DUT Génie Biologique
Option Agronomie

Effects of Agroforestry on the agro-ecosystem: a study of the crops-soil-climate-biodiversity system in Short Rotation Coppice temperate agro-silvopastoral system

Effects de l'Agrofrestery sur l'agro-écosystème : étude du système sol-climat-plante-biodiversité en agro-sylvipastoralisme en taillis à courte rotation

Report of internship
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Study of the effects of the age of the trees on the agro-ecosystem in SRC agro-silvopastoral system

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Abstract

I carried out my internship at the Organic Research Centre in the agroforestry department. I studied the effects of the SRC trees and their age on the agro-ecosystem in the agro-silvopastoral field of the Elm farm. I carried out the assessments of the oats, the weeds, the earthworms, the ground beetles and the soil. I found no significant effects on the oats concerning its cover, the timing of the growth stage. In this study, we have also shown an effect of the trees and the tree row covered by weed, woodchip, dead litter on the population and the richness of earthworms and on the activity, the diversity and the richness of the ground beetles. The study of the community of weeds showed any contamination from the tree row, an effect of the perennial weeds and the interest of the weeds of the tree row for Wildlife. The soil organic matter has been studied in aim to show or not an increase of this level by the tree. In this report, we present the state of the art about Agroforestry where we will focus on the interactions between the trees, the agro-ecosystem and the climate. We will try to give some tools and way of management of these interactions.

Keys Word: Agro-silvopastoral, SRC, agroforestry, agro-ecosystem, age of the tree.

Résumé

J'ai réalisé mon stage de fin d'étude à The Organic Research Centre dans le département agroforestier. J'étais chargé d'étudier les effets des arbres et leur âge sur l'agro-système sur le champ expérimental de l'Elm Farm en agro-silvopastoralisme. L'étude s'est concentrée sur le suivi de l'avoine, la flore adventive, les lombrics, les carabes et le sol. J'ai montré aucun effet significatif des arbres sur l'avoine et notamment l'apparition des stades phénologiques et sa couverture. L'intérêt et l'effet de la couverture de la rangée d'arbres, par la végétation spontanée, du BRF et des résidus morts sur les populations de lombrics et de carabes, ont aussi été étudiés. Concernant la flore adventive, aucune contamination issue de la rangée des arbres n'a été prouvée. L'intérêt de cette flore a aussi démontré et particulièrement pour la biodiversité de la parcelle. Dans ce rapport, une partie est consacrée à l'établissement de l'état de l'art de l'agroforesterie en se concentrant sur l'interaction sol-climat-culture-arbres-biodiversité. Nous essaierons aussi de donner les outils les plus adaptés afin de manager ces interactions.

Mots clés : Agro-silvopastoralisme, Taillis à courte rotation, Agroforesterie, agro-écosystème, âge des arbres

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Indeed, I would like to thank Rémi Cardinael for the sharing of knowledge. It was very useful in the constitution of important parts of my state of the art of Agroforestry.

Then, I thank also my family who supported me during these three months. Specifically, my brother who advised me in the redaction of this report.

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Introduction

First, I discovered the concept of Agroforestry in 2014 thanks a conference about this subject delivered by Agroof. I was surprised by this practice because trees planted into a farming field is very uncommon and in confrontation with our practices. Since the mechanization of farming, tree is viewed as a constraint. But since the beginning of Farming, Trees, Crops and Animals have already interacted as we can saw on engraving of the Middle-Age. After, in 2016, I discovered how agroforestry could be an adaption to the climate change and fight against it during my teaching project. At this moment, I realized that planting trees into a farming field is necessary But I wanted to know more. So, I choose to realize my end-of-UIT internship about this subject. Then, I desired to realize this internship in United Kingdom in aim to improve my English and established my first experience abroad. So, I choose The Organic Research Centre because it researches on ground-breaking way of produce (agroecology and organic farming) and works on Agroforestry. And this internship is in total correlation with my professional project: work as a researcher in agroforestry.

Secondly, The Organic Research Centre began to work on Agroforestry twenty years ago. They began to study the effect of silvoarable in Wakelyn Agroforestry. After, they worked on the management of hedgerows and the interaction between livestock and trees. In 2011, they created the first agroforestry field in the Elm Farm for the SOLID project follows by the AGFORWARD project. And during this time, The Organic Research Centre began the following of agroforestry field in a vegetable organic farm and in a arable organic farm. During this internship, I oversaw the study of the effect of the trees and their age on the agro-ecosytem in the new SRC silvoarable field. I aim to create the starting point of this field and this study for the following years. My hypothesis were 1. SRC trees and their age have an increasing influence on the agro-ecossytem and 2. This influence increase close to the tree row.

In this report, we will present The Organic Research Centre, its vision, missions and aims. After, we will continue by the state of Agroforestry's Art with this issue: Why Agroforestry could be the future of an arable farm? Finally, we will present the study of the effects of the trees and their ages on the agro-ecosystem. This part we will begin by the presentation of the experimental field, the materiel used and the protocol of each assessment. Then, we will finish with the presentation of our results and their discussion.

I. The Organic Research Centre: a Progressive Farming Trust Ltd for organic farming development

1. General presentation

The Organic Research Centre (ORC) is the trading name of the Progressive Farming Trust Ltd. It was created as a limited company and is registered as a charity. It was founded in 1980 by David and Bridget Astor with Lawrence Woodward. It aims to advance public education by the promotion, encouragement, advancement of knowledge, research and experiments into sustainable agriculture, biological husbandry and technical, economic and social sciences or intermediate technology within the United-Kingdom and further afield.

It is located at Elm Farm in Hamstead Marshall: a small village close to Newbury in Berkshire in Great Britain (Figure 1). It was a farm at the beginning which was transformed into an independent research centre. In fact, offices and laboratory were created from the original farmhouse and stables. This refurbishment began in 1999 and finished in May 2009. It was carried out with the respect of the environment and the building's history. It took place in two phases: first, creation of office and renovation of the future conference hall and secondly, the creation of the conference hall and more offices. At the beginning, the research centre was named *Elm Farm Research Centre*, then since 2005, theOrganic Research Centre.

<u>Figure 1:</u> Localation of ORC (Source: Google)

Today, twenty-eight people work at ORC in diverse research and communication areas (Figure 2). The ORC has an annual turnover of £1 million. National and European projects income provide 80-90 % of ORC's budget. Moreover, Elm Farm provides 94 hectares of meadow and cereals crops for ORC's trials. There are stalls for cows on the Elm Farm site. ORC also work closely with Prof Martin Wolfe at Wakelyns Agroforestry in Suffolk, in eastern England. Wakelyns is specialized in silvoarable agroforestry and provides a location for agroforestry trials.

2. ORC's visions, missions and aims

ORC's vision was shaped by its history and its primary aim. It is: "a world which meets the nutritional needs of current and future generations with safe, affordable, high quality food, produced in a way that sustains and enhances the natural environment, and ensures the health and wellbeing". So, ORC's work, mission and aims follow this vision in order to realise it. ORC's missions are 1. Researching and developing practical, sustainable land management and food production systems based on organic and agro-ecological principles 2. Encouraging knowledge exchange with and between current and future producers, food businesses and related professionals and 3. Influencing policy and public debates on the future of food and farming bases on sound evidence.

Therefore, the main aims of ORC are 1. Organic and agro-ecological approaches widely recognized as relevant to sustainable food production 2. A wider range of agro-ecosystem management practices adopted by producers, organic and non-organic 3. More organic producers adopting best practice, leading to improve in minimum standards 4. Greater food industry and retailer engagement with organic and agro-ecological approaches 5. A positive policy environment to support the development of the organic sector.

Finally, the objectives of the research department are: 1. Improving the productivity and sustainability of such approaches and addressing key technical problems where current practice falls short of agro-ecological and organic principles 2. Developing this by working with farmers and other participants of the farming world; and 3. Evaluating and improving, the economic, social, environmental, quality and other impacts of such systems, including delivery of ecosystem services, greenhouse gas emissions, potential for climate change mitigation, food quality and safety, human and animal health and wellbeing.

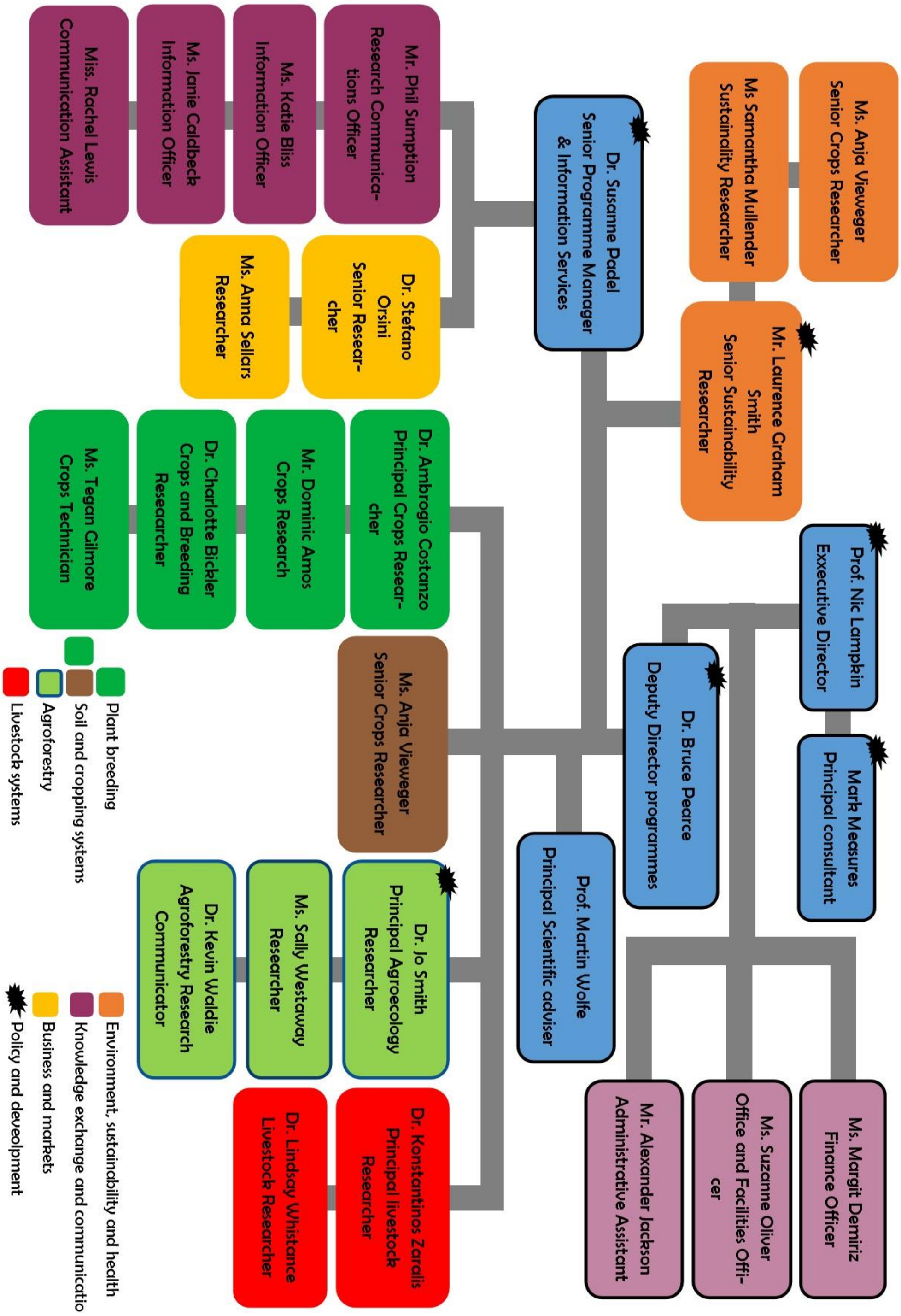


Figure 2: Organigram of the ORC. This organigram is up to date at the end of May 2017.

3. Research at ORC

At ORC, research focuses on six themes:

- Plant breeding for crop resilience: This theme focuses on increasing genetic diversity. They aim to increase plant's resilience to climate and weather variations, weed, pest and disease pressures. The creation of breeding programme allows the development of sustainable crops varieties for organic farming.
- Soils and cropping systems: In this theme, ORC develops practices which use legumes, cover crops and reduced tillage. It aims to increase the productivity of organic farming.
- Agroforestry: ORC agroforestry researchers consider the performance of a range of agroforestry systems in terms of their productivity, their environmental and economic impacts and their potential for farming and environment policy. They develop also a program on hedgerow management for woodfuel and other products including tree fodder.
- Livestock systems: this focuses on the nutrition of cattle, sheep, pigs and poultry. They develop research programmes on feed self-sufficiency, mineral and protein for livestock, impacts of all practices (forage, husbandry, grass management …) on livestock health and the productivity.
- Environment, sustainability and health: Researchers study impacts of organic farming and other farming systems, their sustainability and their ecosystem services. They focus on interactions between soil, plants, animals and humans and their health.
- Business and markets: ORC researchers analyse incomes and costs of production of organic farmers, the organic market, the behaviours and attitudes of consumers and the development of organic market.
- Policy development and evaluation: This focuses on the development and the evaluation of policy supports and payments for public good services. They work on regulations and certification in organic systems. They also promote and influence the development of organic farming at local, national and international scales.
- Knowledge exchange and communication: They involve organic farmer and other actors of the organic world in the program of research. They also share information with people by all communication tools (publication, events, internet, …) to promote ORC's works, agroecology and organic farming.

II. The state of the agroforestry's art: Why agroforestry could be the future of Farming?

1. What is agroforestry: definition of this traditional production system

Agroforestry received its first definition in 1977. Bene, J.G. et al wrote this definition: "Combining the growing of certain trees and agricultural crops on the same land or growing them sequentially". But five years later, Lundgren and Raintree detailed this definition and talked about the complexity of this land use. For them, agroforestry is growing woody perennials such as trees or shrubs with crops and/ or animals in the same unit of land. And the agroforestry system is a combination of ecological and economical interactions between woody species, crops and/or animals (Lundgren, B et al, 1982). To summarise, an agroforestry system must be a combination of two or more species of plants (tree and crops) and/or animals. It must produce two or more outputs (wood, crops' biomass, meat, milk …). Therefore, the cycle of an agroforestry's field is longer than one year. This field is more complex ecologically and economically than a conventional field. (Nair, P.K.R, 1993). And all definitions, found in the literature, take roots in this previous definition. Agroforestry systems must be biologically possible, ecologically sustainable, socially acceptable and economically feasible to be a successful form of land use. (Sharrow, S.H. et al, 2009).

Using these definitions, we can identify three kinds of agroforestry: silvopastoral, silvoarable, and agrosilvopastoral system. (Figure 3). And there are many variations in the functions of each farm. Thereafter, we will focus on the silvoarable system which is at the base of this study.

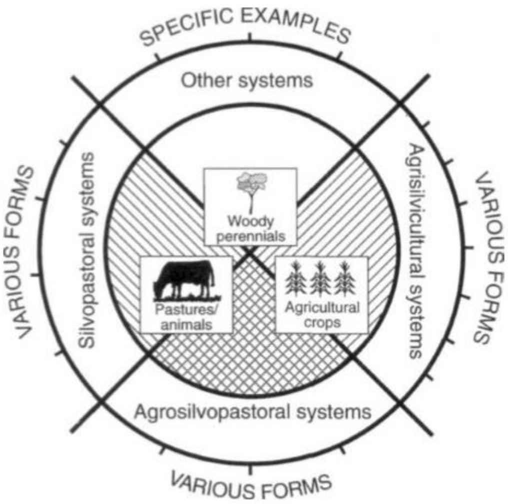


Figure 3: Scheme of the different kinds of agroforestry (Nair, P.K.R 1993). This rank is in function of the different species that we can find in agroforestry's system.

1.1. Silvopastoral systems

Silvopastoral agroforestry creates interactions between animals and trees (Nair, P.K.R 1993). There are different ways to create a silvopastoral system: 1. Livestock grazing within a forest or 2. Trees planted into a pasture

1.2. Silvoarable systems

In silvoarable agroforestry, crops are intercropped within alleys of trees (Nair, P.K.R 1993). This kind of agroforestry could take many applications: trees can be planted into an industrial crop field, a cereal field or on a vegetable farm,

1.3. Agrosilvopastoral systems

This kind of agroforestry is the combination of the silvoarable and silvopastoral systems (Nair, P.K.R 1993). Trees are planted into a field where crops grow and animals are included. This increases the sustainability of the farm and reduces competition for feed for livestock, humans and to produce wood and/or biofuel (Russo, R, 1996).

2. Agroforestry products and environmental benefits

Depending on the tree, crop and livestock species included in the agroforestry system, a range of products can be farmed (Annex 2). In addition to these products, agroforestry is recognised as supporting a range of other ecosystem services as the carbon sequestration, soil enrichment, the conservation of the biodiversity, the increasing of air and water quality (Jose, S. 2009). But agroforestry system can also fight against soil erosion, the floods and forest fire and modify the landscape (Dupraz, C., et al. 2011)

3. Diversity of agroforestry designs

First of all, consideration of the main purpose of the agroforestry project is very important before to plant trees. Two parameters need to enter in this reflexion: the density of tree and the width of the alley. In fact, they need to correspond with farmer's aims because they will influence the degree of competition between trees and crops. Dupraz, C.et al (2011) identified the most important indicators. They use the coefficient of the equivalent density. It is the ratio between the density of each species in agroforestry field and these species grown in conventional way:

$$CED = \frac{dt}{Dt} + \frac{dc}{Dc}$$

$$dt: density\ of\ trees\ in\ a\ agroforestry\ field. Dt: density\ of\ trees\ in\ a\ conventional\ field.$$

$$dc: density\ of\ crops\ in\ a\ agroforestry\ field. Dc: density\ of\ crops\ in\ a\ conventional\ field.$$

This coefficient allows to define three principal levels of tree-crops (cash crops or forage crops) mixture. First, the easiest way is to mix trees and crops at their normal density: the number of trees per surface unit is the same as in a forest. Crops are drilled on all the surface of the field without the tree row. We obtain a maximal CED of 2: this is additive agroforestry. Then, the second is to reduce the forest tree density by two and crops are drilled on the half of the surface. So, we obtain a CED of 1: this is replacement agroforestry. And between these two values, we have three different sublevels where only the tree's density is of interest. They are more specific in the case of a silvoarable field.

First, if we plant trees with a density greater than 200 trees per hectare as in forestry, we design a short-lived silvoarable system. Crops are drilled during the first years after tree planting. At this density, the cultivation of cash crops becomes unprofitable when trees cover all the surface of the field. The first years of crops allow to cover the soil, increase the growth and the homogeneity of the trees by the attention given to the crop (e.g. fertilisation, weed, …) (Dupraz, C. et al, 2011).

Secondly, when we plant trees with a density of 50 to 200 trees per hectare, we create an evolving silvoarable system. Crops could grow with trees during the whole cycle of the trees. However, the yields will decrease when the indicators of competition will be greater than on (Dupraz, C. et al, 2011). The surface of cultivation will be reduced because it isn't possible to drill the surface close to trees. In fact, the yield in these parts are not profitable when trees are dominant. Another option could be to drill species with a lower light requirement such as pasture species. The start of yield loss could happen quickly, if tree density is high (e.g. close to 200 trees per hectare) and/or if trees species have a fast growth (e.g. poplar, alder, willow). Dupraz, C. et al (2011) noted a decrease of crop yields six years after the planting of poplar with a density of 140 trees per hectare. But they showed that during three quarters of the life of trees, the crop yields represents 40 % of the yields of a conventional crops (Figure 4).

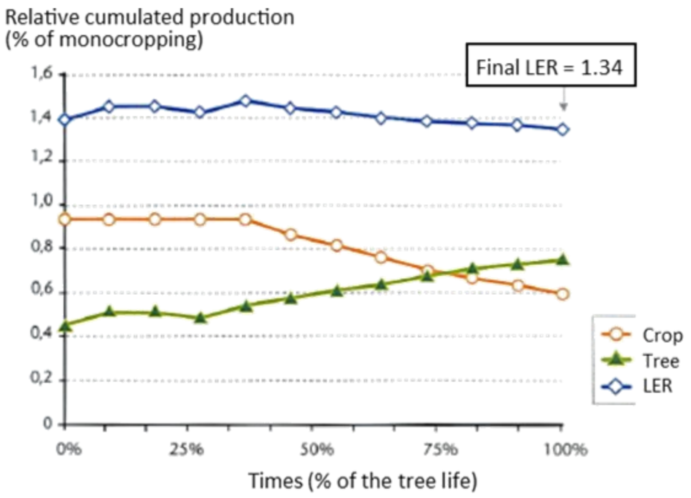


Figure 4: Evolution of the yield of crops and trees and the LER of the agroforestry field (From Dupraz, C., et al, 2011). The crop yield decreases after the first tire of the tree life. This graphic is a generally for all field which are equivalent to this poplar agroforestry field.

And finally, the third kind is when trees are planted at a density of 20 to 50 trees per hectare. It is a stable silvoarable system and it is the most common design in new projects. This approach produces sustainable crop yields during all the life of trees (the decrease begins after the twentieth year) (Figure 4) and all the indicators of competition stay inferior to one during all this period (Dupraz, C. et al, 2011). At the lowest density, the crops will keep a sustainable level of production like a conventional field.

4. Silvoarable system and productivity

Planting trees into a farm plot or crops into an agroforestry field could increase the overall productivity of the land. The Land Equivalent Ration (LER) evaluates this increase. Its formula was defined by Mead and Willey for the first time (reference). It compares averages of tree and crops yields in a conventional system to the ones of an agroforestry field (the crop yield is determined for the whole rotation when there is more than one crop):

$$LER = \frac{Tree\ agroforesty\ yield}{tree\ conventional\ yield} + \frac{crop\ agroforestry\ yield}{crop\ conventional\ yield}$$

The LER shows the biological efficiency when we are using a physical unit (e.g. tons per hectare) and the economic efficiency when are using a monetary unit (Smith, J. et al, 2011). Dupraz et al (2011) showed a LER of 1.4 for a poplar silvoarable field (II. 3.). It means that one hectare of poplar-cereals agroforestry is as productive as a field of 1.4 hectare where trees and crops are grown separately. Moreover, the LER of a walnut-cereal field is around 1.6 (Dupraz, C., et al 2011). But the LER changes during the life of the tree (Figure 4). However, the difference is more significant when we focus on the economic efficiency. This indicator gives an idea of the surface that a farmer needs to be more profitable than an agroforestry field of one hectare. For example, in the poplar-cereals field, the economic efficiency is around 2.4: one hectare of this field produce more than 2.4 hectare monetary speaking where poplar and cereals are growing separately! But, this indicator is of 1.7 in the walnut-cereals field Dupraz, C., et al 2011).

Another kind of indicator compares the economic performance of agriculture, forest, rotation tree-crops and silvoarable systems. It is the Net Present Value (NPV). It determines the profitability of a project by considering all the expenses and incomes. Table 1 shows the NPV of different projects.

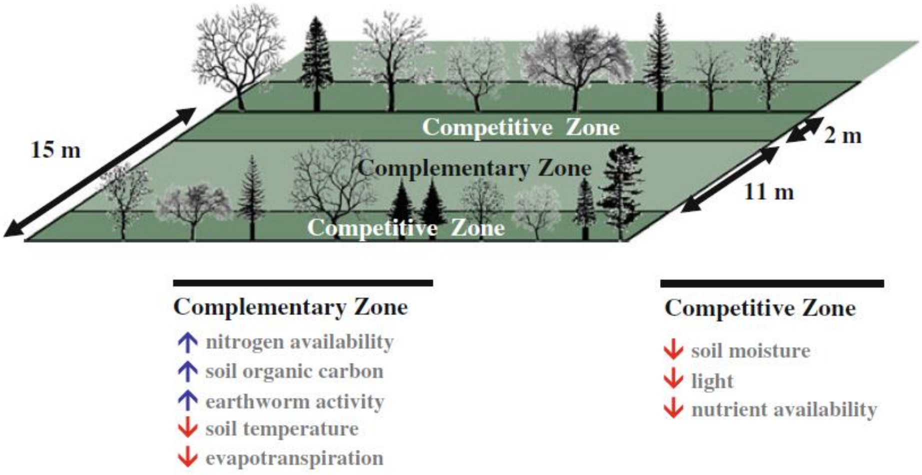
	Agriculture	Agroforestry	Rotation trees-crops	Forestry field
Tree with a low value (e.g. poplar)	1	0.85	0.35	0.14
Tree with an average value (e.g. cherrywood)	1	1.5	0.83	0.75
Tree with a high value (e.g. walnut)	1	2.25	1.28	1.42

Table 1: The NPV obtain for different kinds of production in function of the value of trees (Dupraz, C. et al, 2011). Result of fifteen years of trial in France.

We could see that agroforestry is more profitable than trees-crops rotation and forestry field for all tree values. But agroforestry is less profitable than the agriculture for a lower tree's value. For agroforestry, expenses are more important than the income when the tree value is low (compared to a farm plot). In contrast, agroforestry becomes the most profitable as the value of the tree increases. But the NPV doesn't include the indirect income supported by trees (e.g. increase of the quality, environment services …) (Dupraz, C. et 2011). An economic study realized by Fernández-Nùnez et al in 2007, showed that agroforestry needs more investment at the beginning (compared to agricultural field and forestry) because it needs more inputs (e.g. trees, crops, mulch, trees' protection, mixture of seeds for the tree row, labour, …). But after thirty years, agroforestry is more profitable than the conventional way (+ 17% compare to livestock and + 53% compare to forest). Another study in United-State compared the profitability of a narrow alley (8,5 meters) and a wider alley (12.2 meters) in walnut agroforestry systems (Benjamin, T.J., et al.2000). They showed that the wider alley is the most lucrative because crops produce a profitable yield during a longer time. These studies showed the importance of project management to obtain a profitable project and to correspond to farmer's aims. They showed also that the profitability of agroforestry depends on the density of trees (indicators of competition), the values of trees, the species of trees and the kind of agroforestry.

5. Silvoarable: an association of trees and crops

In an agroforestry field, trees-crop interactions have many impacts on the tree and crops. These impacts could be good (i.e. facilitation). Or they could be negative competition. The University of Guelph Agroforestry Research Station identified the location of facilitation and competition in a 24 years old trees mixture agroforestry fields in Canada. In an alley of 15 meters, the competition zone is 2m from the tree row. The rest of the field is covered by the facilitation zone (Figure 5). In this zone, species modify the environment of the other species and the resources are shared. The shared resources could be increased directly (e.g. increase water infiltration) or indirectly (e.g. deeper roots system) (Dupraz, C. et al, 2011). In agroforestry systems, these impacts will be beneficial for trees and crops but we could observe more negative effects on crops than on trees.



<u>Figure 5:</u> Scheme of the location of the facilitation zone (or complementary zone) and the competitive zone. (Cardineal, R. et al, 2012). In these zone, we can observe different the comportments and impact of agroforestry.

5.1.Impacts on crops

As we saw, impacts of trees are a function of the distance between trees and crops. This distance is determined by the density of trees, the age of trees, the height of mature trees, the alley width, the species, the crop, the part of the crown on the total height. And we will see that the direction of the tree row has an importance.

5.1.1. Competition for water

Dupraz, C. et al (2011) showed that the competition for water depends of the precocity of trees, the kind of crops and the age of trees. They identified three periods of water according to a numerical model. The first period corresponds to the first third of the life of trees: trees are young and the pruning is frequent. So, their needs are low due to their low foliar surface. Competition for water between crops and trees is rare and insignificant. In the second third, everything is different: the pruning has stopped and trees have increased their foliar surface. They need a lot of water: competition is common and inevitable if the water storage and the rainfall are low. And during the last third, trees finish their growth and their root system is limited. The consumption of water is stable and competitions are a function of the rainfall. This model is applicable for densities greater than 50 trees per hectare. Below this level, trees continue to grow and the competition for water persists in the time.

Furthermore, the competition for water will be stronger if: 1. the crops are drilled in spring; 2. the trees begin its growth early in the season; 3. the storage of water into the soil is low; 4. the climate has a low level of rainfall (Dupraz, C. et al, 2011). For the spring crop, their requirement for water during the end of spring and the summer coincides with peak demand of the trees. This point explains the sensitivity of spring crops for water competition in comparison to a winter crop. A decrease in the water use of a maize crop has been already observed (31.4 %) when tree roots were present in the cropping alley close to the maize roots (Jose, S. et al, 2000). But, we will see that this competition could be reduced by a modification of the rooting of trees.

5.1.2. Competition for nutrients

Agroforestry also has similar impacts on crop nutrition as with competition for water. But trees could also have a beneficial impact (Jose, S. et al, 2000) due to two mechanisms: 1. enrichment of organic matter and 2. biological nitrogen fixation by certain tree species (e.g. alder). In tropical silvoarable system studies, N fixation has been estimated between 20 to 500 kg N_2. ha^{-1}. yr^{-1} (Dommergues, Y. R., 1987). This range is very high because it depends of the trees species and the fixator microorganism.

An American study showed a quick release of nitrogen and phosphorus from tree leaves and fine roots (reference). In fifteen days, 39 % of nitrogen content in the leaves and fine roots of walnut and 17.7 % of nitrogen from red oak were released. At the same time, 30 % of phosphorus content in leaves and fine roots were released from the both species (Jose, S. 2000). Fine roots have a higher contribution to the release of nitrogen.

However, this study showed also that competition between tree and crop roots have an impact on crop growth and yield (Jose, S., 2000). In a system without competition, a yield gain has been observed (+67.3 %) and the assimilation of fertilizer was less important. (Jose, S., 2000). It was due to a competition for water and mineralized nitrogen. And a lower fertilizer use efficiency was observed where trees roots and crops roots are in competition. This study showed the need to control the rooting of trees in order to reduce competition between trees roots and crops roots by root pruning.

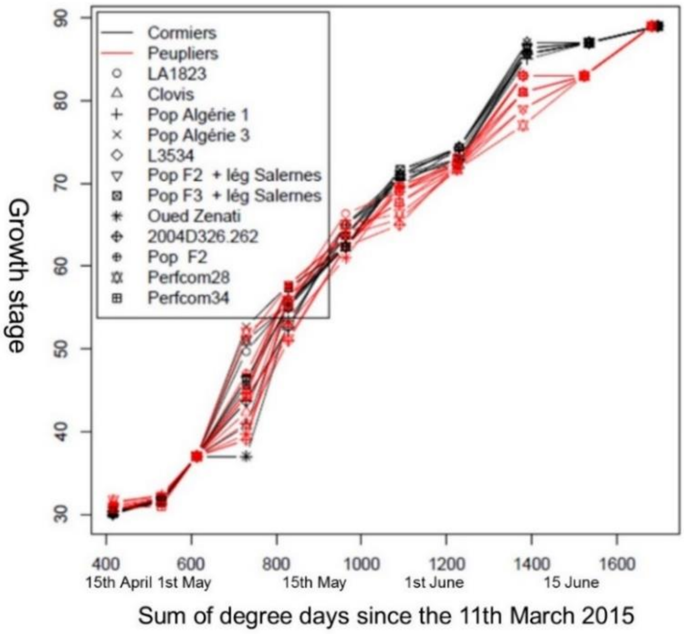
5.1.3. Light and photosynthesis.

In agroforestry systems, as in forests, trees will develop at the top of herbaceous stratums. As a consequence, trees could reduce the light received by crops. The University of Guelph worked on this subject in its poplar-maize-soybean agroforestry and in silver maple (reference). The authors showed that trees reduce the quantity of Photosynthetically Active Radiation (PAR) and Net Assimilation in the competitive zone (Figure 5). They showed that the impact of trees is dependent on the time of the day: the effect moved with sun. So, we can observe a balanced distribution of this effect with tree row oriented North-South (Annexes 3). The PAR and NA is correlated with crop growth and yields (Reynold, P.E. et al, 2006). This study focused on spring crops. Furthermore, we would expect that this impact is different for winter crops which finish growing at this date and the level of pruning.

5.1.4. Crop phenotype

In agroforestry systems, the crop environment is modified compared to a conventional field: reduction of PAR (light), competition (e.g. water, nutrient,), facilitations. All these factors could modify the crop phenotype. Other factors could also influence crop’s phenotype as explained in the next section. The response of a variety could be different in agroforestry field than in an open conventional field (Dupraz, C. et al, 2011).

Reynolds, P.E. et al (2006) studied these modifications in the same system as discussed in section 6.1.3. They showed that corn differed in height and growth as a function of the distance between plots and the tree row and the species of trees. In durum wheat, Gosme, M. et al (2016) in a poplar agroforestry field that many varieties had better performances and phenotypes in agroforestry than in an open conventional field. They also followed the growth stages for the same varieties under poplar and in a conventional field (Figure 6). Mainly varieties in the agroforestry systems were in advance early in the season. But at the end, the conventional field had an advance of two weeks before the agroforestry field. Furthermore, they could observe a higher height in the agroforestry field than in the conventional field for winter crops (Gosme, M., et al. 2016).



<u>Figure 6:</u> Diagram of the apparition of the growth stage for 12 varieties grown in an agroforestry field (red) and in conventional field (black). (From Gosme, M. et al, 2016).

5.1.5. Yields

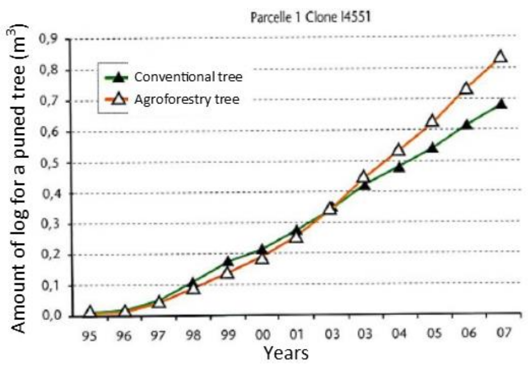
In agroforestry, crop yields could be higher (Gosme, M. et al, 2016. Cardinael, R. et al, 2012) or lower (Reynold, P.E. et al, 2006) as a response to management of the competition, the silvoarable system design (Dupraz, C. et al, 2011), and crop species (e.g. winter and spring or summer).

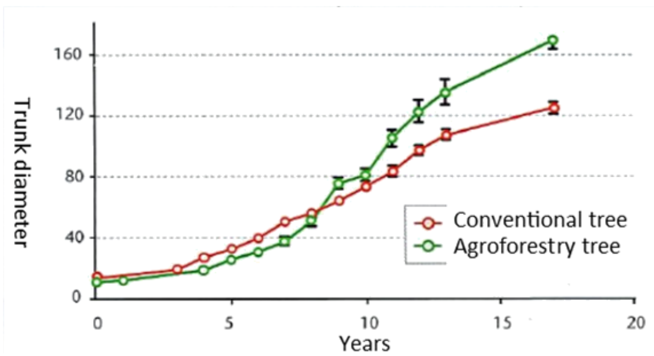
Gosme, M et al, (2016) showed an increase of the yield of durum wheat in a silvoarable system compared to a conventional field. A poplar-durum wheat association, planted in 1995, showed a yield of 5.47 $t.ha^{-1}$ for first variety (Pop Algérie 1) and 5.26 $t.ha^{-1}$ for the second variety (Perfcom28) versus 1.36 $t.ha^{-1}$ (Pop Algérie 1) and 2.17 $t\ ha^{-1}$ (Perfcom28) in an open conventional field. In Spain, Moreno, G. et al (2016) obtained the same effect for barley but smaller differences (In 2014: control: 1.19±0.65 $t.ha^{-1}$ and agroforestry: 1.85±0.80 $t.ha^{-1}$. In 2015: control: 3.03±0.91 $t.\ ha^{-1}$ and agroforestry: 3.48±1.18 $t.ha^{-1}$). But they observed a decrease as a function of the year in the yield of wheat and triticale (e.g. for wheat in 2014: control: 1.16±0.45 $t.ha^{-1}$ and agroforestry: 1.39±1.99 $t.ha^{-1}$. In 2015: control: 3.92±1.53 $t.ha^{-1}$ and agroforestry: 2.14±0.86 $t.ha^{-1}$). However, in this trial, the alley spacing is very small: 6 meters and only four meters of the alley is drilled (Moreno, G. et al, 2015). So, the density is approximately of 333 trees per hectare. In Germany, Jung, L. et al (2014) studied the effect of alley cropping in short rotation coppice (SRC) with different alley widths (48, 96, and 144 metres). They showed a decrease of wheat and barley yields close to the tree row, with increasing yields with increasing distances from the tree row. They also found an increase in grain moisture: +0.5% for barley at 3 meters from the tree row and +2.0 % for oil seed rape at 14 m. Grain quality was higher closer to the tree for barley (+1.5 % for protein content at 3 m) and for the oil seed rape (+2 % and 1.5 % for protein content at 30 m). Dupraz, C. et al (2011) observed a decrease of durum wheat yield in Mediterranean silvoarable. However, the protein content was higher under the trees (18 % under the trees and 10-13% in conventional field). In spring crops, a decrease of 50 % was found in the competitive zone for corn (Reynold, P.E. et al, 2006).

In SRC, Cardinael, R et al (2012) studied the yield of willow clones planted in the complementarity zone between twenty-one years old timber tree mixture. In the agroforestry system, willow clones produced significantly more than in the open field with an average yield of 4.86 dry $t.ha^{-1}.yr^{-1}$ under trees compared with 3.02 dry $t.ha^{-1}.yr^{-1}$.

5.2. Impacts on Trees

Similar to crops, trees in agroforestry systems are also exposed to competition and facilitation. The association with crops could reduce tree growth during the first years: this is the period of competition. The young trees undergo competition for water, nutrients, light and space. This can be be explained by the fact that the trees are K strategists (slower production of biomass) and the crops are, by comparison, R strategists (faster production of biomass). But after a few years (approximately 10 years), the trees begin to dominate the crops with the modification on their anatomy and the end of pruning. (Dupraz, C. et al, 2011). At this moment, an agroforestry tree grows faster with more biomass than a forest tree (Figure 7). This significant growth could be explained by a lower density (reduction of interspecific competitions) and a lower competition with weeds. We could explain this by the attention given to the trees and the inputs which are not used by crop. Farmer's observations are more significant in agroforestry systems than in a forest (Dupraz, C. et al, 2011). This point is important because it allows the rapid identification of issues (e.g. attack of disease or pest …). Competition during the first years could be very significant if the crop is very aggressive with a deep root system such as sainfoin or lucerne (Dupraz, C. et al, 2011).





<u>Figure 7:</u> Evolution of the height of log (left) and the trunk diameter (right). (From Dupraz, C., et al, 2011). Trees perform better in an agroforestry system than in a forest.

Rooting competitions are the most important for the trees because crops develop many roots and fine roots in the top layers of soil particularly for winter crops. They absorb all soil water in the top layers before the start of tree growth (Dupraz, C. et al, 2011). This forces the tree roots to deeper soil layers, under the root system of crops (Annexe 4). This modification can increase the tree's resistance to drought, to use the nutrients released by the crop, to mobilize the nutrients present in the deeper soil layers and to reduce the competition between trees and crops. This is the time of facilitation.

5.3. Impacts on pests, diseases and weeds

In agroforestry, the pressure of pests and diseases can be reduced by an enrichment of the diversity of the niches with more complexity compared to a conventional system (Smith, J. et al, 2011). An agroforestry system creates: 1. a modification of the distribution of the host plant making it more difficult for pests to locate; 2. a species' association where one species could divert the pest's attention and protect the other species; 3. one species could be repellent for pests or diseases; 4. increase the density and diversity of predators and parasitoids; 5. higher interspecific competition between non-pests and pests (any references for these points). In a silvoarable trial in the UK, Naeem, M. et al (1994) found a decrease of 50% of aphid's population in winter barley compared to a conventional system. This reduction was explained by the increase of the predators (Syrphidae) which used trees row as a refuge (Phillips, D.S., et al. 1994). Then, Rekany (2014) showed a higher diversity and abundance of predators in and close to the tree row. He observed also a decrease of these two factors when the distance between the plot and the tree row increases (Rekany, N. 2014). However, other authors have found an increase of some pests such as slugs (Griffiths, J., et al. 1996. Dupraz, C. et al.2011). they observed more damage close to the tree row where these kinds of pests find better conditions. However, INRA, CTIFL, ACTA found many positive impacts of mainly trees' species on predator populations (Annexes 5) (Dupraz, C., et al. 2011).

Trees create shade and modify the microclimate in the field. Many weeds in a conventional field have a high light requirement. Therefore, the shade created by trees could impact the weed population. In France, Meziere, D. et al (2015) showed a lower density of weeds with more diversity in a silvoarable than in a conventional field. However, the tree row could be a source of many species (e.g. thistle, rumex, …) (Dupraz, C., et al, 2011). But no contamination by the tree row have been proven. (Meziere, D., et al, 2015).

6. Silvoarable and microclimate: tree's protection

In agroforestry like in a forest, trees modify the microclimate of the field. Wind speed, temperature of the air and the soil and humidity are influenced by the trees (Smith, J., 2011). These modifications could take part in explaining yield gains, crop phenotype modification and biodiversity.

6.1.Wind speed

The trees can reduce wind speed. This modification allows a better distribution and utilization of the water from irrigation and soil, a decrease in evapotranspiration, an increase in yield and crop quality in the zone of protection and improve water use efficiency (Jose, S., et, 2004). However, there are some differences in function of the design of the silvoarable system: for example, tall standard trees and SRC trees don't have the same effects (Dupraz, C., et al. 2011). For tall standard trees, the reduction of wind speed is realized at a higher level (2 to 6 meters in function of pruning's height). The space between the soil and the first leaves could cause some lodging of the crop (effect of Venturi) (Dupraz, C., et al, 2011). But for SRC alleys, the effect on the wind speed is better known. With the studies on hedgerows, we can say that the decrease is extended up to 30 times the height of the shelterbelt height for leeward side and between two and five times for the windward side (TAMANG, B., et al. 2010. WILLIAMS, P.A., at al. 1997). The reduction of the wind speed was estimated at 50 %. An Austrian study showed a saving of 2000 $m^3ha^{-1}yr^{-1}$ of water due to the reduction of wind speed (Donnison, L., 2012).

6.2. Air's modifications

Trees reduce the thermal amplitude and increase the humidity of the air by reduction in wind speed and trees' transpiration (Dupraz, C., et al, 2011). Gosme, M., et al (2016) showed in France in a twenty-year-old poplar system a reduction of the thermal amplitude. This fact allows to obtain colder day temperatures and warmer night temperatures (Figure 8). However, Smith, J., et al (2011) showed in United-Kingdom an increase in air temperature of 1.5 °C in two years old SRC willow regrowth. These modifications could reduce the effect of the last frost which are more frequently observed (e.g. on vineyards and cereals in 2017 in Europe).

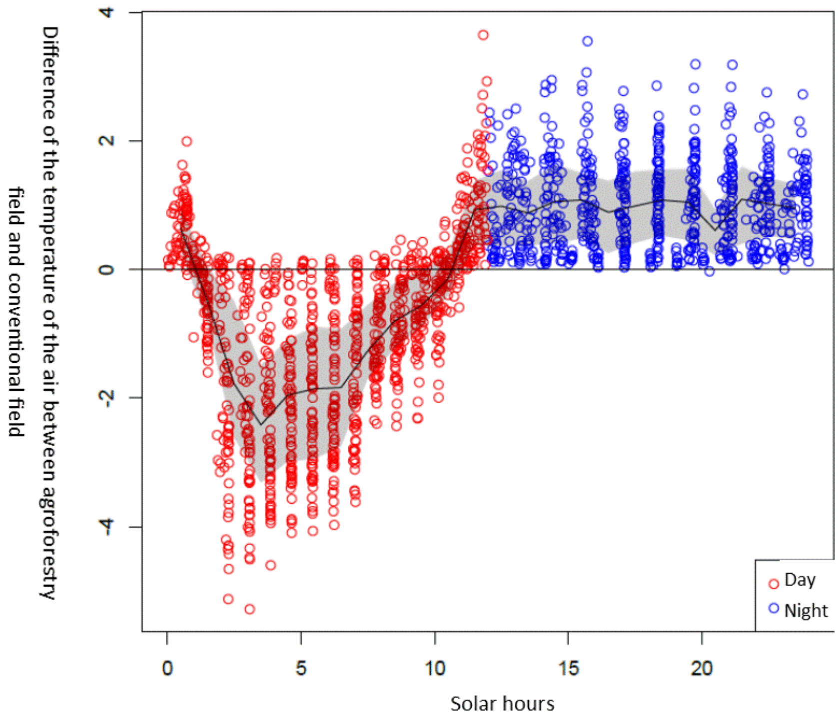
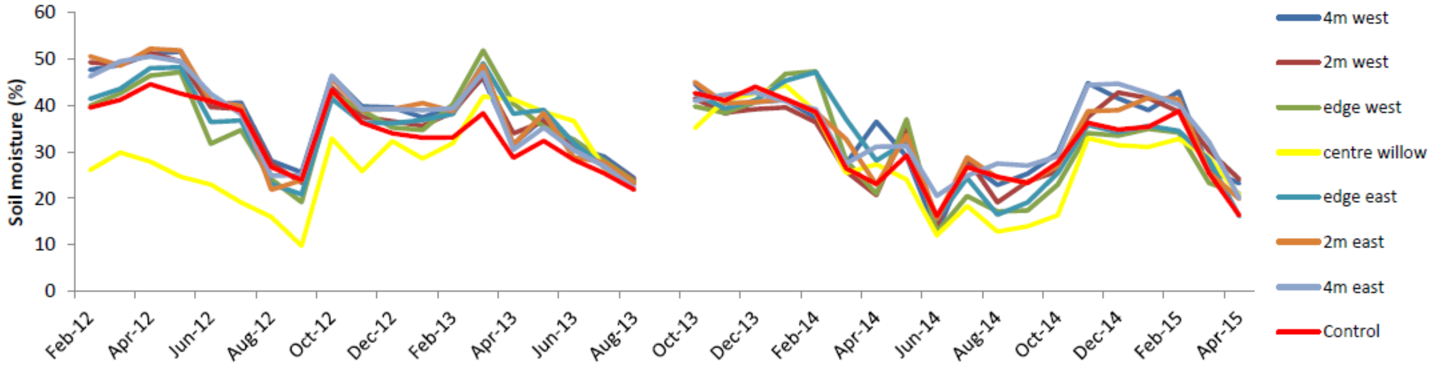


Figure 8: Difference of air's temperatures between an agroforestry field and a conventional field (From Gosme, M., et al, 2016)**.** Tree creates an advantageous environment for crops through microclimate modification.

6.3.Soil impacts

The trees can also modify the temperature and the moisture of the soil. Indeed, Foerid et al, (2002) in Denmark, showed an increase of soil temperature close to the four-year-old hazel row during the day and a decrease during the night. And they showed that the moisture of the soil was significantly higher close to the hedgerow. Smith, J., et al (2016) showed a soil temperature equivalent to the control and a soil moisture variable in function of the season, the year and the distance between plots and the tree row (Figure 9). But soil moisture was lower in the tree row than in the control.



<u>Figure 9:</u> Monthly soil's moisture raised in two-years-old willow in United-Kingdom (Smith, J., et al, 2016)

6.4.The shadow of the trees

In agroforestry, trees vary in the amount of shade they cast on adjacent crops, depending on species, form and management (e.g. coppice vs standard trees) (Dupraz, C., et al, 2011). This shadow could have an impact on the crop (by reduction of light) and can explain the observations seen in the II. 5. 1. 3. mainly when light is the limiting factor such as in our temperate region (Smith, J., et al, 2011). Some studies showed a negative impact on the yield due to reduction in PAR levels (Jose, S., et al, 2004). However, Reynolds, P.E., et al (2006) showed a reduction of PAR, NA and yields only in the competitive zone. Reduction of NA was correlated with the reduction of yield. Gillespie, A.R., et al (2000) in the midwestern USA didn't find significantly effect of the shadow on corn yield in an agroforestry field. And the reduction of yield zone is correlated with an increase of the quality in the competitive zone (Jose, S., et al, 2004. Dupraz, C. et al, 2011. Jung, L., et al, 2014).

7. How to manage the competition in agroforestry system?

As we saw, intercrop trees and crop create some competitions (e.g. water, light, …) and they could be very negative for the crop and the tree. But, farmers can manage his project to reduce at the minimum the competition. This part focus on this point and we try to identify some ways.

7.1. The indicators of competition

First, we can identify five specific variations for each agroforestry field like in silvopastoral system:

- H: the tree height (a function of the species).
- Hp: the height of pruning.
- W: the width of the alley.
- L: the distance between each tree on trees' row.
- D: the density of trees per hectare.

Secondly, we can determine three indicators of the agroforestry footprint (Dupraz, C. et al, 2011). The first is the indicator of the crops alley. It is the report of H on W and it is called IE1 (Figure 10). Then, the second is the indicator of tree density and it is named IE2 (Figure 10). The third is the indicator of the cumulative length of crowns. It names IE3 (figure 10). The length of the crown is the length of the beginning of all branches to the top of the tree. It is obtained by the pruning of the tree. This task allows to obtain the same configuration of forestry tree (Robinson, J. et al, 2006) and to reduce the competition between trees and crops (Dupraz, C. et al, 2011). The part of this length on the total height of the tree is variable: it represents 50 % during the first years after the tree planting and 30 % just before their harvester (Dupraz, C., et al, 2011). The cumulative length of the crown is also a good indicator of the impact of the trees on the crop. (Dupraz, C., et al, 2011).

In aim to keep a profitable crop under trees until their harvester, Dupraz, C et al estimated that these indicators of the agroforestry footprint must stay under 1. So, the distance between each tree row must be equal at least to the tree's adult height. These authors advice to keep a cumulative length of crown bellow the limit of 500 m.

$$IE1 = \frac{H}{W} \qquad IE2 = \frac{H^2}{(W \times L)} \qquad IE3 = \frac{(H - Hp) \times D}{500}$$

Figure 10: Formulas of the three indicators of the agroforestry footprint (Dupraz, C. et al, 2011)**.** According to the authors, 500 meters of cumulative length of crown is the limit to keep the competition between trees and crops at a low level.

7.2.Shade in agroforestry: impact and management

The importance of this shadow depends on the density, the length of alley, the orientation of the tree row, and tree pruning (Dupraz, C., et al. 2011). So, how could we reduce and manage the shadow? The first way is to plant the trees with on orientation of North-South. Through this, we obtain an even distribution of shade on the field. Secondly, if our goal is to maintain a profitable crop during the tree lifespan, we must: 1. have a density less than 80 trees per hectare; 2. keep the indicators of competition close or less than one, and: 3. have a cumulate length of crown under 500 meters per hectare (reference). Crop yields decrease under 60 % of light levels (Dupraz, C., et al, 2011). C3 plants (e.g. wheat, barley, potatoes, …) are more tolerant than C4 plants (e.g. corn, sorghum, …) to shade due a lower saturation level of photosynthesis (Jose, S., et al, 2004). So, if the percent of shade is too high, we can drill plants with a lower need of light such as pasture grass. We can also just drill the complementary zone (Dupraz, C., et al, 2011. Cardineal, R., et al. 2012). And we can breed plants and varieties in an agroforestry environment to obtain plants tolerant to shade; currently all crop varieties are bred in open field conditions.

Finally, microclimate modifications and shade created by trees, help to reduce heat stress for crops, to obtain a better seed survival rate (Jose, S., et al. 2004), an earlier germination, more growth at the beginning of the season (Smith, J., et al, 2011), improve the quality of product, protect the soil (e.g. reduce wind erosion) and promote soil life and biodiversity.

8. Silvoarable: when trees and microclimate modification change the global climate

Agroforestry is recognized by many institutions as a serious way to reduce climate change. And climate change is recognized as the main cause (80 %) of crop yield stagnation (Dupraz, C., et al. 2011). As we saw, the trees create a microclimate which could be negative for crops (competition for light, water and nutrients) but also advantageous (decrease of evapotranspiration, shade, reduction of the thermal amplitude). These modifications could deliver an importance to agroforestry to reduce the climate change effect. Agroforestry allows to stabilize productivity, reduce yield variability caused by climatic variations (drought, storm, frost, high temperature, …), and increase the growing season (Dupraz, C., et al, 2011).

Agroforestry could also modify the global climate of a landscape. If the trees are planted in each field of the same landscape, a microclimate will be created in each field. So, each microclimate will influence the global climate. Furthermore, we saw that the trees reduce air temperature by their transpiration and reduction of wind speed. In fact, this is the small water cycle which allows this! First, the trees release water in a liquid state. And it absorbs many sunlight to become gas. So, sunlight is absorbed by water, and doesn't warm the air and the soil. Secondly, vapour, created by the trees and sun rises into the atmosphere. And when it arrives at colder layers, it condenses itself to make cloud (Kravčík, M., et al, 2007). Finally, water returns into the soil and the plants by the rainfall. And the cycle start again with a reduction of the air temperature similar to what we can observe after a rainfall (Kravčík, M., et al, 2007) (Annexes 6). So, with agroforestry implantation at a landscape scale, the mitigation of climate change effects is possible while maintaining a good productivity.

Furthermore, agroforestry is also a way to manage carbon, the principal greenhouse gas of climate change. On one hand, the trees as crops absorb carbon as a result of photosynthesis and carbon is stored in their tissues and then in the soil through root turnover and leaf litter. This fact is recognized as a good way to reduce the storage of atmospheric CO_2 (Smith, J., et al, 2011). Cardineal, R., et al (2015) showed a high increase of soil organic carbon (SOC) storage in an agroforestry system. They studied the SOC storage at a depth of 0 to 200 cm in southern France, in an eighteen-year-old walnut-durum wheat agroforestry field compared to a conventional field. They found an increase of SOC storage in all the soil profile (0 to 200 cm) in the tree row (21.6 ± 1.0 Mg C. ha^{-1} (depth: 0-10 cm)) compare to the alley (9.8 ± 0.4 Mg C. ha^{-1} (depth: 0-10 cm)) and the conventional field (9.3 ± 0.1 Mg C. ha^{-1} (depth: 0 to 10 cm)) (Annexes 6). They have also showed that the SOC saturation of clay particles amounted 17 to 40 % in the trees row. They observed that as depth increases, more carbon is associated with mineral particles (silt and clay). So, they defined a total organic carbon accumulation rate of 1.11 ± 0.13 Mg C. ha^{-1}. yr^{-1} (at 0 to 100 cm depth with above ground tree C). This way stores more carbon than cover crops (0.32 ± 0.08 Mg C. ha^{-1}. yr^{-1} on 0 to 22 cm) and no-till farming (0.23 Mg C. ha^{-1}. yr^{-1} on 0 to 30 cm) (Cardineal, R., et al. 2015). But SOC storage depend on the system design, tree's species, the age of trees, the climate, soil's texture and the cover of the tree row. (Smith, J., et al, 2011). On another hand, agroforestry substitutes non-renewable carbon for fuel with renewable carbon from woodfuel: we can use trees in SRC to produce biofuel, firewood, … (Smith, J., et al, 2011). We can also reduce the pressure on primary forest by the production of timber wood and precious wood (Dupraz, C., et al. 2011). Agroforestry can also reduce the nitrous oxide emissions by 0.7 kg. ha^{-1}. yr^{-1} thanks the reduction of fertilizer (Thevathasan. N.V., et al. 2004).

9. Silvoarable: trees-soil relationship

Before, we saw how trees and crops influence each other. Trees or crops or cover crops protect, modify and improve the soil. Many authors studied this very important point mainly with regards soil degradation caused by agricultural practice (e.g. ploughing, high exports, fertiliser, no cover during winter and autumn, loss of organic matter, …) (Dupraz, C., et al, 2011. Young, A., 2002).

Trees interfere with the soil by three mechanisms: 1. Increasing organic matter inputs for the soil; 2. reducing losses from the soil; and 3. improving physical, chemical and biological characteristics of the soil (Young, A., 2002). First, as we saw in the nutrient section (II.5.1.2) trees increase the level of organic matter by the input of their leaves and fines roots and nitrogen through biological nitrogen fixation. (Smith, J., et al, 2011). Jose, S., et al (2000) found that 32 to 58 % of the total nitrogen in an alley cropping of corn came from nitrogen fixation of red alder. Cardinal et al, (2012) evaluated leaf inputs at 450 $kg.ha^{-1}.yr^{-1}$ in a twenty-one year old tree mixture. After decomposition, leaves release nutrients and increase soil porosity, and soil storage of water and nutrients (Dupraz. C., et al, 2011). All the physical and chemical characteristics are improved by the enrichment of Soil Organic Matter (SOM). Secondly, thanks by their deeper root systems, the trees could decrease the runoff of nitrates and all mobile nutrients lost by the crops (Dupraz, C., et al, 2011). Thanks to this mechanism, we can reduce the pollution of water by 70 to 97% for suspended solids, 60 to 98% for phosphorus and 70 to 95% for nitrogen (Lee, K.H., et al, 2003. BORIN. M., et al. 2009). If trees are planted along the slope and the ground in the tree rowis covered, soil erosion can be reduced (Dupraz, C, et al,2011). These two ways therefore create a closed nutrient cycling and an environment with more SOM, resulting in an increase in soil fertility, similar to forest soils.

Because the soil is an ecosystem, agroforestry helps to conserve and increase soil life and health. The trees increase the diversity and quantity of microorganisms, earthworms and other soil invertebrates through increasing the diversity of SOM (e.g. celluloses, lignins, …), root exudates (Smith, J., et al, 2011) and by modification of the microclimate (Dupraz, C., et al, 2011). In the long term, silvoarable systems help farmers to reduce the use of fertilizers and pesticides. But this point depends on many factors in function of each agroforestry field (Dupraz, C., et al, 2011).

Finally, if we want to protect the soil, the environment, the climate, and increase the sustainability of farming, we must be coherent with our practices. With agroforestry, we need also to reduce or avoid soil tillage and the use of fertilizers and pesticides and cover the soil at all times. Generally, we must use all the ways given by the environment. Because multiple ways are better than one!

III. Study of effects of trees and their ages on the agro-ecosystem

1. Materials and methods

1.1. The experimental field

This study take place in the agroforestry field of the Organic Research Centre. It is located in Hamstead Marshall close to Newbury in Berkshire (GPS localization: 51°23'14.19''N; 1°24'08.34''W). The climate of this area is oceanic and is characterized by an average annual temperature of 11.14°C and an annual precipitation of 667 mm in 2016 (From Mett Office, 2017). The texture of the soil is very variable. At the top of the field, the soil contains clay and loam in dominancy. At the bottom, it contains loam and sandy. This field is surrounded by a mixed species hedgerow and grassy strip.

In the field, two species were planted in 2011: Common Alder (*Alnus cordata*) and basket willow (*Salix viminilas*). They are used as biofuel in SRC. The species were planted separately and as a mixture in plots measuring 50m in length (north/south) with three tree rows per plot (Annexes 7). The field counts nine tree rows: only six are studied because the trees have a good development in these rows. Two years ago (Feb 2016), three tree rows were coppiced. In January 2017, a further three rows were coppiced (Figure 11). In the final three rows, the trees have not yet been harvested. Thanks this, we can realize this study. The distance of the alley is 20 meters. In the tree row, trees were planted as twin rows at a distance of 0.7 m. All trees are 1 m apart in the same row (Annexes 7). So, the density of trees is 1175 trees per hectare. This density is very high compared to the other densities we saw in the state of the art. This field was a pasture and the trial was used to determine the interaction between dairy cows and trees for the SOLID project (www.solidairy.eu). Last spring, the alleys between the tree rows were ploughed. before being drilled with winter oat (*Avena sativa*) on 10th October 2016 at a rate of 185kg/ha.

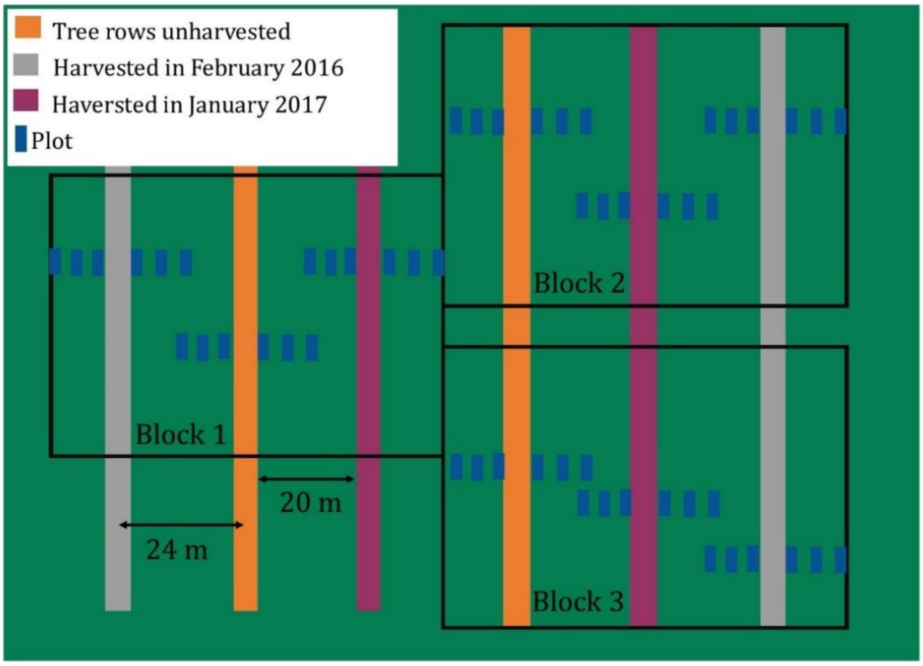


Figure 11: Scheme of the experimental field with the rhythm of trees' harvest. The unstudied tree rows are not include. The blue plots are the plots of the assessments of the oat and the weeds. This scheme is not to scale.

1.2. Earthworm Assessments

Samples were taken in April 2017 in the tree row, and at 4 and 9 meters from the tree row. We took six soil cores per plot including two at each distance. For this study, we repeated it three times for the Common Alder and two times for the Basket Willow, giving a total of 30 samples. This work consisted of collecting a soil core at each location and to crumble this core by hand. We collected all earthworms which are alive and not cut. The dimensions of the core are 13 cm long, 13 cm wide and 22cm deep. So, we took a soil volume of 0.0037 m^3 and a surface of 0.0182 m^2. At the same time, we counted the number of earthworms for each soil core. And we used this formula to determine the total population per square meter:

$$Earthworms\ per\ square\ meter = \frac{Mean\ per\ sample}{suface\ of\ the\ samples}$$

After this work, for each sample, we separated juvenile individuals and mature individuals with one criteria: the present or absent of the clitellum. For the juveniles, we counted the number of pale and red individuals as an indication of eco-type. Then, the mature earthworms were preserved in alcohol in aim to observe the clitellum and the male part. These two characters are at the base of the identification key used (reference). And all the samples were stored at 4 °C until the moment of the identification (the next day). Concerning the identification, we used an identification key (1: Sherlock, E. 2012) and a binocular microscope. We noted the species of each earthworm in aim to study the richness of the different plots

1.3. Ground beetles' assessments

For this assessment, we used pitfall traps which are designed by two small cups protected by an aluminium roof. In the trap, there was a liquid mixture of water and soap to kill and keep beetles in the bottom of the trap. Traps are buried into the soil with the aim to have the top of the trap at the same height of soil surface. The traps were positioned under the tree and at different distances from the tree row (4, 8, 12 meters). We focused on the oldest alder trees in aim to study the greatest effect of trees on these invertebrates. One trap was set up at each distance on different place of the field at the West of trees rows (Annexes 9). Two control plots were established in the top and the bottom of the field (i.e. with no trees) with respectively six and five traps. The second control was moved to the highest point of the field for the second round of the trapping. And three traps were added on the grassy strip in front of the trees. Traps were emptied every two days. The first round took place at the end of April during 6 days and the second at the end of May 2017 during 8 days. Each sample was filtered with a sieve with a square mesh of 1 mm and the beetles were collected with forceps. Then each beetle was identified with a key (2: Luff, M.L. 2007) and a binocular microscope at 10x or 30x zoom. We noted the species of each individual and determined the number of beetles per species for each sample. So, we studied the diversity, the richness and ground beetles' population between the different factors (age of tree growth and distance between the tree row and the plot). For the diversity, we used the reverse of Simpson's index:

$\gamma = 1 - \frac{(n(n-1))}{N(N-1))}$ N: Total number of beetles per plot. n: number of beetles per species and per plot

1.4. Soil assessment

1.4.1. Soil mapping

For this assessment, we began by locating thirty-two GPS points on the different plots delimited by the constitution of the trees species (Annexe 7). We used GSPMAP 62stc with the QGIS 2.0.1 software. After this, we collected soil samples for each point. We collected ten soil cores around within 2 meters of the point with an auger at a depth of 20 cm. These ten cores were collected into a bucket and mixed to obtain a single sample per point to represent this area and this point. All samples were analysed by NRM laboratory to obtain soil texture. The results allow us to map the soil texture of the field by linking similar points.

1.4.2. Organic matter assessment

This assessment is similar to the earthworm assessments in terms of the location of plots, with an additional sample. Samples were located at 0, 4, 8, and 12 meters of the tree row. Soil cores were collected with an auger at a depth of 20 cm. For each plot, two soil cores were taken at a distance of two meters and mixed to obtain a composite sample. This assessment took place in the alleys with the oldest alder trees. This protocol was repeated twice per plot for the three blocks. So, in total we collected twenty-four samples which were sent to the NRM laboratory for analyses of total soil organic matter.

1.5. Crop Assessments

Concerning this assessment, we focused on the growth stage, the cover of oats, the cover of diseases and the height of the oats. These characterizes were assessed each week. These assessments began on the 11th of April and finished on the 18th May for the cover of the oats and weeds and the 2nd of June 2017 for the two other assessments. We collected these characterizes at different distances from the tree rows (4; 8; 12 meters) and age of trees (1st year regrowth; 2nd year regrowth; unharvested). These assessments were repeated twice for each plot.

We followed Zaddock's scale to determine the growth stage and its evolution (reference). The first time, we determined the number of tillers per plant. For that, we counted the number of tillers for one plant and we repeated that three times for each sample location. After, three main stems were collected per plot. We determined the growth stage as a function of the number of nodes. Afterwards, we followed the booting, the ear emergence and the flowering for each sample location. At the same time, we have also determined and followed the cover of the oats and diseases. For each plot, we analysed a square of 0.5 m^2 in order to determine the cover of the oats and weeds. For the cover of diseases, we collected the third leaf in beginning to the top of the main stem. The first leaf was this which were not wrapped around the stem. And we determined all diseases present and their cover. Then, after the last leaf emergency, we focused on this leaf because it is the most important. For this assessment, we collected three leaves on three different main stems for each sample location.

Furthermore, we studied the height of the oats for each sample location. For that, we measured the height of a representative main stem in order to obtain a mean height. We have complemented this assessment by an in-depth study in the alley with the oldest trees. We took eight heights for each distance (2; 4; 8; 12) from the tree row, species and orientation (East & West). For the alder alleys, the distance between each measure was approximately 4 meters and for willow, this distance was shorter (2 meters). Finally, we focused on the gain of height. We used a ratio of the heights at 2.5; 4; 8 meters of the tree row to the average height at 12 meters.

1.6. Weed assessments

Concerning the weeds, we focused on their cover and diversity. Weekly, at the same time as the crop assessments, we determined the cover of the weeds at the same locations. We also collected the community of weeds on the 18th of May 2017 for each sample location, twice in each tree rows. This study was carried out on a surface area of 0.5 m² at the same locations as for crop assessments. We studied the total cover, the cover of each specie, the diversity, the number of species, their value for wildlife and their lifetime (perennial and annual). We used the encyclopaedia of arable weeds (Clarke, J., et al) to determine the value and the lifetime of each species. And we attributed the number one for each specie which have a value for wildlife and zero for no value for wildlife. We multiplied this number by the species cover at each location. Then, we added all the values of each species of the plot to know the value of the community for wildlife. For the lifetime, we added the cover of the perennial weeds of the sample. And we calculated the ratio of the cover of perennials weeds on the total cover for each plot. We obtained the diversity using the reverse of Simpson's index, using the cover of each species, therefore adapting the formula:

$\gamma = 1 - \frac{c(c-1)}{C(C-1)}$ C: Total cover of weeds per plot. c: cover of weeds per species and per plot

1.7. Results and analyses

After the assessments, we entered data in Excel to obtain the different means for each of the variables, relevant graphics and to prepare files for statistical analyses. For that, we used R studio version 0.98.1103. First, we used the Bartlett test to know if our data, for each factor, have similar variances. Secondly, we used the Shapiro test to know if our data follow the normality law. Thirdly, if these two tests were insignificant, we run a one, two or three way anova in function of the number of factors.

Then, we followed with a post-hoc test (HSD test) to show the differences between each group. The HSD test was run if and only if anova showed significant differences. If the Bartlett test and/or the Shapiro test showed significant differences, we instead carried out a Kruskal test: the equivalent of an anova test but for non-parametric data. This was followed by a Wilcox test as the post hoc test to show the differences between each factor.

2. Results

2.1. Earthworm study

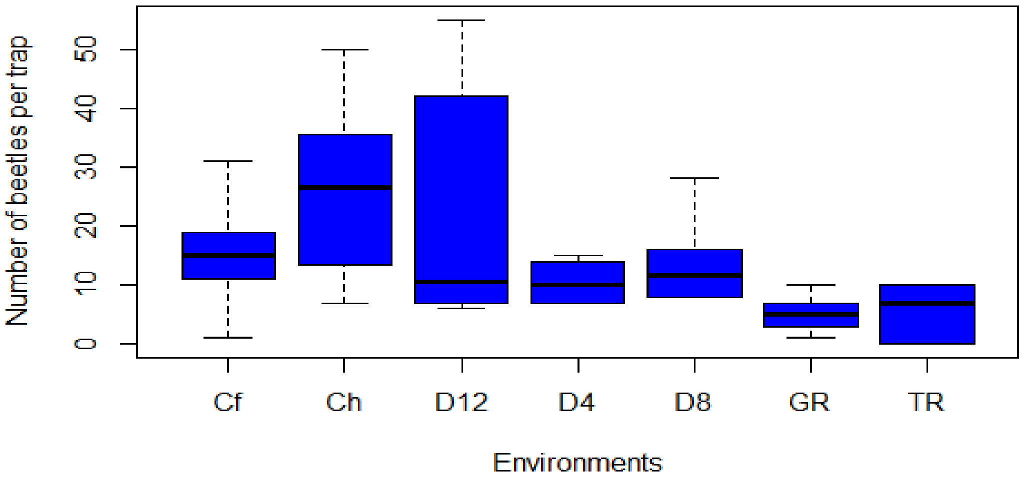
Concerning the size of the population for each, we found 814 earthworms/m² in the alder tree row and 549 earthworms/m² in the willow tree row. In the crop alleys, we found respectively 238 and 348 earthworms/m^2 in the alder alley and 178 and 218 earthworms/m^2 for willow at 2 and 9 meters of the tree rows respectively. These averages per meter square were significantly different (X^2= 15.854, p=0.007) (Annexes 8). Only in alder tree rows, we have found a population statistically higher. We can observe a higher population in the alder tree rows than in willow tree rows (+ 48.3%) without significant differences between these two species. This fact may be explained by a higher development of the alder trees and by the nitrogen fixation by the alder trees which releases more SOM. The cultivation of the meadow by plough and the decrease of soil moisture in April could be an explication of the reduction of the earthworm populations in the alleys (Duiker, S., et al. 2008). But we can't found statistically differences between willow tree rows and the alleys due to the enrichment of SOM by the pasture (Duiker, S., et al. 2008). Concerning earthworm species richness, we didn't find any significant differences between each plot (X^2=8.719, p=0.121) (Annexes 8). We can explain that by the high proportion of juveniles in all samples (mean of 67.46 %). But we found frequently more species in the tree rows compared to the other plots. *Lumbricus terrestris*, *Aporrectodea longa*, *Eisenia fetidia* were found only on the tree rows, perhaps due to a high level of organic matter on the soil surface (litter and woodchip). The tree rows were not ploughed. This fact can also explain the higher richness in this part of the field. Only *Lumbricus castaneus* was found in the tree rows and in plots at 4 meters of the tree row. We can explain that by connexions between the tree rows and the first meter of the alleys close to the trees (Dupraz, C., et al, 2011).

2.2. Ground Beetles study

In April, we found 0.33 ground beetles per trap in the tree row, 4.25 ground beetles per trap at 4 meters of the tree row, 4.89 ground beetles per trap at 8 meters, 4.44 ground beetles per trap at 12 meters and 6.45 ground beetles per trap on the control around by hedgerows. The differences between each average number of ground beetles are significant (X^2=24.897, p=5.276.10^{-5}). However, we found statistically the same average number in the alleys and in the control (Annexes 8).

We found different results for the richness and the diversity of ground beetles. For the richness, we found a mean of 0.333 species per trap in the tree row, 2.125 species per trap at 4 meters of the tree row, 1.667 species per trap at 8 and 12 meters and 1.871 species per trap in the control. The differences between the tree row, the alley and the control were significant (X^2=20.306, p=0.0004). We found more species at 4 meters of the tree row compared to the rest of the field without significant differences (Annexes 8). The study of the biodiversity (Simpson's Index) showed no effect of SRC trees on the diversity of ground beetles in the alley compared to the control (Annexes 8). But, we found a higher biodiversity in the alley and in the control than in the tree row (X^2=1.873, p=0.018). We found also a higher biodiversity at 4 meters of the tree row without significant results.

Secondly, we found more ground beetles in the second round than in the first (Figure 12). We found significant differences in the average number of ground beetles per trap in function of the environment of the sample location (X^2=20.457, p=0.002) (Annexes 8). But, the activity of ground beetles was statistically the same in the controls and in the alleys. We made the same observation between the alleys and the tree rows (grassy strips included) (Figure 12). But we found a higher activity in the middle of the alleys than close to the trees without significant differences.



Cf: Field control around by grassy strip

Ch: Field control around by hedgerow

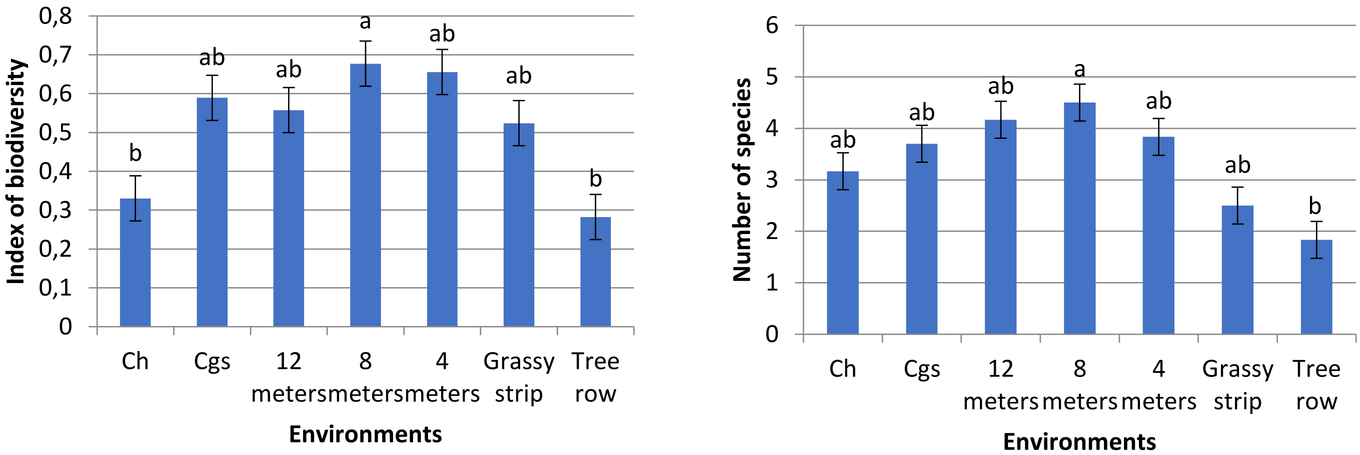
Dx: Plot at x meters of the tree row

GR: Grassy strip

TR: Tree row

<u>Figure 12</u>: Effects of three years old SRC trees on the activity densities of ground beetles in May 2017. We can observe a decrease of the number of beetles per trap in the tree row (including the grassy strip compare to the other environments)

Concerning the richness, our observations are different: more species in the alleys compared to the controls (Figure 13). Anova showed significant differences (F=2.657, p=0.027) (Annexes 8). However, we can show a higher richness at 8 meters of the tree row than in the tree rows (Figure 13).



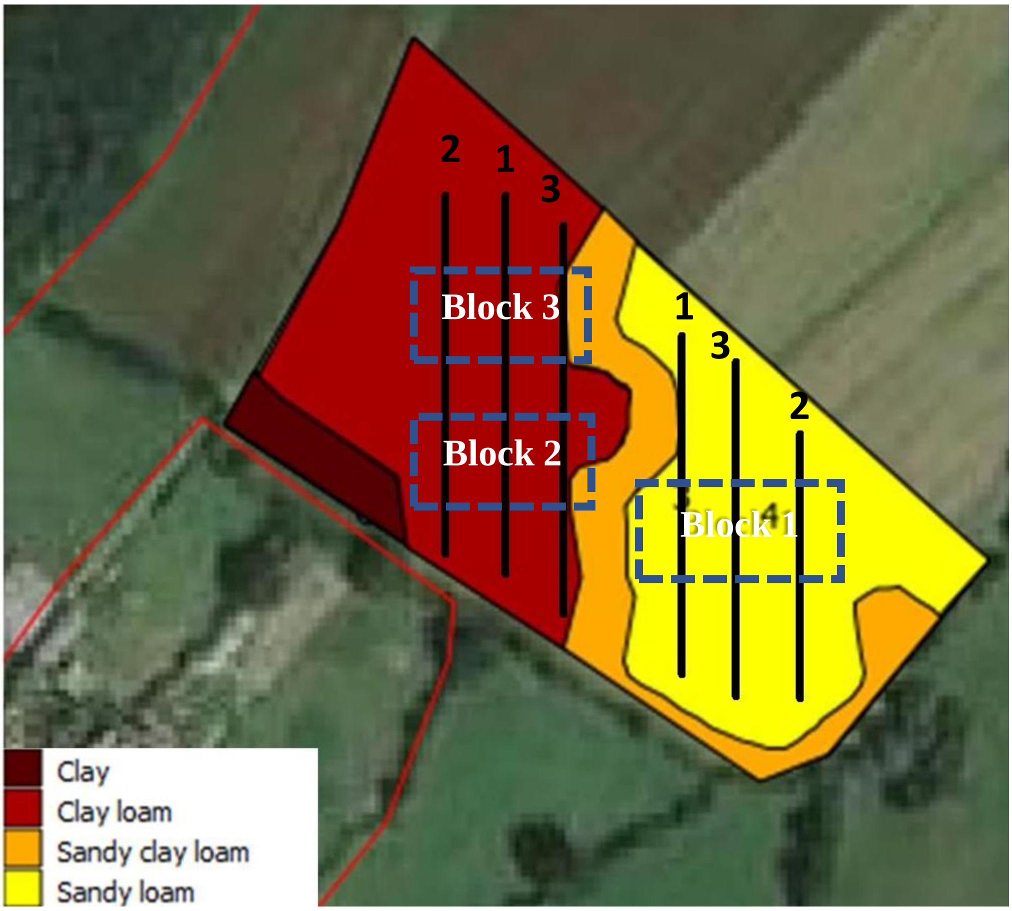
<u>Figure 13:</u> Effects of three years old SRC trees on the biodiversity and the richness of ground beetles sampled in May 2017. Ch: Control with hedgerows. Cgs: control with grassy strips. Groups established by Tukey test with a factor risk of 0.05.

Furthermore, we did the same observation for the study of the diversity. We found significant different on ground beetles' diversity (F=3.851, p=0.003). Then, a post hoc test showed significant differences between the plots at 8 meters of the tree row, the control surrounded by hedgerows and the tree rows (Annexes 8). The plots close to the tree row (4 and 8m from the tree row) had the highest biodiversity (Figure 13). However, the plots close to the tree row had statically the same biodiversity as that in the middle of the alley, the control surrounded by grassy strips and the grassy strip in front of the tree row (Figure 13). This point showed the interest of the cover of the tree row by grass and legumes to increase the biodiversity of an agroforestry field. The lack of vegetation cover in the middle of the tree rows may have an impact of the population of ground beetles because tree row traps were placed in the middle of the tree rows just covered by woodchip and leaf litter.

Finally, we can't show an effect of the young SRC trees (3 years old) on the number, the richness and the biodiversity. In fact, ground beetles prefer open area than closer area. This point could explain the insignificant result. Then, the tree row is covered by woodchip, dead litter. So, it is hard for ground beetles to explore this area. In the next Winter, it would be good if we repeat this assessment. Then in the next year, it would be interesting to follow the evolution of this population in the ORC silvoarable field and to compare with an open field. This long study would aim to show an increase of these parameters by the SRC trees.

2.3. Soil mapping

We found four different soil textures in the experimental field (Figure 14). The first is close to the hedgerow at the West corner. It contents 26.00 % sand, 36.00 % silt and 38.00 % of clay. It is characterized as a clay texture. The second is at the western half of the field. It is characterized by a clay loam texture with 36.67 % sand, 33.33 % silt and 30.00 % clay. The third is a strip between of the second zone and the fourth zone. It follows also the limit of field's bottom. It is composed by sandy clay loam texture with 55.20 % sand, 24.20 % silt and 20.60 % clay. The fourth covers the eastern half of the field and it is characterized by a sandy loam texture. It contains 66.00 % sand, 18.86 % silt and 15.64 % clay.



<u>Figure 14:</u> Map of the soil texture of the ORC agroforestry field. The numbers at the top of each row give their age.

2.4. SOM

At the same locations as the earthworm's assessments, we found a SOM level of 4.05 % in the tree rows, 3.77 % at 4 meters of the tree rows, 3.53 % at 8 meters and 3.73 % at 12 meters. There were no significant differences between these levels of SOM (F=0.484, p=0.697) (Annexes 8). In fact, we can explain this by the enrichment due the destruction of the meadow. Also, samples were taken during the growing season of the oat, so, roots of oat or weed could influence these results. To be sure, it would be interesting to repeat this assessment in autumn and in the following years. So, we could follow the enrichment of SOM by the SRC trees in this silvoarable field over time. We also found no correlation between earthworm abundance per sample and SOM levels.

2.5. Crop assessments

First, sometimes we found significant differences in response to the age of the tress and an interaction of the distance and the age of the trees in terms of mainly growth stage: second nodes detectable (Age: X^2=10.671, p=0.005 and interactions: X^2=19.174, p=0.014) and ear emergence (Age: X^2=7.360, p=0.025) (Annexes 8). However, we can't show an impact of the age of trees because the one year old alleys had the same behaviour as the unharvested alleys. The two years old alleys were late in comparison to the others. We can explain that by the heterogeneity of soil which could contain different storage of water and nutrients (Figure 14). Then, we observed an average number of tillers per plant higher in the unharvested alleys (4.185 tillers) than in the two years old and the one year old alleys (3.815 tillers for the two years old alleys and 3.407 tillers for the one year old alleys). But, these averages were significant with a risk of error of 0.1 (F=2.846, p=0.069). We will see in the next year if this effect is validated or not with oldest SRC trees. But we didn't find any significant differences in ear emergence (X^2=9.403, p=0.310) and the number of tillers (F=0.860, p=0.495) in the case of the interactions (Annexes 8). Indeed, we observed no significant effects of the age of the trees and the interaction of distance and age on the appearance of the other growth stage: first node detectable (Age: X^2=3.726, p=0.155 and Interaction: X^2=7.846, p=0.449), stem elongation (12^{th} May) (Age: F=0.048, p=0.953 and Interaction: F=0.555, p=0.697), flag leaf emergence (Age: X^2=0.813, p=0.666 and Interaction: X^2=5.574, p=0.695) and the beginning of flowering (Age: F=0.083, p=0.921 and Interaction: F=1.658, p=0.177) (Annexes 8). The distance between the tree row and the plot had no influence on the apparition of the different growth stages: the number of tillers (F=0.162, p=0.851), the first node detectable (X^2=1.984, p=0.371), the second node detectable (X^2=4.244, p=0.120), the stem elongation (F=0.434, p=0.651), the flag leaf emergence (F=3.882, p=0.144), the ear emergence (X^2=0.670, p=0.715) and the beginning of the flowering (F=1.658, p=0.720) (Annexes 8). It may be that the trees are too small, even the oldest, to significantly influence the timing of growth stages. In the next years, we expect that the trees will impact the development of the oat as Gosme, M., et al (2016) saw in their poplar-cereal trial in France.

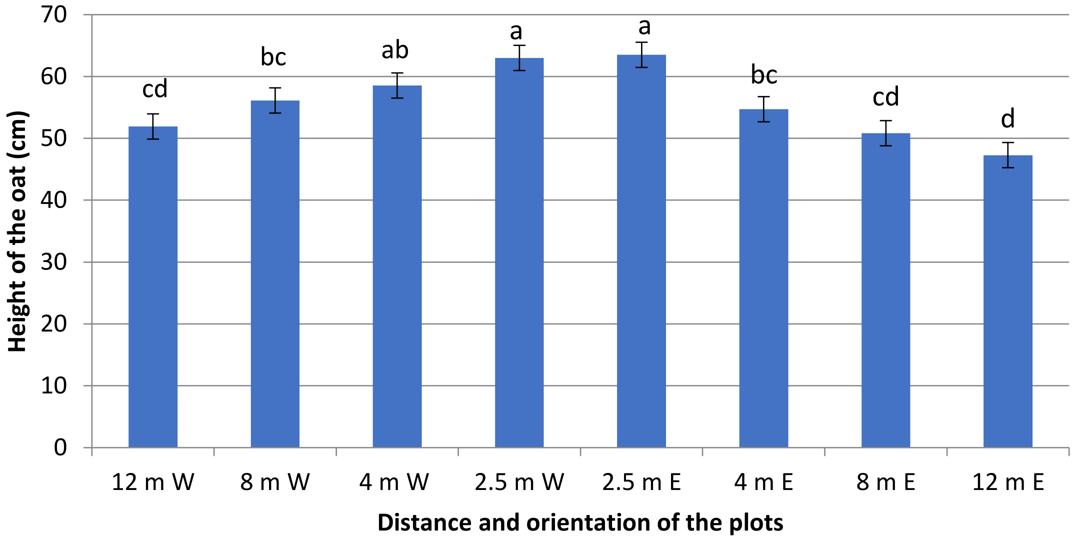
Secondly, concerning the cover of diseaeses, we found only the Helminthosporium Leaf Spot at a low pressure (mean of 1.19% on the third leaf). We observed no significant influence of the age of the trees and the localation of the sample on the cover of diseases on the third leaf (The 21th April: Age: $X^2=0.065$, $p=0.968$, Distance: $X^2=2.288$, $p=0.319$ and interaction: $X^2=4.301$, $p=0.829$. The 5th May: Age: $X^2=2.141$, $p=0.348$, Distance: $X^2=0.484$, $p=0.785$ and interaction: $X^2=3.178$, $p=0.416$. And the 12th May: Age: $X^2=2.259$, $p=0.323$, Distance: $X^2=0.069$, $p=0.966$ and interaction: $X^2=3.651$, $p=0.887$) (Annexes 8). But, we found significant differences in response to tree age on the 28th April (Age: $X^2=7.374$, $p=0.025$, Distance: $X^2=2.386$, $p=0.303$ and interaction: $X^2=14.830$, $p=0.063$) (Annexes 8). The one year old and the unharvested alleys had statistically different the cover of diseases on the third leaf (0.56% for the one year old alley and 0.72% for the unharvested alley). Then, only the two years old alley had a higher cover of diseases but it was very low: 1.44%. Concerning the last leaf, we found no diseases on this leaf. So, we can conclude that the SRC trees currently do not effect on the cover of diseases in the beginning of their life. However, the weather of wetter weight but without high temperature.

Finally, we found no significant influences of the distance between the tree row and the plot and the interaction of distance and age of the trees on the cover of oats (Annexes 8). The cover of oats or cereals is directly linked by the establishment of plant after the drilling and this establishment is influenced by the size of the aggregates, the temperature of the soil, soil texture, the depth of seeding, the rainfall, the date of seeding ... (Blake, J.J., et al, 2003).Trees may indirectly influence manly of these factors by the enrichment of SOM. Accordingly, the soil becomes easier to work with more nutrients and water and the cover of the soil by the oats or the crop could be increase. However, we found a significant cover of oats in function of the age of the trees except on the 28th April (The 21th April: $F=4.285$, $p=0.020$. The 5th May: $F=6.404$, $p=0.004$. The 12th May: $F=4.565$, $p=0.017$. The 19th April: $F=3.591$, $p=0.036$). But, the unharvested trees and the one year old alleys had statistically the same cover (respectively 46.488 % and 50. 646 %). And the twoyear alleys had always a lower cover of the oat (38.144%). So, we can't show now the effect of agroforestry on the cover of the oats because the soil texture is too variable (Figure 14). This fact influences oat establishment by the variability of aggregate size, and the storage of water and nutrients.

2.6. Height's assessments

On one hand, we found no significant differences between each factor (age, location of the sample, interaction) (Annexes 8). We can explain that by the heterogeneity of the soil (Figure 14). Indeed, we run anova to show the effect of block and found significant differences. For example, the 19th May, Block 3 and 2 had a higher height (46.833 cm and 45.222 cm) than the Block 1 (39.778) ($F=4.734$, $p=0.013$) (Annexes 8). But, we observed a higher height of oats at 4 meters of the oldest alder tree rows (Annexe 8) without significant differences (Annexes 9).

On other hand, we focused on the oldest tree row alley. On this part, we found significant differences between the different distances ($F= 64.521$, $p<2.2.10^{-16}$), the orientation of the alley (West and East of the trees row) ($F=21.251$, $p=7.94.10^{-6}$), the species and development of trees ($F=31.771$, $p=1.982.10^{-12}$). We also found significant interactions between: 1. the different distances and the orientations ($F=3.2999$, $p=0.022$) (Figure 15), 2. the orientations and the species and the development of the trees ($F=4.484$, $p=0.013$), 3. the different distances and the species and the development of trees ($F=5.447$, $p=3.581.10^{-5}$). Only the first interaction is interesting for us. In fact, the others show the effect of the texture of the soil and its heterogeneity because we compare different heights at different locations of the field with different soil's textures (Figure 14). So, we can observe a higher height at 2.5 meters of the tree rows (Figure 14).



<u>Figure 15:</u> Effect of the SRC trees on oat's height. We can see a higher height close to the tree and a higher increase in the eastern side but no significant differences. Group established with a risk of error of 0.05.

The oat height at 4 meters of the trees row in the western side was statistically the same as the first group. But it was also the same as the other plots except at 12 meters and at 8 meters in the west of the alley. We explain that by the reduction of the light which influences internode elongation. The microclimate, the enrichment of nitrogen by the fine roots, the dead leaves and the biological fixation could also explain this observation. When the trees are more developed with a higher density of leaves (i.e. alder at the bottom of the field), we found a significant height difference in comparison to the alder at the top and the willow. We have also tested the gain of height in the eastern alley and in the western alley in aim to remove the heterogeneity of the soil. We found no significant influence of the orientation ($F=0.3212$, $p=0.572$). So, we can't show an effect of the reduction of wind speed.

2.7. Weeds' Assessments

First, we found no significant influences of the age of the trees, the distance between the tree row and the sample and the interaction distance-age during the weekly crop assessments. But, we found significant differences between the cover of weeds in the tree row in comparison to the cover in the alley ($F=7.542$, $p=0.0002$). We found no effects of the age of the trees and the interaction (Age: $F=0.188$, $p=0.829$ and interaction: $F=1.086$, 0.381). This higher cover of the weeds in the tree row is due to the non-utilisation of this part and the last pasture. We will see that this cover could have a high interest but also some negative impacts.

Concerning species richness, we found an average species of 3.39 for the trees row, 4.89 species at 4 meters of the trees row, 4.78 species at 8 meters and 5.06 species at 12 meters. These differences are significant for the different ages (F=3.510, p=0.036) and distances (F=5.247, p=0.003). But, we found no significant results for the interaction age-distance (F=1.037, p=0.411). Only, the effect of the distance was interesting because tree age effect reflected soil heterogeneity (like for crops' assessments). Furthermore, the richness of the weeds was the same in the alleys statistically speaking. This difference between the alley and the trees row is explained by the cultivation of the meadow by a plough and the tillage before oat seeding. This work allows annual weeds to grow in the alley.

Secondly, concerning the biodiversity of the weeds, we found a significant effect of distance on the biodiversity of weeds (F=6.653, p<0.001) (Figure 16). The age and interaction age-distance had no statistical effects on Simpson's index (age: F=0.925, p=0.402 and interaction: F=1.372, p=0.241). This higher diversity is explained by the enrichment of weed flora thanks the annual weeds. In fact, we observed a lower proportion of perennial weeds on the total cover of the weeds in the alley (X^2=22.464, p=5.223.10^{-5}) but with statistically the same cover in the alley. We have also found an effect of the age of trees on this point (X^2=32.984, p=0.047). The cover of perennial weeds was lower in the alley of the oldest trees and statistically the same in alleys with 1 and 2 years old trees.

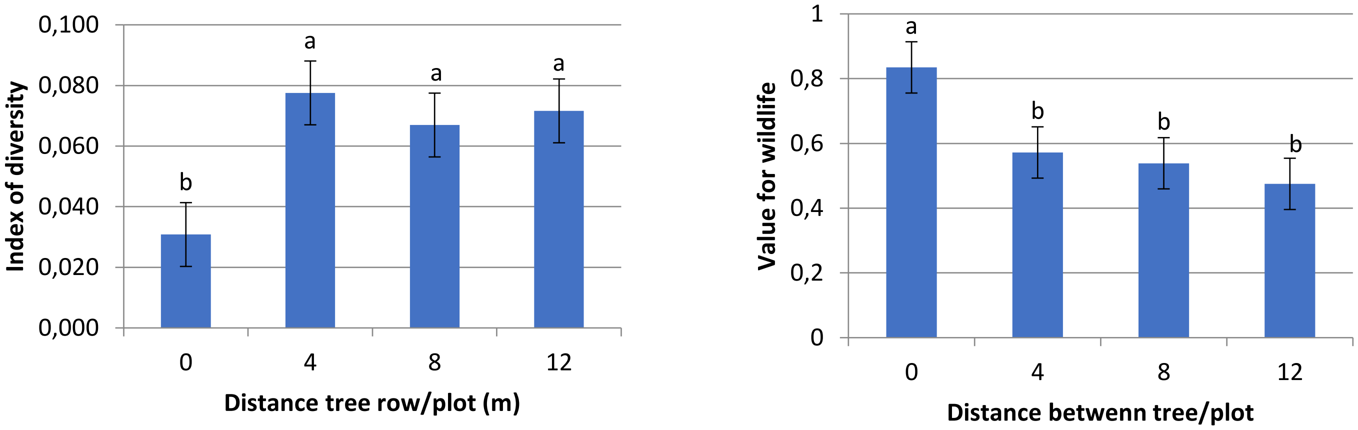


Figure 16: Effect of agroforestry on weeds' diversity (left) and the value of the association of weeds (right). Groups established by the Wilcoxson test with a risk of error of 0.05.

Finally, we found a different response of weed values for wildlife (pests predators) (Figure 16). We could observe a higher value of weeds associated with the tree rows than in the alleys (X^2=19.57, p<0.001). We can explain this high value of the trees row as also seen in the literature (II. 6.3) by this point: the weeds bring a high value for wildlife (e.g. food, refuge, …). But the weeds of the trees row are in majority: cock's-foot, creeping thistle and rumex. Despite their interest in wildlife, we have to keep in mind that these weeds could become problematic and difficult to manage. To keep the value for wildlife and a sustainable productivity, we need to control weeds on the trees row by the seeding of grass, legumes and other plants with a high interest for wildlife. To conclude, we didn't observe any contamination of the alleys by the tree rows. Sometimes, we observed also good effects of the trees on the management of weeds (reduction of the cover of perennials weeds in the oldest trees row). In many cases, the weeds are the legacy of the meadow.

Conclusion

In this study, we showed effects of SRC silvoarable system on the agro-ecosystem. On the oat, any negative impacts of the trees and their age was found. We found a significant stem' s elongation due mainly to the competition for light. We have also found no significant effect of the apportion of the growth stage, the cover of the oat and the cover of diseases. Concerning the weeds, we observe any significant differences on their covers. However, we found a higher richness and biodiversity in the alley than in the tree row. But, the community of weeds brings a higher value for wildlife in the tree row than in the alley. Then, we found a significant population of earthworms in the tree row in comparison with the alley. We showed also an effect of the species of tree's specie on earthworms. Concerning ground beetles, we found less individuals in the tree row than in the alley and the controls. But, the diversity and the richness were higher in the alley and the grassy strips in front of the trees than in the controls. and concerning the SOM, we found no significant increasing by the trees at this moment and with the design of this study.

Furthermore, this study will continue in the next years in aim to follow the evolution of my observation and my results. This study will take part in the AFINET project or an others European project because the AGFROWARD project finish this year. My result could use in these study as a starting point. This study will increase the few references in SRC silvoarable and agro-silvopastoral system. And it brings more information the effect of the young SRC trees on the agro-ecosystem, the effect of agroforestry on weeds, ground beetles and earthworms.

Finally, silvoarable and in general agroforestry systems are the future of farming because agroforestry field can produce crops, wood and/or animals with less surface. Then, the competition between food and non-food production is significantly reduce. With the trees, farmers can increase their diversity of their production. Thanks that, agroforestry farmers can be more profitable and increase the sustainability of their farm. With that, the trees can mitigate the climate change y the creation of the microclimate, the storage of carbon, the production of renewable energy and the reduction of the pressure on the primary forest. Agroforestry can increase the relationship between farmers, politicians and the public entities. Because agroforestry farmers could help the community in the energy transition by the produce of renewable energy. And if the storage of carbon and the ecosystem service are paid to the farmer, Agroforestry will be more attractive and benefiting than the conventional farming. However, Agroforestry needs large policy to expense its area and its development.

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Glossary-Glossaire

SOLID project: European project: Sustainable Organic and Low Input Dairying

Projet SOLID: Projet Européen: Production laitière durable biologique et à bas intrants

AGFORWARD project: European project: AgroFORestry that will Advance Rural Development: Its aims are to understand agroforestry system in Europe, to make advances in these systems and to promote the agroforestry systems in Europe by the policy development and dissemination. (source: agforwar.eu)

Projet AGFORWARD : Projet Européen : Agroforesterie améliorera le développement rural. Il a pour but de de comprendre les pratiques agroforestières en Europe, d'améliorer les connaissances sur ces systèmes et de promouvoir l'agroforesterie auprès des élus.

SRC: Short Rotation Coppice: Trees are harvested after the same period of growth (all 2, 3, 5, 8, x years). The wood is used as fuel, woodchip, manure, ….

TCR : Taillis à courte rotation : les arbres sont récoltés puis les repousses sont exploitées et récoltées à intervalle régulier. (tous les 2, 3, 4, 5, 8, x années). Le bois est utilisé pour fabriquer du carburant, du BRF, de la litière, …

ORC: The Organic Research Centre

LER: Land Equivalent Ratio

SEA : Surface Equivalente Assolé

NPV: Net Present Value

VANR : Valeur actualisées nettes relatives

SOM: Soil Organic Matter

MOS : Matière Organique du Sol

PAR: Photosynthetically Active Radiation: It is the light available for photosynthesis included between 400 to 700 nm wavelength range. (source: www.fondriest.com)

RPA : Rayons photosynthétiquement Actifs : Ce sont les rayons lumineux disponible pour la photosynthèse et compris entre 400 et 700 nm.

NA: Net Assimilation: it gives an idea on the photosynthetic efficiency. (source: www.nature.com)

NA : Nette Assimilation : Ce rapport donne une idée de l'efficacité de la photosynthèse.

INRA: National Institut of Agronomic Research of France

INRA : Institut National de la Recherche Agronomique

CTIFL: Fruits and Vegetables Inter-professional and Technical Centre

CTIFL : Centre Technique et Interprofessionnel des Fruits et des Légumes.

ACTA: Trust of Farming Technics' Coordination

ACTA : Association pour la Coordination Technique Agricole

Leeward side: It's the side sheltered from the prevailing wind by the tree row

Coté protégée du vent : C'est le coté de la rangé d'arbre protégée des vents dominants

Windward side: It's the side which is exposed to the prevailing wind (source: www.Thoughtco.com)

Coté exposé au vent : C'est le coté de la rangé d'arbres exposée aux vents donimants

Pruning: cutting the lower lateral branches in aim to obtain the highest trunk without nodes (Dupraz, C., et al. 2011)

Elagage : C'est l'élimination des branches situées sur a partie latérale base du tronc afin d'obtenir une bille sans noeuds la plus grande possible.

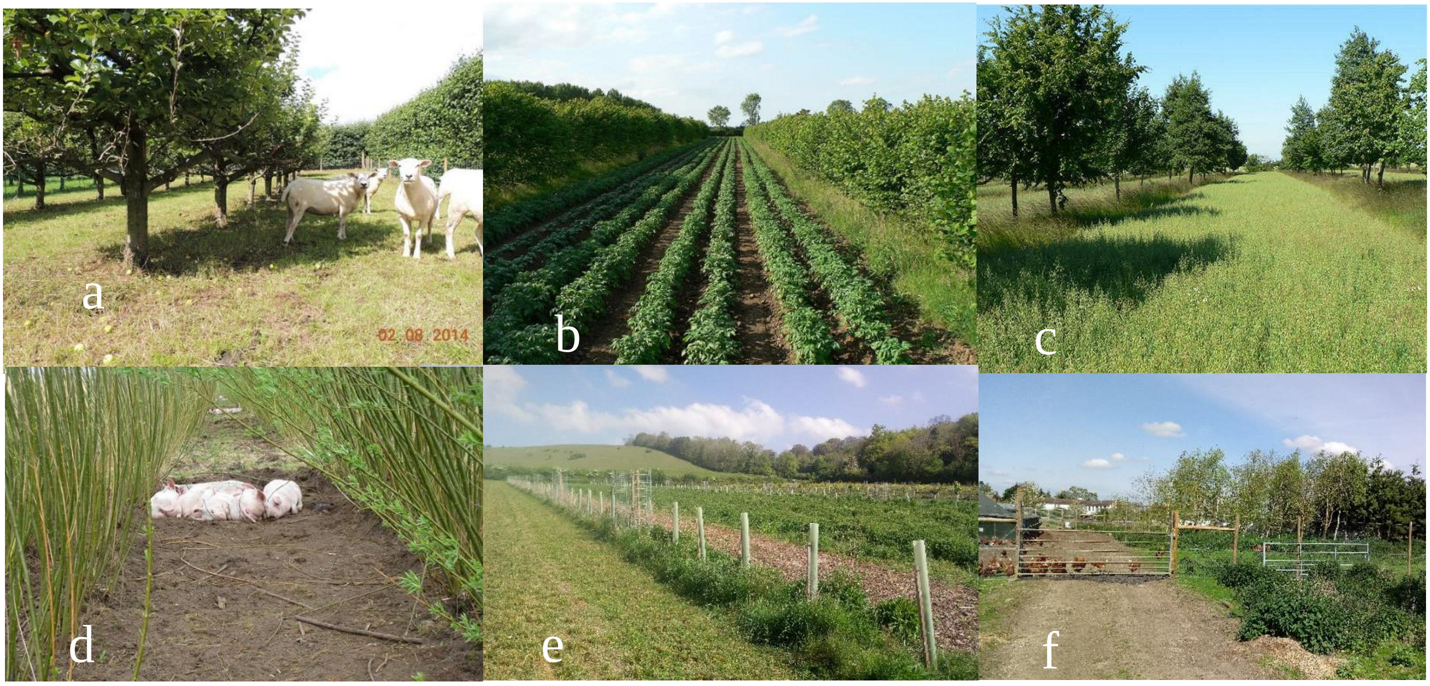
Crown: it's all branches and leaves of the superior part of the trunk (Dupraz, C., et al. 2011)

Houppière : C'est l'ensemble des branches, des ramifications et des feuilles de l'arbres.

AFINET: European project: AgroForestry Innovation NETwork. It aims to improve the practices, the knowledge exchange between scientists and practitioners thanks the research. (source: www.agroforestry.eu/afinet)

AFINET : Projet Européen : AgroForesteri Innovation Réseau : Il a pour but d'améliorer les pratiques et les échanges de connaissances entre les scientifiques et les autres intervenants du monde agroforestier.

Annexe 1: Photos of different kinds of agroforestry in Europe



a: silvopastoral sheep in Ireland.

b: silvoarable vegetable in United-Kingdom.

c: silvoarable oat in United-Kingdom

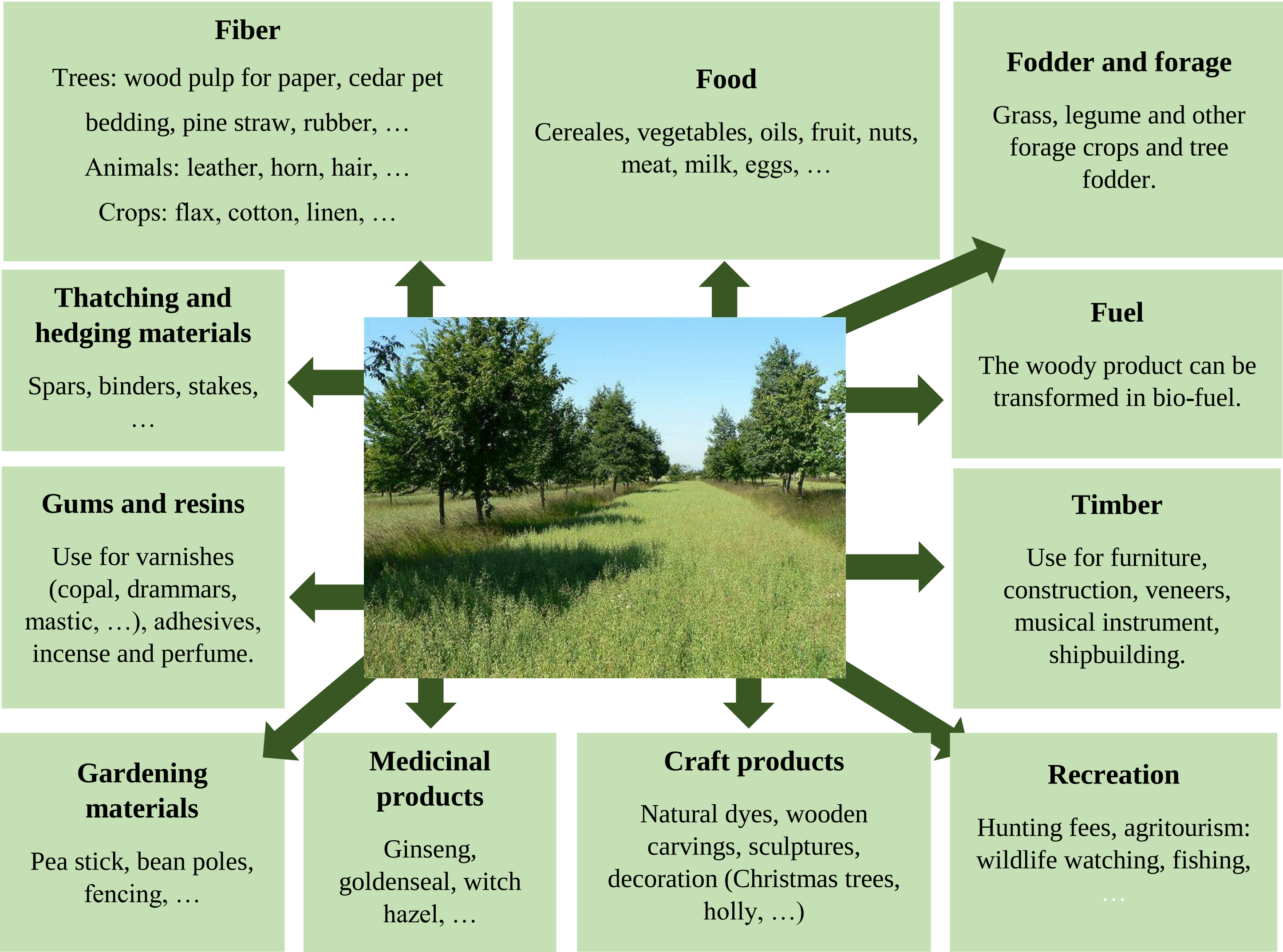
d: silvopastoral pig in Denmark with.

e: silvoarable vegetable in United-Kingdom.

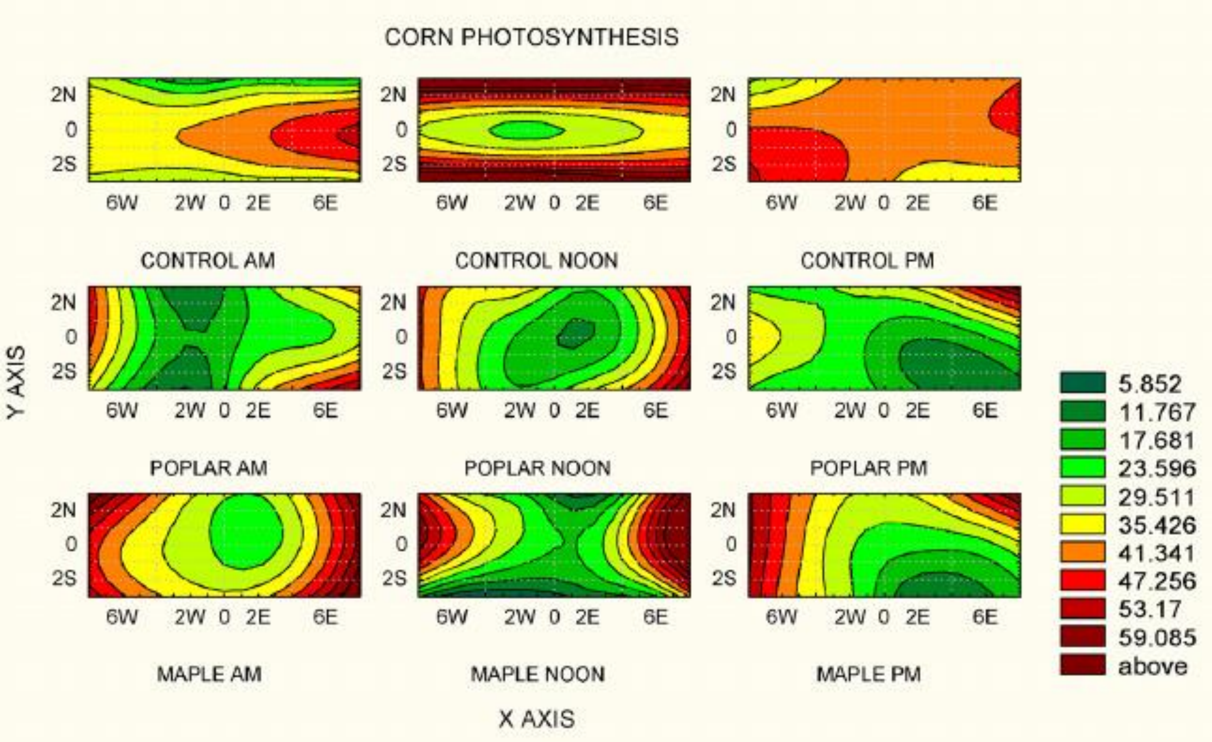
f: silvopoultry in United-Kingdom.

(source: Agforward and personal).

Annexe 2: Scheme products from an agroforestry agro-ecosystem. (from Smith, J., 2011).

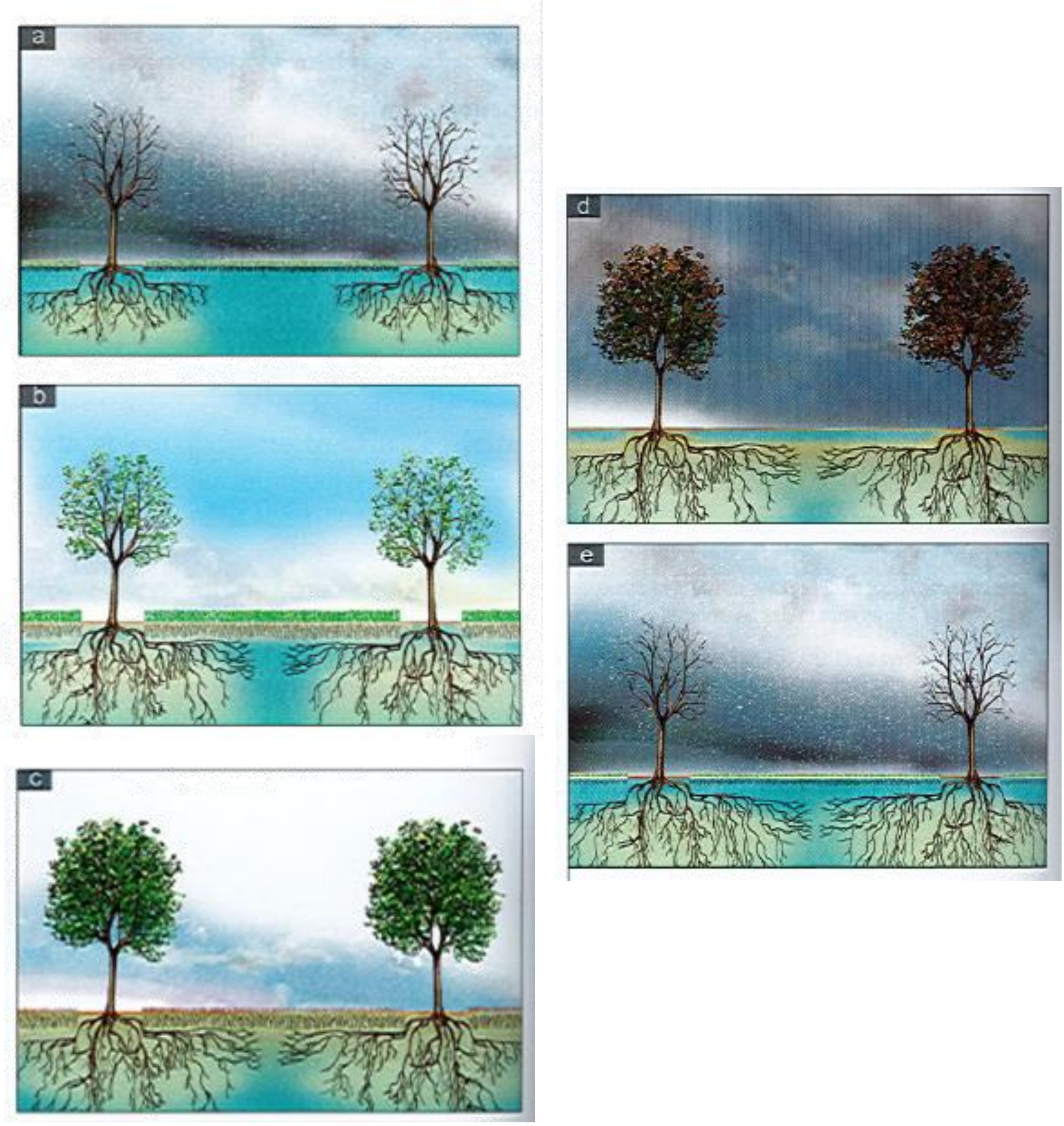


Annexe 3: Impact of different species of trees on the corn's NA (Reynolds, P.E. et al, 2006).



We can see that the NA is different by the localisation (Competitive or complimentary zone), tree's specie and the moment of day.

Annexe 4: Evolution of the tree's root system and the water storage in an agroforestry soil (Dupraz, C., et al, 2011)

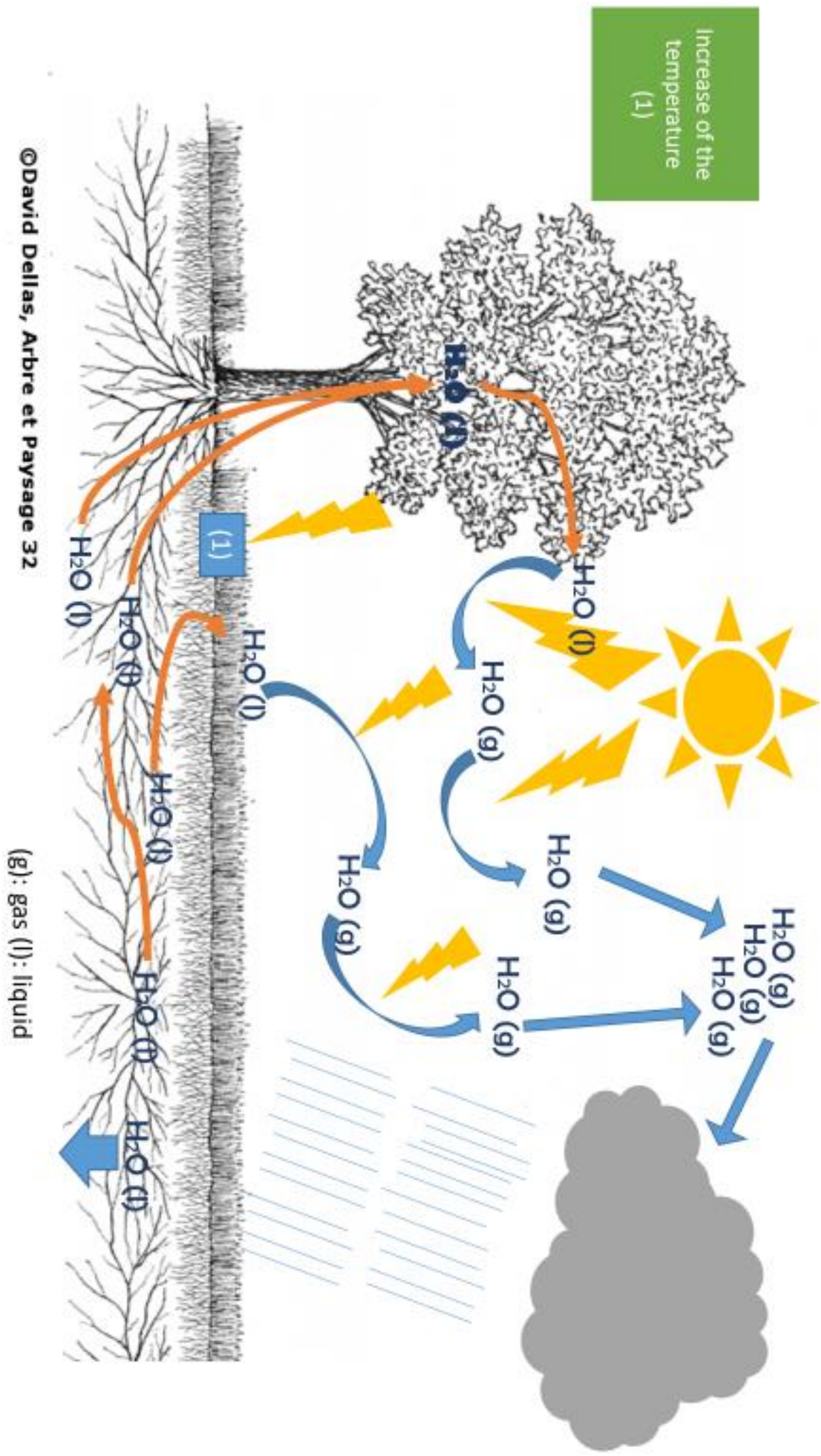


Annexe 5: Impacts of trees species on predator's populations

From Dupraz, C., et al, 2011.

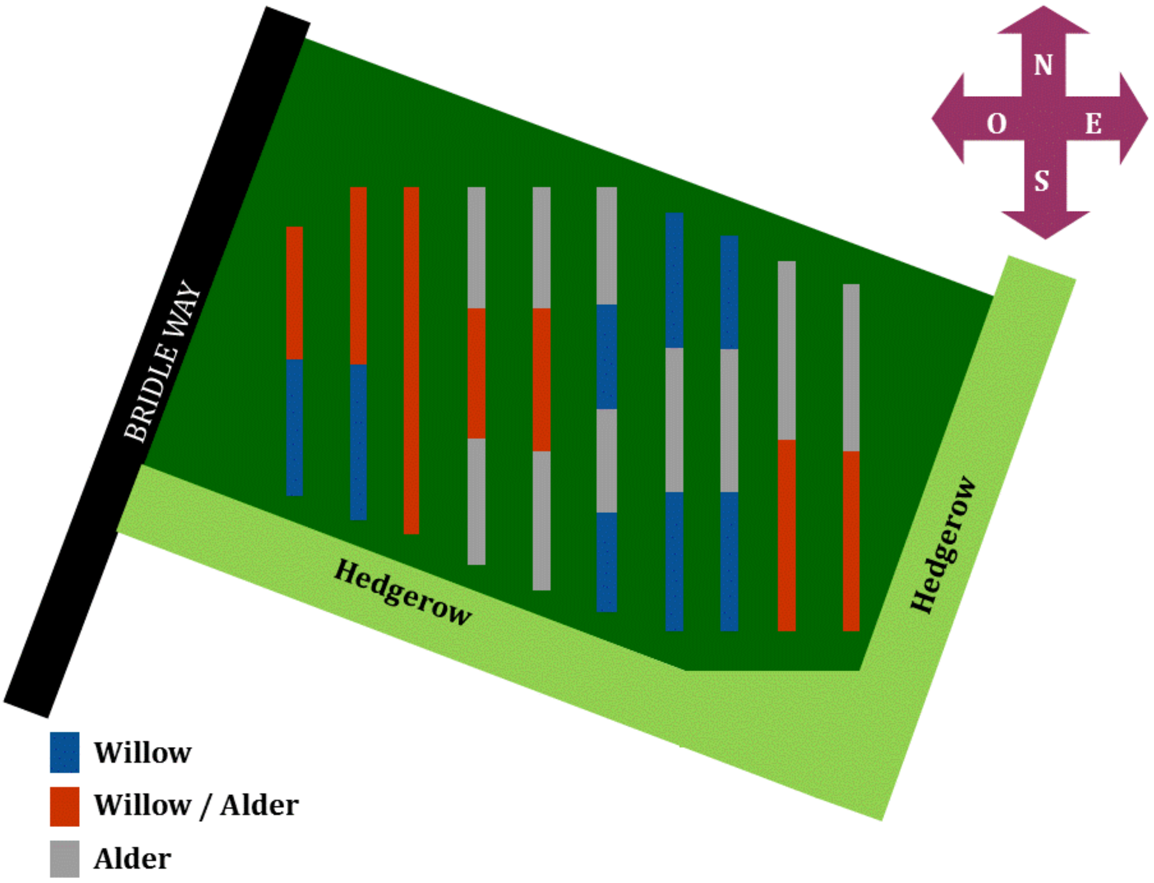
Species	Sheltered predators	Targets	Beneficiary crops
Walnut	Ladybirds	Aphids, cochineal, mites	Corn, fruiterers, beets, cereals, oil seed rape, sunflower, peas, soybeans.
	Predatory bug	Mites, aphids, psylla	
	Lacewing	Mites, Aphids	
	Earwigs	Aphids	
	Diptera: syrphadea, …	Aphids	
Black Alder	Aphid's predators	Aphids, cochineal	Corn, fruiterers, beets, cereals, oil seed rape, sunflower
	Mites' predators	Mites	
Hornbeam	Mites' predators	Mites	Cereals, fruit trees, beans
	Spiders: insect's predators	Flying insects	
Oak	Diversified predators	Diversified pests	Fruiterer, beets, cereals, oil seed rape, sunflower
Hedge maple	Lacewing, ladybirds, rove beetles, cantharides	Aphids	Corn, fruiterers, beets, cereals, sunflower
	Mirids	Psylla	
Ash	Anthocorids, microhymenopterans	Mites, psylla	Corn, fruiterers, beets, cereals, oil seed rape, sunflower, peas.
	Ladybird	Aphids	
Cherrywood	Syrphadea, Lacewing, ladybird	Balck aphids	Cereals, fruiterers, beans, corn, beet.
Hackberry	Spiders, phytoseiids, coniopterigidae and hymenopterans		Cereals, vineyard, fruiterers
Elm	Chrysomelid, aphid's predators	Aphid	Cereals
Locust tree	Aphid's predators,	Aphids, cochineals	Fruiterers, mulberry, sunflower, peas, corn, Peeper, potatoes, beet, olivier
	Parasitoid hymenopterans, empidridea	Lepidoptera, hymenopterans, symphyta	
Lime-tree	Diversified predators	Mites and aphids	Fruiterers, oil seed rape, cereals, sunflower, peas

Annexes 6: Effect of tree on the microclimate and smal water's cycle

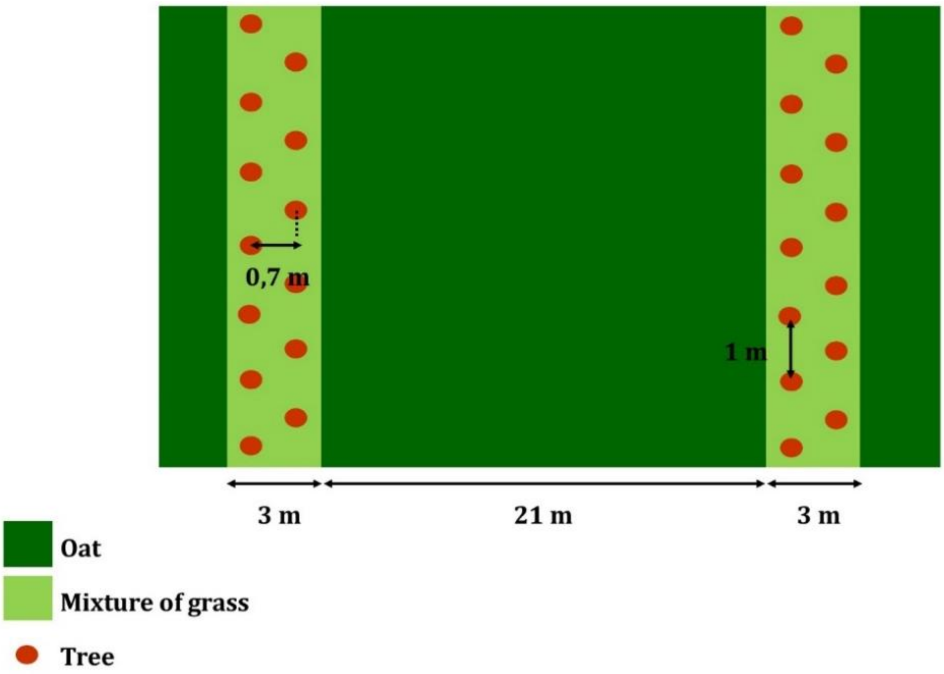


From Kravčík, M., et al, 2007

Annexes 7: Scheme of the experimental field and the plantation of twin rows trees



From SMITH J, at al 2015.
This scheme is not at the scale.



This scheme is not at the scale

Annexes 8: Statistic

3. Earthworms' Assessments

1.1. Quantity's study

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	K²	P value
Interaction tree-distance	11.470	0.043

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 0 m	0.747	0.019
Willow 0 m	0.818	0.139
Alder 4 m	0.972	0.907
Willow 4 m	0.849	0.224
Alder 12 m	0.906	0.408
Willow 12 m	0.939	0.653

P value>0.05 (for the majority): H0 is accepted. Data follows the normality law at risk of error of 5 %.

- Kurskal test:

	X²	P value
Interaction tree-distance	15.854	0.007

1.1. Diversity's study

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	k²	P value
Interaction tree-distance	15.854	0.007

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 0 m	0.950	0.804
Willow 0 m	0.827	0.161
Alder 4 m	0.640	0.001
Willow 4 m	0.630	0.001
Alder 12 m	0.496	$2.073.10^{-5}$
Willow 12 m	0.729	0.024

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error 5 %.

- Kruskal test:

H0: the richness of earthworms is the same in each plot

	X²	P value
Interaction distances trees row-plots	8.719	0.121

P value>0.05: H0 is accepted. The richness is the same is each plot at the risk of error 5 %

2. The assessment of the ground beetles

2.1. First round - Quantity

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	K^2	P value
Environments	28.058	$1.214.10^{-5}$

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 0 m	0.617	0.0002
Alder 4 m	0.956	0.771
Alder 8 m	0.723	0.003
Alder 12 m	0.920	0.433
Control	0.949	0.143

P value>0.05 (for the majority): H0 is accepted. Data follows the normality law at the risk of error of 5 %.

- Kurskal test:

H0: the quantity of ground beetles per trap is the same for each environment

	X^2	P value
Environment	24.897	$5.276.10^{-5}$

P value<0.05: So H0 is rejected. The number of ground beetles per trap depends of the environment at the risk of error of 5 %

- Wilcoxson test:

Shapiro test	Alder 4 m	Alder 8 m	Alder 12 m	Control
Alder 0 m	0.0008	0.0005	0.0008	$1.468.10^{-5}$
Alder 4 m		0.557	0.750	0.096
Alder 8 m			0.694	0.096
Alder 12 m				0.310

2.1. First round – Richness

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	K^2	P value
Environments	3.456	0.486

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 0 m	0.617	0.0002
Alder 4 m	0.835	0.067
Alder 8 m	0.710	0.002
Alder 12 m	0.835	0.067
Control	0.858	0.0008

P value<0.05 (for the majority): H0 is rejected. Data don’t follow the normality law at the risk of error 5 %.

- Kurskal test:

H0: the richness of ground beetles per trap is the same for each environment

	X^2	P value
Environments	20.306	0.0004

P value<0.05: So H0 is rejected. The richness of ground beetles per trap depends of the environment at the risk of error 5 %

- Wilcoxson test:

Shapiro test	Alder 4 m	Alder 8 m	Alder 12 m	Control
Alder 0 m	0.001	0.002	0.002	$5.453.10^{-5}$
Alder 4 m		0.219	0.577	0.458
Alder 8 m			0.498	0.307
Alder 12 m				0.970

2.2. First round – Index of diversity

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	K^2	P value
Environments	Inf	$<2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 0 m	Values are identical	
Alder 4 m	0.856	0.111
Alder 8 m	0.753	0.006
Alder 12 m	0.861	0.122
Control	0.889	0.004

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error 5 %.

- Kurskal test:

H0: the diversity of ground beetles per trap is the same for each environment

	X^2	P value
Environments	11.873	0.018

P value<0.05: So H0 is rejected. The diversity of ground beetles per trap depends of the environment at the risk of error 5 %

- Wilcoxson test:

Shapiro test	Alder 4 m	Alder 8 m	Alder 12 m	Control
Alder 0 m	0.003	0.034	0.009	0.001
Alder 4 m		0.549	0.594	0.204
Alder 8 m			0.799	0.868
Alder 12 m				0.582

2.3. Second round – Quantity

- Explanation of the test:

H0: no differences between variances of each factor

Bartlett test	K^2	P value

Environments	28.058	$1.214.10^{-5}$

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Grassy strip	0.988	0.983
Alder 0 m	0.826	0.099
Alder 4 m	0.850	0.158
Alder 8 m	0.814	0.079
Alder 12 m	0.777	0.036
Control field	0.957	0.750
Control hedgerows	0.926	0.340

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at risk of error 5 %.

- Kurskal test:

H0: the quantity of ground beetles per trap is the same for each environment

	X²	**P value**
Environment	20.457	0.002

P value<0.05: So H0 is rejected. The number of ground beetles per trap depends of the environment at the risk of error 5 %

- Wilcoxson test:

Shapiro test	**Alder 0 m**	**Alder 4 m**	**Alder 8 m**	**Alder 12 m**	**Control field**	**Control hedgerow**
Grassy strip	0.871	0.029	0.020	0.045	0.022	0.002
Alder 0 m		0.147	0.089	0.171	0.019	0.004
Alder 4 m			0.332	0.872	0.155	0.024
Alder 8 m				0.809	0.549	0.083
Alder 12 m					0.957	0.373
Control field						0106

2.4. Second round – Richness

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Environments	9.882	0.130

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Grassy strip	0.701	0.006
Alder 0 m	0.908	0.425
Alder 4 m	0.775	0.035
Alder 8 m	0.960	0.820
Alder 12 m	0.838	0.126
Control field	0.966	0.854

Control hedgerows	0.801	0.010

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- One-way Anova test:

H0: the richness of ground beetles per trap is the same for each environment

	F	**P value**
Environment	2.657	0.002

P value<0.05: H0 is rejected. The richness of ground beetles per trap depends of the environment at the risk of error of 5 %

- HSD test:

Shapiro test	**Grassy strip**	**Alder 0 m**	**Alder 4 m**	**Alder 8 m**	**Alder 12 m**	**Control field**	**Control hedgerow**
Environments	Ab	B	Ab	A	Ab	Ab	Ab

2.5. Second round – Richness

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Environments	5.458	0.487

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Grassy strip	0.885	0.2942
Alder 0 m	0.864	0.202
Alder 4 m	0.935	0.620
Alder 8 m	0.980	0.952
Alder 12 m	0.890	0.320
Control field	0.736	0.002
Control hedgerows	0.936	0.445

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %.

- One-way Anova test:

H0: the richness of ground beetles per trap is the same for each environment

	F	**P value**
Environment	3.851	0.003

P value<0.05: H0 is rejected. The richness of ground beetles per trap depends of the environment at the factor risk of 5 %

- HSD test:

Shapiro test	**Grassy strip**	**Alder 0 m**	**Alder 4 m**	**Alder 8 m**	**Alder 12 m**	**Control field**	**Control hedgerow**
Environments	Ab	B	Ab	A	Ab	B	Ab

3. SOM's Assessments

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	k²	P value
Distance	3.266	0.352

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	k²	P value
0 m	0.898	0.355
4 m	0.928	0.561
8 m	0.910	0.435
12 m	0.895	0.344

P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %.

- One-way anova:

H0: the trees have any effects of the level of the soil organic matter

	F	P value
Distance	0.484	0.697

P>0.05: H0 is rejected. The trees have any of the level of the soil organic matter at the risk of error of 5 %.

4. Crops' assessments

4.1. The 21th of April: Tillers

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	7.372	0.497

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.952	0.757
Age 1 Distance 8 m	0.853	0.167
Age 1 Distance 12 m	0.911	0.444
Age 2 Distance 4 m	0.963	0.847
Age 2 Distance 8 m	0.908	0.421
Age 2 Distance 12 m	0.888	0.306
Age 3 Distance 4 m	0.709	0.008
Age 3 Distance 8 m	0.876	0.252
Age 3 Distance 12 m	0.915	0.473

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way Anova test:

H0 Age: the age of trees has any effect on the tillering.
H0 Distance: the distance between the tree row and the plot don't influence the tillering
H0 Interaction: The interaction distance & age have any effect on the tillering

	F	P value
Age	2.846	0.069
Distance	0.157	0.855

Age & Distance	0.860	0.495

P value<0.05: all the H0 are accepted. The tillering is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %

4.2. The 21th of April: First node

- Explanation of the test:

H0: no differences between the variances of each facto

Bartlett test	**K²**	**P value**
Environments	Inf	< $2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.496	$2.073.10^{-5}$
Age 1 Distance 8 m	0.640	0.001
Age 1 Distance 12 m	0.496	$2.073.10^{-5}$
Age 2 Distance 4 m	0.701	0.006
Age 2 Distance 8 m	0.822	0.091
Age 2 Distance 12 m	0.822	0.091
Age 3 Distance 4 m	Values are identical	
Age 3 Distance 8 m	0.496	$2.073.10^{-5}$
Age 3 Distance 12 m	0.683	0.004

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error of 5 %.

- Kruskal test:

H0 Age: the age of trees has any effect on the apparition of the first node.
H0 Distance: the distance between the tree row and the plot don't influence the apparition of the first node
H0 Interaction: The interaction distance & age have any effect on the apparition of the first node

	X²	**P value**
Age	3.726	0.155
Distance	1.984	0.371
Age & Distance	7.846	0.449

P value>0.05: all the H0 are accepted. The first node is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %

4.3. The 21th of April: Cover of the oat

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	5.818	0.668

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.823	0.094
Age 1 Distance 8 m	0.673	0.003
Age 1 Distance 12 m	0.850	0.158

Age 2 Distance 4 m	0.866	0.212
Age 2 Distance 8 m	0.921	0.514
Age 2 Distance 12 m	0.931	0.586
Age 3 Distance 4 m	0.897	0.358
Age 3 Distance 8 m	0.933	0.600
Age 3 Distance 12 m	0.770	0.031

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error 5 %

- Two-way Anova test:

H0 Age: the age of trees has any effect on the cover of the oat
H0 Distance: the distance between the tree row and the plot don't influence the cover of the oat
H0 Interaction: The interaction distance & age have any effect on the cover of the oat

	F	**P value**
Age	4.285	0.020
Distance	0.314	0.732
Age & Distance	0.626	0.647

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error %.

- HSD test: Age

	Age 1	**Age 2**	**Age 3**
Age	A	B	Ab

4.4. The 21th of April: Cover of diseases

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	13.029	0.111

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.705	0.007
Age 1 Distance 8 m	0.841	0.133
Age 1 Distance 12 m	0.762	0.027
Age 2 Distance 4 m	0.640	0.001
Age 2 Distance 8 m	0.744	0.017
Age 2 Distance 12 m	0.773	0.033
Age 3 Distance 4 m	0.666	0.003
Age 3 Distance 8 m	0.851	0.161
Age 3 Distance 12 m	0.826	0.099

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error of 5 %

- Kruskal test

H0 Age: the age of trees has any effect on the cover of diseases
H0 Distance: the distance between the tree row and the plot don't influence the cover of diseases
H0 Interaction: The interaction distance & age have any effect on the cover of diseases

	X²	**P value**

Age	0.065	0.968
Distance	2.288	0.319
Age & Distance	4.301	0.829

P value>0.05: all H0 are accepted. The cover of diseases is not influenced by tree' age, the distance and the interaction at the risk of error 5 %.

4.5. The 28th of April: Cover of the oat

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	4.389	0.820

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.938	0.644
Age 1 Distance 8 m	0.891	0.324
Age 1 Distance 12 m	0.916	0.480
Age 2 Distance 4 m	0.890	0.316
Age 2 Distance 8 m	0.960	0.820
Age 2 Distance 12 m	0.975	0.926
Age 3 Distance 4 m	0.831	0.110
Age 3 Distance 8 m	0.840	0.130
Age 3 Distance 12 m	0.902	0.389

P value>0.05 .H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way Anova test:

H0 Age: the age of trees has any effect on the cover of the oat
H0 Distance: the distance between the tree row and the plot don't influence the cover of the oat
H0 Interaction: The interaction distance & age have any effect on the cover of the oat

	F	P value
Age	3.143	0.053
Distance	0.594	0.557
Age & Distance	0.116	0.976

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

4.6. The 28th of April: Cover of diseases

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	9.572	0.296

P value<0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.640	0.001

Age 1 Distance 8 m	0.772	0.033
Age 1 Distance 12 m	0.701	0.006
Age 2 Distance 4 m	0.907	0.415
Age 2 Distance 8 m	0.709	0.008
Age 2 Distance 12 m	0.640	0.001
Age 3 Distance 4 m	0.827	0.101
Age 3 Distance 8 m	0.701	0.006
Age 3 Distance 12 m	0.666	0.003

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error of 5 %

- Kruskal test

H0 Age: the age of trees has any effect on the cover of diseases
H0 Distance: the distance between the tree row and the plot don't influence the cover of diseases
H0 Interaction: The interaction distance & age have any effect on the cover of diseases

	X^2	P value
Age	7.375	0.025
Distance	2.386	0.303
Age & Distance	14.83	0.063

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

- Wilcox test

	Age 2	Age 3
Age 1	0.012	0.513
Age2		0.049

4.7. the 05th of May: Cover of diseases

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	18.405	0.018

P value<0.05: So H0 is rejected. Variances of each factor are not similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.866	0.212
Age 1 Distance 8 m	0.814	0.078
Age 1 Distance 12 m	0.640	0.001
Age 2 Distance 4 m	0.799	0.059
Age 2 Distance 8 m	0.666	0.003
Age 2 Distance 12 m	0.701	0.006
Age 3 Distance 4 m	0.838	0.126
Age 3 Distance 8 m	0.853	0.167
Age 3 Distance 12 m	0.815	0.080

P value>0.05 (in majotity) .H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Kruskal test:

H0 Age: the age of trees has any effect on the cover of diseases
H0 Distance: the distance between the tree row and the plot don't influence the cover of diseases

H0 Interaction: The interaction distance & age have any effect on the cover of diseases

	X^2	P value
Age	2.141	0.343
Distance	0.484	0.785
Age & Distance	3.178	0.923

P value>0.05: all H0 are accepted. The cover of diseases is not influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

4.8. The 05th of May: Cover of the oat

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	8.950	0.347

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.920	0.506
Age 1 Distance 8 m	0.866	0.212
Age 1 Distance 12 m	0.911	0.445
Age 2 Distance 4 m	0.701	0.006
Age 2 Distance 8 m	0.902	0.389
Age 2 Distance 12 m	0.866	0.211
Age 3 Distance 4 m	0.822	0.091
Age 3 Distance 8 m	0.865	0.205
Age 3 Distance 12 m	0.803	0.062

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of the oat
H0 Distance: the distance between the tree row and the plot don't influence the cover of the oat
H0 Interaction: The interaction distance & age have any effect on the cover of the oat

	F	P value
Age	6.404	0.004
Distance	1.333	0.274
Age & Distance	0.252	0.907

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	A	B	A

4.9. The 05th of May: Growth stage: second node

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	Inf	$< 2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are not similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.853	0.167
Age 1 Distance 8 m	0.700	0.006
Age 1 Distance 12 m	0.853	0.167
Age 2 Distance 4 m	Values are identical	
Age 2 Distance 8 m	0.866	0.212
Age 2 Distance 12 m	0.496	$2.073.10^{-5}$
Age 3 Distance 4 m	0.822	0.101
Age 3 Distance 8 m	0.496	$2.073.10^{-5}$
Age 3 Distance 12 m	0.496	$2.073.10^{-5}$

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error of 5 %.

- Kruskal test:

H0 Age: the age of trees has any effect on the apparition of the second node.
H0 Distance: the distance between the tree row and the plot don't influence the apparition of the second node
H0 Interaction: The interaction distance & age have any effect on the apparition of the second node

	X²	P value
Age	10.671	0.005
Distance	4.244	0.220
Age & Distance	19.174	0.014

P distance value>0.05: the H0 is accepted. The apparition of the second node is not influenced the distance. But, p value interaction and age < 0.05: H0 are accepted: The interaction and trees' age influence second node's apparition at the risk of error of 5 %

4.10. The 12th of May: Cover of diseases

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	Inf	$<2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are not similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.683	0.004
Age 1 Distance 8 m	0.800	0.059
Age 1 Distance 12 m	0.822	0.091
Age 2 Distance 4 m	Values are identical	
Age 2 Distance 8 m	0.821	0.091
Age 2 Distance 12 m	0.775	0.035
Age 3 Distance 4 m	0.496	$2.073.10^{-5}$
Age 3 Distance 8 m	0.906	0.421

Age 3 Distance 12 m	0.496	$2.073.10^{-5}$

P value<0.05 (for the majority) .H0 is rejected. Data don't follow the normality law at the risk of error of 5 %

- Kruskal test:

H0 Age: the age of trees has any effect on the cover of diseases
H0 Distance: the distance between the tree row and the plot don't influence the cover of diseases
H0 Interaction: The interaction distance & age have any effect on the cover of diseases

	X²	**P value**
Age	2.259	0.323
Distance	0.069	0.966
Age & Distance	3.651	0.887

P value>0.05: all H0 are accepted. The cover of diseases is not influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

4.11. The 12th of May: Cover of the oat

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	9.325	0.316

P value >0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.902	0.389
Age 1 Distance 8 m	0.822	0.091
Age 1 Distance 12 m	0.960	0.820
Age 2 Distance 4 m	0.882	0.278
Age 2 Distance 8 m	0.709	0.008
Age 2 Distance 12 m	0.909	0.433
Age 3 Distance 4 m	0.809	0.070
Age 3 Distance 8 m	0.786	0.045
Age 3 Distance 12 m	0.866	0.212

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of the oat
H0 Distance: the distance between the tree row and the plot don't influence the cover of the oat
H0 Interaction: The interaction distance & age have any effect on the cover of the oat

	F	**P value**
Age	4.565	0.016
Distance	1.075	0.350
Age & Distance	0.300	0.877

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

- HSD test: Age

	Age 1	**Age 2**	**Age 3**
Age	A	B	Ab

4.12. The 12th of May: Growth stage: stem's elongation

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	Inf	$< 2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are different at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.853	0.167
Age 1 Distance 8 m	0.700	0.006
Age 1 Distance 12 m	0.853	0.167
Age 2 Distance 4 m	Values are identical	
Age 2 Distance 8 m	0.866	0.212
Age 2 Distance 12 m	0.496	$2.073.10^{-5}$
Age 3 Distance 4 m	0.822	0.101
Age 3 Distance 8 m	0.496	$2.073.10^{-5}$
Age 3 Distance 12 m	0.496	$2.073.10^{-5}$

P value<0.05 (for the majority): H0 is rejected. Data don't follow the normality law at the risk of error of 5 %.

- Kruskal test:

H0 Age: the age of trees has any effect on of stem' elongation.
H0 Distance: the distance between the tree row and the plot don't influence stem' elongation H0 Interaction: The interaction distance & age have any effect on the apparition of stem' elongation

	X^2	P value
Age	10.671	0.005
Distance	4.244	0.120
Age & Distance	19.174	0.014

P distance value>0.05: the H0 are accepted. The apparition of the second node is not influenced by tree' age, the distance. But, p value interaction and age < 0.05: H0 are rejected: The interaction and the age of the tree influence second node's apparition at the risk of error of 5%

4.13. The 19th of May: Cover of diseases

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	Inf	$2.2.10^{-16}$

P value<0.05: So H0 is rejected. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	Values are identical	
Age 1 Distance 8 m	Values are identical	
Age 1 Distance 12 m	Values are identical	
Age 2 Distance 4 m	Values are identical	
Age 2 Distance 8 m	Values are identical	

Age 2 Distance 12 m	Values are identical	
Age 3 Distance 4 m	Values are identical	
Age 3 Distance 8 m	Values are identical	
Age 3 Distance 12 m	0.496	$2.073.10^{-5}$

P value<0.05 .H0 is rejected. Data don't follow the normality law at the risk of error of 5 %

- Kruskal test:

H0 Age: the age of trees has any effect on the cover of diseases
H0 Distance: the distance between the tree row and the plot don't influence the cover of diseases
H0 Interaction: The interaction distance & age have any effect on the cover of diseases

	X²	**P value**
Age	2	0.368
Distance	2	0.368
Age & Distance	8	0.434

P value>0.05: all H0 are accepted. The cover of diseases is not influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

4.14. The 19th of May: Cover of the oat

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	7.950	0.438

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.701	0.0006
Age 1 Distance 8 m	0.866	0.212
Age 1 Distance 12 m	0.873	0.238
Age 2 Distance 4 m	0.873	0.238
Age 2 Distance 8 m	0.751	0.002
Age 2 Distance 12 m	0.983	0.963
Age 3 Distance 4 m	0.927	0.554
Age 3 Distance 8 m	0.850	0.158
Age 3 Distance 12 m	0.908	0.425

P value>0.05 (for the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of the oat
H0 Distance: the distance between the tree row and the plot don't influence the cover of the oat
H0 Interaction: The interaction distance & age have any effect on the cover of the oat

	F	**P value**
Age	3.591	0.036
Distance	0.186	0.831
Age & Distance	0.542	0.706

P age value<0.05: H0 age is rejected. The other H0 are accepted (p>0.05). The cover of the oat is influenced by tree' age and not by the distance and the interaction at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	A	A	A

4.15. The 19th of May: Growth stage: the flag leaf emergence

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	3.290	0.915

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.640	0.001
Age 1 Distance 8 m	0.866	0.212
Age 1 Distance 12 m	0.853	0.167
Age 2 Distance 4 m	0.866	0.212
Age 2 Distance 8 m	0.640	0.001
Age 2 Distance 12 m	0.775	0.035
Age 3 Distance 4 m	0.866	0.212
Age 3 Distance 8 m	0.866	0.212
Age 3 Distance 12 m	0.701	0.006

Q-Q plot unnormal: H0 is rejected. Data don't follow the normality law at the risk of error of 5 %.

- Kruskal test:

H0 Age: the age of trees has any effect on of the flag leaf emergence.
H0 Distance: the distance between the tree row and the plot don't influence flag leaf emergence
H0 Interaction: The interaction distance & age have any effect on the apparition of the flag leaf emergence

	X²	**P value**
Age	0.813	0.666
Distance	3.882	0.144
Age & Distance	5.574	0.695

P value>0.05: all H0 are accepted. Ear emergence is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %

4.16. The 26th of May: Growth stage: the flag leaf emergence

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	8,817	0.358

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.640	0.001
Age 1 Distance 8 m	0.770	0.031
Age 1 Distance 12 m	0.907	0.415
Age 2 Distance 4 m	0.915	0.473

Age 2 Distance 8 m	0.701	0.006
Age 2 Distance 12 m	0.640	0.001
Age 3 Distance 4 m	0.827	0.101
Age 3 Distance 8 m	0.702	0.007
Age 3 Distance 12 m	0.907	0.415

P value < 0.05: H0 is rejected. Data don't follow the normality law at the risk of error of 5 %.

- Kruskal test:

H0 Age: the age of trees has any effect on of the ear emergence.
H0 Distance: the distance between the tree row and the plot don't influence ear emergence
H0 Interaction: The interaction distance & age have any effect on the apparition of the ear emergence

	X^2	**P value**
Age	7.360	0.025
Distance	0.670	0.715
Age & Distance	9.403	0.310

P value (distance and interaction) >0.05: H0 are accepted. Ear emergence is not influenced by the distance and the interaction at the risk of error 5 %. But Age's P value < 0.05. H0 is rejected: the ear emergence is influenced by the age of the trees.

- Wilcox test

	Age 2	**Age 3**
Age 1	0.092	0.131
Age2		0.016

4.17. The 02[nd] of June: Growth stage: the flowering

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K^2**	**P value**
Age & Distance	4.024	0.855

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Distance 4 m	0.915	0.473
Age 1 Distance 8 m	0.823	0.093
Age 1 Distance 12 m	0.907	0.421
Age 2 Distance 4 m	0.958	0.804
Age 2 Distance 8 m	0.982	0.960
Age 2 Distance 12 m	0.933	0.607
Age 3 Distance 4 m	0.751	0.020
Age 3 Distance 8 m	0.853	0.167
Age 3 Distance 12 m	0.781	0.039

P value > 0.05 (in majority): H0 is accepted. Data follow the normality law at the f risk of error of 5 %.

- Two-way Anova test:

H0 Age: the age of trees has any effect on of the flowering.
H0 Distance: the distance between the tree row and the plot don't influence of the flowering
H0 Interaction: The interaction distance & age have any effect on the apparition of flowering

	F	P value
Age	0.083	0.921
Distance	0.332	0.720
Age & Distance	1.658	0.177

P value >0.05: all H0 are accepted. Flowering is not influenced by the distance, the age of the trees and the interaction at the risk of error of 5 %.

5. Height's assessments

5.1. The 28th April

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	3.250	0.917

P value>0.05: So H0 is accepted. Variances of each factor are similar at the factor risk of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.923	0.530
Age 1 Distance 8 m	0.908	0.423
Age 1 Distance 12 m	0.921	0.513
Age 2 Distance 4 m	0.879	0.264
Age 2 Distance 8 m	0.869	0.219
Age 2 Distance 12 m	0.941	0.673
Age 3 Distance 4 m	0.857	0.178
Age 3 Distance 8 m	0.888	0.308
Age 3 Distance 12 m	0.862	0.197

All P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	P value
Age	3.306	0.046
Distance	0.850	0.434
Age & Distance	0.184	0.946

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	A	B	Ab

5.2. The 05th May

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	4.831	0.776

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.826	0.100
Age 1 Distance 8 m	0.862	0.195
Age 1 Distance 12 m	0.892	0.331
Age 2 Distance 4 m	0.931	0.588
Age 2 Distance 8 m	0.837	0.123
Age 2 Distance 12 m	0.854	0.168
Age 3 Distance 4 m	0.816	0.081
Age 3 Distance 8 m	0.896	0.351
Age 3 Distance 12 m	0.874	0.242

All P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	P value
Age	6.759	0.003
Distance	1.149	0.326
Age & Distance	0.517	0.723

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	A	B	A

5.3. The 12th May

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	5.994	0.648

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.887	0.301
Age 1 Distance 8 m	0.921	0.513
Age 1 Distance 12 m	0.892	0.330
Age 2 Distance 4 m	0.960	0.819
Age 2 Distance 8 m	0.914	0.465
Age 2 Distance 12 m	0.853	0.165
Age 3 Distance 4 m	0.966	0.863
Age 3 Distance 8 m	0.784	0.955
Age 3 Distance 12 m	0.865	0.206

All P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	P value
Age	5.073	0.010
Distance	1.093	0.344
Age & Distance	0.940	0.449

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	A	B	A

5.4. The 19th May

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	5.817	0.668

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.833	0.115
Age 1 Distance 8 m	0.886	0.296
Age 1 Distance 12 m	0.913	0.457
Age 2 Distance 4 m	0.662	0.002
Age 2 Distance 8 m	0.850	0.157
Age 2 Distance 12 m	0.825	0.098
Age 3 Distance 4 m	0.943	0.686
Age 3 Distance 8 m	0.898	0.363
Age 3 Distance 12 m	0.967	0.883

All P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	P value
Age	6.683	0.003
Distance	1.194	0.313
Age & Distance	1.059	0.388
Block	4.734	0.474

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	AB	B	A

5.5. The 26th May

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	2.725	0.950

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.887	0.305
Age 1 Distance 8 m	0.724	0.011
Age 1 Distance 12 m	0.880	0.271
Age 2 Distance 4 m	0.889	0.315
Age 2 Distance 8 m	0.734	0.014
Age 2 Distance 12 m	0.951	0.744
Age 3 Distance 4 m	0.912	0.448
Age 3 Distance 8 m	0.915	0.469
Age 3 Distance 12 m	0.952	0.755

P value (in majoriy)>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	P value
Age	3.938	0.027
Distance	0.622	0.541
Age & Distance	0.670	0.616

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	Age 2	Age 3
Age	AB	B	A

5.6. The 02th June

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	12.391	0.135

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value

Age 1 Distance 4 m	0.945	0.696
Age 1 Distance 8 m	0.800	0.059
Age 1 Distance 12 m	0.862	0.198
Age 2 Distance 4 m	0.966	0.866
Age 2 Distance 8 m	0.783	0.041
Age 2 Distance 12 m	0.860	0.190
Age 3 Distance 4 m	0.845	0.144
Age 3 Distance 8 m	0.896	0.349
Age 3 Distance 12 m	0.866	0212

P value (the majority) >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don't influence the height
H0 Interaction: The interaction distance & age have any effect on the height

	F	**P value**
Age	5.047	0.011
Distance	0.380	0.686
Age & Distance	0.690	0.603

P value (age) <0.05: H0 is accepted. The other H0 are accepted (p>0.05). The height of the oat is influenced by the age of the trees at the risk of error of 5 %.

- HSD test: Age

	Age 1	**Age 2**	**Age 3**
Age	AB	B	A

5.7. The study of the height on the oldest alley

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	19.168	0.691

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 1 Distance 2.5 W	0.876	0.173
Alder 1 Distance 4 m W	0.824	0.051
Alder 1 Distance 8 m W	0.925	0.469
Alder 1 Distance 12 m W	0.787	0.021
Alder 1 Distance 2.5 E	0.956	0.780
Alder 1 Distance 4 m E	0.957	0.779
Alder 1 Distance 8 m E	0.885	0.208
Alder 1 Distance 12 m E	0.880	0.187
Alder 2 Distance 2.5 m W	0.897	0.271
Alder 2 Distance 4 m W	0.972	0.916
Alder 2 Distance 8 m W	0.834	0.065
Alder 2 Distance 12 m W	0.749	0.008
Alder 2 Distance 2.5 E	0.949	0.702
Alder 2 Distance 4 m E	0.958	0.790
Alder 2 Distance 8 m E	0.954	0.752
Alder 2 Distance 12 m E	0.878	0.180
Willow Distance 2.5 W	0.954	0.748
Willow Distance 4 m W	0.950	0.712
Willow Distance 8 m W	0.810	0.038
Willow Distance 12 m W	0.864	0.132
Willow Distance 2.5 E	0.954	0.748
Willow Distance 4 m E	0.902	0.301
Willow Distance 8 m E	0.830	0.058
Willow Distance 12 m E	0.916	0.402

All P value (the majority) >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Development: the development of the trees has any effect on the height
H0 Distance: the distance between the tree row and the plot don’t influence the height
H0 Interaction: The interactions have any effect on the height

	F	P value
Development	64.521	$<2.2.10^{-16}$
Distance	21.251	$7.943.10^{-6}$
Orientation	31.771	$1.982.10^{-12}$
Distance & Orientation	3.300	0.022
Development & Orientation	4.484	0.013
Development & Distance	5.447	$3.581.10^{-5}$
Development & Distance & Orientation	0.974	0.445

P value <0.05: H0 is accepted. The height of the oat is influenced by the development, by the orientation, by the distance between trees-plots and the interaction of these factor without the interaction of all (P<0.05) at the risk of error of 5 %.

5.8. The study of the gain of the height on the oldest alley

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	11.692	0.818

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Alder 1 Distance 2.5 W	0.876	0.173
Alder 1 Distance 4 m W	0.824	0.051
Alder 1 Distance 8 m W	0.925	0.469
Alder 1 Distance 2.5 E	0.956	0.770
Alder 1 Distance 4 m E	0.957	0.779
Alder 1 Distance 8 m E	0.885	0.208
Alder 2 Distance 2.5 m W	0.897	0.271
Alder 2 Distance 4 m W	0.972	0.916
Alder 2 Distance 8 m W	0.834	0.065
Alder 2 Distance 2.5 E	0.949	0.702
Alder 2 Distance 4 m E	0.958	0.790
Alder 2 Distance 8 m E	0.954	0.752
Willow Distance 2.5 W	0.954	0.748
Willow Distance 4 m W	0.950	0.712
Willow Distance 8 m W	0.810	0.038
Willow Distance 2.5 E	0.954	0.748
Willow Distance 4 m E	0.902	0.301
Willow Distance 8 m E	0.830	0.058

All P value (the majority) >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Development: the development of the trees has any effect on the gain of height
H0 Distance: the distance between the tree row and the plot don't influence the gain of height
H0 Interaction: The interactions have any effect on the gain of height

	F	P value
Deveolpment	83.061	$<2.2.10^{-16}$
Distance	50.478	$<2.2.10^{-16}$
Orientation	0.321	0.572
Distance & Orientation	5.650	0.004
Development & Orientation	23.626	$1.935.10^{-9}$
Development & Distance	4.517	0.004
Development & Distance & Orientation	1.493	0.208

P value (Distance, development, double interactions) <0.05: H0 is accepted. The other H0 (orientation and interaction of all the factor) are accepted (p>0.05). The gain of height is influenced by the development by the orientation, by the distance between trees-plots and the interaction of these factor without the interaction of all (P<0.05). But not by the interaction at the risk of error of 5 %.

6. Weeds' assessments

5.1. The 21th of April: Cover of weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	6.353	0.608

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.829	0.105
Age 1 Distance 8 m	0.912	0.453
Age 1 Distance 12 m	0.958	0.801
Age 2 Distance 4 m	0.940	0.659
Age 2 Distance 8 m	0.912	0.452
Age 2 Distance 12 m	0.958	0.804
Age 3 Distance 4 m	0.912	0.452
Age 3 Distance 8 m	0.971	0.896
Age 3 Distance 12 m	0.866	0.210

P value>0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	F	P value
Age	0.445	0.644
Distance	0.457	0.636
Age & Distance	0.766	0.553

P value>0.05: H0 is accepted. The cover of weeds is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %.

5.2. The 28th of April: Cover of weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	3.075	0.930

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.950	0.744
Age 1 Distance 8 m	0.891	0.324
Age 1 Distance 12 m	0.783	0.041
Age 2 Distance 4 m	0.988	0.982
Age 2 Distance 8 m	0.878	0.262
Age 2 Distance 12 m	0.496	$2.073.10^{-5}$
Age 3 Distance 4 m	0.920	0.505
Age 3 Distance 8 m	0.892	0.331
Age 3 Distance 12 m	0.889	0.314

P value (the majority) >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	F	P value
Age	2.347	0.107
Distance	0.069	0.934
Age & Distance	0.195	0.940

P value>0.05: H0 is accepted. The cover of weeds is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %.

5.3. The 05th of May: Cover of weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	7.652	0.468

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.797	0.055
Age 1 Distance 8 m	0.866	0.212
Age 1 Distance 12 m	0.982	0.960
Age 2 Distance 4 m	0.920	0.578
Age 2 Distance 8 m	0.912	0.452
Age 2 Distance 12 m	0.827	0.101
Age 3 Distance 4 m	0.880	0.271
Age 3 Distance 8 m	0.908	0.421
Age 3 Distance 12 m	0.800	0.059

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	F	P value
Age	2.615	0.084
Distance	0.481	0.621
Age & Distance	0.325	0.857

P value>0.05: H0 is accepted. The cover of weeds is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %.

5.4. The 12th of May: Cover of weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	5.582	0.694

P value>0.05: So H0 is accepted. Variances of each factor are similar at the factor risk of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Distance 4 m	0.874	0.243
Age 1 Distance 8 m	0.853	0.167
Age 1 Distance 12 m	0.866	0212
Age 2 Distance 4 m	0.963	0.846
Age 2 Distance 8 m	0.934	0.614
Age 2 Distance 12 m	0.924	0.535
Age 3 Distance 4 m	0.908	0.421
Age 3 Distance 8 m	0.890	0.320
Age 3 Distance 12 m	0.902	0.389

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	F	P value
Age	1.642	0.205
Distance	0.025	0.977
Age & Distance	0.267	0.898

P value>0.05: H0 is accepted. The cover of weed is not influenced by tree' age, the distance and the interaction at the risk of error of 5 %.

5.5. The Cover of weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	16.673	0.118

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Tree row	0.683	0.004
Age 1 Distance 4 m	0.701	0.006
Age 1 Distance 8 m	0.815	0.080
Age 1 Distance 12 m	0.982	0.960
Age 2 Tree row	0.897	0.357
Age 2 Distance 4 m	0.957	0.794
Age 2 Distance 8 m	0.939	0.654
Age 2 Distance 12 m	0.974	0.917
Age 3 Tree row	0.496	$2.073.10^{-5}$
Age 3 Distance 4 m	0.738	0.015
Age 3 Distance 8 m	0.823	0.094
Age 3 Distance 12 m	0.950	0.737

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	F	P value
Age	0.188	0.829
Distance	7.541	0.0002
Age & Distance	1.086	0.381

P value (Distance) <0.05: H0 is rejected. The cover of weed is influenced the distance at the risk of error of 5 %.
P value (Age and Interaction) > 0.05. H0 are accepted. The cover is not influenced by the age of the trees and the interaction.

- HSD test:

	Tree row	4 m	8 m	12 m
Distance	A	B	B	B

5.6. The Cover of perennials weeds

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	26.437	0.006

P value<0.05: So H0 is rejected. Variances of each factor are not similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Tree row	0.768	0.029
Age 1 Distance 4 m	0.766	0.028
Age 1 Distance 8 m	0.806	0.066
Age 1 Distance 12 m	0.957	0.795
Age 2 Tree row	0.496	$2.073.10^{-5}$
Age 2 Distance 4 m	0.804	0.064
Age 2 Distance 8 m	0.828	0.104
Age 2 Distance 12 m	0.946	0.708
Age 3 Tree row	0.957	$2.073.10^{-5}$
Age 3 Distance 4 m	0.874	0.245
Age 3 Distance 8 m	0.906	0.411
Age 3 Distance 12 m	0.818	0.084

P value >0.05 (the majority): H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Kruskal test

H0 Age: the age of trees has any effect on the cover of weeds
H0 Distance: the distance between the tree row and the plot don't influence the cover of weeds
H0 Interaction: The interaction distance & age have any effect on the cover of weeds

	X^2	P value
Age	6.132	0.047
Distance	22.464	$5.223.10^{-5}$
Age & Distance	32.984	0.0005

P value <0.05: H0 are rejected. The cover of perennial weeds is influenced by the distance the age of the trees and the interaction.at the risk of error of 5%.

- Wilcox test: Distance

	Tree row	4 m	8 m	12 m
Tree row		0.0007	0.001	$2.808.10^{-6}$
4 m			0.556	0.149
8m				0.568

Age:

	A1	A2	A3
A1		0.769	0.044
A2			0.027

5.7. The value for wildlife

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K²	P value
Age & Distance	34.978	0.0002

P value<0.05: So H0 is rejected. Variances of each factor are not similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Tree row	0.859	0.187
Age 1 Distance 4 m	0.795	0.053
Age 1 Distance 8 m	0.666	0.003
Age 1 Distance 12 m	0.934	0.611
Age 2 Tree row	0.903	0.391
Age 2 Distance 4 m	0.975	0.927
Age 2 Distance 8 m	0.754	0.021
Age 2 Distance 12 m	0.899	0.366
Age 3 Tree row	0.640	0.001
Age 3 Distance 4 m	0.875	0.248
Age 3 Distance 8 m	0.923	0.527
Age 3 Distance 12 m	0.938	0.645

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Kruskal test

H0 Age: the age of trees has any effect on the value of weeds
H0 Distance: the distance between the tree row and the plot don't influence the value of weeds
H0 Interaction: The interaction distance & age have any effect on the value of weeds

	X²	P value
Age	1.432	0.489
Distance	19.570	0.0002
Age & Distance	25.024	0.009

P value (Distance and interaction) <0.05: H0 is rejected. The value of weeds is influenced by the distance and the interaction at the risk of error of 5 %.
P value (Age) > 0.05. H0 is accepted. The value is not influenced by the age of the trees

- Wilcox test: Distance

	4 m	8 m	12 m
Tree row	0.015	0.0003	$1.552.10^{-5}$
4 m		0.466	0456
8 m			0.536

5.8. The richness

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	**K²**	**P value**
Age & Distance	7.989	0.714

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	**W**	**P value**
Age 1 Tree row	0.958	0.804
Age 1 Distance 4 m	0.815	0.080
Age 1 Distance 8 m	0.866	0.212
Age 1 Distance 12 m	0.822	0.091
Age 2 Tree row	0.827	0.101
Age 2 Distance 4 m	0.951	0.752
Age 2 Distance 8 m	0.775	0.035
Age 2 Distance 12 m	0.960	0.820
Age 3 Tree row	0.921	0.514
Age 3 Distance 4 m	0.915	0.473
Age 3 Distance 8 m	0.977	0.933
Age 3 Distance 12 m	0.866	0.212

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the richness of weeds
H0 Distance: the distance between the tree row and the plot don't influence the richness of weeds
H0 Interaction: The interaction distance & age have any effect on the richness of weeds

	F	**P value**
Age	4.232	0.019
Distance	4.963	0.004
Age & Distance	1.246	0.301

P value (Distance and age) <0.05: H0 is rejected. The richness of weeds is influenced the distance and the age of the trees at the risk of error of 5 %.
P value (Interaction) > 0.05. H0 is accepted. The richness is not influenced by the interaction.

- HSD test: Distance

	Tree row	**4 m**	**8 m**	**12 m**
Distance	B	A	A	A

5.9. The diversity

- Explanation of the test:

H0: no differences between the variances of each factor

Bartlett test	K^2	P value
Age & Distance	18.528	0.070

P value>0.05: So H0 is accepted. Variances of each factor are similar at the risk of error of 5 %

H0: Data for each factor follow the normality law

Shapiro test	W	P value
Age 1 Tree row	0.913	0.457
Age 1 Distance 4 m	0.929	0.571
Age 1 Distance 8 m	0.862	0.197
Age 1 Distance 12 m	0.863	0.198
Age 2 Tree row	0.843	0.138
Age 2 Distance 4 m	0.806	0.066
Age 2 Distance 8 m	0.956	0.790
Age 2 Distance 12 m	0.929	0.575
Age 3 Tree row	0.982	0.962
Age 3 Distance 4 m	0.942	0.678
Age 3 Distance 8 m	0.984	0.968
Age 3 Distance 12 m	0.950	0.738

P value >0.05: H0 is accepted. Data follow the normality law at the risk of error of 5 %

- Two-way anova test

H0 Age: the age of trees has any effect on the diversity of weeds
H0 Distance: the distance between the tree row and the plot don't influence the diversity of weeds
H0 Interaction: The interaction distance & age have any effect on the diversity of weeds

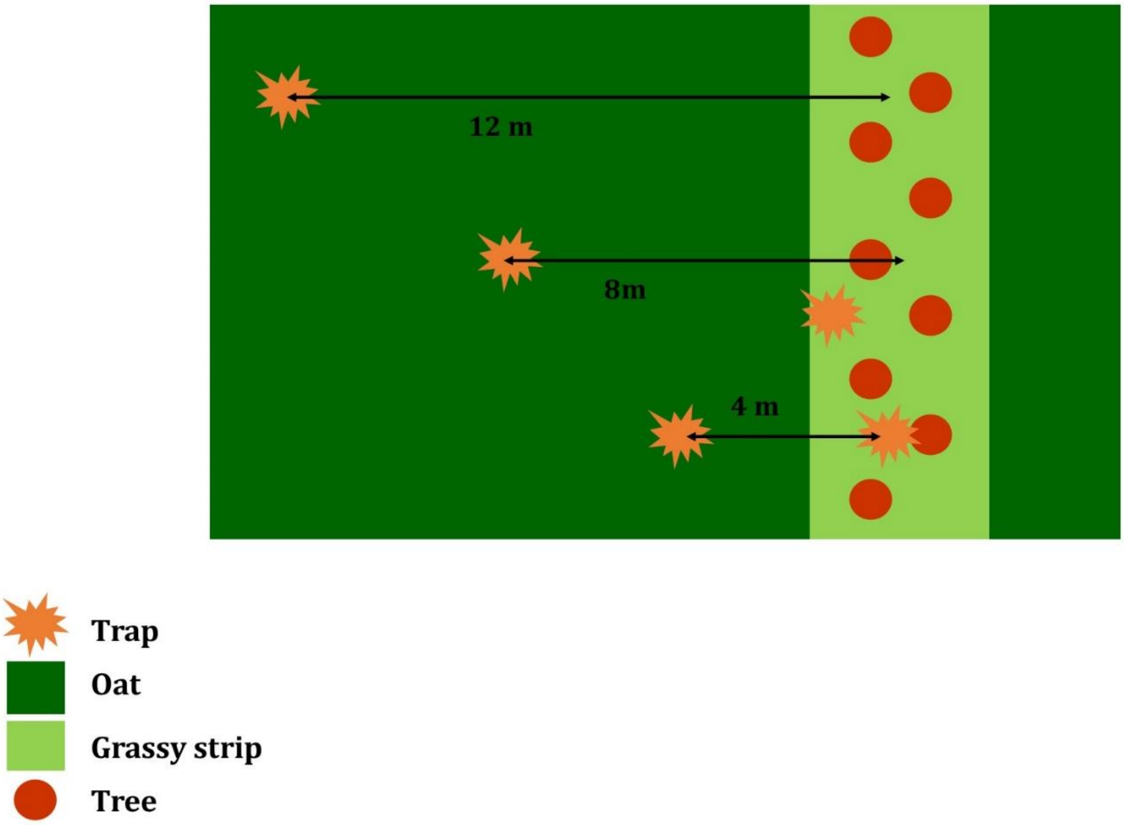
	F	P value
Age	0.925	0.402
Distance	6.653	0.0006
Age & Distance	1.372	0.241

P value (Distance) <0.05: H0 is rejected. The diversity of weeds is influenced the distance at the risk of error of 5 %.
P value (Age and Interaction) > 0.05. H0 are accepted. The cover is not influenced by the age of the trees and the interaction.

- HSD test: Distance

	Tree row	4 m	8 m	12 m
Distance	B	A	A	A

Annexes 9: Scheme of the loacation of the pitfall traps



This scheme is not at the scale.