soil, generally containing more organic matter and more exchangeable cations (Lal, 1988). Ants can act as natural enemies to pests. They belong to the same insect order as bees and wasps – Hymenoptera, yet, ants are often confused with termites, which belong to the suborder Isoptera (order Blattodea) (Rust & Choe, 2012).

2.4.2 Termites (Isoptera)

Termites are a large group of insects, and many termite species are common in Africa (Akol et al., 2011). Termites are often considered as pests, especially in maize plantations, since they are feeding on woody parts such as roots and stems.

They can cause extensive losses of yield for the farmers. However, termites are also contributing to the soil structure when making tunnels and decomposing soil organic matter (Akol et al., 2011).

Termites are a very important component of the tropical soils since they are increasing the soil fertility when digesting and shredding residues from the vegetation. Their impact on the ecosystem might continue for as long as over 100 years, thus, disturbance of the termite mounds are likely to have negative consequences on the ecosystem functions (Okwakol & Sekamatte, 2007).

Termites are an important food source for other animals, and they have to defend themselves for survival. To protect themselves, termites use both mechanical and chemical defence mechanisms. Both workers and soldiers are important defenders of the colonies. Signals such as vibrations when drumming with their head or abdomen are one way of alerting the rest of the community when defence is needed. The way of vibration and how it reaches other community members are different depending on species. Release of chemicals is also a way of alarming each other against enemies such as termites from other communities and predatory ants (Šobotník et al., 2010).

Figure 3. Termites, photo taken during fieldwork

2.4.3 Earthworms (Megadrilacea)

There are more than 7000 species of earthworms throughout the world and they can be from about 2 cm long up to about 90 cm long (Edwards, 2013). There are three types of earthworms: epigeic, which are living in the litter and are consuming plant litter, endogeic, which are feeding mostly on organic matter and are making many tunnels, both vertically and horizontally, and anecic, which are feeding on organic matter that they fetch from the soil surface, mixed with soil particles. Their tunnels are often deep and vertical and they are important for mixing of soil in the profile (Chapuis-Lardy et al., 2011).

Earthworms are hermaphrodites, having both female and male features. They get their nutrients from fungi and bacteria living on the organic matter that they are decaying. Their nutrient recycling is an important contribution to the soil organic matter and their presence can often be an indicator of a healthy soil. Their altering of the soil structure, along with other activities is beneficial for the soil. Earthworms are stimulating microbial growth by making the organic matter more available for smaller organisms. They are also mixing and aggregating the soils, increasing the water infiltration, improving the water-holding capacity, making tunnels and they are burying and shredding plant residues (Edwards, 2013). The construction of tunnels is important and beneficial to the soil functions, since the tunnels are making it easier for plant roots to penetrate the soil, and it is a good place for water to pass (Lal, 1988). Their activities are improving plant production, and studies have shown that the earthworm biomass is correlated to the yield of bananas, in banana plantations (Okwakol & Sekamatte, 2007). It has furthermore been noticed that the earthworm activities are five times greater under banana mulch than in systems without mulch (Lekasi et al., 1999), mulch is favouring the environment for earthworms as well as contributing to their food stock (Lal, 1988). When disturbing the environment, such as in cultivated land, earthworm populations are decreasing (Lal, 1988).

2.4.4 Millipedes (Diplopoda)

Millipedes live in organic matter, such as plant residues and mulch (Ogg, 2013). Millipedes have a large number of legs, compared to insects that have six legs. They also have many body segments, and on each segment, there are two to four pairs of legs. They belong to the same group (phylum) of animals as insects, the arthropods. Their body length can range from 1.3 to 16.5 cm long. Millipedes are important for the decaying processes in the soil, when eating rotting litter and plant residues. Large populations of millipedes might damage seeds and fruits that are close to the surface (Fayard, 2012).

The activities performed by millipedes are reported to improve the release of nutrients, since their shredding of plant residues are contributing to the exposure of substances to the microflora (Tian et al., 1995). In northern Uganda, millipedes are causing damage in sweet potatoes, groundnuts and maize. When millipedes feed on living plants, they go for the soft parts that are easy to digest (Ebregt et al., 2005).

2.4.5 Centipedes (Chilopoda)

Centipedes are similar to millipedes in general appearance, but they have only one pair of legs for each body segment (Fayard, 2012) and the length of their body range from 0.4 cm to 15.2 cm (Orkin, 2013). Most centipedes are carnivores

(Orkin, 2013) and feed on insects (Sparks, 2012). They paralyze their targets using claws positioned behind their head. The claws contain poison, the poison is toxic enough for centipedes to catch small insects, but it´s not dangerous to humans (Ogg, 2013; Orkin, 2013).

2.4.6 Woodlice (Isopoda)

Woodlice are land living crustaceans. Their body consists of 12 segments and 7 pairs of legs. They prefer habitats with low levels of disturbance, such as agricultural fields with no- or minimal tillage, and environments where crop residues are left (Paoletti & Hassall, 1999). They will die from dehydration if not living in a moist environment (The Natural History Museum, 2013). They are, as many other macrofauna, important for many soil functions, such as decaying organic matter and recycling nutrients and they do not cause big problems as pests, except occasionally if they lack other sources of food (Paoletti & Hassall, 1999).

2.5 Macrofauna, vegetation and soil properties

Crop growth benefits from improved soil properties. In some areas, termite activities are stimulated by leaving plant residues, in order to restore degraded soils (Lal, 1988). Soil from termite mounds can also be used as a fertilizer (Lal, 1988; Okwakol & Sekamatte, 2007). However, the termites are sometimes also harmful for the crops, since they might feed on them (Lal, 1988). Earthworms benefit plant growth indirectly by improving the soil texture and structure (Lal, 1988).

The vegetation type often determines the macrofaunal abundance. When vegetation cover is declining, it will also affect the macrofauna that is associated with that vegetation, thus lowering the ecosystems biological capacity (Okwakol & Sekamatte, 2007). A study made on leguminous species show that the quantity and quality of the biomass produced affects the abundance of a number of macrofaunal species (Sileshi & Mafongoya, 2007). Measurements on soils without any fauna showed lower content of organic matter, nitrogen and exchangeable cations. Those soils also had lower water infiltration rates, higher bulk densities and lower gravimetric moisture (Okwakol & Sekamatte, 2007).

Earthworm casts tend to have a higher content of P (phosphorus) than the surrounding soil, and the available P content is generally higher in earthworm casts. Moreover, studies have shown that there is a greater enzymatic activity as well as a higher microbial activity in earthworm casts than in the surrounding soil (Chapuis-Lardy et al., 2011). A study made on earthworms and millipedes shows that the combination of the two groups are breaking down the organic matter faster than when only one of the groups were present (Tian et al., 1995).

3 Materials and methods

3.1 Study area and farm selection

The study was carried out in Kkingo district, a rural area west of Masaka, Uganda. The agroforestry farms were part of a project that the organization Vi Agroforestry was carrying out from 1995 to 2006. The farms were selected in cooperation with Vi Agroforestry and members of Kkingo Farmers' Cooperative. Kkingo Farmers' Cooperative is a farmers' organization situated in the study area and the agroforestry farms were members of the cooperative. The study was running from April to June 2013, during the rainy season. The temperatures varied between about 25 30°C and the weather was unreliable, varying between sunny and rainy weather.

This study was running parallel and in cooperation with two other bachelor studies. One study was observing the soil properties and the other study observed the vegetation cover and yield differences in the two farming systems. Therefore, farms and sampling spots were chosen to fit all studies.

Five farms that have been using agroforestry methods for about 18 years and five farms that had not been using agroforestry methods at all were chosen. To be able to measure the effect from the agroforestry system, criteria for selecting the farms were developed. The clay content had to be about the same (25-30%) and they all had to grow Matooke, which is a cooking banana. The farms had to have animals and the sample sites selected needed to have about the same amount of sun radiation, tree density and disturbances. All fields were similar in plant composition, and all of them had to have Matooke.

Agroforestry farms were selected using the following criteria:

- The intercropped trees had to be agroforestry trees promoted by Vi agroforestry
- They had to apply zero grazing for their animals

- The trees had to be planted in a mixed pattern at the field (e.g. spread out at the field, and not as boundaries around the field, or in lines etc.)
- They had to have participated in the program of Vi Agroforestry between 1995 and 2006, and continued the practises even after Vi Agroforestry left the area
- They had to apply mulch
- They had to grow Matooke

For the non-agroforestry farms, the following criteria were used:
- They did not use the agroforestry methods promoted by Vi Skogen
- They had to grow Matooke

Table 1. Comparison of the different farms used in the study, showing average values and range (Andersson, 2013)

Average	Agroforestry farms (n=5)	Non-agroforestry farms (n=5)
Ha	2.0 (0.8-2.4)	1.7 (0.4-2.4)
Banana yield (kg/ha*season)	680 (200-1600)	558 (120-1600)
Cows	2.8 (2-4)	3.4 (0-17)
Goats	5.2 (0-10)	0.6 (0-2)
Pigs	5.4 (0-17)	0.8 (0-4)
Hens	47.4 (7-150)	1.6 (0-4)

3.2 Sampling design and sampling method

At each agroforestry farm at the examined field, sampling was made as following:

1. Two samples near a tree (to be able to see the impact of agroforestry trees)
2. Two samples where the manure were mostly distributed (to see the impact of animals)
3. Two samples in the middle of the field

At the non-agroforestry farms at the examined field, sampling was made as following:

1. Two samples near a tree
2. Two samples where the manure were mostly distributed, or at the most fertile part of the field at farms were no manure were applied
3. Two samples in the middle of the field

GPS coordinates of the sample sites were noted.

Table 2. Design of soil macrofauna sampling

	Agroforestry farms	Non-agroforestry farms
Farms	5	5
Sampling sites per farm	3	3
Samples at each site	2	2
Total samples	30	30

To collect soil macrofauna, monoliths (25 cm x 25 cm x 20 cm) were dug out at each sampling site. Sampling occurred in two layers, 0-10 and 10-20 cm. All fauna were hand sorted, and a sieve was used if necessary and possible. The ants and termites were preserved in alcohol while other group were not saved after counting and classification. The protocol for sampling macrofauna is constructed using inspiration from the TSBF-method developed by CIAT (Moreira et al., 2008).

3.3 Identification and statistical analyses

Identification and analyses of macrofauna was carried out at Makerere University in Kampala with expertise help. Earthworms, millipedes, centipedes and woodlice were counted but not classified further than to main groups, whilst ants were classified to genus and termites were classified to subfamilies.

The statistical analyses were made using SPSS software, and the method used was ANOVA. The statistical results showed if there was a difference in the abundance of macrofauna between the different farming systems (agroforestry compared to non-agroforestry), as well as if there was a difference between the different sampling sites (near tree, middle of the field, where they put most manure/had their most fertile part of the field). The ANOVA also showed if there was an interaction between the different farming systems and sampling sites.

4 Results

In total, 3294 individuals of soil macrofauna were collected and identified. For easier comparison with literature data, the results for abundance are presented as individuals per m^2. Not all non-agroforestry farms applied manure, therefore the most fertile part of the field was used instead. For that reason, the table column is named “most manure” for agroforestry farms and “most manure or most fertile” for non-agroforestry farms.

Four different sub-families were found among the ants. They could be determined to genus, with expert help. The absolute number of ants was larger in agroforestry farms compared to non-agroforestry farms (Table 3).

Table 3. Number of individuals of different genera of ants found in the different farming systems, sampled with monoliths (25 cm x 25 cm x 20 cm), calculated to individuals/m^2

Ants	Number of ants/ m^2 at agroforestry farms			Number of ants/ m^2 at non-agroforestry farms		
	Near tree	Middle of field	Most manure	Near tree	Middle of field	Most manure or most fertile
Ecitoninae						
Dorylus	1	0	10	41	0	0
Formicinae						
Camponotus sp1	0	0	7	0	0	1
Camponotus sp2	0	0	0	1	0	0
Paraparatrechina	0	0	0	0	1	6
Paratrechina	0	0	0	1	0	0
Myrmicinae						
Crematogaster	0	0	0	1	0	0
Pheidole	225	16	146	42	23	70
Solenopsis	0	0	0	1	0	0
Strumigenys	0	0	0	0	0	2
Tetramorium	14	20	23	15	2	6

Ponerinae						
Anochetus	3	0	0	0	0	0
Bothroponera sp1	3	0	1	0	1	3
Bothroponera sp2	1	0	0	0	0	0
Odontomachus	0	0	0	0	10	0
Pseudoponera sp1	3	3	14	3	2	12
Pseudoponera sp2	2	1	6	4	1	3
Total number	252	40	207	109	40	103

Three different sub-families of termites were found, and they all belonged to the family Termitidae. The absolute number of termites was greater in non-agroforestry systems than in agroforestry systems (Table 4).

Table 4. Number of individuals of different sub-families of termites found in the different farming systems, sampled with monoliths (25 cm x 25 cm x 20 cm), calculated to individuals/m^2

Type of termite	Number of termites in agroforestry farms (m^2)			Number of termites in non-agroforestry farms (m^2)		
	Near tree	Middle of field	Most manure	Near tree	Middle of field	Most manure or most fertile
Termitidae						
Apicotermitinae	2	6	0	34	8	3
Macrotermitinae	0	1	0	0	1	0
Termitinae	0	7	0	7	5	4
Total number	2	14	0	41	14	7

The other groups of soil macrofauna examined were mostly found in agroforestry farms, compared to non-agroforestry farms. Earthworms, millipedes and centipedes were most abundant in agroforestry farms whilst woodlice occurred more often in non-agroforestry farms (see Table 5).

Table 5. Number of other macrofauna found in the different sampling sites, sampled with monoliths (25 cm x 25 cm x 20 cm), calculated to individuals/m^2

Type of macrofauna	Number of fauna in agroforestry farms (m^2)			Number of fauna in non-agroforestry farms (m^2)		
	Near tree	Middle of field	Most manure	Near tree	Middle of field	Most fertile
Earthworms	91	86	201	102	55	57
Millipedes and centipedes	30	47	62	26	26	41
Woodlice	20	4	20	13	4	53
Total number	141	137	283	141	85	151

The data for the different faunal groups were transformed logarithmically in order to fit into the ANOVA model (see Appendix for histograms, scatter plots and outputs). The results from the ANOVA show that there is a significant difference between the abundance of ants in the different sampling sites, compared to an α-level 0.05.

Table 6. Results from ANOVA, comparing sampling sites (under tree, most fertile/most manure and middle of the field) and farming type (agroforestry vs. non-agroforestry). n=10

Type of macrofauna	Type tested	P-value
Ants	Sampling site	0.023*
Ants	Farm type	0.463
Ants	Interaction site*farm type	0.798
Termites	Sampling site	0.227
Termites	Farm type	0.060
Termites	Interaction site*farm type	0.829
Earthworms	Sampling site	0.330
Earthworms	Farm type	0.207
Earthworms	Interaction site*farm type	0.188
Millipedes + Centipedes	Sampling site	0.179
Millipedes + Centipedes	Farm type	0.322
Millipedes + Centipedes	Interaction site*farm type	0.609
Woodlice	Sampling site	0.070
Woodlice	Farm type	0.725
Woodlice	Interaction site*farm type	0.665

Comparing to an α-level of 0.05, the Tukey test is showing a significant difference in the abundance of ants between the sampling sites where the farmer put most manure/pointed out their most fertile part of the field and the sampling site at the middle of the field (Table 7).

Table 7. Tukey test showing that the difference in abundance of ants is significant between the middle of the field and at the most fertile part of the field or where most manure was put

Test	Site	Site	P-value
Tukey HSD			
	Fertile	Middle	0.031*
	Fertile	Tree	0.960
	Middle	Tree	0.053

5 Discussion

The ANOVA results showed that there was a significant difference between the abundance of ants at the different sampling sites (P-value 0.023). To know what the difference referred to, a Tukey test was made. It showed that the abundance of ants was larger at the most fertile part of the field, or where they put most manure, compared to the site in the middle of the field (P-value 0.031). The difference between the sampling site near a tree and middle of the field, when looking at ant abundance, was close to significant (P-value 0.053). Those results are not surprising; other studies have also shown increased macrofauna abundance where manure and/or fertilizers are added (Ayuke et al., 2011; Sileshi & Mafongoya, 2006). It is furthermore not surprising that the ant abundance decreases in the middle of the field where more annual crops are grown, compared to close to the tree where there is less management. There is generally a lower abundance of macrofauna in annual cropping systems, where the land is more frequently managed (Rahman et al., 2011; Sileshi & Mafongoya, 2005; Sileshi & Mafongoya, 2006; Tabu et al., 2004). None of the other macrofaunal groups was significantly more abundant at agroforestry farms. However, the difference of termites at the different farming types were close to significant (P-value 0.060), although they were most abundant at non-agroforestry farms.

The number of farms included in the study was low (n=5 per farming system), a larger sampling size may have decreased the standard error of mean. Other studies (Rahman et al., 2011; Rousseau et al., 2013) show that the abundance of macrofauna generally is higher in more complex systems such as agroforestry systems and forest systems than in cropping systems with non-agroforestry or monoculture. However, there are also studies that have shown that land use does not affect termites (Sileshi & Mafongoya, 2005), which may explain why the number of termites were larger in non-agroforestry systems.

Reasons why this study didn´t confirm what other studies have found when comparing agroforestry with non-agroforestry may be that the farms included in this study did not differ very much. The non-agroforestry farms did sometimes put mulch and they were intercropping trees and crops, although they did not follow Vi Agroforestry´s methods. The biggest difference between the farms seems to be that the agroforestry farms often had more animals than the non-agroforestry farms (Table 1) and could thus access manure. Also, it was unfortunate that we first after collecting the samples found out that even the non-agroforestry farms had started with agroforestry methods, promoted by Vi Agroforestry in 1995, but did not continue practicing the methods due to different reasons.

5.1 Ants

In both farming systems, ants from the sub-family Formicinae as well as ants from the sub-family Ponerinae were most frequently found where the farmer put most manure or pointed out their most fertile part of the land. The sub-family Ecitoninae was mostly found where the farmers put most manure at agroforestry farms and near a tree at non-agroforestry farms. The sub-family Myrmicinae was found at all sampling sites, although less frequently in the middle of the field, however, these differences are observations and not tested for statistical significance. The ant sub-families Myrmicinae, Formicinae and Ponerinae (found in this study) are involved in different types of mutualistic relationships with plants, for example regarding plant protection or pollination (Rico-Gray & Oliveira, 2007). Among the ants found in this study, the sub-family Myrmicinae and especially the genus *Pheidole* are common harvester ants, but also ants from the Formicinae and Ponerinae sub-families are harvesting. The harvesting ants mostly occur in arid environments in tropical areas, where the availability of especially seeds is unpredictable. The ants are mostly looking for seeds at the ground, and then bringing them back to the nest, for consumption or storage. In turn, plants may benefit from this if the seed is abandoned where it can germinate (Rico-Gray & Oliveira, 2007). *Pheidole* was in this study found mostly near trees at the agroforestry farms, however in the non-agroforestry farms they were more frequently found at the most fertile part of the field, though as for above, no test for statistical significance was made.

Species of *Crematogaster* (Myrmicinae) are protecting their host trees (for example the whistling-thorn tree) against parasitic midges. Different species of *Crematogaster* vary in their way of protecting plants against parasites; some are more aggressive than others are. They also seem to be more aggressive than species of *Tetraponera* (Pseudomyrmicinae) that also protect plants. Some species of *Crematogaster* can temporarily make the trees sterile (Schumer et al., 2013). In this study, only one specimen of *Crematogaster* was found, it was collected near a tree in a non-agroforestry farm.

Species of the fire ant, *Solenopsis* (Myrmicinae), are protecting honey dew producing hemipterans, such as the mealybug, from their natural enemies (Zhou et al., 2013), for example by moving them to shelters built by leaf rollers (Zhou et al., 2012). In exchange, the ants are feeding on the honeydew secreted by the hemipterans, which is very rich in sugar and amino acids and a good food source (Zhou et al., 2012; Zhou et al., 2013). The colonies found to feed on the honeydew seem to grow larger than other colonies of *Solenopsis* that only feed on proteins. The survival of hemipterans where predators were present seems to be larger where the fire ant is protecting them (Zhou et al., 2013). *Solenopsis invicta*, a dangerous pest with negative impacts on human health, agriculture and forestry production and poultry production, is commonly found protecting hemipterans, such as the invasive *Phenacoccus solenopsis* (mealybug) from their natural enemies in exchange of honeydew. This mutualism seems to be beneficial for the survival of both species (Zhou et al., 2012).

Pseudoponera sp. was the only ant genera in this study that occurred most frequently at the same sampling site in both farming systems. They were mostly collected where the farmer put most manure or where the most fertile part was at the field, although, this difference was not statistically tested for significance (Table 3).

5.2 Termites

The total number of termites found at non-agroforestry farms was larger than at agroforestry farms, although not significantly so. However, many of the samples did not contain any termites, which might give a biased result.

Other studies on termites have shown that their abundance may increase under monocropping (Zida et al., 2011) or that they are not very sensitive to different land use strategies (Sileshi & Mafongoya, 2005). In this study, they were however not significantly more abundant in non-agroforestry farms than in agroforestry farms. All sub-families found in this study belonged to the family Termitidae. The subfamily Apicotermitinae was most abundant and they were mostly collected at the sampling site near a tree at non-agroforestry farms, though that is an observation and not statistically measured.

The Termitidae family is a higher termite (Bignell et al., 1979) and the largest termite family, including 70 % of the world's termite species (Evans et al., 2012). Flagellate symbiosis is present in all termite families except Termitidae. Termitidae is also the family of termites having the widest range of feeding as well as nesting strategies (Eggleton & Tayasu, 2001).

Genera from the sub-family Macrotermitinae, found in this study, are known as fungus-growing termites (Erpenbach et al., 2013), which seem to be an evolutionary newer mutualistic relationship replacing the flagellate symbiosis found in other families (Eggleton & Tayasu, 2001). Thanks to their fungus-growing activities, organic material is able to decompose much faster in their nests than outside (Jones, 1990). They are also ecosystem engineers. Their activities are creating nutrient hot-spots (Erpenbach et al., 2013) which are important at a local scale at savannahs, where they are contributing to the heterogeneity of vegetation cover in the area. Their building of termite mounds is contributing to the growth of trees, and the tree flora seems to be more diverse on the mounds than in the neighbouring area. The water availability is usually high in termite mounds and the impact of fires is lower on termite mounds. Those features might be a reason why the trees inhabiting termite mounds have less woody parts and more leaves than the tree species occupying the surrounding savannah (Van der Plas et al., 2013). Only two Macrotermitinae individuals were found, one in each farming system and both were found at the sampling site in the middle of the field.

Apicotermitinae is a soil-feeding group of termites that do not form above ground nests. They often occur in undisturbed tropical forests (Eggleton & Tayasu, 2001). The sub-family Termitinae consists of genera that act as pests. In West Africa, they can be a problem in yam, groundnut, cassava and sugar cane plantations (Rouland-Lefèvre, 2011).

5.3 Other macrofauna

Earthworms, millipedes and centipedes were more abundant in agroforestry systems whilst woodlice where more frequently found at non-agroforestry farms. None of the macrofaunal groups showed a significant difference between the farming systems using ANOVA, however, the difference of woodlice among the different sampling sites was close to significant (P-value 0.070).

Estimations of earthworm populations are difficult due to their large variation in population size, and the population density is probably often underestimated in the literature (Edwards & Bohlen, 1996). In this study, earthworm abundance was larger where most manure was applied in agroforestry systems and near a tree in non-agroforestry systems, although not significantly so. Manure wasn´t always applied in non-agroforestry systems. Other studies show that animal manure is increasing the abundance of earthworms (Riley et al., 2008). Earthworms are feeding on organic matter (Curry & Schmidt, 2007), thus it´s not surprising that their abundance was higher where manure was placed. The differences of millipedes and centipedes did not vary considerably across the different sampling sites, yet, they were slightly more abundant at the site where manure was mostly distributed. The woodlice were least abundant in the middle of the field, in both systems. None of these differences were statistically significant.

5.4 Limitations of this study & suggestions for future studies

Time was a limiting factor during this study; hence, just a small part of the soil macrofauna was examined to lower taxonomic levels. Inventory work on millipedes, centipedes and woodlice wasn´t carried out, even though they were a large part of the soil macrofauna found. The earthworms were not identified either. Consequently, not much attention has been brought to those faunal groups in this report. When sampling, it would have been good to sort out the fauna using a sieve to a bigger extent, but due to the varying weather condition, with wet and sticky soil many days, a sieve couldn´t always be used in this study. Furthermore, using the monolith method is not suitable for collecting smaller ants or flying ants, meaning that the results might be biased, and the estimations of ants in this study may be an underestimation. The lack of keys for identifying fauna were affecting in such a way that the only fauna that could be examined further, were those that someone knew how to identify.

There is a need for written identification knowledge and keys on a number of groups of macrofauna in Uganda. There are not much documentation about what macrofauna there is and what they are doing. Lack of identification keys makes identification hard, and expertise knowledge is currently needed to type those macrofauna. When collecting the fauna, it would be good to use complementary methods, for example the Winkler method or a transect walk. A comprehensive collecting of macrofauna and written documentation and keys are needed and would be a good study for the future. In articles such as (Smith et al., 2012), many benefits that farmers and the environment can get from agroforestry systems are described. Ecological interactions, both direct and indirect, financial benefits, climate regulations as well as many other processes that is beneficial at many levels (Smith et al., 2012). A study examining farms before agroforestry is introduced, looking at soil macrofauna and measuring soil properties that are known to be improved with macrofauna, and doing the same study after introducing agroforestry at the same farms could be a way to see the that agroforestry has on the farming systems. Interviewing the farmers both before introducing agroforestry and after would give an idea if the agroforestry system were beneficial to them economically. Looking at a big number of farms would help getting a more reliable result. However, developing a good agroforestry system and to be able to measure any effects takes a long time. Perhaps the ownership of the farms has changed during time and other natural changes may have occurred, which might interrupt the study.

6 Conclusion

An ANOVA showed that the distribution of ants differed among the sampling sites (p-value 0.023), and that the abundance was significantly larger where the farmer spread most manure or had their most fertile part of the land than at the sampling site in the middle of the field (p-value 0.031). The other faunal group's didn´t show any significant difference among any of the farming methods or sampling sites, which might depend on the complexity of the farms. The farms used in this study were quite similar, even though they used different farming systems. The complexity of the systems did not differ very much, which might contribute to why the results didn´t show a significant difference, more than for earthworms when looking at the difference between farming systems. However, the total number of macrofauna found in agroforestry systems was greater than in non-agroforestry systems.

Acknowledgements

I want to thank Jan Lagerlöf at the Swedish University of Agricultural Sciences, who has supervised throughout the work. I also want to thank Dr. Anne Akol at Makerere University who has been very helpful during the identification of ants and termites. Many thanks also to all the staff at Vi Agroforestry in the Masaka office in Uganda, that have been very helpful with all the practical issues such as translations, housing, office space, choosing farms and driving during the field work period. Special thanks to all the farmers that let us do sampling at their farms. I also want to thank Ylva Nyberg and Ingrid Öborn who introduced us to Vi Agroforestry in the first place. This study was made possible by a Minor Field Study scholarship from Sida.

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Appendix

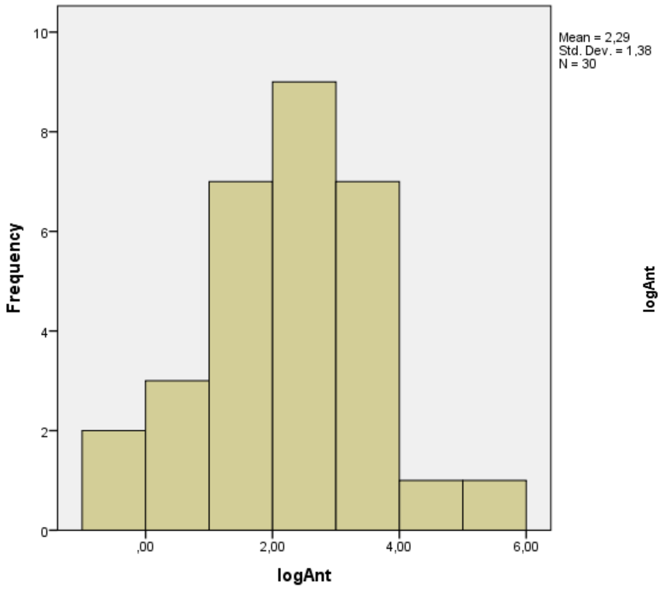

Figure 4. Histogram showing distribution of ants after a logarithmic transformation

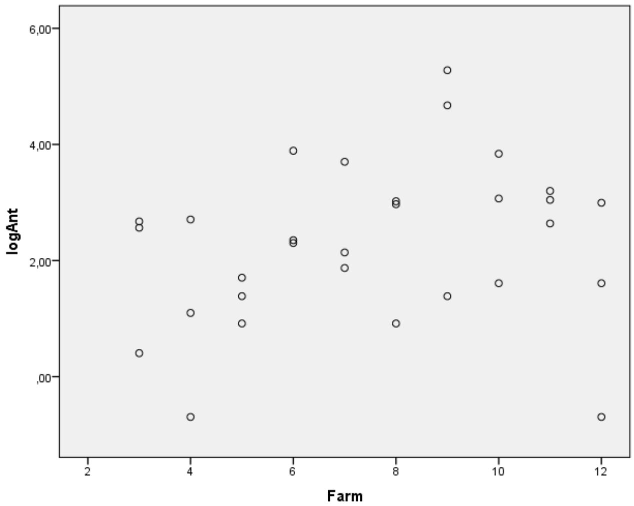

Figure 5. Scatter plot of ants after a logarithmic transformation

Table 8. SPSS ANOVA-output, ants after the logarithmic transformation

Tests of Between-Subjects Effects

Dependent Variable: logAnt

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	156,774	1	156,774	64,370	,000
	Error	19,484	8	2,436[a]		
Site	Hypothesis	12,713	2	6,357	4,848	,023
	Error	20,981	16	1,311[b]		
Type	Hypothesis	1,447	1	1,447	,594	,463
	Error	19,484	8	2,436[a]		
Farm(Type)	Hypothesis	19,484	8	2,436	1,857	,139
	Error	20,981	16	1,311[b]		
Site * Type	Hypothesis	,601	2	,300	,229	,798
	Error	20,981	16	1,311[b]		

a. MS(Farm(Type))

b. MS(Error)

Table 9. Tukey HSD and Bonferroni showing that the difference in abundance of ants is significant between the middle of the field and where the farmers put most manure or had their most fertile part of the field

Multiple Comparisons

Dependent Variable: logAnt

	(I) Site	(J) Site	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Fertile	Middle	1,4456*	,51211	,031	,1242	2,7670
		Tree	,1400	,51211	,960	-1,1814	1,4614
	Middle	Fertile	-1,4456*	,51211	,031	-2,7670	-,1242
		Tree	-1,3056	,51211	,053	-2,6270	,0158
	Tree	Fertile	-,1400	,51211	,960	-1,4614	1,1814
		Middle	1,3056	,51211	,053	-,0158	2,6270
Bonferroni	Fertile	Middle	1,4456*	,51211	,037	,0767	2,8145
		Tree	,1400	,51211	1,000	-1,2289	1,5089
	Middle	Fertile	-1,4456*	,51211	,037	-2,8145	-,0767
		Tree	-1,3056	,51211	,064	-2,6745	,0633
	Tree	Fertile	-,1400	,51211	1,000	-1,5089	1,2289
		Middle	1,3056	,51211	,064	-,0633	2,6745

Based on observed means.
The error term is Mean Square(Error) = 1,311.

*. The mean difference is significant at the 0,05 level.

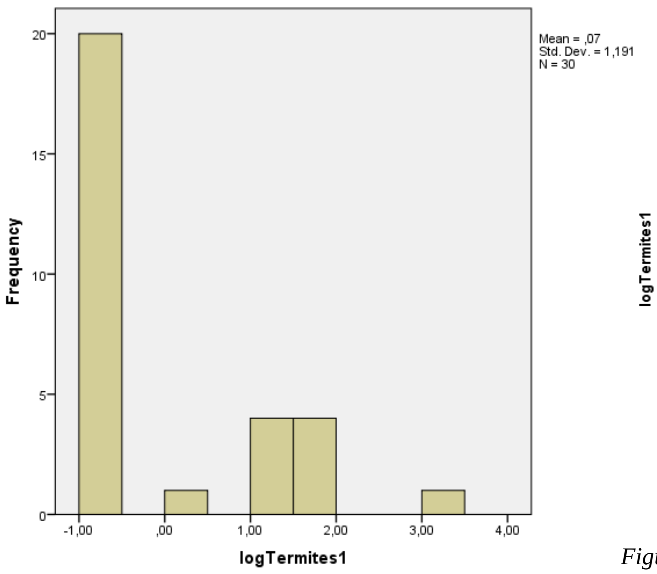

Figure 6. Histogram showing distribution of termites after a logarithmic transformation .

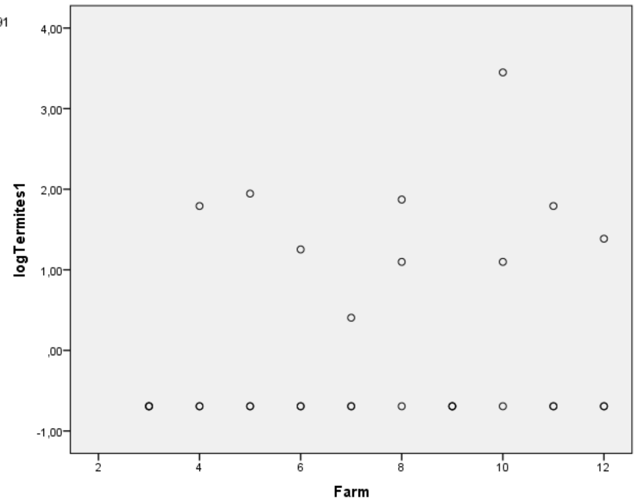

Figure 7. Scatter plot of termites after a logarithmic transformation

Table 10. SPSS ANOVA-output, termites after a logarithmic transformation

Tests of Between-Subjects Effects

Dependent Variable: logTermites1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	,166	1	,166	,214	,656
	Error	6,210	8	,776[a]		
Site	Hypothesis	5,170	2	2,585	1,627	,227
	Error	25,413	16	1,588[b]		
Type	Hypothesis	3,731	1	3,731	4,806	,060
	Error	6,210	8	,776[a]		
Farm(Type)	Hypothesis	6,210	8	,776	,489	,847
	Error	25,413	16	1,588[b]		
Site * Type	Hypothesis	,602	2	,301	,190	,829
	Error	25,413	16	1,588[b]		

a. MS(Farm(Type))

b. MS(Error)

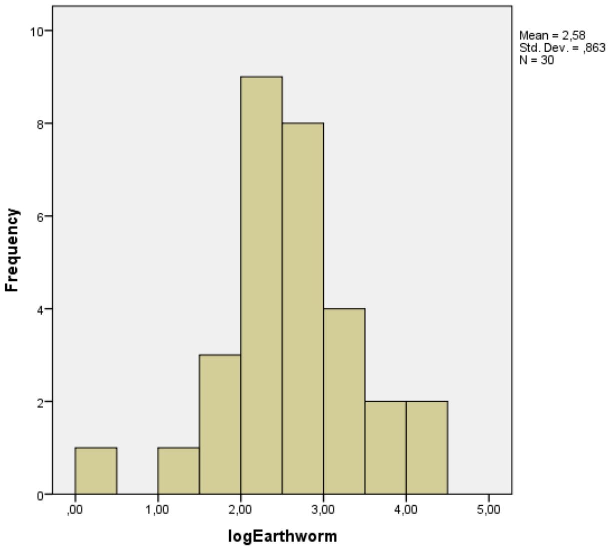

Figure 8. Histogram showing distribution of earthworms after a logarithmic transformation

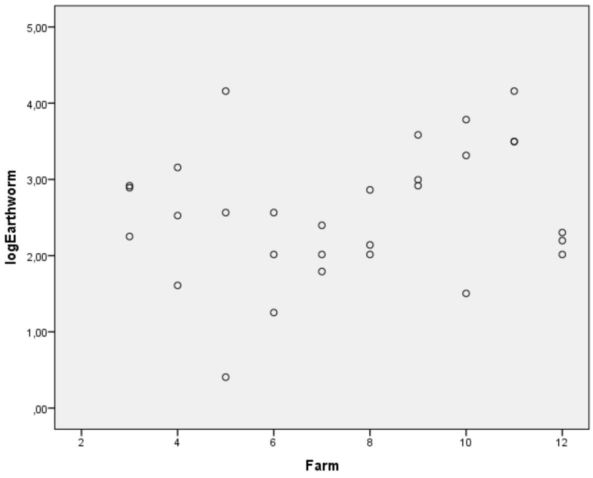

Figure 9. Scatter plot of earthworms after a logarithmic transformation

Table 11. SPSS ANOVA-output, earthworms after a logarithmic transformation

Tests of Between-Subjects Effects

Dependent Variable: logEarthworm

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	199,183	1	199,183	244,333	,000
	Error	6,522	8	,815[a]		
Site	Hypothesis	1,459	2	,729	1,188	,330
	Error	9,824	16	,614[b]		
Type	Hypothesis	1,534	1	1,534	1,881	,207
	Error	6,522	8	,815[a]		
Farm(Type)	Hypothesis	6,522	8	,815	1,328	,299
	Error	9,824	16	,614[b]		
Site * Type	Hypothesis	2,284	2	1,142	1,860	,188
	Error	9,824	16	,614[b]		

a. MS(Farm(Type))

b. MS(Error)

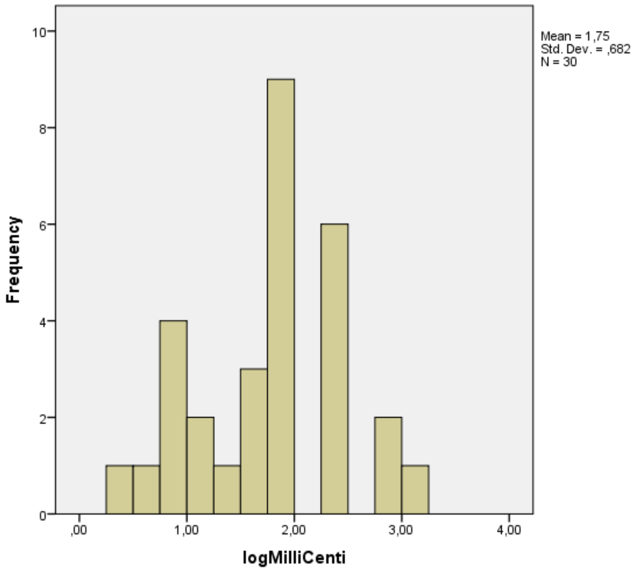

Figure 10. Histogram showing distribution of millipedes and centipedes after a logarithmic transformation

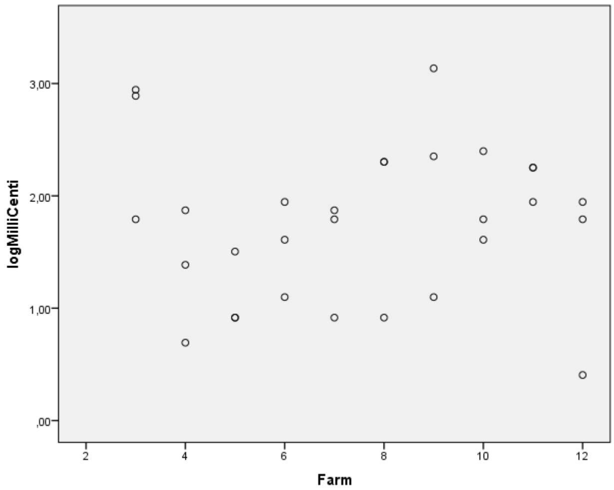

Figure 11. Scatter plot of millipedes and centipedes after a logarithmic transformation

Table 12. SPSS ANOVA-output, millipedes and centipedes after a logarithmic transformation

Tests of Between-Subjects Effects

Dependent Variable: logMilliCenti

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	92,387	1	92,387	152,016	,000
	Error	4,862	8	,608[a]		
Site	Hypothesis	1,463	2	,731	1,922	,179
	Error	6,087	16	,380[b]		
Type	Hypothesis	,677	1	,677	1,115	,322
	Error	4,862	8	,608[a]		
Farm(Type)	Hypothesis	4,862	8	,608	1,597	,202
	Error	6,087	16	,380[b]		
Site * Type	Hypothesis	,389	2	,195	,511	,609
	Error	6,087	16	,380[b]		

a. MS(Farm(Type))

b. MS(Error)

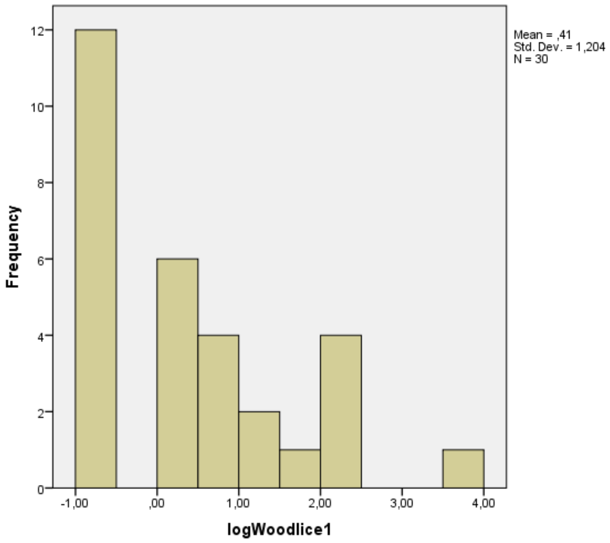

Figure 12. Histogram showing distribution of woodlice after a logarithmic transformation

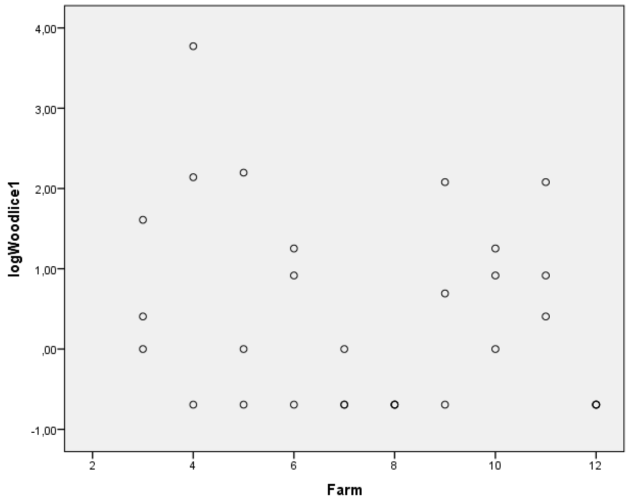

Figure 13. Scatter plot of woodlice after a logarithmic transformation

Table 13. SPSS ANOVA-output, woodlice after a logarithmic transformation

Tests of Between-Subjects Effects

Dependent Variable: logWoodlice1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	5,059	1	5,059	2,386	,161
	Error	16,964	8	2,120[a]		
Site	Hypothesis	6,770	2	3,385	3,160	,070
	Error	17,140	16	1,071[b]		
Type	Hypothesis	,282	1	,282	,133	,725
	Error	16,964	8	2,120[a]		
Farm(Type)	Hypothesis	16,964	8	2,120	1,979	,117
	Error	17,140	16	1,071[b]		
Site * Type	Hypothesis	,898	2	,449	,419	,665
	Error	17,140	16	1,071[b]		

a. MS(Farm(Type))

b. MS(Error)