Optimizing the potential of silvicultural agroforestry systems in Flanders

Increasing the understanding of silvicultural alley cropping systems in the temperate climate of Belgium focussed on colonization of arthropods on arable land and crop yield.

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by

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Preface

I would like to thank Bert Reubens, Victoria Nelissen, and Paul Pardon for giving me the opportunity to conduct this research at the Institute of Fisheries and Agriculture, Belgium. Specifically, I would like to thank them for their guidance through the project and all things that they taught me.

For the ILVO field crew, thank you for helping with yield measurements and help with counting of the insects. I could not have done it without you! It was not the most fun sort of work, but you helped me through it and made it more enjoyable!

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Then I want to thank Jesse Hermens for helping me with statistics, which before this research I knew nothing about. I still have a lot to learn, but I control the basics now.

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Emiel van Riet

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Abstract

Past decades traditional agricultural landscapes characterized by a wide variety of grasslands, field boundaries, watercourses, and trees started to disappear. Population growth required an ever-increasing demand for food and traditional agricultural systems were converted to monocultures. With this conversion, arthropods started to disappear effecting the ecosystem since they contribute to ecosystem services such as decomposition, nutrient cycling, carbon storage, water infiltration and storage, natural pest control, and pollination. Also, monoculture farming systems are more susceptible to erosion and are often polluted due to nutrients, agrochemicals (pesticides), organic matter, drug residues, sediments, and saline drainage.

These problems led to the necessity that more sustainable systems are needed. A more sustainable system is agroforestry, which is recognized by the world as an integrated approach to sustainable land use. Agroforestry is the multi-functional use of agricultural land were crops are combined with trees, shrubs and/or animals to create a diverse system in order to increase social, economic and environmental benefits of the land. In Belgium, the agroforestry system of alley cropping is subsidized by the government. Despite this subsidy, implementation is still low. Currently, the main challenge is to utilize the potential of agroforestry systems and show benefits for converting to agroforestry. For this more insight is needed on interactions occurring on the field and how farmers can respond to them. Previous research showed that in alley cropping systems the yield is lower closer to the alleys. Another research showed that alleys increase arthropod abundance in the arable zone. The question remained if this increased abundance was through colonization of arthropods from the alley to the arable land.

The main objective of this research was to increase understanding of silvicultural alley cropping systems in the temperate climate of Belgium focussed on colonization of arthropods on arable land and crop yield.

During this research no visible colonization from the alley to the field took place. Increases and decreases of insect abundance changed simultaneously per measured period.
In two periods 04-06-18 to 15-06-2019 rove beetles, carabids, spiders, and centipedes showed the highest abundance. Most crops had further development in this period, possible increasing abundance of other insect species, and increasing food availability. It is possible that it has to do with climatological factors, such as temperature, moist, or wind because the trend was seen on all fields, which varied in crops, trees, undergrowth, and openness op the landscape. To understand why this increase in this period occurs more research is needed. Woodlice, centipedes, millipedes, and spiders showed the highest abundance in the alleys showing that the most suitable habitat is in these areas. Organic farming plots showed a slightly increased insect abundance for carabids and spiders, suggesting organic farming can stimulate insect abundance.

Crop yield was in most scenarios reduced for crops (summer wheat, and maize) planted in spring. Closer to the alley a lower yield was observed. Barley which was sown in autumn showed a lower yield, but this alley contained hedges creating shade. For summer wheat, maize, and barley the trees provided to much shade and reduced crop growth. Possibly there was competition between trees and crops. Winter wheat showed similar growth and the alley did not seem to be affected by trees. The organic farming plot showed a lower yield compared to the other wheat species, due to a lower sowing density.

Overall agroforestry reduces production but increases insect abundance. Reduced yield is a more sustainable option then losing biodiversity and with it system health. In time trees will give products in return and compensate for the lost yield.

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Nomenclature

Agroforestry	The multi-functional use of agricultural land where crops are combined with trees, shrubs and/or animals to create a diverse system in order to increase social, economic and environmental benefits of the land
Arthropods	Animals having an exoskeleton (spiders, beetles, etc.)
ILVO	Institute of agriculture and fisheries
Monoculture	System were per growing season one type of crops is grown on a agricultural land

1 INTRODUCTION

1.1 BACKGROUND

Past decades traditional agricultural landscapes were characterized by a wide variety of grasslands, field boundaries, watercourses, and trees (Stoate et al., 2001). Due to population growth past decades, an ever-increasing demand for food occurred and new methods to produce foods were needed (Convention on Biological Diversity, n.d.). The traditional agricultural landscapes were then replaced by monoculture farming systems, which could produce more food due to intensification and mechanization of agricultural land (Verma, 2005). Monoculture farming systems expanded and tripled agricultural production between 1960 and 2015 (Liu, 2017), and the traditional landscape disappeared. Despite the higher production the loss of traditional agricultural landscapes effects the land and food security in two major ways.

1. The disappearance of landscape elements in combination with fallow periods between crop rotations makes the land susceptible to wind and water erosion (Blair, 1995). Erosion removes organic carbon and nutrients from the soil, which prevents vegetation growth (Panagos et al., 2018; Niggli et al., 2009). Leeching of these nutrients into surface/groundwater can pollute it. Low biodiversity and variety of plants species in monoculture farming systems create possibilities for pest and diseases to develop (King & Lively, 2012). To prevent pest and diseases agrochemicals are used which can also pollute surface water. 38% of the water bodies in Europe are under pressure of agricultural pollution (Mateo-Sagasta, Marjani Zadeh, & Turral, 2017). Main pollutants are nutrients, agrochemicals (pesticides), organic matter, drug residues, sediments and saline drainage (Mateo-Sagasta et al., 2017).
2. Loss of landscape elements results in the disappearance of several plants, bird and arthropod species (Stoate et al., 2001; Geiger et al., 2010). The loss of arthropod species seriously affects agricultural systems. Arthropod pollinates plants if plants are not pollinated there is no yield (Cock, 2012). The importance of soil arthropod is underestimated. Soil arthropod determines the structure and functions of natural ecosystems and play a key role in food security (Cock, 2012). They contribute to ecosystem services such as decomposition, nutrient cycling, carbon storage, water infiltration and storage, and natural pest control (Geiger et al., 2010). Loss of these species can result in a long-term decline of soil fertility and reduce the agricultural productive capacity (Cock, 2012).

Monoculture farming systems are not sustainable unless the effect of loss of landscape elements is solved. More sustainable agricultural systems that protect and enhance natural resources are needed (Liu, 2017). Currently, in Europe, there is a growing interest to a more sustainable system called agroforestry. Agroforestry is the multi-functional use of agricultural land where crops are combined with trees, shrubs and/or animals to create a diverse system in order to increase social, economic and environmental benefits of the land (ICRAF,2018; FAO, 2018).

Agroforestry is recognized around the world as an integrated approach to sustainable land use, because of its production and environmental benefits (Nair, Kumar, & Nair, 2009). Despite the EU Rural Development policy recognizes the economic, ecological, and social advantages implementation is low (Riqueiro-Rodriguez, McAdam, & Mosquara-Losada, 2009a). An agroforestry technique that can offer many possibilities in Europe is alley cropping because it can be efficiently combined with modern farming techniques (P. Pardon et al., 2018). Alley cropping reduces erosion from wind and water, diversifies production, improves water quality, protects crops, enhances wildlife and improves aesthetics (Walter, Jose, & Zamora, 2015).

1.2 PROBLEM DESCRIPTION

In Belgium, alley cropping systems are supported by the government, and grants are given if agroforestry systems are implemented (L&V, 2018). Despite grants, the implementation of agroforestry is still low. Research shows that a lack of information regarding economic benefits and efficient tree/crop/animal combinations are missing (Verdonckt, 2017). Currently, the main challenge is to utilize the potential of agroforestry systems and show benefits for converting to agroforestry. For this more insight is needed on interactions occurring on the field and how farmers can respond to them. Interactions occurring on the field are light competition, root competition, and allelopathy (chemical interactions) (Walter, Jose, & Zamora, 2015).

To collect more data about these interactions with the Institute of fisheries and agriculture (ILVO) started several projects related to agroforestry. Their goal is to promote sustainable agriculture and fishery on an economic, ecological and social level through new knowledge and services(ILVO, n.d.). Two of the researches conducted are related to interaction occurring in agroforestry fields.

The first research performed by Paul Pardon, looks at the effect of alleys on crop yield in Belgium focussed on the most grown crops: wheat, barley, maize, potatoes, and beets. These crops cover half of Belgium arable land (Paul Pardon et al., 2018). The alleys were aged young (2-7 year), medium-old (15-48 year) and old (68-70 year). Yield measurement were taken on 3, 5, 10, 20, and 30 m from the alley. Closer to the alley the yield was significantly lower on medium- old and old fields. The young fields also showed a significantly lower production (Paul Pardon et al., 2018).

The second, also performed by Paul Pardon in Flanders showed that tree row presence can increase abundance and diversity of detritivores in the arable zone (P. Pardon et al., 2018). The increased abundance in the arable zone is probably an effect of the colonization from the tree row through mitigation of increased shade, soil and air humidity, food sources and nesting habitat (Pardon et al., 2018). This research focused on detritivores and carnivore's species.

Due to these researches, new questions occurred for ILVO. Now they are interested to collect more knowledge about how colonization of arable land takes place in alley cropping systems. They suspect that it starts from the alleys, due to a better microclimate which makes it a better habitat (P. Pardon, et al., 2018). They also want to continue yield measurements on the same fields to see how crop yield develops after the tree growth. And they are interested in differences between conventional and organic farming.

1.3 OBJECTIVES & RESEARCH QUESTIONS

The main objective of this research is to increase the understanding of silvicultural alley cropping systems in the temperate climate of Belgium focussed on colonization of arthropods on arable land and crop yield.

1.3.1 Sub-objectives

1. Research colonization of arthropods on arable land and see if colonization takes place from silvicultural alleys.
2. Continue yield measurements focussed on monitoring the effect of trees (growth) on the most common crops in Belgium: summer wheat, winter wheat, potatoes, barley, and maize.
3. Research differences between conventional farming and organic farming.

1.3.2 Research questions

1. What is the influence of silvicultural alley-cropping systems on the colonization of arthropods on agricultural fields?
    a. How does insect abundance develop on arable land during the growing season of crops?
    b. How do silvicultural alleys influence arthropod colonization on agricultural fields?
    c. What are the differences between conventional and organic farming on the colonization of arthropods on arable fields?
    d. How do different crops effect the colonization of arthropods on arable land?

2. What is the effect of trees in silvicultural alley-cropping systems on crop yield?
    a. What are the differences between different type of crops?
    b. What are the effects of conventional farming and organic farming on crop yield?

1. Colonization of arthropods on arable fields

This research focussed on the abundance of woodlice (Isopoda), Millipedes (Myriapoda: Diplopoda), Coleoptera: Carabidae, Rove beetles (Coleoptera: Staphylinidae), Spiders (Arachnida) and Centipedes (Myriapoda: Chilipoda) on arable land.

2. Effect of alleys on crop yield

The researched fields focussed on the important crops in Belgium: winter wheat, summer wheat, barley, potatoes, and maize.

2 BACKGROUND INFORMATION

2.1 BENEFITS AND CHALLENGES AGROFORESTRY

Benefits

Integrating trees in agricultural land creates dynamic, ecologically based, natural resource management systems that diversify and sustain production aimed at increasing social, economic and environmental benefits (FAO, 2017). Three major benefits agroforestry provides are:

1. *Regulating functions:*
   - Trees and shrubs have a deeper and more extensive root system than crops, making them able to capture and recycle more nutrients (Raj, Jhariya, Toppo, & Oraon, 2017).
   - The benefit of having of agroforestry is that trees and shrubs sequestrate carbon in above and below ground biomass lowering greenhouse gasses in the atmosphere (Nair et al., 2009).
   - Tree roots keep soil in place and prevent erosion, also it increases the water holding capacity in the land (Riqueiro-Rodriguez, McAdam, & Mosquara-Losada, 2009b).
2. *Increases biodiversity:*
   - Because trees are large, live long and have a greater structure diversity the can provide habitat for a wide ray of organisms(Riqueiro-Rodriguez et al., 2009b).
3. *Diversifying production*:
   - More different types of production reduce the risk to lose a whole yield of crops. It makes agricultural landscapes more resilient for the future (World Agroforestry Centre, 2018). Products tree can add to production are fruit, nuts, oils, beverages, gums, resins, latex, flavours, leaves for food and nutrition, fodder for livestock, timber, fuel wood and biomass for energy production, and medicines that treat disease (World Agroforestry Centre, 2018).

Challenges

Five challenges occur when implementing agroforestry. Research shows (Walter et al., 2015) that:

1. More intensive farm management is needed, as well as knowledge on tree management and skill to manage multiple crops on a given site. Alley cropping can create difficulties to manage farms or form an obstacle.
2. Alleys remove land of production it takes time before benefits occur from this land.
3. Not for all tree products, there is a market or markets need to grow.
4. Trees and crops have competition for sun, moisture, and nutrients.
5. Agro-chemicals used may damage trees.

2.2 AGROFORESTRY IN EUROPE

Agroforestry is promoted by the European Union (EU). Currently there are two major projects promote the use of agroforestry in Europe (EURAF, n.d.; Riqueiro-Rodriquez, McAdam, & Mosquara-Losada, 2009). In December 2017 the AgForward (AgroFOrestry that Will Advance Rural Development) project finished. The aim of this project was to promote agroforestry practices in Europe that will advance rural development i.e. competitiveness, and social and environmental enhancement ("AGFORWARD," 2018).

The other project is the AFINET (Agroforestry Innovation Network) project which continues until December 2019. This project focusses on the exchange and knowledge transfer between scientists and people who practice or are interested to practice agroforestry (AFINET, 2017). Transformation of knowledge is achieved through a knowledge cloud containing practical information about agroforestry and RAINs (Reagional Agroforestry Innovation Netwerk). Each RAIN group represents a different climate, geographical, social and cultural conditions in Europe (AFINET, 2017).

Currently, there are RAIN groups in Belgium, Finland, France, Hungary, Italy, Poland, Portugal, Spain, and the United Kingdom. Reason is each different situation requires different agroforestry practices. Subdividing it into groups spread through Europe makes it possible to create general guidelines for all regions in Europe. The main goal of the RAINs is to stimulate knowledge transfer and experiences, ideas, the identification of knowledge gaps and solutions and to strengthen contact between researchers and practitioners (AFINET, n.d.).

2.3 Agroforestry in Belgium

In Belgium, the RAIN group in Belgium consists of a consortium of seven institutions: ILVO, University of Gent, Bodemkundige Dienst van België, Inagro, agrobeheercentrum, wervel, and BOS+. In Flanders were the area of agricultural land is limited there is a constant search to more productive systems and agroforestry has potential to contribute to an ecological intensification of current agricultural practices (Agroforestry in Vlaanderen, 2018).

2.4 Law and regulation Flanders Belgium

Agroforestry is promoted in Flanders Belgium. The agroforestry system promoted by the Flanders government is silvi-cultural alleycropping. These are systems where trees and shrubs are grown with food crops, pastures, and animals. If trees are planted on pastures and agricultural fields a maximum of 80% of the planting costs is subsidized, excluding VATs (L&V, 2018). Costs covered are: purchase of trees, labor costs for planting, and protection of trees (L&V, 2018).

Current regulation around agrosilvicultural practices in Flanders is (L&V, 2018):

- Trees need to have a homogeneous distribution on the field, it is not allowed to plant the trees in clusters.
- A minimum of 30 trees and a maximum of 200 trees per hectare
- Allmost all tree species are subsidized, accept for dwarf fruit trees, semi-dwarf fruit trees, conifers and pines, bird cherry (Prunus padus), northern red oak (Quercus rubra), and black locust (Robina pseudoacacia)
- A minimum area of 0,5 hectare need to be planted
- When planted, trees need to remain on the field for ten years, if trees die they need to be replaced within two years.
- Fields need to be situated in Flanders
- The area were trees are planted need to be registered as farmland.

Although implementing agroforestry is almost entirely subsidised implementation of the silvicultural systems is low (Agroforestry in Vlaanderen, 2018). Main problems are bottlenecks around legal and administrative certainties, transformation of farm management, and technical and economic uncertainties (Agroforestry in Vlaanderen, 2018).

Legal and administrative uncertainties

Currently, 65% of Flanders agricultural land is under tenancy (Casier, 2013). Farmers lease land from landowners. However, farmers leasing land willing to implement agroforestry needs permission from the landowner to do so. In case agroforestry is implemented and the lease contract is terminated before the agroforestry system is eighteen years old, any increase in value to the system needs to be compensated by the landowner. In case of value devaluation the farmer leasing the land needs to compensate the value loss (Agroforestry Vlaanderen, 2018c).
In protected/heritage landscapes admission from the Institute of Real Estate is needed (Agroforestry Vlaanderen, 2018c).

Some scenario's in the Nature decree forces a permit to harvest agroforestry plots. In case this permit is denied or conditions are required as example replanting turning agroforestry back to agricultural land is not possible (Agroforestry Vlaanderen, 2018c).

2.5 Institute of Fisheries and Agriculture (ILVO)

Currently, there are 3 major projects in Belgium on agroforestry:

1. P'orchard is a project that looks for possibilities to combine agroforestry with outdoor pig farming and how this can be managed. Stimulating a local, sustainable and qualitative product is the goal. Pigs are free to roam around. Due to the limited knowledge around this topic, the operational group created for this project can help to gather and share knowledge, experiences, innovative ideas and tackle possible bottlenecks (Agroforestry Vlaanderen, 2018b).
2. The goal of the Legcombio project is to see if an increased production can be achieved if land for free-range poultry is combined with trees and shrubs. First existing free-range poultry farms will be evaluated. Secondly, an experiment will be conducted to see where poultry stays during different weather conditions, preference of poultry between hazels and willows, use of the area and influence of the poultry (on quality and yield of woody vegetation, nutrient deposits soil, weed & pest control)(Agroforestry Vlaanderen, 2018a).
3. The Agroforestry Flanders project main goal is to offer solutions and guidance to people willing or working with agroforestry systems. This is achieved on one side by conducting research and on the other site practical experience. The main focus is to promote agroforestry in relatively short time and create achievable, feasible and effective agroforestry systems in Flanders. Expected results are:
    a. Determining possibilities for different type of agroforestry in Flanders.
    b. Increasing knowledge of ecological interactions, ecosystem services, technical impact and economic opportunities for several agroforestry situations in Flanders
    c. Gathering insight about intentions, values, perception and social identity of people practicing agroforestry, aimed at breaking barriers and finding ways to promote agroforestry.
    d. Offering guidelines, practical recommendations and innovative solutions for practising agroforestry.
    e. Stimulating and guiding farmers to implement agroforestry fitted to their situation.

An important output of this project is a tool what can help to choose the right system per farmer.

2.6 Important arthropod groups on agricultural land

Important arthropod taxonomic groups on agricultural land comprise of Nematoda, Oribatida, Collembola, Diptera, Hymenoptera, Isoptera, Myriapoda, Isopoda, Arachnida, Coleoptera, Mollusca and Oligochaeta (Cock, 2012).

This research will focus on soil macro carnivores and detrivores. Detrivores researched were woodlice (Isopoda), and Millipedes (Myriapoda: Diplopoda). Carnivores were: Carabids (Coleoptera: Carabidae), rove beetles (Coleoptera: Staphylinidae), Spiders (Arachnida), and Centipedes (Myriapoda: Chilipoda). Abundance of these species on agricultural land or in alleys can tell something about the systems health and possible natural pest control.

2.6.1 Soil detritivores

Soil detritivores have the important function of mineralising organic matter, and they transform litter into faecal pellets which decompose rapidly releasing nutrients for plants (Curry, 1994).

Woodlice

Woodlice show a higher abundance in semi-natural grassland than woodlands, but are more abundant in woodlands than in cultivated lands (Paoletti & Hassall, 1999). The specie shows a rapid decline in diversity in intensively managed agricultural landscape and sylvicultural landscapes, due to direct and indirect effects (Paoletti & Hassal, 1999).

Millipedes

Millipedes are susceptible to agricultural management. Sustainable farm management on sites without ploughing or other similar techniques or on places were crops are grown for a few years a more species and a higher abundance can be found compared to conventional agriculture (STAŠIOV, HAZUCHOVÁ, VICIAN, KOČÍK, & SVITOK, 2014).

2.6.2 Soil carnivores

Soil carnivores can provide biological pest control in agricultural landscapes.

Carabids and Rove beetles

Carabids and rove beetles are key predators in several cropping systems. They have a high mobility, but they need shelter and alternative foods during periods of disruption in crops (tilling, pesticide application) (Cock, 2012). In winter they need protected undisturbed sites and strips of grasses and herbs can help (Cock, 2012).

Spiders

For spiders the gradient form edges of the field to the centre of the field plays an important role for spiders, and spider body sizes decreases toward the centre of the field (Galle & Batary, n.d.). In field edges a higher trait diversity can be found, which can give a higher biocontrol potential (Galle & Batary, n.d.).

Centipedes

Centipedes are common predators in soil and litter, and can live in a wide variety of biotopes. The specie is usually found in gardens, urban areas and forests (mainly pine forests)(Lock, 2000). Centipedes can be observed whole year round, but during drier summer months they often flee deeper in the soil(Lock, 2000). Little is known about these animals, because they received little attention from ecology and nature conservation(Lock, 200). But they can possible help in biological pest control.

3 METHODOLOGY

3.1 STUDY AREA

To study colonization of arthropods six alley cropping fields in Flanders were chosen (see figure 1.). On the same fields yield measurements were taken to measure the effect alleys have on crop production. The plots were chosen at farmers which were willing to co-operate with the research and grew crops that are commonly grown in Belgium, such as wheat, barley, maize, or potatoes. Because plots were chosen from farmers willing to co-operate the plots are far apart and distinctive from each other. There are differences between distance between alleys, crops grown, tree species and age of the trees in the alley. The plots have at least two alleys per field aging 4-7-year-old. Below a description of the fields is given.

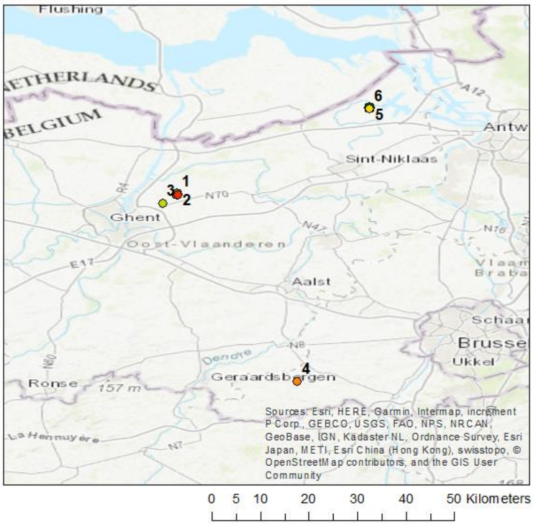

Figure 1. Location of research fields.

Field 1 and 2: owner farmer Kristof Mouton. Both alleys were planted in 2011. Kristof Mouton is a conventional farmer, which uses his land partly to grow fodder for animals.

Figure 2. Alley cropping system with poplar

On field 1 (see figure 2.) poplars are grown in the alley. The current height is around 14m. The distance between the alleys is 26m. In the alley a vegetation of primarily weeds is growing.
This year fodder maize was grown on the field. The maize was sown end of April.

Field 2 has cherry trees in the alley (see figure 3.). The current height is 5-8m and the distance between the alleys is 26m. Between the trees in the alleys a primarily grassy vegetation was present. The crop grown on the field was winter wheat, which was sown in the autumn.

Figure 3. Alley cropping system with cherries

Field 3: owner farmer Bart Mouton. The alleys with walnut trees were planted in 2013 (see figure 4.). Currently the walnuts have a height between 4-7 m. The distance between the alleys is 25m. This year crop was maize, which was sown end of May. When the measurements started few vegetation grew in the alleys, but during the project it slowly transformed to a vegetation containing weeds and wheat. Animal manure was applied before maize was sown.

Figure 4. Alley cropping system with walnut

Field 4: owner farmer Louis-Marie Tennstedt. He started his agroforestry project in 2011. In 2011 he planted cherries, hornbeam, chestnut, filbert, broom, holly, walnut, elder berries, leaved lime, eglantine and Nordman fir. The distance between the alleys is 56m. Currently, the alleys in this plot have a hedge like structure (see figure 5.). Due to the dense hedge-like structure the alley has no undergrowth, and only on the edges weeds and some grass were growing. The species chosen are to promote biodiversity and create hidings for wild animals (birds, rabbits, etc.). This year winter barley was grown on the field, which was sown in autumn. The field is on a slight slope. Louis-Marie Tennsteds is a conventional farmer.

Figure 5. Alley cropping system Louis-Marie Tennstedt

Field 5 and 6: owner farmer François Ongeneart. He is an organic farmer and started producing organic products 20 years ago. Agroforestry is an addition to his biological farm.

Field 5 has cherry trees in the alley and the alleys are 22 m apart (see figure 6.). The cherry trees were planted in 2013. Currently the cherries have a height of 5-7m. In the alleys a mixture of grass-clover was sown. This year potatoes were planted in spring.

Figure 6. Alley cropping system with cherries

Field 6 has a combination of lime, plums and maple trees in the alleys alternately spread in the alley. These trees were planted in 2014. The alleys are 23 m apart and a mixture of grass-clover is growing in the alleys. In early spring summer wheat was sown between the alleys.

Figure 7. Alley cropping system with lime, plums and maple

3.2 COLONIZATION OF ARTHROPODS ON AGRICULTURAL FIELDS

The data collection methodology for this study was taken from the PhD research of Paul Pardon: 'Gradients in abundance and diversity of ground-dwelling arthropods in temperate silvoarable fields'. This research was conducted for ILVO and the Gent University to research the gradients in abundance and diversity of beneficial ground-dwelling artropods as function of tree row presence, distance to tree rows and effect of different kind of crops.

In this research pitfall traps were placed to see if there was a colonization of arthropods from the alley to the arable land. The pitfall traps were placed in two transects per field vertically on the alleys (see figure 8.). The aim was to measure insect abundance in the alley and on several distances from the alley. The distances from the alley varied from 0.5 – 1.5 m, 4,5-6m, 8-11m, and >14. This was depending on the fields and mainly the distance between the alley and possible tracks of machines in the field. The placement of the transect can be found in appendix 1.

Figure 8. This figure shows 2 transect where pitfall traps were placed on field 5. The distances marked in the picture indicate the distance from the alley were a pitfall trap was placed. The alley is 22 m wide.

The pitfall traps were open containers with a diameter of 9 cm and a volume of 300 ml (see figure 9). The containers were sunken into the ground on the same level as the soil. They had a roof so flooding and disturbances were prevented (see figure 11.) (Work, Buddle, Korinus, & Spence, 2002). In the pitfalls, 250 ml of propylene (antifreeze) was added with a drop of detergent to break the surface tension (see figure 10). Propylene is a safe and effective liquid to capture insects (Donald, 2008).

Figure 10. Pitfall trap sunken in the ground.

Figure 11. Pitfall trap filled with 250 ml propylene with a drip of detergent.

Figure 9. Pitfall trap covered by roof to prevent flooding and disturbances

The placement of traps started on 23-4-2018 and ended on 5-7-2018. The traps were emptied and replaced every 10 days. Table 1 shows when traps were placed and emptied per field. Placement and replacement took place at the same time, so a continuous data set was created.

Table 1. Dates when pitfall traps were placed and emptied per field

Period (P)		1	2	3	4	5	6	7
Field 1.	Placed	x	3-5-2018	14-5-2018	24-5-2018	4-6-2018	14-6-2018	25-6-2018
	Emptied	x	14-5-2018	24-5-2018	4-6-2018	14-6-2018	25-6-2018	5-7-2018
Field 2.	Placed	23-4-2018	3-5-2018	14-5-2018	24-5-2018	4-6-2018	14-6-2018	x
	Emptied	3-5-2018	14-5-2018	24-5-2018	4-6-2018	14-6-2018	25-6-2018	x
Field 3.	Placed	x	x	x	24-5-2018	4-6-2018	14-6-2018	25-6-2018
	Emptied	x	x	x	4-6-2018	14-6-2018	25-6-2018	5-7-2018
Field 4.	Placed	23-4-2018	3-5-2018	14-5-2018	24-5-2018	4-6-2018	x	x
	Emptied	3-5-2018	14-5-2018	24-5-2018	4-6-2018	14-6-2018	x	x
Field 5.	Placed	24-4-2018	4-5-2018	15-5-2018	25-5-2018	5-6-2018	15-6-2018	x
	Emptied	4-5-2018	15-5-2018	25-5-2018	5-6-2018	15-6-2018	26-6-2018	x
Field 6.	Placed	24-4-2018	4-5-2018	15-5-2018	25-5-2018	5-6-2018	15-6-2018	x
	Emptied	4-5-2018	15-5-2018	25-5-2018	5-6-2018	15-6-2018	26-6-2018	x

A total of 578 traps was placed during the research. Some fields were measured for this whole period. On fields 1 and 3 the crops were not sown when the project started, for this reason measurements started later. On plot 2, 4, 5 and 6 traps were removed early, because of possible yield. Table 2 shows the number of traps per distance per period, and the total number of traps per field.

Table 2. Pitfall trap information per field and distance

Field	Distance (m)					Traps per period	Total number of traps placed
	0	0.5-1.5	4.5-6.0	8.0-11.0	>14.0		
1	4	4	4	2	2	16	96
2	4	4	4	2	2	16	96
3	4	4	4	2	0	14	56
4	4	4	4	4	2	18	90
5	4	4	4	2	0	14	84
6	6	8	8	4	0	26	156

The arthropods captured per pitfall trap were separated into groups and counted. The groups consisted of the taxon of woodlice (Isopoda), Millipedes (Myriapoda: Diplopoda), Carabids (Coleoptera: Carbidae), Rove beetles (Coleoptera: Staphylinidae), Centipedes (Myriapoda, Chilipoda), and spiders (Arachnida). Per pitfall trap the groups were placed in test tubes, with a test tube for each group. The test tubes were filled with 70% ethanol, so groups could be identified to species level for future research.

3.3 EFFECT OF ALLEYS ON CROP YIELD

The data collection methodology to see the effect of alleys on crop yield was taken from the report: 'Biomassaproductie en kwaliteit van landbouwgewassen en bomen in lijnvormige agroforestrysystemen', by Paul Pardon et al. Yield measurements of barley, summer wheat, winter wheat, and maize were taken.

Barley, Summer wheat, and Winter wheat

For yield measurements of barley, summer wheat and winter wheat the same method was used. To measure yield transects of 15 m in length were placed on the field on various distances from the alley (see table 2.).

Table 3. Shows distances from alley to transects per field, and number of transects per field per distance.

Field 2.	Winter wheat (distance to alley)	1,5m	5m	13,5m	
	Number of transects	6	6	3	
Field 4.	Barley (distance to alley)	1,5m	5m	10m	28m
	Number of transects	6	6	6	3
Field 6.	Summer wheat (distance to alley)	1,5m	5m	11,5m	
	Number of transects	6	6	3	

Location of transects depended on the field and accessibility. Figure 12 and 13 show location and transects of field 2 as example. Transects of all fields can be found in appendix 2.

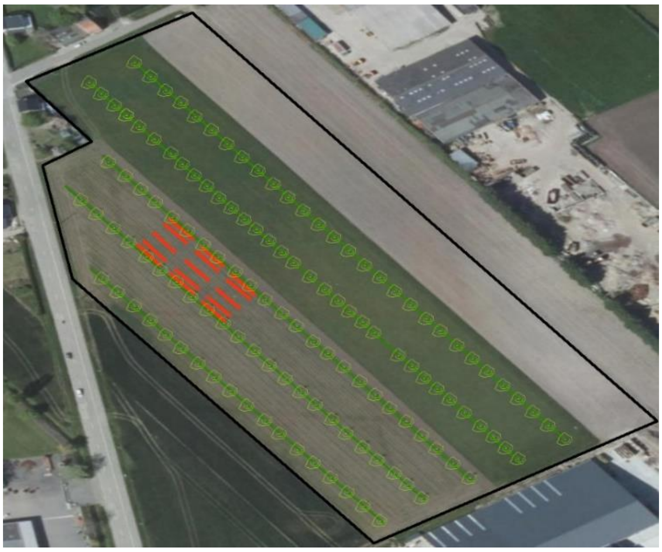

Figure 12. Location transects yield measurements field 2.

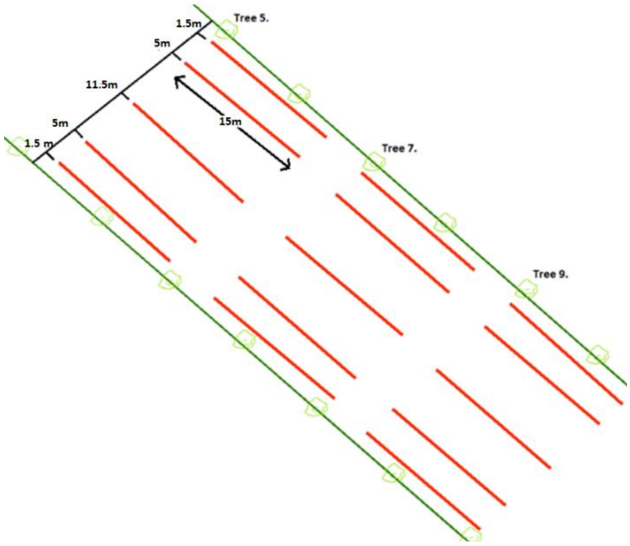

Figure 13. Shows location and length of transects and distance from alley to transect.

The transects were harvested with a machine which has a 1.5 m width. The grain harvested was weighted per transect. A sample of grain was taken per transect to determine the dry matter content. Per transects an area of around 22.5m^2 was harvested. To calculate the exact area, transects were remeasured after being harvested. Due to inaccuracy of the machine it was not possible to harvest an exact 15 m. After remeasuring the total area harvested per transect could be calculated with the formula:

Area harvested = 1.5 m * real length transect (m)

With weight, area, and dry matter known the yield per hectare for each transect could be calculated with the formula:

$$\text{Yield (ton/ha)} = \frac{(\text{ yield per m2 } * 10000 * (\text{Dry matter}/100))}{1000}$$

Maize

Yield measurements of maize were taken on several distances from the alley on plot 1 and 3 (see table 4).

Table 4. Shows distances from alley to transects per field, and number of transects per field per distance

Field 1.	Maize (distance to alley)	2m	5m	13m	50m
	Number of transects	6	6	3	3
Field 3.	Mazie (distance to alley)	2m	5m	12.5m	
	Number of transects	6	6	3	

Depending on the accessibility of the field transects were chosen, as example see figure 14 and 15 (see appendix 3 for transects of field 1 and 3).

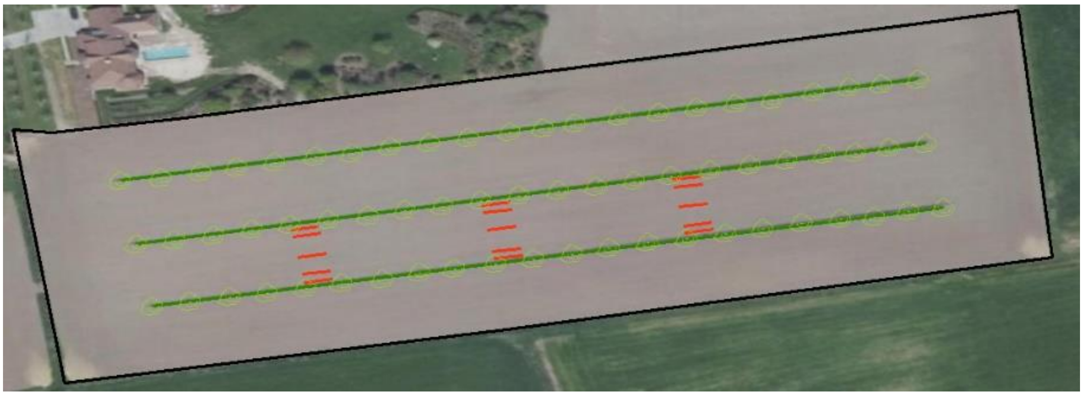

Figure 14. Location transects maize field 1

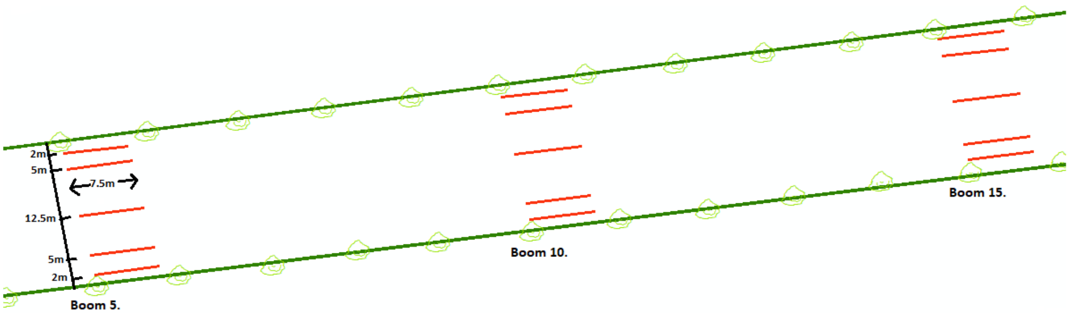

Figure 15. Red line indicates transects on several distances from the alley on field 1.

The transects had a length of 5 and were 1.5 m wide, each consisting two rows of fodder maize. The total area harvested was 7.5m^2 per transect. The whole plants were harvested (see figure 16 and 17).

Figure 16. Harvest of corn stalks

Figure 17. Harvested corn stalks of one transect

The total weight of all plants combined (corn stalks and corn cobs) were weighted per transect. After weighting five corn stalks (including corn cobs) were taken to determine the moist content.
Per transect the yield per hectare was calculated. Following calculations were used:

$$\textbf{Yield per m2} = \frac{\textbf{Weight of corn stalks and corn cobs}}{\textbf{7.5 m2}}$$

$$\textbf{Yield (ton/ha)} = \frac{\textbf{Yield per m2 * 10000 * Dry matter content}}{\textbf{1000}}$$

During the yield measurements one of the ovens caught fire, and samples of field 3 to determine the dry matter of maize were burned. To save the test new samples were taken from the field, near the plots to calculate the dry matter content and a comparison between different distances could be made. The new samples were taken couple of days after the oven burned. During this period the moist content in the maize could have changed. This data was used to calculate the yield per hectare, but due to possible moist changes the exact yield cannot be determined, and the data can only be used to compare transects of the field.

3.4 DATA ANALYSIS

1. Colonization of arthropods on agricultural fields

The insect abundance was analysed per field. Because that there were lots of differences between fields regarding soil, tree height, undergrowth, management, climate and different crops, and sowing/planting period of crops.
SPSS v.25 was used to create a Generalized Linear Mixed Model (GLMM) with a loglinear Poisson distribution. The GLMM was used to show if there was a significant difference ($p>=0,005$) for:
abundance per distance * abundance per period, abundance per period, and abundance per distance.

The book ecological methods 1 uses a Poisson distribution to analyse data containing: count data sampled over different periods on the same plots (Boer, Heitkoning, & Langevelde, 2017). For this research Poisson is used because count data is usually not normally distributed and 0's can be analysed in this model. Poisson can manage count data and is a good model to progress this data. Count variables often follow a Poisson distribution (Karen Grace, n.d.). A Poisson distribution can take integer values 0, 1, 2, 3, … and counts of the number of insects in a region take integer values only (Jongman, Braak, & Tongeren, 1995).

The GLMM did not work on centipedes, millipedes, and woodlice. The data was zero inflated and an error occurred. To tell something about these measurements per group the sum of insects per distance has been taken per field, and the sum of insects per period per field. The sum of insects per distance has been recalculated to 10 traps per distance. Because a different number of traps was used on several distances. Observations or trends seen in this data will be mentioned, but further research will be necessary.

2. Effect of alleys on crop yield

Per field a one-way anova was conducted to see if there was a significant difference in crop yield (variable factor) on different distances (fixed factor) using SPSS v25 (see table 5 for example). An oneway-anova can be used to see if there is a significant difference be two factors (Boer, Heitkoning, & Langevelde, 2017). To see if the data had a normal distribution a test of normality was conducted, if data is not normally distributed a one-way anova will not give reliable results (Boer, Heitkoning, & Langevelde, 2017). To test normality the Shapiro-Wilk test was used.

Field 4 was the only field that did not have a normal distribution. For this field the variable factors were transformed using log10, which is commonly used to transform data of growth or biomass (Boer, Heitkoning, & Langevelde, 2017). After transforming the data, the Shapiro-Wilk test was repeated, and the data showed a normal distribution. After normality was checked and confirmed the one-way anova was executed.

Table 5. Example of data input in SPSS v 25. for Anova.

Distance to alley (m)	2	5	12,3
Yield ton/ha	13,4	16,1	14,7
	11,0	13,0	8,3
	9,1	9,8	14,7
	8,7	6,9	
	11,5	15,5	
	17,3	17,7	

4 RESULTS

4.1 COLONIZATION OF ARTHROPODS ON AGRICULTURAL FIELDS

Table 6 shows the total number of insects captured per field in the research period. The GLMM used to see if there was a difference in abundance per period, abundance per distance and abundance per period*distance worked on rove beetles, carabids, and spiders. It did not work on woodlice, centipedes, and millipedes, because for this model not enough insects were captured and there were to many zeros to run the model. Trends and observations for these groups will be given.

Table 6. Number of insects per group captured per field

	Plot 1. Maize	**Plot 2.** Winter wheat	**Plot 3.** Maize	**Plot 4.** Barley	**Plot 5.** Potatoes	**Plot 6.** Summer wheat
Woodlice	117	356	225	408	92	251
Centipedes	137	4	198	157	127	85
Millipedes	0	3	23	125	26	17
Rove beetles	1454	1386	736	2115	911	2209
Carabids	1290	1184	1261	1510	1831	4677
Spiders	1542	2700	761	2251	2317	6497

Within the results the effects of different crops will be discussed, as well as possible differences between conventional and organic farming.

16 of 18 insect groups showed a similar trend in abundance of insects on arable land. The trend was that increase and decrease of insect abundance occurred simultaneously on fields, as example see figure 18 (see appendix 4 for all trends). Only two situations were statistically different. There was no clear trend or development from alleys to the field, meaning the abundance of insects is dependable on different factors.

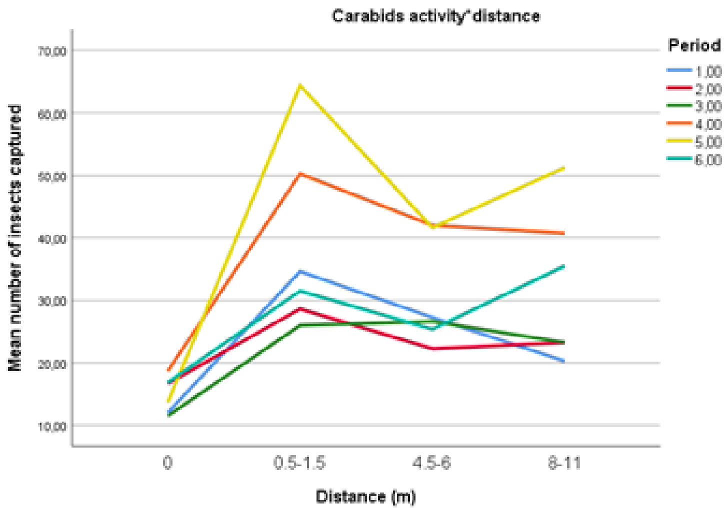

Figure 18. Carabid abundance per period per distance field 6. Per distance insect abundance develops simultaneously

4.1.1 Development of insect abundance on during growing season

Table 1 shows mean rove beetle abundance during all periods for all plots. The GLMM is determined per field and results can be found in appendix 5. The dark green colour presents the highest insect abundance and the red colour the lowest (see figure 19). Despite differences between the fields, highest insect abundance occurs in period 4 and 5, and the lowest in period 1, 2 and 3 (see table 7). There are no major differences between organic (plot 5 & 6) and the other plots. In period 6 the abundance is lower for most plots. In general, all plots follow a similar trend meaning that crops do not influence rove beetle abundance on a field.

Figure 19. Colour chard insect abundance

Table 7. Rove beetle abundance per period (mean number of insects captured per trap represented in table)

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-06-2018	5-07-2018
1			16	9	21	16	8	3
2		6	6	6	13	24	27	
3					13	16	5	13
4		22	17	6	42	25		
5		9	2	9	17	15	7	
6		6	5	8	23	31	6	

Table 8 displays the carabid abundance. Same as the rove beetles the highest abundance occurs in period 4 and 5. The overall abundance in organic plots is higher than the conventional plots. Plot 1 had a constant insect abundance.

Table 8. Carabid acticity

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-06-2018	5-07-2018
1			12	8	19	12	11	12
2		2	6	4	12	7	31	
3					23	18	11	29
4		11	18	10	24	20		
5		22	18	22	32	26	7	
6		22	22	21	36	37	26	

Table 9 illustrates the spider abundance per period. The highest abundance occurs in period 4, 5 and 6. Spiders abundance in period 1, 2 and 3 is low. There are no major differences in abundance between organic and conventional farming. Organic farming plot 6 shows a slightly increased abundance.

Table 9. Spider abundance

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-06-2018	5-07-2018
1			6	6	13	24	16	15
2		7	13	13	39	41	51	
3					8	17	9	9
4		15	19	12	22	50		
5		11	21	17	41	31	38	
6		9	33	25	61	66	47	

Observations

Marked with green are the two periods were most insects were captured. Centipedes are most caught in period 4, 5 and 6. It shows that during this period the abundance is the highest. There is not a lot of difference between conventional and organic plots. Field 4 shows the highest abundance. See appendix 6.

Table 10. Sum of centipedes captured per field per period.

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-6-2018	5-7-2018
1			1	1	25	48	55	7
2		0	0	0	0	1	3	
3					7	5	5	4
4		21	43	27	26	40		
5		6	3	7	80	25	6	
6		9	7	14	26	23	6	

Millipedes are almost not active on arable land. Few millipedes were caught, showing that a different habitat is preferred (see table 11). The activities on plot 4, 5 and 6 are higher, but there is not a period that they are most active.

Table 11. Sum of millipedes captured per field per period

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-6-2018	5-7-2018
1			0	0	0	0	0	0
2		0	0	0	1	1	1	
3					13	4	3	3
4		12	20	46	28	19		
5		12	6	2	5	1		
6		7	7	1	2	0	0	

There is no clear trend or period with most abundance for woodlice (see table 12). Showing that they are probably less influenced by local climate, but are more dependent on different factors.

Table 12. Sum of woodlice captured per field per period

	Period	1	2	3	4	5	6	7
Field	**Pitfall trap emptied:**	3/4-05-2018	14/15-05-2018	24/25-05-2018	4/5-06-2018	14/15-06-2018	25-6-2018	5-7-2018
1			21	38	25	6	9	18
2		26	56	50	156	46	22	
3					83	26	39	67
4		44	129	66	111	58		
5		35	28	12	12	4	1	
6		43	60	96	25	24	3	

4.1.2 Influence of alleys on insect abundance

Because insect abundance increases and decreases simultaneously it is possible to compare the mean abundance per distance on a field. Meaning despite increases or decreases per period, the insect abundance per distance, remains compared to each other the same.

Table 13 shows the rove beetle abundance per distance. On four plots there is no difference between the tree line and the centre of the field. This means that for four plots alleys have no influence on rove beetle abundance. On plot 4 and 5 there is an increase in abundance moving away from the tree lines. This means that the trees or the undergrowth in the alley influenced rove beetle abundance. Compared to other fields, field 4 shows a higher abundance.

Table 13 Mean rove beetle abundance per distance per field

Field	0	0,5-1,5	4,5-6	8-11	>14
1	6	15	14	15	6
2	11	14	11	10	10
3	10	16	11	9	
4	8	17	21	21	40
5	6	6	12	11	
6	11	9	11	10	

In 3 scenarios distance from tree line does not influence the carabid abundance (see table 14). In plot 3 there is a higher abundance in the alley and a lower abundance on the field. On plot 5 and 6 the highest abundance occurs between 0,5 and 6 m from the alley. In all three scenarios the alleys have a certain effect on insect abundance. The highest abundance was found close to the trees. The conventional field 3 and the organic fields 5 and 6 show a slightly higher abundance of insects.

Table 14 Mean Carabid abundance per distance per field

Field	0	0,5-1,5	4,5-6	8-11	>14
1	15	15	11	9	10
2	10	11	7	5	5
3	30	20	14	17	
4	14	17	15	14	20
5	15	20	27	16	
6	15	37	30	31	

On three plots there is no distance effect from tree line on spider abundance, meaning alleys do not have an effect in these scenarios (see table 15). In plot 1 and 3 a higher abundance seems to occur in the alley and decreases further away from the trees. Plot 6 shows a lower abundance in the boundary and higher abundance in the field. For field 1 and 3 a clear effect is visible and alleys effect

Table 15. Mean spider abundance per distance per field

Field	0	0,5-1,5	4,5-6	8-11	>14
1	24	15	11	8	8
2	16	26	20	26	22
3	25	11	6	6	
4	19	24	22	23	18
5	29	25	20	21	
6	25	40	34	38	

Observations

The two highest values are marked with a green colour per field. See appendix 7.

Centipedes

Centipedes show the strongest abundance on 0,5 – 6 m. Here is the highest abundance of centipedes.

Table 16. Number of centipedes captured per 10 pitfall traps per distance per field

Field	0	0,5-1,5	4,5-6	8--11	>14
1	**10**	**29**	**24**	**29**	**11**
2	**2**	**1**	**0**	**0**	**0**
3	**3**	**6**	**3**	**1**	
4	**16**	**19**	**20**	**17**	**14**
5	**5**	**6**	**23**	**38**	
6	**6**	**6**	**6**	**3**	

Millipedes

Millipedes have the highest abundance from 0 – 1,5 m. Further from the alley the abundance decreases. Field 3 is an exception and on field 1 no abundance.

Table 17. Number of millipedes captured per 10 pitfall traps per distance per field

Field	0	0,5-1,5	4,5-6	8--11	>14
1	**0**	**0**	**0**	**0**	**0**
2	**1**	**0**	**0**	**0**	**0**
3	**3**	**2**	**5**	**10**	
4	**17**	**17**	**17**	**10**	**6**
5	**8**	**2**	**1**	**0**	
6	**4**	**1**	**0**	**0**	

Woodlice

Most abundance of woodlice occurs from 0 to 1,5 m in the alley. The huge number of woodlice shows that the abundance is probable due to suitable conditions tree provide.

Table 18.Number of woodlice captured per 10 pitfall traps per distance per field

Field	0	0,5-1,5	4,5-6	8--11	>14
1	**42**	**3**	**2**	**3**	**0**
2	**66**	**53**	**20**	**9**	**2**
3	**84**	**4**	**1**	**1**	
4	**99**	**50**	**34**	**19**	**7**
5	**33**	**3**	**1**	**2**	
6	**50**	**7**	**4**	**9**	

4.2 CROP YIELD

Because different types of crops were grown results will be discussed separately. Unfortunately, no yield measurements were taken of plot 5.

Field 1 shows that at 45 m the maize yield is higher than closer to the tree line (see figure 19). The yield is almost doubled on the distances 1.5, 4.5 and 10.5 variated between 7.5 and 8.4 ton/ha. On 45 m the yield was 12 ton per hectare. Meaning the yield in between the allies is 30-38% lower than the yield at 45 m.

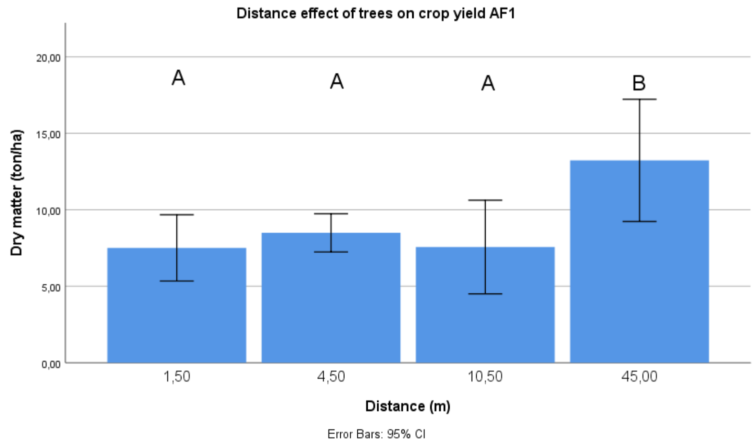

Figure 20. Yield measurement per distance (ton/ha) maize

On field 2 were winter wheat is grown the alleys had no effect on the crop yield (see figure.

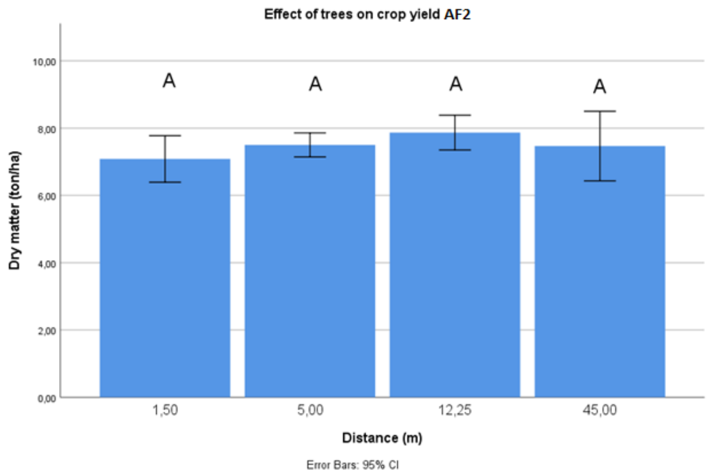

Figure 21. Yield measurement per distance (ton/ha) winter wheat.

No effect on maize yield was observed on field 3.

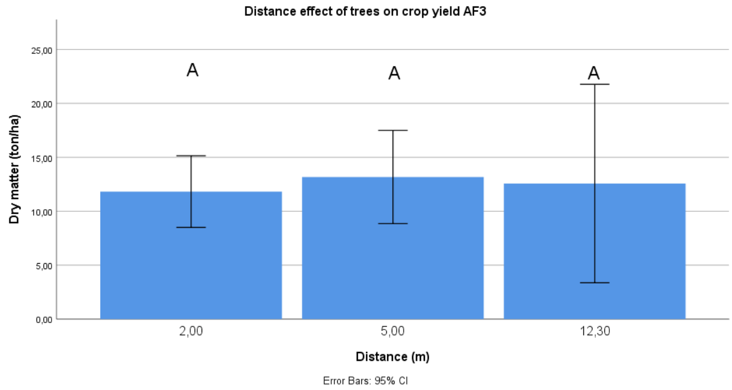

Figure 22. Yield measurement per distance (ton/ha) maize

There was a significant difference on field 4. The further away from the alley the higher the yield. Compared to 22 m the yields at 1.5, 5 and 10.6 m were between 21,5 and 25% lower.

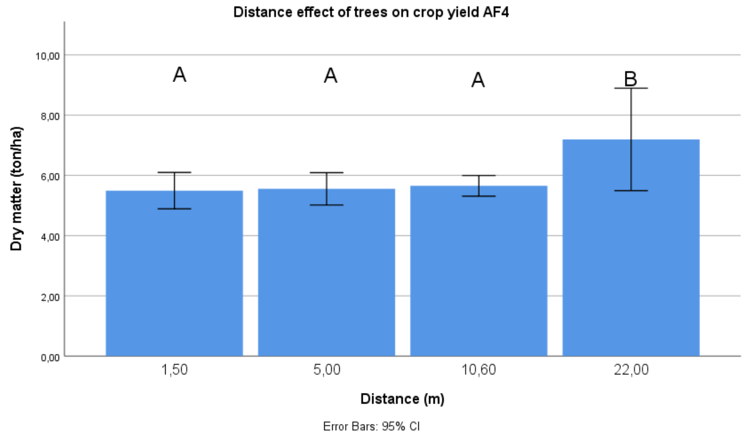

Figure 23. Yield measurement per distance (ton/ha) barley

Plot 6 shows that if moving from the alley the yield is increasing. Compared to the highest yield at 1,9 m there is a yield reduction of 17 % and on 4,85 there is a yield reduction of 7 %.

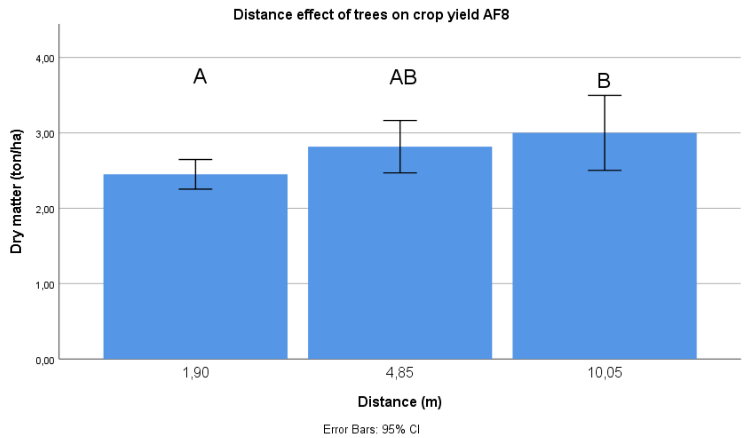

Figure 24. Yield measurement per distance (ton/ha) summer wheat

5 DISCUSSION

In general, there were lots of differences between the field regarding: soil, the distance between different fields, distance between alleys, orientation of alleys, trees and undergrowth in alley, management practices, different crops, and time insect abundance was measured. Due to the high variety it was difficult to compare data. During the research several outside influences effected the research, possibly influencing the results. Firstly, the outside influences will be discussed. Secondly, the results will be discussed. The discussion of the results follows the same order as previous chapter.

5.1 OUTSIDE INFLUENCES

Arthropod abundance in alley cropping systems

During the insect capture some traps contained a mouse. If a mouse was in a trap it could be smelled, meaning the odour spreads and attracts another insects/animal. It was noticed in most cases that if a mouse was trapped flies were also present in the container, proving a dead mouse can attract insects. Possible, the dead mouse also attracts more species of the target groups, leading to a higher insect abundance.

When open containers were placed the goal was to sink them into the ground on the same level as the soil. Sometimes, this was not entirely possible due to drought, which resulted in that some edges were not on the same level as the soil, possible preventing insects to enter the pitfall traps, reducing number of insects captured. Some traps were also moved by mouse or moles, moving the traps a little up, possible preventing insects to enter.

A total of four traps have been damaged by a farmer on field 5 and data from these traps could not be used. The damage occurred during several periods, so data was not influenced much, and per period still enough traps remained to tell something about the data.

At the start of the research some difficulties were encountered to separate different insect groups from each other and some groups were mixed with others, leading to possible higher counts in the beginning of the research.

Effect of alleys on crop yield

On field 4 with barley the farmer used by accident more fertilizers in the centre of the field, which probably increased yield in the centre of the field. Transects of centre of the fields were moved to a part where the same quantity of fertilizer was used.

Field 5 were potatoes were planted no yield measurement was taken. Parts of the field were invaded by the Colorado beetle, effecting big parts of the field, and in this way effecting the yield. Also, part of the field was harvested, which would have made it more difficult to do yield measurements. For this reason it was chosen not to conduct yield measurements.

Field 6 with summer wheat was sown in rows of 4 and 6. During the harvest for different distances some distances contained 4 rows and other 6 rows. The distance between rows was the same, for this reason the 4 rows were recalculated to match the 6 rows, so yield could be compared. However, difference might have occurred in growth, because of this difference effecting the yield measurements and comparison between the different distances.

5.2 ARTHROPOD ABUNDANCE

Colonization of arthropods on agricultural fields
Most fields (16 out of 18) with rove beetle, carabids, spiders showed that increases and decreases occur simultaneously on the field. This means that during the time the measurements were taken no visible colonization from alley to the field took place.

Development of insect abundance during growing season
All carnivore's species (rove beetles, carabids, spiders, and centipedes) showed a higher abundance in period 4 and 5 (4-06-2018 -15-06-2018) on all fields. Most crops had a further development in this period, possible increasing abundance of other insect species, and increasing food availability. It is possible that it has to do with climatological factors, such as temperature, moist, or wind, because the trend was seen on all fields, which varied in crops, trees, undergrowth, and openness op the landscape. To understand why this increase in this period occurs more research is needed.

Observations from a research in Canada to rove beetles showed a similar most active period in June/July (Brunke, Bahlai, Klimaszewski, & Hallett, 2014). This research analysed to specie level, and showed difference between species living in hedges and species living on arable land, but outside growing season all species were found in hedgerow habitats (Brunke et al., 2014). Despite lower abundance in some scenarios this still suggests that hedgerow/ alleys are necessary for rove beetles.

Carabids showed a higher abundance on organic fields compared to conventional fields. Other research showed that increases in both species richness and abundance occurs on field together if not treated with herbicides (Purvis & Curry, 1984).

Spiders showed a slightly increased abundance on the organic plots. A possible cause is that distance between alleys is shorter and due to trees a higher variety of spiders is active (Galle & Batary, n.d.).

The detritivores species (millipedes, and woodlice) did not show a similar trend, meaning abundance was depending on different factors. This probably has to do with the availability of organic matter, and during growing season less dead plant material is available. Higher abundance in the alleys shows that here is more organic matter on the surface. On the agricultural field, due to turning the soil, organic matter goes to deeper surface layers and is not available for woodlice (Paoletti & Hassall, 1999)., but it can be available for woodice

Influence of alleys on insect abundance

Analysing results for abundance per distance shows that in most scenarios no difference occurs in abundance per distance. For situations were a higher abundance occurred on a certain distance the circumstances are analysed.

The rove beetle abundance is not influenced by the alley on four field. Only field 4, and 5 show a decrease in abundance, which might be a result of undergrowth on these plots. On field 4 no undergrowth is present due to the dense structure, possibly reducing pray for rove beetles and on plot 5 a combination of grass-clover is present.

The carabid abundance is increased in plot 3, compared to the other plots, in the alley were several types of weeds and grain grow. Manure was added on the fields before the maize was sown. Application of fertilizer is generally beneficial to carabids (Holland & Luff, 2000). Also, non-crop habitat is important to carabids since they provide margins for shelter, breeding or dispersal (Holland & Luff, 2000). Despite the lower abundance in the alley on field 5 and 6 it is possible the alley still provides shelter, since the overall abundance of arthropods was highest on these fields.

Spider abundance is increased on fields 1 and 3, compared to other plots. On these plots the undergrowth are weeds and wheat. A higher variety of plants can be the reason for the higher abundance of spiders on these fields. Towards the centre of the fields the abundance decreases. Crops grown on these fields are maize, with leaves a lot of barren land, possibly effecting the abundance of the spiders to the centre of the field. Field edges show a higher trait of diversity and can give a higher biocontrol potential (Galle & Batary, n.d.).

For centipedes and millipedes, a higher abundance is observed from 0,5-6 m of the trees. Centipede richness is mainly related to diversity of hedgerow tree layer (Stašiov, Diviaková, Svitok, & Novikmec, 2017). An alley with trees has a similar structure to a hedgerow. Hedgerow are important refuges for several species of woodlice and centipedes (Stašiov et al., 2017).

Woodlice are mainly active in the ally and close to the alley. This can be explained, because woodlice rapidly decline in intensively managed agricultural landscape and are more common in woodlands (Paoletti & Hassall, 1999).

5.3 EFFECT OF TREES ON CROP YIELD.

Summer wheat is sown in spring and its development takes place at the same time as trees are growing their leaves. There is a clear difference between wheat sown in winter and wheat sown in spring.

Competition between trees and summer wheat is visible if sown in spring. And a higher yield occurs closer to the centre of the field and a lower yield occurs closer to the alleys. Same results were found in the research impact of spatio-temporal shade on crop growth and productivity, perspective for temperate agroforestry (Artru, 2017).

Winter wheat is sown in autumn. Main growth takes place before trees grow leaves. For this reason, trees do not influence growth much, making wheats a suitable crop to grow alongside trees.

Barley shows a higher yield further away from the trees, despite being sown in autumn. This might be possible due to more hedge-like structure of the alley, providing shade even in winter, reducing yield closer to the alley. This can also be explained by shade effect. Also, a reason why yield between alleys is lower is because competition between trees and crops occur.

Maize also shows a higher yield further away from the trees, which can also be explained by the shade effect.

6 CONCLUSION

After analysing the results and answering the sub questions the main questions can be answered. The first main question was: ’What is the influence of silvicultural alley-cropping systems on the development of arthropod abundance?’. The second was: ‘What is the effect of trees in silvicultural alley-cropping systems on crop yield?’.

In general implanting alleys improves insect abundance and provides undisturbed areas where insects can take shelter in winter. Compared between conventional and organic farming organic farming shows in general a higher insect abundance. Converting from conventional farming to organic farming can be a major step to increase insect diversity. During the research another factor occurred and that is the undergrowth of the alley. A low diversity has a lower insect abundance and a more diverse vegetation seems to increase insect abundance. Diversifying undergrowth could significantly increase insect abundance in both conventional and organic farming. More research on this topic is necessary.

Despite the benefits to insect abundance alleys decreases yield. More effect is seen in crops sown in spring and have light competition with trees, because they grow simultaneously. Crops sown in autumn are less/not affected by the alleys. Unless the alley is having a hedge like structure, preventing light to reach the field, in this case yield is lower despite being sown in autumn. Overall, there is a clear shade effect on the growth of crops in alley cropping systems.

The yield of organic farming is significantly lower than yield from conventional farming plots. This has mainly to do with different management practices and lower density of crops on the field. Reason is that machines used to remove weeds else cannot enter.

Despite the difference in mean insect abundance on different plots the increases and decreases of abundance have a similar trend on all the fields. This means that these are not dependable on management practices. Overall abundance is dependent on crops and management practices but varied very per field.

Overall agroforestry reduces production but increases insect abundance. Biodiversity of soil arthropods is important for ecosystem health and are needed for decomposition, nutrient cycling, carbon storage, water infiltration and storage, and natural pest control. Reduced yield is a more sustainable option then loosing this biodiversity and loosing these functions. On time the trees will produce fruits, nuts and other products, which can compensate for the lost yield.

7 RECOMMENDATIONS

Following recommendations are based on the results of this research and on problems encountered during the research. These recommendations are aimed to improve agroforestry practices in Flanders and research regarding agroforestry.

Many different variances between plots and farmers made it difficult to analyse and compare data. It is not possible to tell farmers what trees to grow or what distances need to be between there alleys, because these are dependable on machines used and the products the farmer wants to produce with his/her alley. In order to collect more similar data, it is a possibility to see if farmers are willing to follow the same crop rotations, with same variances of crops. In the alleys it is suggested that farmers plant/sow the same undergrowth, a mixture of grasses could be a possibility. This way more similar circumstances are created making it easier to understand trends.

Capturing insects only took place for a couple of months from 23-4-2018 to 5-7-2018. To understand insect abundance, it is better to measure insect abundance during the whole year. After harvest there might be abundance to the field, or before crops are sown or planted, some abundance might already be occurring on the field.

Many mice died during the research, for future research this can possible be prevented by putting chicken wire on the traps, so mouse do not fall in.

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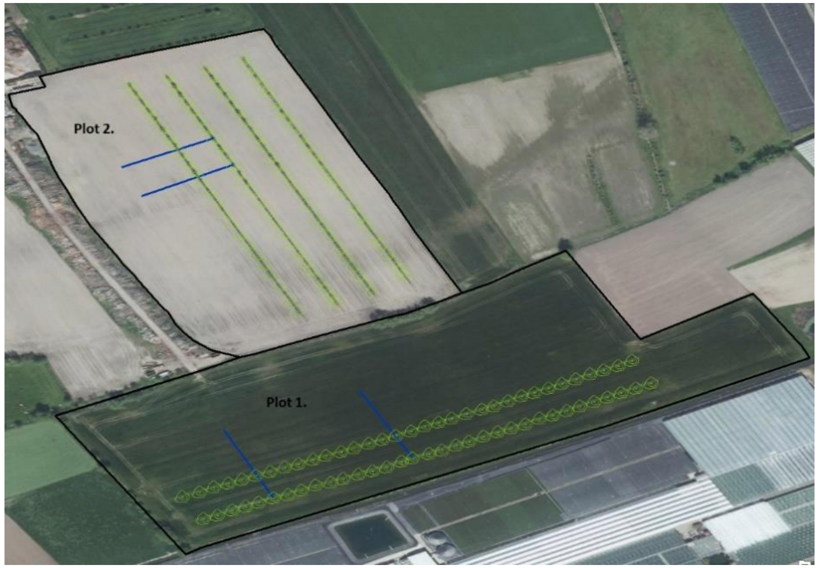
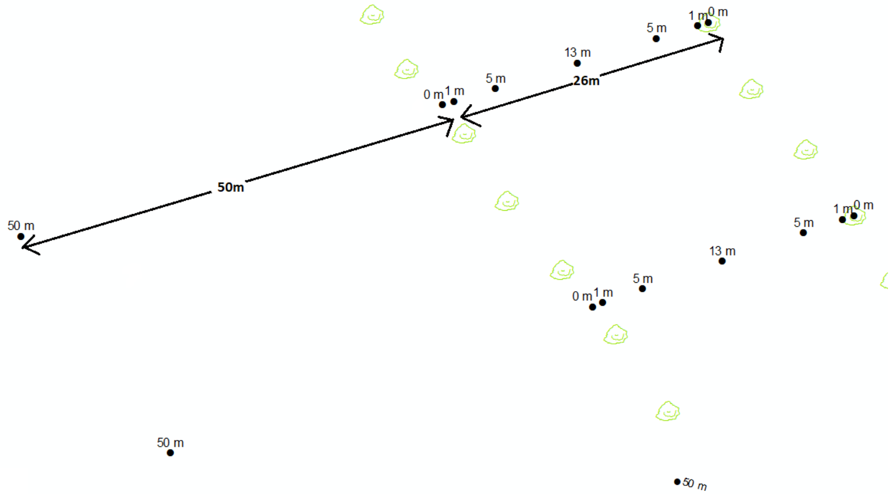
Appendix 1. Location of transects and placement of pitfall traps

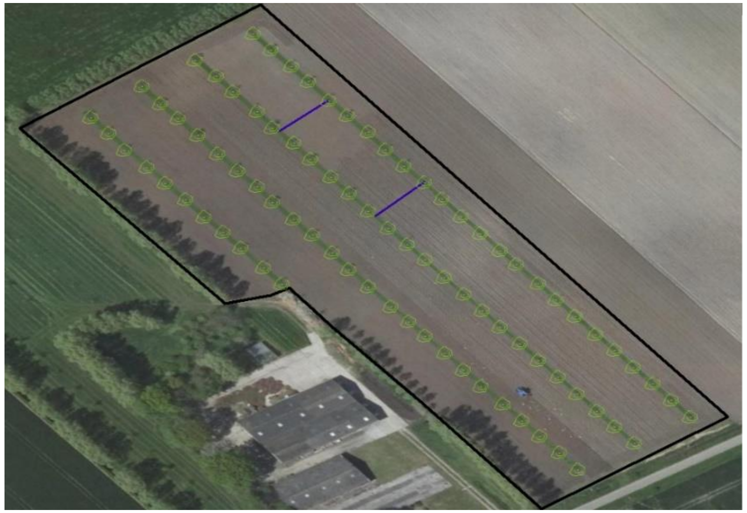
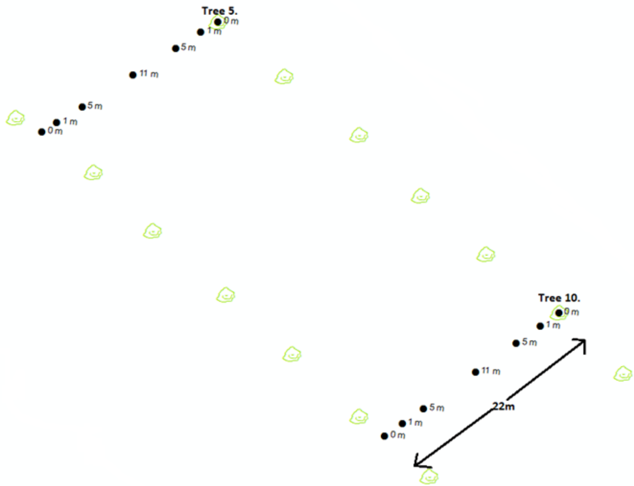
Field 1 & 2.





Field 3.

Field 4.

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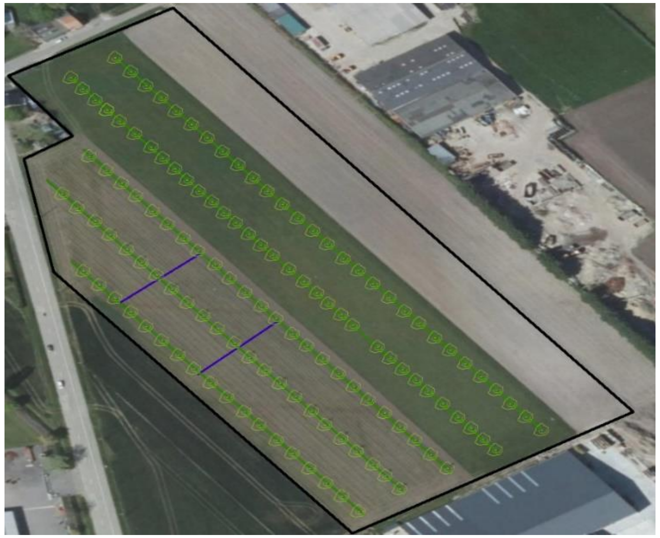
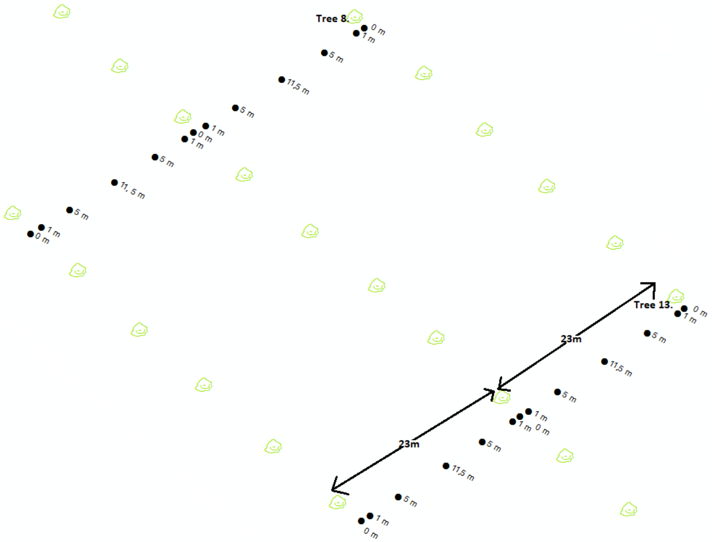
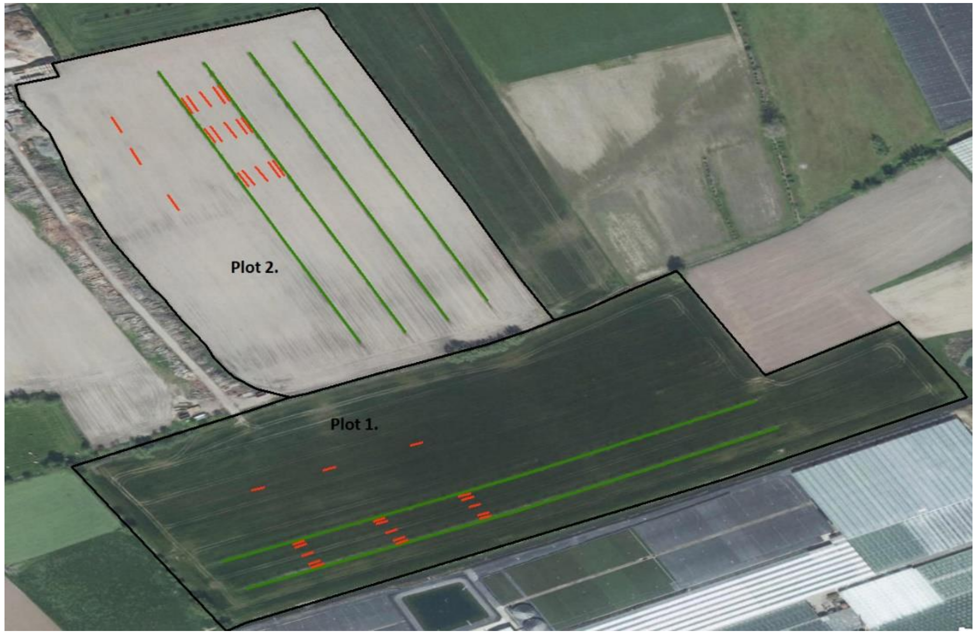
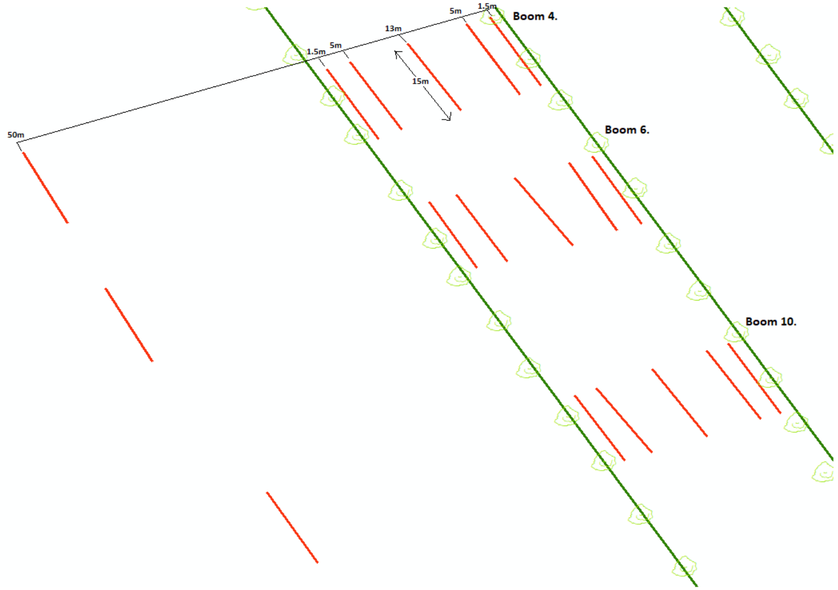
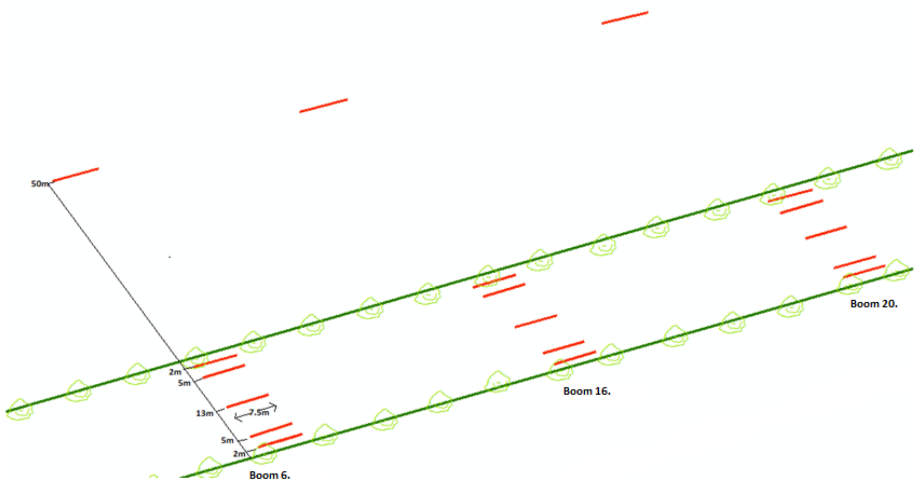



Field 6.

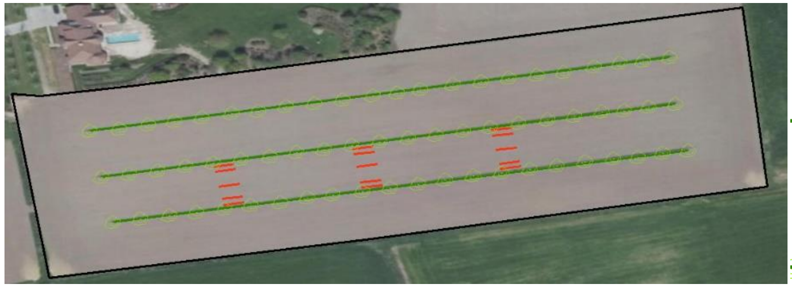
APPENDIX 2. TRANSECTS YIELD MEASUREMENTS PER FIELD

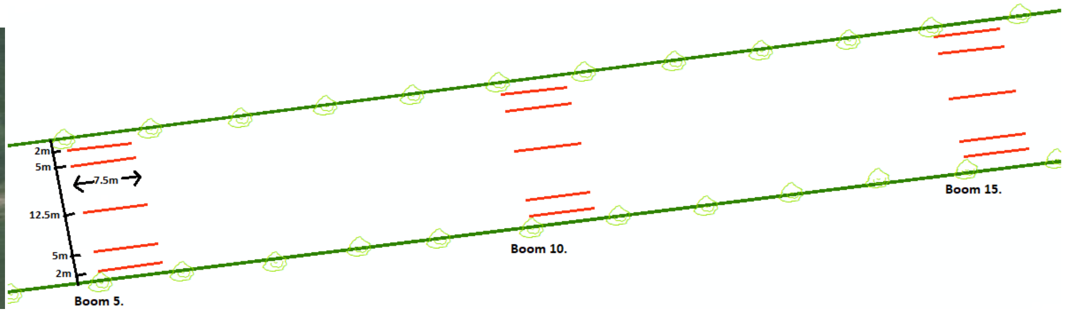






Field 1 & 2.





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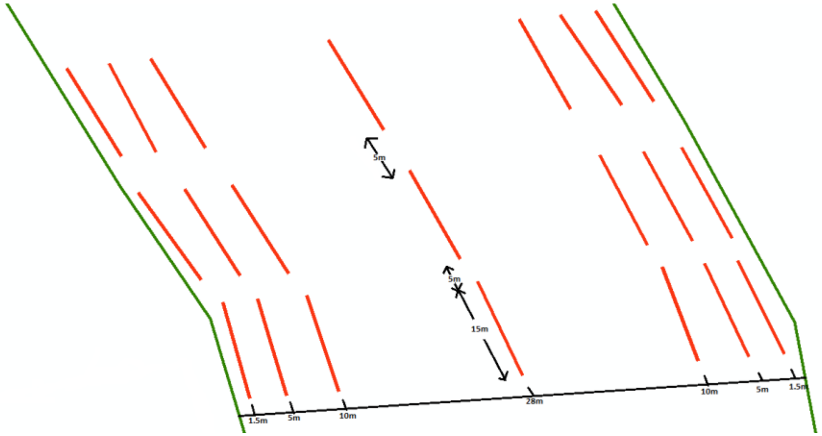

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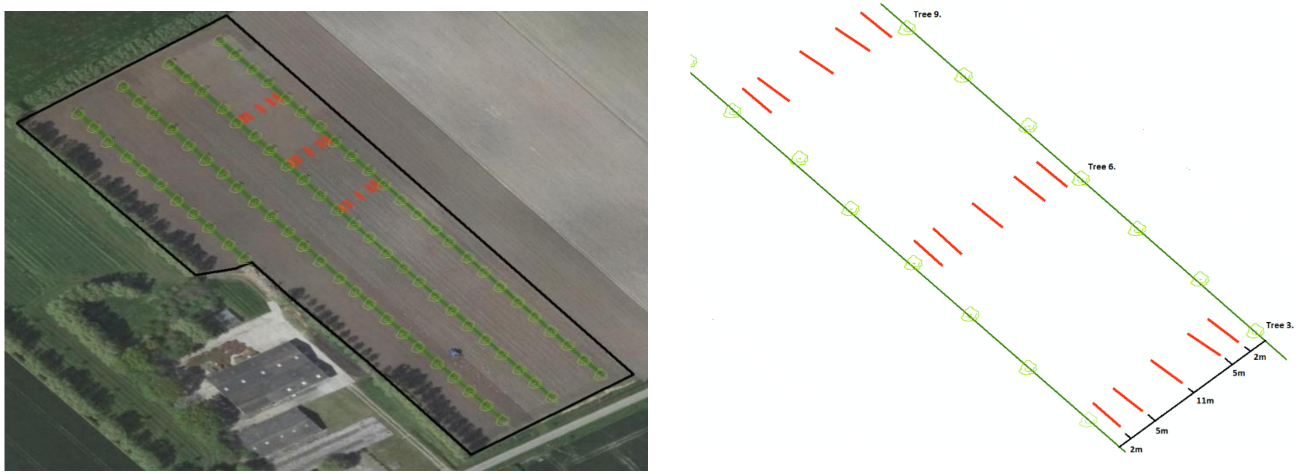
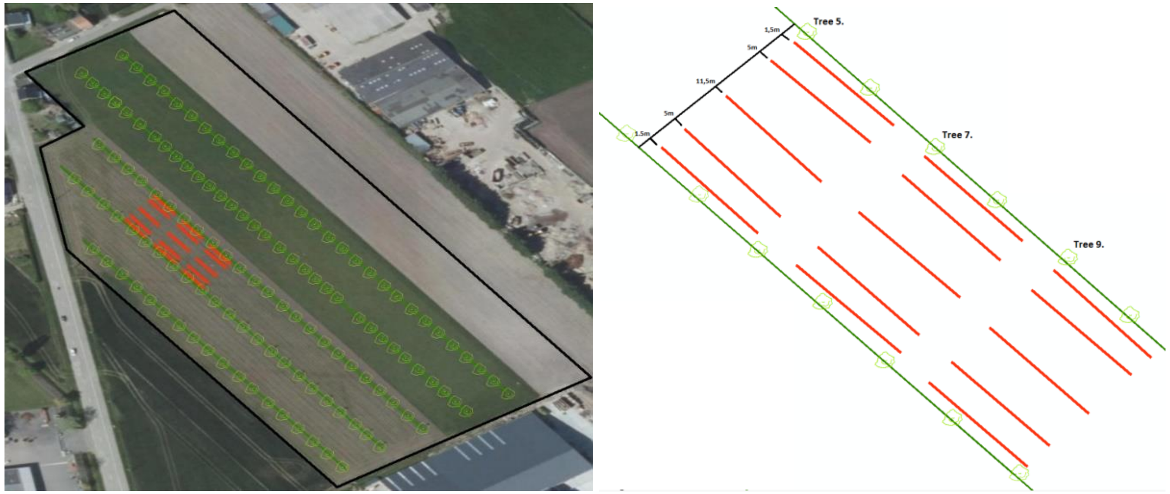


Field 5.

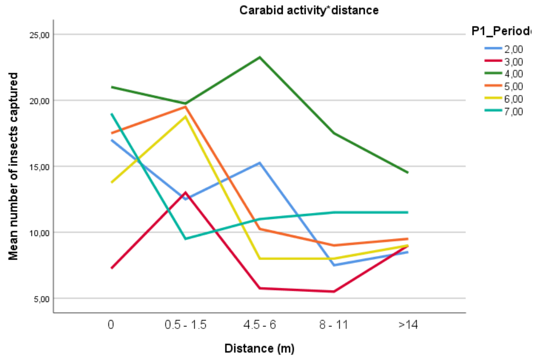


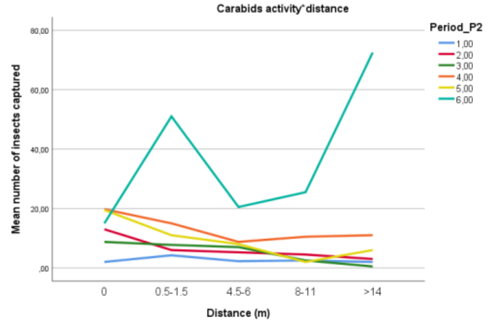
Field 6.

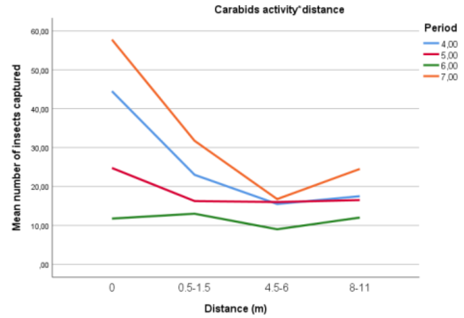
Appendix 3. Distance*Period per Field

Field 1. **Field 2.** **Field 3.**

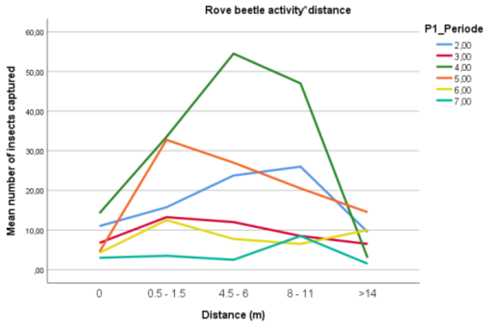
Carabids

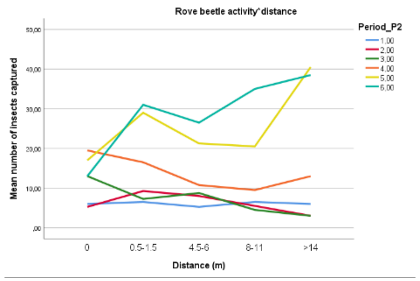


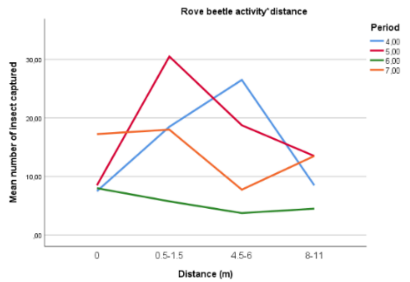




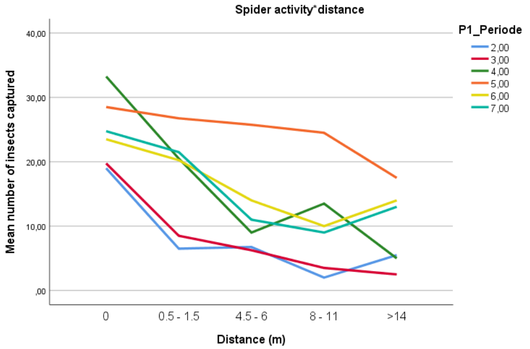
Rove beetles

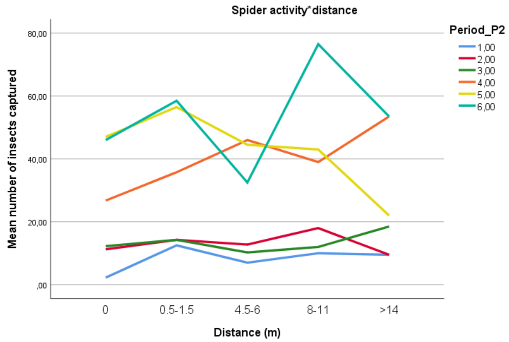


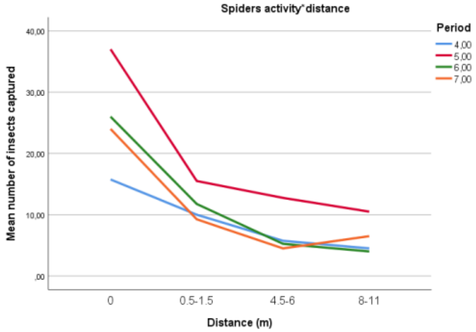




Spiders

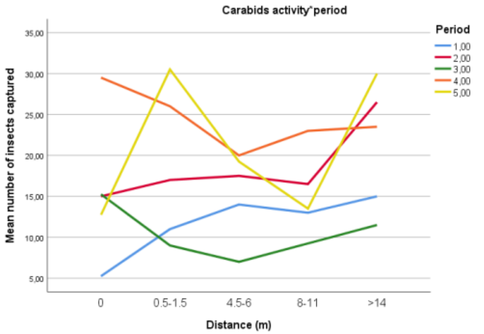


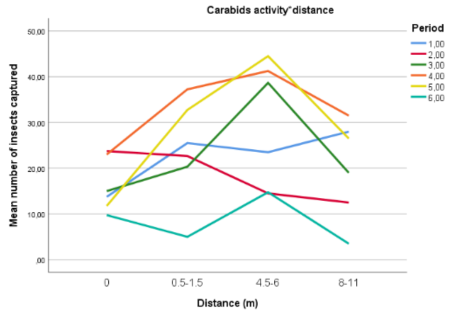


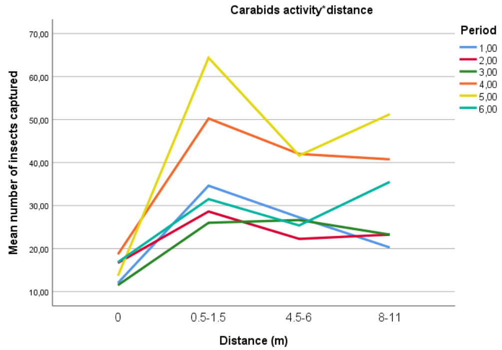


Plot 4. **Plot 5.** **Plot 6.**

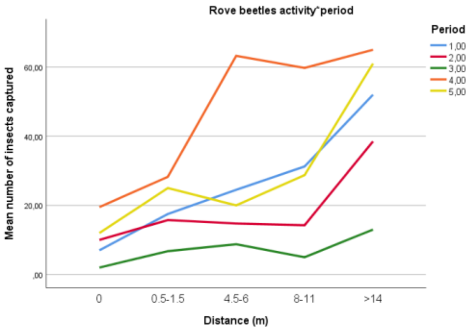
Carabids

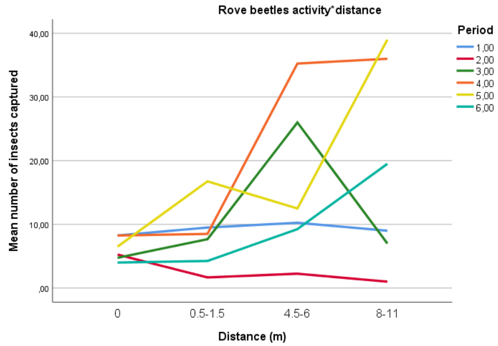


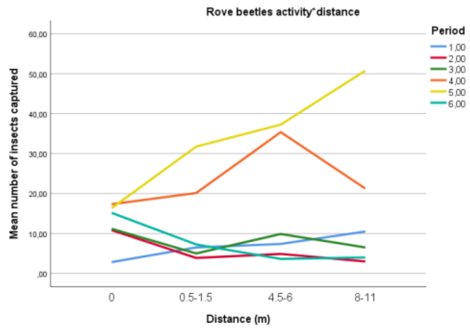




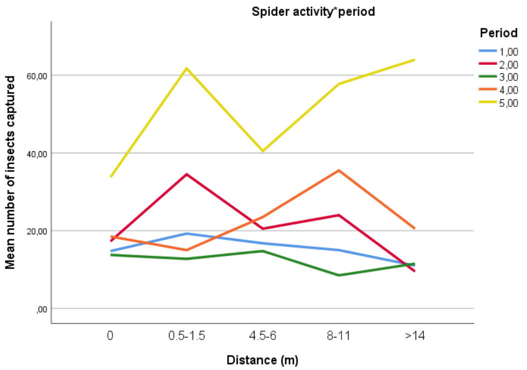
Rove beetles

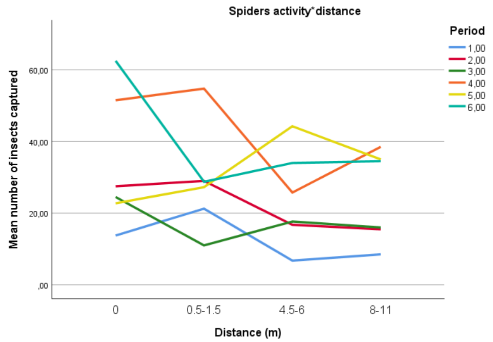


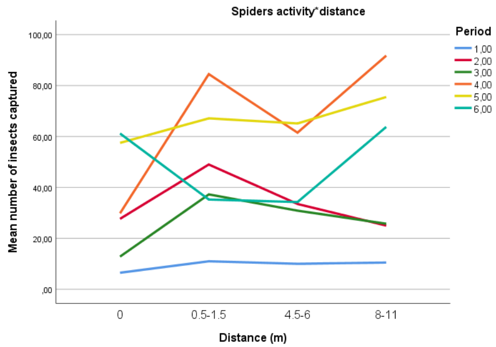




Spiders



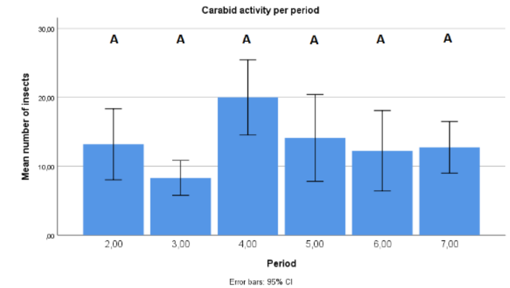


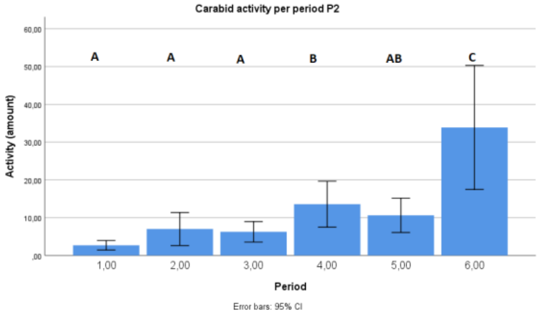


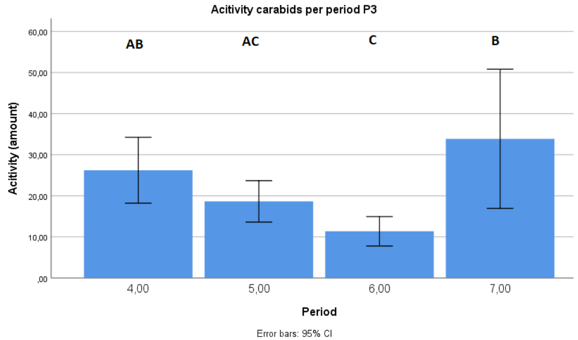
APPENDIX 4. MEAN NUMBER OF INSECTS CAPTURED PER PERIOD

Plot 1. **Plot 2.** **Plot 3.**

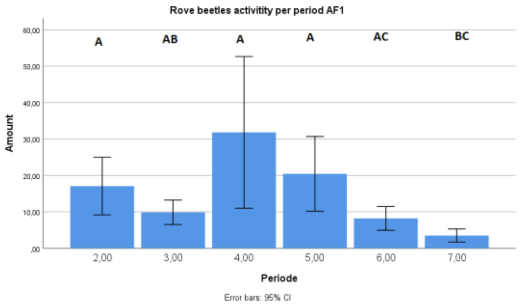
Carabids

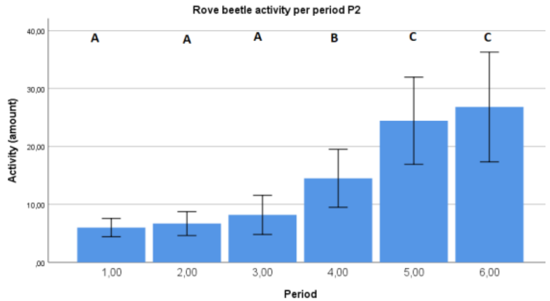


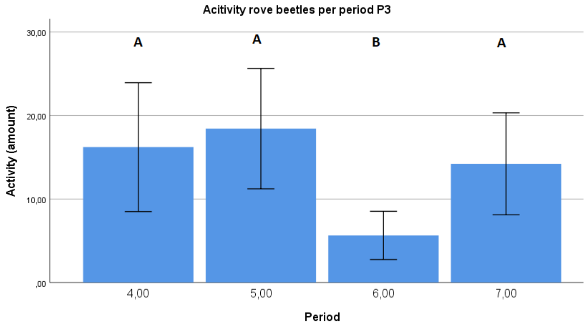




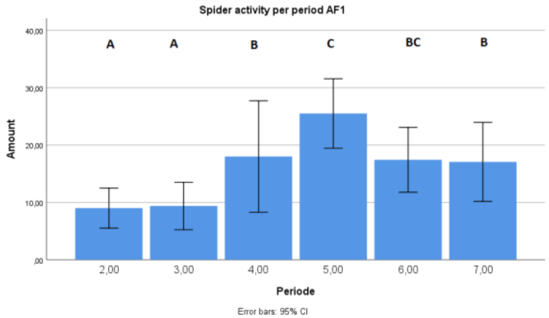
Rove beetles

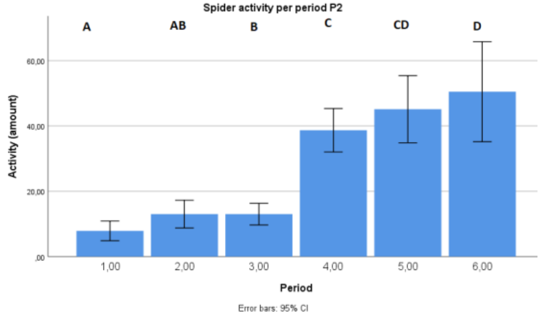


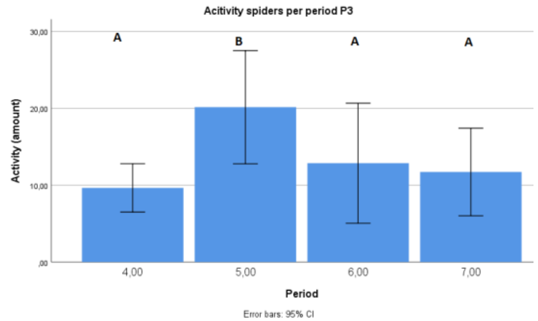




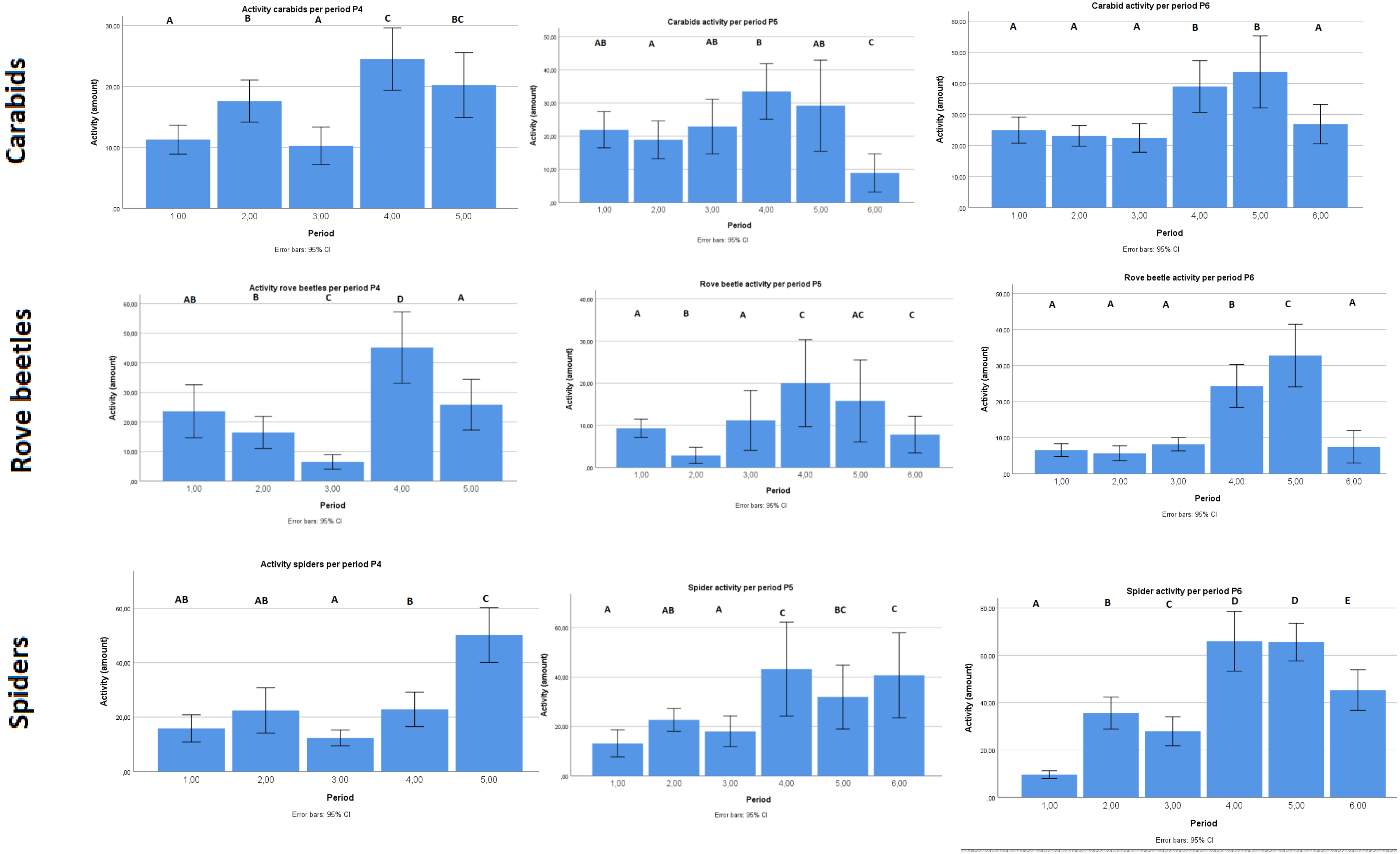
Spiders







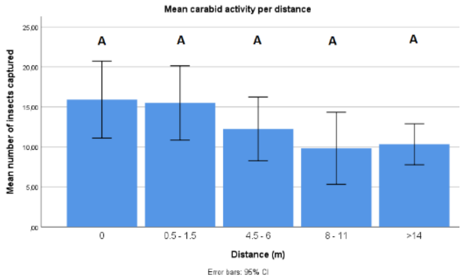
Plot 4. **Plot 5.**

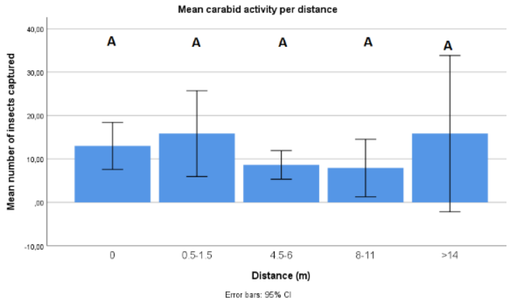

Carabids
Rove beetles
Spiders
Activity carabids per period P4
A B A C BC
Carabids activity per period P5
AB A AB B AB C
Carabid activity per period P6
A A A B B A
Activity rove beetles per period P4
AB B C D A
Rove beetle activity per period P5
A B A C AC C
Rove beetle activity per period P6
A A A B C A
Activity spiders per period P4
AB AB A B C
Spider activity per period P5
A AB A C BC C
Spider activity per period P6
A B C D D E
Activity (amount)
Period
Error bars: 95% CI

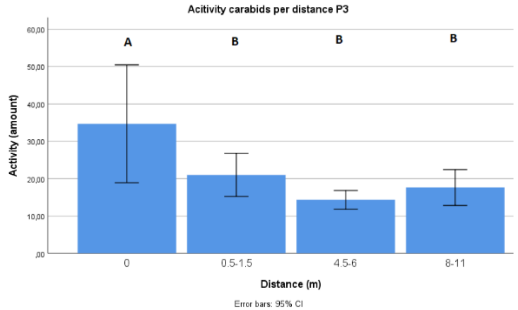
APPENDIX 5. MEAN NUMBER OF INSECTS CAPTURED PER DISTANCE

Plot 1. **Plot 2.** **Plot 3.**

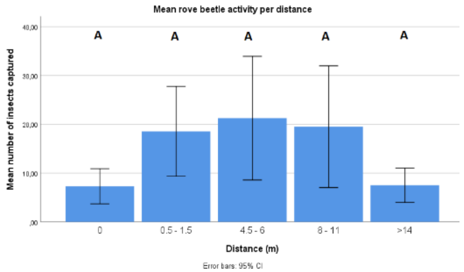
Carabids

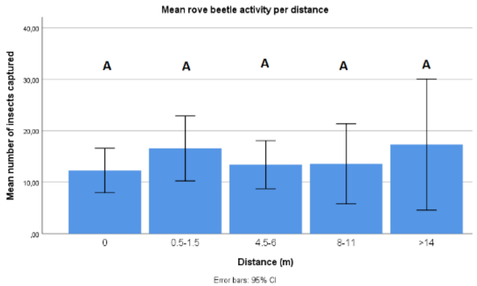


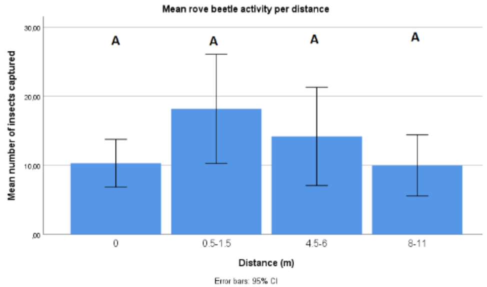




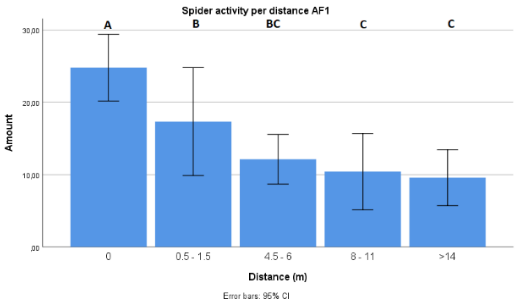
Rove beetles

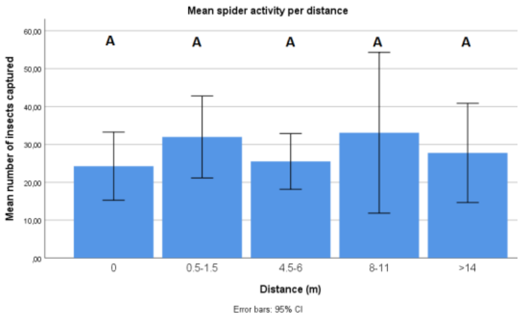


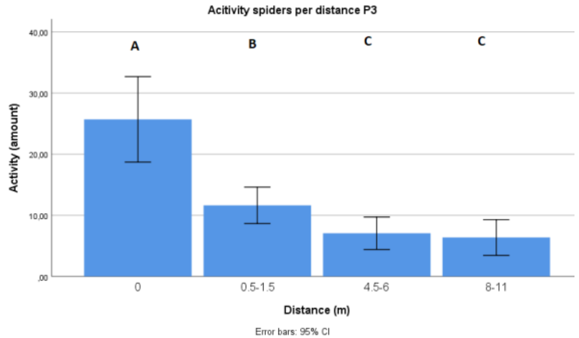




Spiders





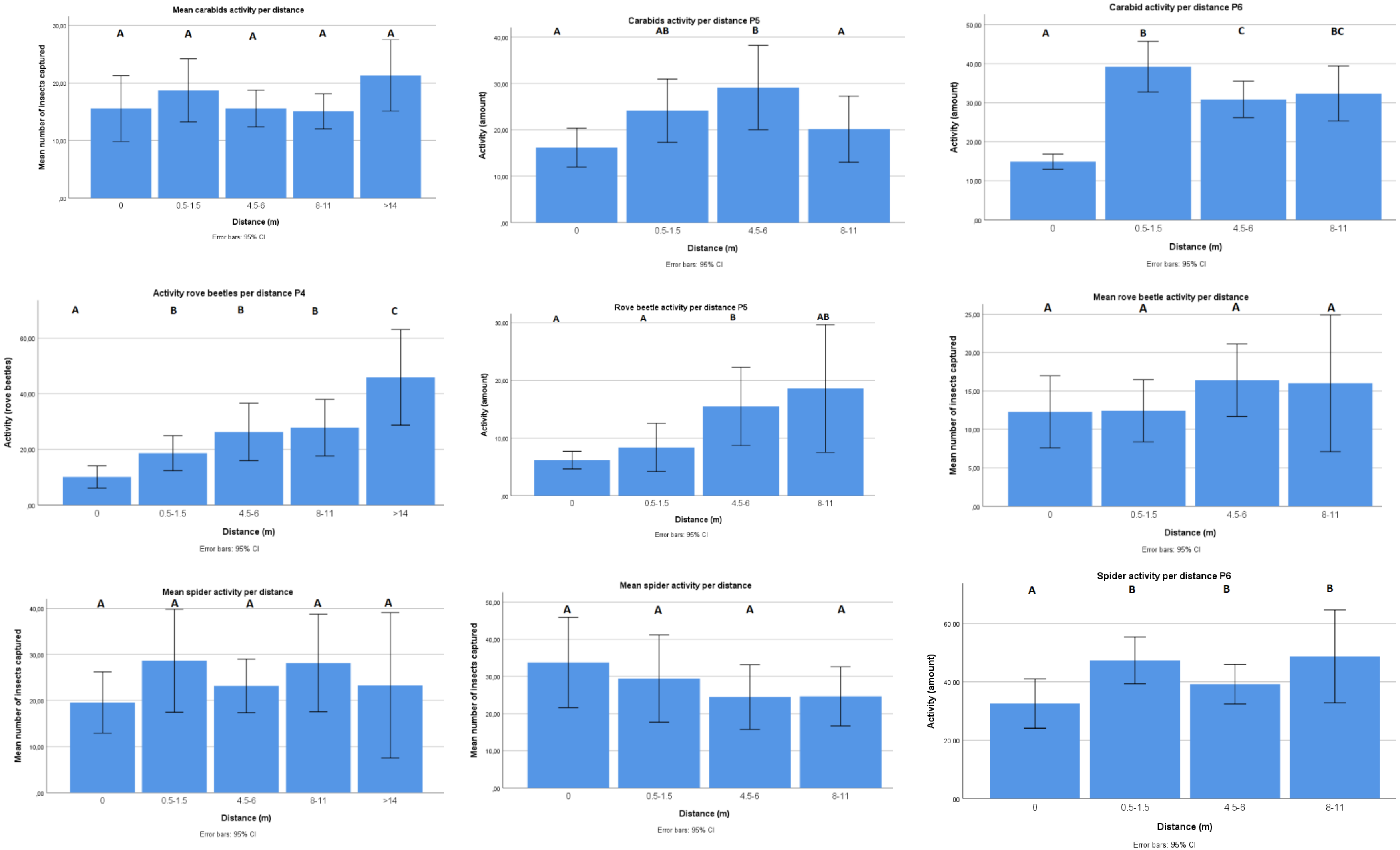


Plot 4. **Plot 5.** **Plot 6.**

Carabids

Rove beetles

Spiders

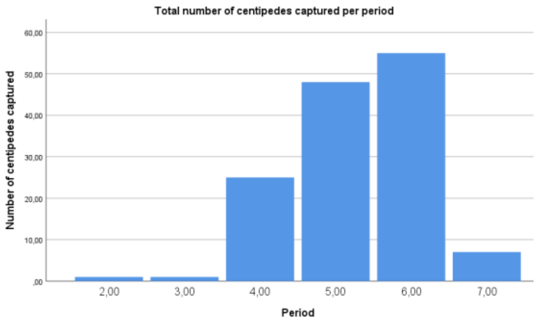


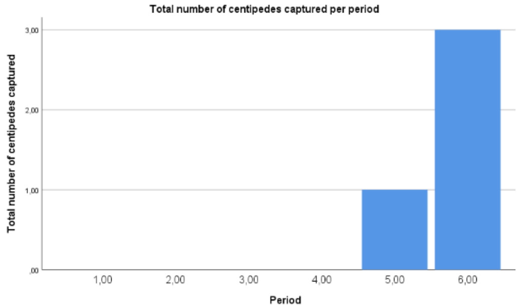
APPENDIX 6. SUM OF ABUNDANCE PER PERIOD

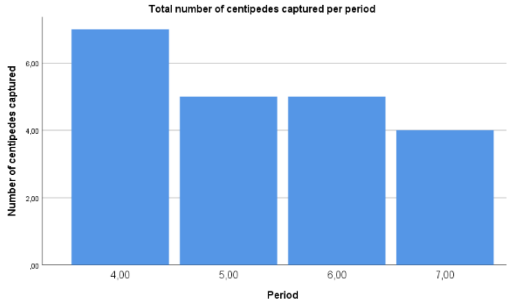
Unfortunately, the GLMM data could not be used for centipedes, millipedes, and woodlice. For this reason the total number of captured insects is shown for

Field 1. **Field 2.** **Field 3.**

Centipedes

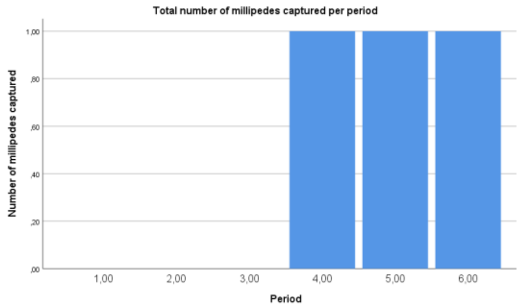


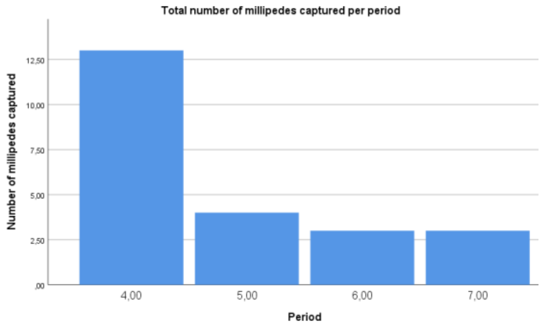




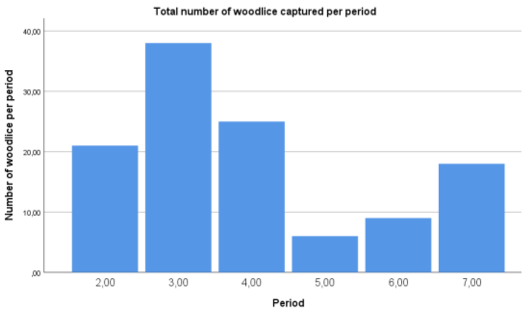
Millipedes

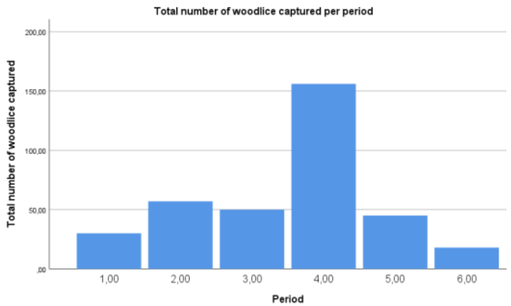
No millipedes were captured on field 1.

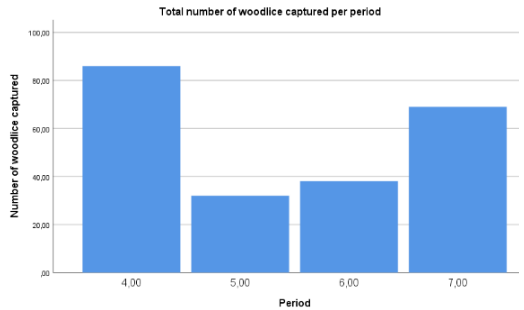




Woodlice

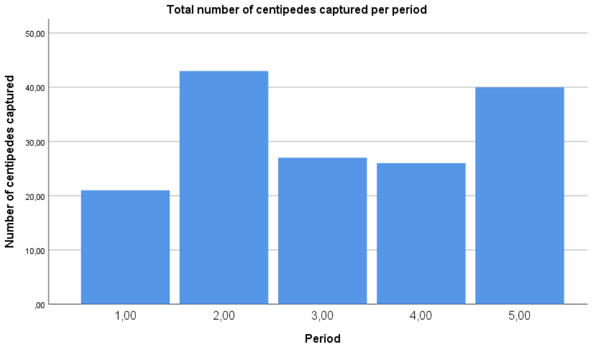


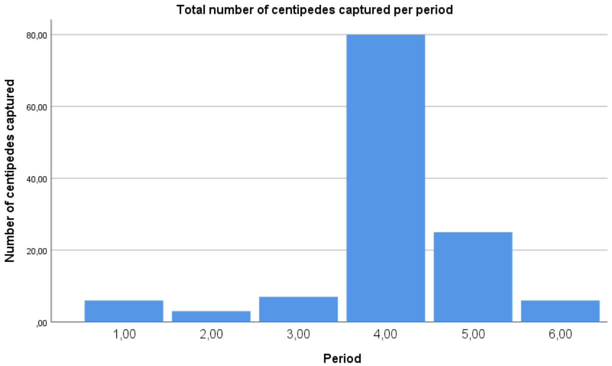


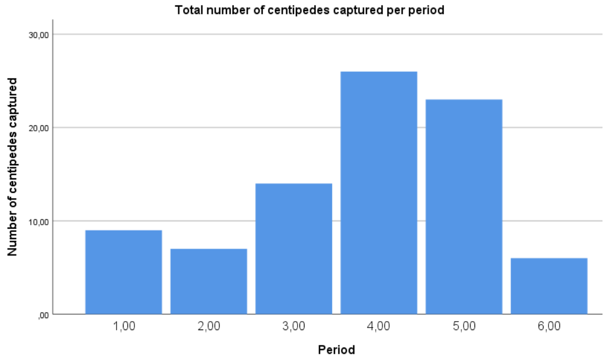


Field 4. **Field 5.** **Field 6.**

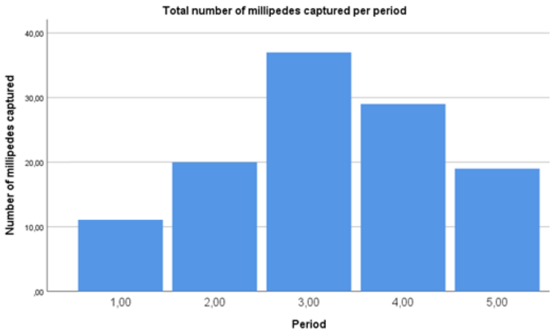
Centipedes

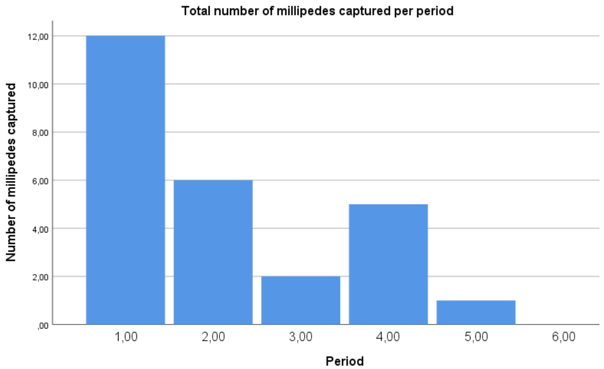


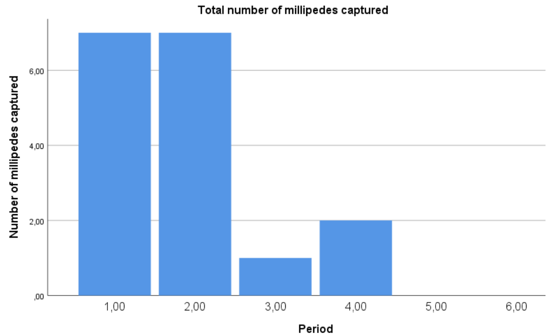




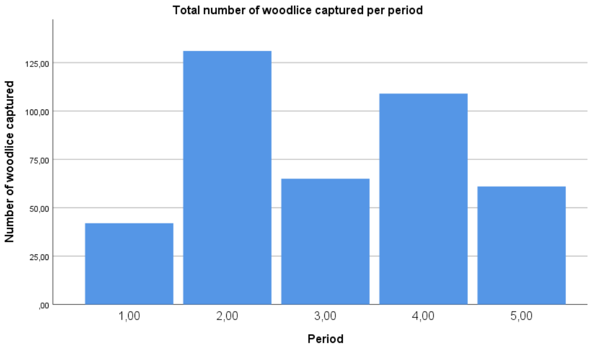
Millipedes

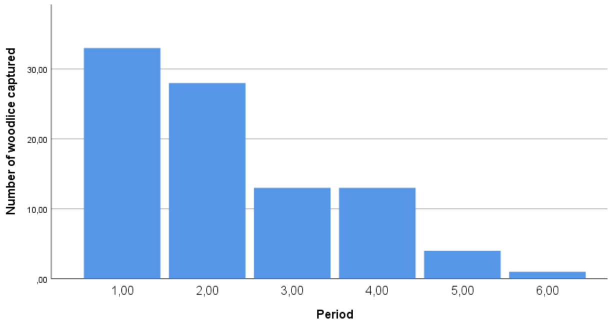


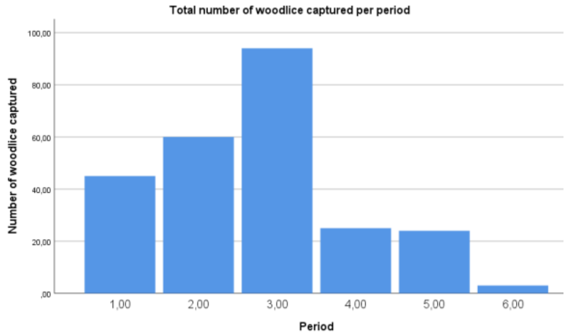




Woodlice



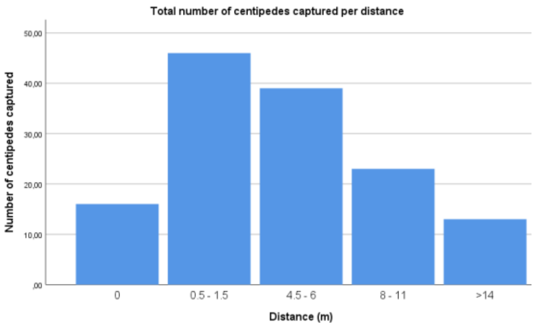


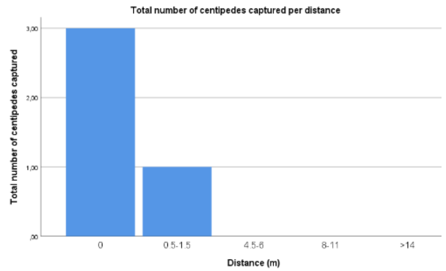


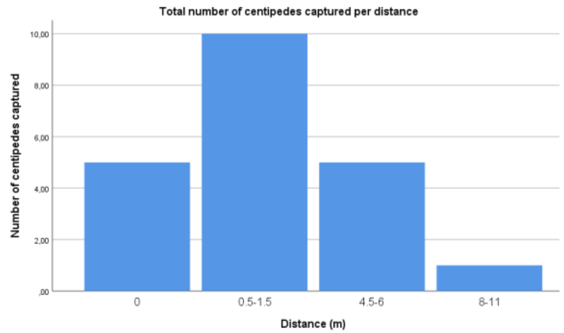
APPENDIX 7. ABUNDANCE OF INSECT PER 10 TRAPS

Field 1. **Field 2.** **Field 3.**

Centipedes

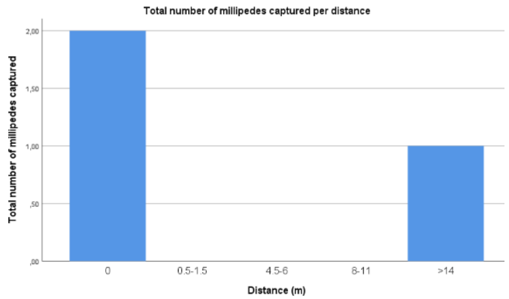


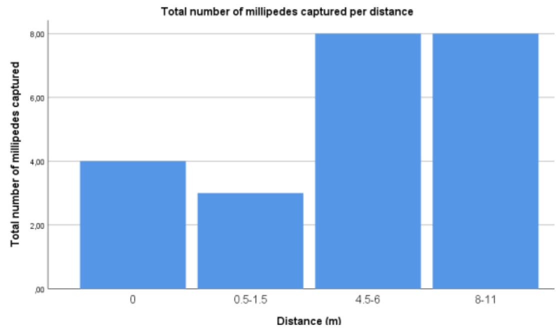




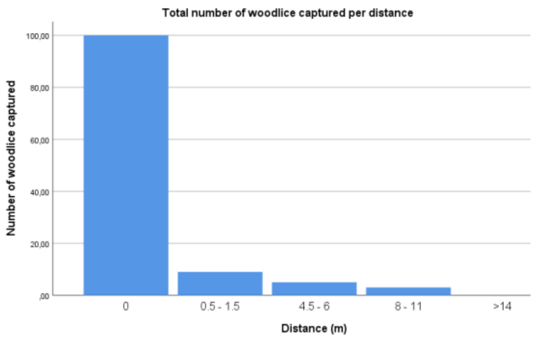
Millipedes

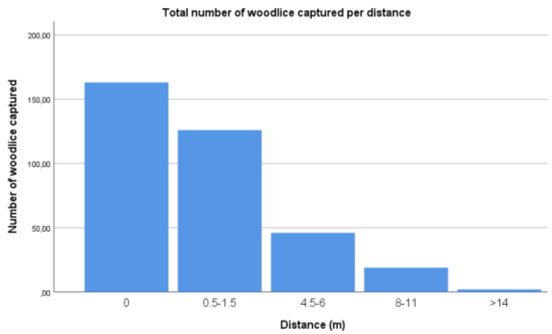
No millipedes were captured on field 1.

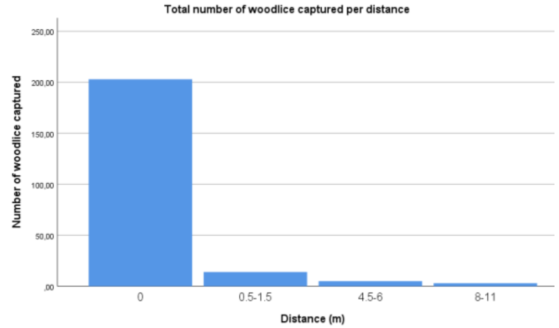




Woodlice

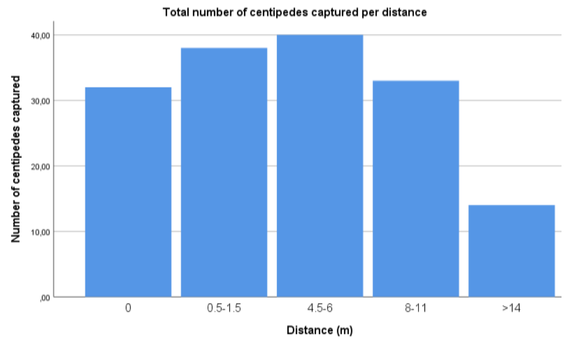


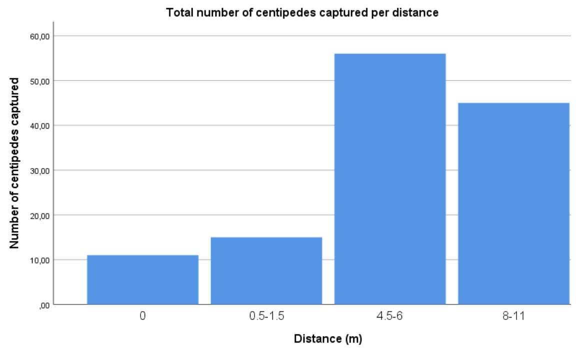


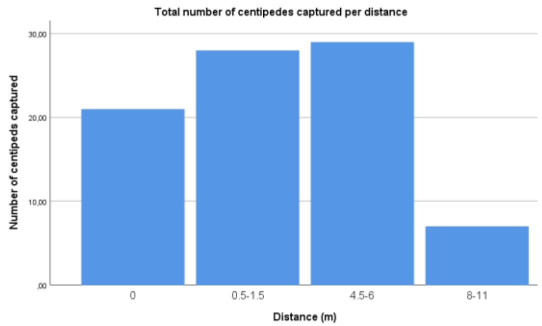


Field 4. **Field 5.** **Field 6.**

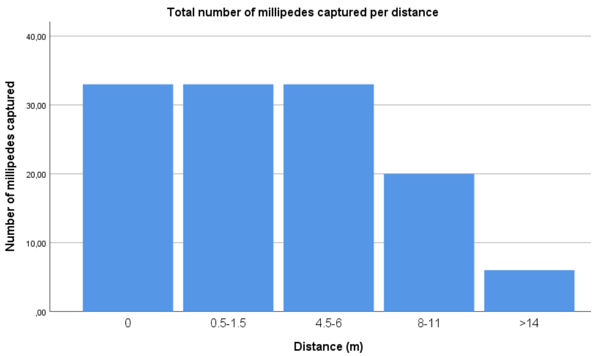
Centipedes

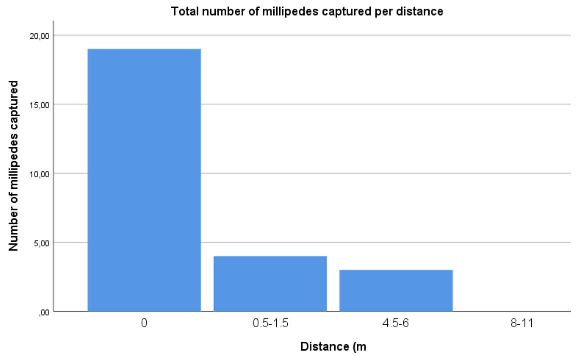


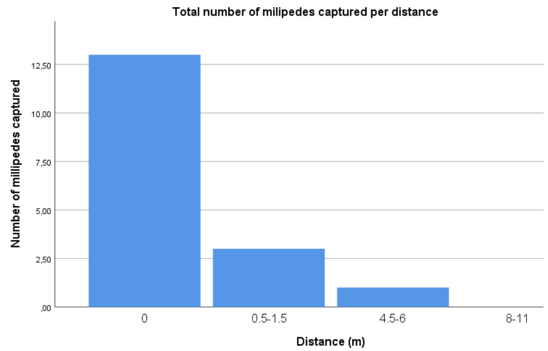




Millipedes







Woodlice