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Master's Thesis – Master Sustainable Business and Innovation

Does money grow on trees?

A case study on the long-term financial and socio-economic performance of silvopastoral agroforestry practices in the Netherlands

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Abstract

Agriculture has a large environmental impact and contributes to various ecological problems and therefore farmers are increasingly looking for more eco-friendly agricultural models. A promising example of such a model is agroforestry, which is based on the re-introduction of trees into the agricultural landscape. In previous research, the ecological benefits of agroforestry have already been demonstrated, but little is known about the financial aspects of agroforestry. This makes the transition towards agroforestry uncertain for many farmers, hampering its adoption. In this research, the financial aspects of agroforestry are studied in more detail, answering the following research question: 'What is the long-term financial and socio-economic performance of silvopastoral agroforestry practices in the Netherlands?'

To get insights into the profitability of agroforestry in the Netherlands, six case studies were performed. Interviews were held with the farmers to get an overview of the costs associated with agroforestry. As the farm only recently implemented agroforestry, future revenues had to be estimated based on desk research. By combining the two data sources, the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback Time (DPBT) and the first year of positive cash flow were calculated for the six projects. Additionally, a socio-economic analysis was performed in which the value of the ecosystem services provided by agroforestry were economically valued. In this research the carbon sequestration, and the reduction in ammonia emission and nitrogen runoff as a result of the implementation of agroforestry were valued.

The results indicate that agroforestry projects are in general profitable and resistant to fluctuations in fruit and nut yield and sales. Especially the farms that implemented walnut trees seem to be highly profitable based on their NPV, mainly as a consequence of the high value of walnut timber. The projects that involved fruit trees were also financially attractive as the DPBT was lower and a positive cash flow was reached earlier compared to the walnut farms as fruit trees reach their potential yield earlier than walnut trees. Combining these two business models leads to an optimal financial performance with a high NPV, a low DPBT and an early positive cash flow. Furthermore, this research shows that the ecosystem services provided by agroforestry have substantial economic value and that financially valuing these ecosystem services would be a viable alternative to the current subsidies. Together, this thesis showed that agroforestry not only has a promising ecological future, but also a financial one.

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1. Introduction

World population has risen more than 3-fold since 1950 which resulted in strong increases in global food demand (UN-DESA, 2020). In order to meet this demand, rapid advances in technology, substantial public investments and policy support for agriculture took place (Hazell, 2009). During this period of intensification and specialization (i.e., monocultures) of agriculture, also known as the *Green Revolution*, a substantial increase in agricultural output was realised (Pingali, 2012). Despite the impressive increase in productivity, these developments also had adverse impacts on the environment. In order to make more land available for agricultural purposes and to ease the use of large modern machinery, trees have been progressively removed from the agricultural landscape (Nerlich et al., 2013; Palma, 2006). The increased removal of trees, and the increased frequency and depth of tilling, comes at the expense of the ecosystem services relevant for agricultural production (Jezeer et al, 2018), as these practices are known to cause a significant reduction in soil organic matter which reduces the carbon stock in both soils and trees and reduces the fertility, permeability, and water retention capacity of soils (Rosati et al., 2020). Consequently, agricultural systems destabilized and became dependent on extensive use of water, inorganic fertilizers, pesticides and fossil fuels (Campbell et al., 2017). Agriculture can therefore be identified as the source of various problems, such as soil erosion and degradation, depletion of aquifers, eutrophication, climate forcing and biodiversity loss (called negative externalities) (Pretty et al., 2018). With the current and future challenges in mind, it is important to identify agricultural practices with lower negative environmental impacts while meeting economic goals as well (Jezeer et al., 2018; Nerlich et al., 2013). At the same time, more consumers are looking for high-quality and locally produced products with more attention to the environment, animal welfare and a fair price for the farmer (Reubens et al., 2020). A promising example of such a model is agroforestry.

Agroforestry can be defined as any land-use management system that involves the growing of woody perennials, such as trees or shrubs, together with agricultural crops or livestock farming on the same land unit (Nair, 1993). Agroforestry systems can be classified into two main types, depending on the combination of elements; silvopastoral systems (trees combined with pasture and livestock) and silvoarable systems (trees combined with agricultural crops) (Mosquera-Losada et al., 2018). Trees used in agroforestry systems can be of any kind and with any function, including biomass, wood, fodder, nut and fruit production (Rosati et al., 2020). The fundamental idea behind agroforestry is that trees are a crucial part of natural ecosystems and provide several ecosystem services when they are integrated into agricultural systems (Murth et al., 2016). For instance, studies increasingly show that agroforestry systems are a promising solution for the conservation of biodiversity in human dominated landscapes (Bhagwat et al., 2008). By including trees in the agricultural system, new habitats can be created that connect different nature reserves, which contributes to biodiversity at larger spatial scales (Bhagwat et al., 2008). Furthermore, agroforestry practices are increasingly recognized as a tool to mitigate climate change by carbon sequestration (capturing and storing atmospheric carbon dioxide) in vegetation and, more importantly, soil (Jose, 2009; Lorenz and Lal, 2014). Additionally, trees provide long-term soil productivity and sustainability, as they enhance soil biological, chemical and physical properties by adding substantial amounts of organic matter and releasing and recycling nutrients in agroforestry systems (Dhillon et al., 2017; Jose, 2009). Finally, agroforestry practices are also a proven strategy to improve water quality by cleaning runoff water, reduce particulate matter in the air, limit wind erosion and noise pollution and mitigate odor from concentrated livestock farming, among others (Jose, 2009).

The vast majority of studies performed on agroforestry systems is focussed on assessing their biophysical performance (Amare and Darr, 2020). To date, only a small percentage of agroforestry studies have analysed its economic implications, while it is often economic concerns that limit its adoption (Jezeer et al., 2018; Montambault and Alavalapati, 2005; Nair, 1998; Palma, 2006; Rosati et al., 2020). Most economic studies of agroforestry practices have been limited to crop yield and disregarded economic aspects as management costs and externalities. Consequently, the effects of agroforestry practices on economic performance metrics (e.g. investment and management costs, labour and long-term profitability) remain largely unknown (Oosterbaan and Kuiters, 2009; de Leijster et al., 2020). However, these economic performance metrics do have a considerable influence on farm profitability as well (de Leijster et al., 2020). Therefore, crop yield alone is not a comprehensive indicator of farm economic performance (Jezeer et al., 2018; de Leijster et al., 2020). For example, Jezeer et al. (2018) found that high input Peruvian coffee systems had significantly lower net income, mainly due to higher costs of fertilizer and fungicides, land and labour costs which were not fully compensated for by higher coffee yields. As a result, long-term profitability metrics are more appropriate as they consider all the costs and income generated throughout the lifespan of a project (de Leijster et al., 2020). Additionally, long-term analyses are needed since economic settings are not static as market prices and costs of, for instance, labour and equipment do change over time (de Leijster et al., 2020).

The cultivation of conventional commodities often results in negative externalities, which are not internalised in the market process (Bommarco et al., 2013; de Leijster et al., 2020). An analysis based on only these market processes is called a *financial* analysis. Financial analyses do not consider non-market costs and benefits (i.e. externalities) of agricultural systems, while the ecosystem services provided by agroforestry practices do have considerable value to both farmers and society (De Leijster et al., 2020; Lehmann et al., 2020). Therefore, it is also important to take the value of ecosystem services into consideration and perform a *socio-economic* analysis of agroforestry systems that does include these non-market costs and benefits. Negative externalities might decrease as a result of agroforestry practices, but the profitability of these practices might be lower than a conventional approach as well. Based on the difference in profitability of conventional farming compared to agroforestry, dedicated subsidy schemes or other (financial) incentives can be developed to stimulate the adoption of agroforestry practices by farmers (de Leijster et al., 2020; Luo et al., 2014).

There are a few studies that focused on the financial and socio-economic performance of agroforestry systems, but these were mainly performed in (sub)tropical regions (Alavalapati and Mercer, 2006; Amare and Darr, 2020). The results of these regions can greatly differ from more temperate regions, like the Netherlands, as biophysical aspects, management conditions, national legislation and regional policy can have a large impact on the profitability of agroforestry (Palma et al., 2007). For example, Palma (2006) found that even the profitability of silvoarable agroforestry within Europe can greatly differ. Most agroforestry projects in the Netherlands were less profitable than projects in France and Spain, due to relatively low timber prices (Palma, 2006). Furthermore, the research showed that regional biophysical conditions can have a large impact on the profitability of agroforestry too. For example, in France the average yield of walnut timber was roughly 40 percent higher than in the Netherlands due to more favourable precipitation and soil conditions. As a result, a similar project could be profitable in France while unprofitable in the Netherlands. Thus, these results show that regional differences have a large impact on the profitability of agroforestry, which emphasizes the need of location specific analyses. In this research, the profitability of agroforestry will be analysed for the Netherlands specifically, answering the following research question:

'What is the long-term financial and socio-economic performance of silvopastoral agroforestry practices in the Netherlands?'

In order to answer this research question, the economic performance of silvopastoral agroforestry compared to conventional farming will be estimated, both from a financial and socio-economic perspective. For these analyses, cash flow plans were made and long-term profitability metrics that include all costs and benefits generated during the project lifespan like, Net Present Value (NPV), Internal Rate on Return (IRR) (Godsey, 2008) and discounted payback time (DPBT) (de Leijster et al., 2020) were calculated. Due to the long lifespan of agroforestry systems, it is important to reflect the present value of future net cash flows for which investments are made in the present and will only pay off in the long term (Godsey, 2008). For the socio-economic analysis, also the value of carbon sequestration in both the soil and trees provided by agroforestry was internalised. Also, the value of the reduction in ammonia emission and nitrogen runoff was included. The values of these long-term profitability metrics were used to estimate whether agroforestry in the Netherlands is profitable or not and which type is most profitable.

As mentioned, the empirical evidence on the economic performance of agroforestry practices, especially in temperate regions, is scarce. Additionally, few studies attempt to value the ecosystem services provided by agroforestry systems. By performing this research, additional insights can be gathered. Furthermore, the lack of economical knowledge on agroforestry systems makes the adoption of agroforestry a financially uncertain transition for farmers (De Leijster et al., 2020). By conducting this research more insight will be gathered on the long-term profitability of agroforestry. However, farmers' decisions are probably more driven by changes in income and return on investment, rather than on projections of NPV (Jezeer et al., 2018). The main reason being that investments in agroforestry will mainly pay off in the long term, which some (elderly) farmers cannot profit from anymore during their life. Therefore, cash flow plans were also provided. Long term profitability may however be interesting for younger farmers or family farms that will continue for at least one more generation. Therefore, the calculation of the long-term profitability of agroforestry practices could stimulate the large-scale implementation of agroforestry practices. If the financial analyses provide evidence that agroforestry is at least as profitable as conventional agriculture, this can be communicated to conventional farmers in order to stimulate them in the transition towards agroforestry. If it turns out that Dutch agroforestry systems are only at least as profitable as conventional practices from the socio-economic analyses, then this research can provide insights in the need for policy instruments to overcome financial barriers for agroforestry adoption.

2. Theory

2.1 Agroforestry in the Netherlands

From the 1950s onwards, land prices and labour costs have started to increase while food prices considerably dropped, and consequently Dutch farmers were forced to expand their farms for large-scale agricultural production to reduce costs (Oosterbaan and Kuiters, 2009). In order to reach this large-scale production, farmers resorted to monocultures and increasingly used fertilisers and chemicals to enhance growth and minimize weeds and diseases (Oosterbaan and Kuiters, 2009), which caused detrimental environmental impact. In addition to the intensification of agriculture, also the increasing deforestation in the Netherlands caused an increase in the interest for more sustainable agricultural practices (Oosterbaan and Kuiters, 2009; van Staalduine, 2017).

In the Netherlands, mainly silvopastoral systems (trees combined with pasture) can be found (Oostbaan and Kuiters, 2009). For instance, fruit trees are combined with pasture in the clay soils between the river Rhine and Meuse, poplar trees are combined with pasture in the province of Noord-Brabant and farming between rows of alder is carried out in the wetlands in the northern part of the Netherlands (Oostbaan and Kuiters, 2009). More recently, there has been an increasing interest in agroforestry systems combining nuts (mainly walnuts and hazelnuts) with pasture due to an increasing demand and technological innovations for the cultivation of nuts (Baltissen and Oosterbaan, 2017; Oosterbaan et al., 2004).

As has become clear in the introduction, the ecological benefits of agroforestry systems are numerous (Jose, 2009). Nevertheless, the adoption of agroforestry practices in the Netherlands remains limited. Especially silvorarable systems are scarce in the Netherlands since these systems can have a negative impact on the yield of crops (Mirck, 2016). The trees in the agroforestry system reduce the amount of direct light on the crop, which is usually the limiting resource in northern temperate regions, resulting in lower yields (Benavides et al., 2009). Therefore, crop species that are adapted to the shade of the trees should be used (Benavides et al., 2009). Another barrier in the adoption of agroforestry systems is that this type of agriculture is often more labour-intensive, because moments of harvesting are more dispersed than for monocultures and large machinery cannot always manoeuvre between the different crops (Wilschut, 2019). Since it is not clear whether higher return on labour can be obtained compared to monocultures, farmers are often hesitant with implementing agroforestry. Finally, profit in agroforestry systems is almost never achieved in the short term because trees and shrubs grow slower than annual crops. As a result, the implementation of agroforestry systems is not the most obvious in today's society where people prefer to achieve high returns in the short term (Luske et al., 2020).

2.2 Cost-Benefit analysis

There is a lack of empirical evidence on the economic feasibility of agroforestry practices in the Netherlands. In order to get a more holistic view into the feasibility of agroforestry in the Netherlands, analyses that consider all costs and benefits of agroforestry need to be performed. A simple, powerful tool that is often used for comparing the profitability of alternative land uses is cost-benefit analysis (Mercer et al., 2014). Cost-benefit analysis is a process of identifying, measuring and comparing costs and benefits of an investment project (Campbell and Brown, 2003).

2.2.1 Cash flow plan

A cost-benefit analysis starts with a cash flow plan. A cash flow plan is a tool to determine how a business generates and spends money over a specific time period (Godsey, 2008). This tool provides insights into yearly losses or incomes caused by a certain project. However, a cash flow is not a useful tool to compare different alternatives since a cash flow is a series of annual net incomes or losses and does not result in a single value that indicates the financial performance. Furthermore, it also disregards the time value of money which makes it inadequate for long-term financial analyses. Unlike most agricultural commodities, agroforestry has a relatively long lifespan and most of the costs and revenues do not occur at regular intervals throughout its lifespan (Godsey, 2008). In order to determine the long-term profitability of a project, additional tools should be used.

2.2.2 Long-term profitability indicators

A long-term analysis is especially useful for the economic evaluation of agroforestry systems due to the long lifespan of the tree element. Most agroforestry systems take several years before benefits begin to be fully realized compared to conventional agricultural systems with annual crops (Godsey, 2008). Therefore, a short-term evaluation of agroforestry will underestimate its total benefits relative to other agricultural practices (Nair, 1993).

2.2.2.1 Net Present value

Since implementing agroforestry normally involves costs in the present and benefits in the future, the net cash flows will first be negative for a certain period and will then become positive (Campbell and Brown, 2003). Costs and benefits incurred in different years cannot be compared outright since the value of money decreases over time (Nair, 1993). In order to summarize the overall net benefits of agroforestry in one measurement unit, all costs and benefits have to be converted to values at the same point in time, usually the present (Campbell and Brown, 2003). The Net present value (NPV) is the sum of all discounted future net cash flows of the project to reflect their current value (Godsey, 2008). The discount rate is an indicator for the rate at which people are willing to give up consumption in the present in exchange for additional consumption in the future (Campbell and Brown, 2003).

The NPV can be calculated using the following formula (Nair, 1993):

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t}$$

Where: B are the benefits in year t,
C are the costs in year t,
r is the selected discount rate and
n is the number of years included in the analysis

A disadvantage of the NPV is that it can be complex to accurately select at a discount rate that represents the investment's true risk premium (Gallant, 2021). A small difference in the selected discount rate can cause considerable changes in the NPV. Therefore, it can be interesting to also calculate the internal rate of return.

2.2.2.2 Internal Rate of Return

Another common indicator of economic performance is the Internal Rate of Return (IRR). The IRR is the maximum rate of interest that a project can repay on loans while still recovering all investment and operating costs (Nair, 1993). It is the discount rate that will equal the discounted total costs and benefits of a project (Nair, 1993). However, the IRR is not a strictly valid evaluation indicator if cost and benefit relations radically change over the lifespan of a project, which does occur in agroforestry practices (Nair, 1993). Therefore, it does not always capture the uncertainty of returns over time (Godsey, 2008). On the other hand, an advantage of the IRR is that no specific discount rate needs to be preselected for its calculation (Nair, 1993).

The internal rate of return is given by i in (Nair, 1993):

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1 + IRR)^t} = 0$$

Where: B are the benefits in year t,
C are the costs in year t,
IRR is the internal rate of return and
n is the number of years included in the analysis

2.2.2.3 Discounted Payback Time

Although the NPV is a great tool to determine the long-term profitability of a project, it does not provide information on the time it takes for a project to become profitable. To get insight into this, the discounted payback time (DPBT) can be used. The DPBT is the point in time (n) that it takes (in years) for the initial investment of a project to equal the discounted returns of the project. In other words, the year wherein the projects break even from an investment. DPBT does not include cash flows that are produced after this break-even point and therefore excludes information of the overall project profitability (de Leijster et al., 2020).

The DPBT can be calculated using the following formula (de Leijster, 2020):

$$\sum_{n_0}^{DPBT} CF_n \, (1 + r)^{-n} - IC = 0$$

Where: CF is the annual cash flow in period n
IC is the investment cost of the project
r is the selected discount rate and
n is the number of years included in the analysis

Since these three long-term profitability metrics all have its advantages and disadvantages, it is important to use them together in determining the long-term financial and socio-economic performance of agroforestry (Godsey, 2008; de Leijster et al., 2020).

2.3 Valuing ecosystem services

Ecosystem services provided by agroforestry practices do have considerable value to both farmers and society (De Leijster et al., 2020; Lehmann et al., 2020) and should therefore be accounted for. However, assigning monetary value to ecosystem services is a complex task. A lot of research has been dedicated to this topic, but a clear-cut economic value of the different ecosystem services has not yet been determined (Pandeya et al., 2016). One of the major difficulties is that the value of an ecosystem service is highly context dependent (Holzman, 2012). For instance, the value of a watershed that serves all the nine million inhabitants of London with fresh water would be much higher than that of a watershed serving the inhabitants of Oxford. A second major challenge of valuing ecosystem services is that they are not supported by much data, which makes it necessary to use a lot of assumptions which in turn leads to large 'error bars' (Holzman, 2012). Over the years, many different valuation methods for ecosystem services have been used to deal with these difficulties (Cordier et al., 2014). In this chapter an overview will be given of the available ecosystem valuation methods, their potential applications and the main limitations.

2.3.1 Direct Market Valuation

The most straightforward method is the *market value method* which makes use of direct market prices (De Groot et al., 2002). This methodology is often preferred as it is the most direct way to measure the value of an ecosystem service as there are actual market prices available. Consequently, this methodology can only be applied to a small subset of ecosystem services as this valuation method is only possible when there is a market for the ecosystem service of interest. An example of an ecosystem service that can be analysed based on market prices is the carbon sequestration by trees (based on the carbon price on the voluntary carbon market) (Horlings et al., 2019).

2.3.2 Indirect Market Valuation

For the valuation of ecosystem services where no real market prices can be assigned, different methods need to be used. In previous research a lot of different methods have been identified. The first one is the cost-based method called *avoided costs*. This method estimates the value of ecosystem services based on the costs that would have been incurred when these ecosystem services were absent (De Groot et al., 2002). This method is especially useful when assigning a monetary value to regulating services (e.g. air purification by forest, which avoids health costs) (Horlings et al., 2019). The main limitation of this method is that it is hard to precisely determine the costs that can be avoided. If a forest contributes to air purification, there are a lot of questions to be asked to determine the value of the forest. Most of these questions, however, cannot be answered without extensive research, for instance: to what extent does the forest contribute to air purification? What would be the exact health impact when the forest would not be there? How much would the health costs be if the forest would not be there? Hence, by using the avoided costs method it is hard to get a detailed and precise estimation of the costs that are actually avoided by an ecosystem service.

Related to the avoided costs approach is the *replacement costs* method, which estimates the value of an ecosystem service based on the costs of a man-made alternative to the service or the costs associated with restoring the ecosystem after damage due to human activity (De Groot et al., 2002).

For instance, Sundberg (2004) estimated the value of the habitat of fish species based on the costs that were needed to restore them after these habitats were severely affected by human activity. During this research also the main limitations of the cost-based methods became apparent. When estimating the value of an ecosystem service based on the replacement cost method, three assumptions are made (Sundberg, 2004, p.4):

1. *The human engineered system provides functions that are equivalent in quality and magnitude to the ecosystem service.*
2. *The human engineered system is the least cost alternative way of replacing the ecosystem service.*
3. *Individuals in aggregate would in fact be willing to incur these costs if the ecosystem service was no longer available.*

However, in most of the cases either one of the assumptions is not fulfilled, which can lead to severe over or underestimations of the actual value of the ecosystem services of interest (Sundberg, 2004).

2.3.3 Revealed preferences methods

Another group of ecosystem valuation methods are the revealed-preferences methods. These methods infer the value of ecosystem services by analysing the choices that consumers make in the market (Boyle, 2003). The two most relevant examples of revealed preferences methods are *hedonic pricing* and the *travel costs* method. Hedonic pricing is used to estimate the economic value of an ecosystem service by the effect it has on the actual market prices. An example is that houses located near the beach, or a forest are normally higher valued than houses in a less attractive environment (De Groot et al., 2002). Based on these pricing differences, the value of the ecosystem service is inferred. The travel cost method values ecosystem services based on the price people pay to travel to a certain destination. For example, the value of a certain recreation area can be determined based on the distance people travel to visit this area, assuming that the value that the visitors place on the area must be at least what they paid to travel to it (De Groot et al., 2002). For both of these methods the values are determined based on a lot of assumptions and therefore they suffer from several limitations. For instance, the value of a service or object (e.g. a house near the beach) is not solely determined based on the ecosystem service that it is located near to, but is based on many more variables (e.g. access to jobs, facilities located nearby, etc.). Therefore, a valuation based on hedonic pricing can lead to serious over-estimations of the ecosystem service at hand. The travel costs method suffers from similar limitations, and hence it is highly challenging to estimate a realistic value of ecosystem services based on these methods.

2.3.4 Stated preferences method

Related to the previous two methods is the *willingness to pay* (WTP) methodology. As the name suggests, the WTP method uses the amount of money users are willing to pay for a certain ecosystem service to value the ecosystem service. The previous methods (hedonic pricing and travel costs) assume the willingness to pay based on market prices, however the willingness to pay can also be determined in a more direct manner by performing surveys or interviews. As data are retrieved in a more direct manner, this WTP method is often categorized as a stated preferences method instead of a revealed preferences method (Horling et al., 2019). An example of a study using the WTP method to determine the value of ecosystem services is the one of Tian et al. (2020). In their research, the value of urban green spaces in three major cities in central China was determined by performing a survey with 3000 residents asking them about their willingness to pay for the conservation of these green spaces (roughly 32 USD per year). The research by Tian et al. (2020) also shows the main limitations of the WTP methodology, as it is very time consuming. A large number of surveys need to be performed to get a reliable estimate of the value of a certain ecosystem service and the results are also highly context dependent which limits the generalizability of the results. For instance, green spaces can be valued way higher or lower in countries other than China or even within other regions of China.

In Table 1 an overview can be found of the discussed methods for ecosystem valuation as well as their main limitations. In this research, a combination of direct market valuations and avoided costs were used. A more detailed explanation on how these methods were used can be found in section 3.3.

Table 1: Overview of the methods to monetize ecosystem services and their main limitations.

Category	**Method**	**Description**	**Main limitation**
Direct market valuation	Direct market valuation	Determine value based on market prices for the ecosystem service	Only applicable to limit amount of ecosystem services
Indirect market valuation	Avoided costs	Determine value based on costs that would have been incurred when these ecosystem services were absent	Difficult to precisely estimate avoided costs resulting in overestimations of the value
	Replacement costs	Determine value based on the costs of man-made alternative to ecosystem service	Difficult to precisely estimate replacement costs resulting in overestimations of the value
Revealed preferences methods	Hedonic pricing	Determine value based on the effect a certain ecosystem service has on the market prices	Difficult to isolate the effect of the ecosystem services, as market prices are complex
	Travel costs	Determine value based on the travel costs that visitors have to make to visit a certain destination	Data intensive as you need to know where visitors come from
Stated preferences method	Willingness to pay	Determine value based on the amount of money users are willing to pay for a certain ecosystem service	Very time-consuming approach and highly context dependent

3. Methodology

In this section the methods used to perform the financial and socio-economic analysis will be discussed in more detail. Since the methods used for the financial and socio-economic analyses are slightly different, the methodology section will have a section for both analyses separately. First, a more detailed description of the farm selection is given.

3.1 Farm selection

In a previous master thesis research by Sven van der Valk (2021), some of the biophysical aspects of ten Dutch agroforestry farms have been studied. All of these farms were located in the Dutch province Noord-Brabant. Among others, the percentage of soil organic matter of these farms has been identified compared to conventional pastures. Since the biophysical data, necessary for the socio-economic analysis, was known already for these farms, it was preferred to conduct the financial and socio-economic analyses of this research on some of these farms as well. In order to indicate the long-term financial and socio-economic performance of agroforestry systems in the Netherlands, six case studies were performed. These six agroforestry farms can be categorized in four groups, based on the tree type (nut trees, fruit trees, fodder trees and a combination of nut and fruit trees). The other farms were left out of this research because of difficulties during the data collection. Table 2 provides an overview of the studied farms and their characteristics.

Table 2: Overview of the characteristics of the studied farms.

Farm	Farm type	Cattle	Tree species	# Trees	Plantation size (ha)	Tree density (tree/ha)
1	Conventional	Goats	Walnut (*Juglans regia*)	360	4	90
2	Organic	Cows	Walnut (*Juglans regia*)	120	2,5	48
3	Organic	Cows	Walnut (*Juglans regia*)	45	1	45
4	Organic	Pigs	Standard apple (*Malus domestica*), standard pear (*Pyrus communis*)	30	0,5	60
5	Organic	Cows	Walnut (*Juglans regia*), half standard apple (*Malus domestica*), half standard pear (*Pyrus communis*)	400	10	40
6	Organic	Cows	White willow (*Salix alba*), common alder (*Alnus glutinosa*), common aspen (*Populus tremula*), common oak (*Quercus robur*), field maple (*Acer campestre*), common hornbeam (*Capinus betulus*), common hawthorn, small-leaved lime (*Tilia cordata*)	500	0,2	2,500

3.2 Cost-benefit analysis

In this research, farms were analysed that first executed conventional/organic farming and made the transition to agroforestry. Therefore, it was more efficient to focus on the differences between the costs and revenues of the conventional and agroforestry practices of these farms. By this means, fixed costs could be disregarded (as the same farm is analysed for both conventional farming and agroforestry) and thus, fewer sensitive data was required. Based on the differences in costs and revenues between the conventional and agroforestry practices the NPV, IRR and DPBT were calculated, indicating whether the shift to agroforestry by the farmers is a profitable one and the time it takes.

3.2.1 Data collection

3.2.1.1 Literature

The trees of all farms were planted quite recently. Therefore, data about future costs and revenues (such as yields and timber prices) had to be obtained through desk research. After conducting literature research, interviews were held with farmers to collect essential, missing data that could not be derived from literature (such as farm characteristics, subsidies and investment costs).

3.2.1.2 Interviews

Interviews provide the opportunity to get more insights in farm specific costs and revenues. Interviews were performed in line with the economic budgeting guide for agroforestry practices of Godsey (2008). Accordingly, the interviews were structured into three main steps: (1) defining the enterprise, (2) estimating revenues, (3) estimating variable costs. Due to the COVID-19 outbreak, interviews were conducted digitally via Microsoft Teams. An overview of the interview guide can be found in appendix A.

3.2.2 Data processing

In order to determine the long-term profitability of agroforestry, first a cash flow plan was made for each farm. Based on the cash flows the net present value (NPV), internal rate of return (IRR) and the discounted payback time (DPBT) were calculated as an indicator for the long-term financial and socio-economic performance of agroforestry compared to conventional practices. The calculations were performed as described in the theory section (see 2.2.2 Long-term profitability indicators). Based on the data from the desk research and interviews, the NPV, IRR and DPBT were calculated using Microsoft Office 365 Excel 32-bit. For the calculations of the NPV and DPBT, a discount rate of 4% was used. This discount rate is in line with the most recent recommendations by the European commission on discount rates for EU member states (Sartori et al., 2014).

3.2.3 Variance of input variables and sensitivity analysis

Since several assumptions were made to determine the economic performance of agroforestry, it was necessary to conduct sensitivity analyses. For the studied farms, deviation in the nut price, nut yield, timber price, fruit price and fruit yield can be expected. Therefore, sensitivity analyses were executed for these variables. For the nut price, fruit price and timber price a range of possible prices was found in literature and accordingly these values were used for the sensitivity analyses. For the nut yield and fruit yield the range was unknown and therefore sensitivity analyses were performed for the effect of a 10% and 20% increase or decrease in yield.

3.2.3.1 Worst-case scenario

For the worst-case scenario, the lowest value of each assumption was used in order to calculate the worst-case profitability of the farms: €1/kg, €250/tree, €0.35/kg, for walnut, walnut timber and fruit prices, respectively. For the nut and fruit yield a decrease of 20% was assumed for the worst-case scenario.

3.3 Ecosystem service valuation

The reintroduction of trees to the agricultural landscape may provide various ecosystem services. The main challenge remains to value the large range of ecosystem services that these trees provide. Based on the literature, interviews and the websites of the analysed farms, the ecosystem services that agroforestry provides could be identified, also specifically for the farms of interest. The ecosystem services for which monetary values were determined in this study are carbon sequestration by the trees, increase in soil organic carbon concentration, reduction of ammonia emissions and reduction of nitrogen runoff. For the economic valuation of these ecosystem services the direct market valuation and the avoided costs methods were used, which will be discussed separately.

3.3.1 Carbon sequestration

The direct market valuation method was used to calculate the value of carbon sequestered by trees and the additional carbon stored in soil organic matter due to the introduction of trees. Often, the carbon price of the European Emission Trading System (ETS) is used to value carbon. The ETS, however, does not cover the agricultural sector and therefore using ETS is not a realistic measure ("EU Emissions Trading System (EU ETS) - European Commission", 2021). Alternatively, the carbon price of the voluntary carbon market (VCM) can be used to put a more realistic economic value to the carbon sequestration by trees in agroforestry systems. In 2019 the average price for one tonne of carbon on the voluntary carbon market was €2.10 (Donofrio et al., 2020). In contrast, the value of one tonne of carbon on the ETS is more than ten times as much at roughly €24 per tonne of carbon (European Commission, 2020).

To determine the value of the additionally stored carbon by the reintroduction of trees, two important carbon sequestration sources were considered: soil organic carbon (SOC) and the carbon sequestered in the standing biomass of the tree.

Carbon sequestration by trees:

Several types of trees and many different tree species were introduced by the agroforestry farmers. Some farmers introduced walnut trees, whereas others chose to implement fodder trees (e.g. alder, poplar, willow, oak) or fruit trees (e.g. apple trees). These trees all have different carbon sequestration capacities, which were retrieved from various studies. In table 3 an overview is shown of the different yearly carbon sequestration capacities of the various tree species.

Table 3: Overview of the carbon storage capacity of different tree species used in agroforestry.

Tree type	Tree species	Carbon storage capacity (t C/year)	Source
Nut tree	Walnut	0.015	Wotherspoon et al. (2014)
Fodder tree	Willow	0.014	Van Bussel (2006)
	Alder	0.06	Kim et al. (2009)
	Poplar	0.026	Wotherspoon et al. (2014)
	Oak	0.021	Wotherspoon et al. (2014)
Fruit tree	Standard fruit (apple and pear)	0.025	Anthony (2013); Wu et al. (2012)
	Half standard fruit (apple and pear)	0.021	Anthony (2013)

The overview in table 3 shows that there are no large deviations in the carbon storage capacity of the different tree species, and only the Alder tree seems to store considerably more carbon than the rest of the tree species. Next, the value of the stored carbon was calculated by multiplying the carbon storage capacity of the tree species by the number of trees and then by the carbon price of either the voluntary market or the price under the ETS. Table 4 shows an overview of the calculated value of the stored carbon for each of the farms, on a yearly basis. For the fodder trees the average storage capacity of the different fodder tree species was used (0,030 t C/year) as only data on the total number of fodder trees was available (and thus not on the exact number of trees per species).

Table 4: Annual value of tree carbon sequestration per farm, based on the voluntary carbon market and the European emission trading system.

Farm	Tree type	Carbon storage capacity (t C/year)	# Trees	Value voluntary market (€/year)	Value ETS (€/year)
1	Walnut	0.015	360	€11.34	€129.60
2	Walnut	0.015	120	€3.78	€43.20
3	Walnut	0.015	40	€1.26	€14.40
4	Standard fruit	0.025	30	€1.57	€18.00
5	Walnut	0.015	200	€6.30	€72.01
	Half standard fruit	0.021	200	€8.82	€100.81
6	Fodder	0.030	500	€31.50	€360.00

Carbon sequestration in soil organic matter (SOC):

Besides the storage of carbon in the tree itself, the introduction of trees into the agricultural landscape can also increase the quantity of SOM, which consist for 50 to 60 percent of carbon (SOC), depending among other on the intensity of agriculture (Hoorman and Islam, 2010; Lefèvre et al., 2017). In this research a conservative baseline of 50 percent was assumed. In the research of Wotherspoon et al. (2014) no significant increase in the SOC content was measured after the introduction of walnut trees. This is contrary to the findings of Sven van de Valk (2021) who measured the SOM contents of the farms that are studied in this research and did find a significant difference. A baseline of 90t SOC/ha is used for conventional farms to calculate the actual SOM quantities. This specific baseline was chosen based on the study of Conijn and Lesschen (2015) who found a concentration of 90t SOC/ha in the top 30 centimeters of the soil for croplands in Noord-Brabant. Based on the increases in SOM content measured by Van de Valk (2021), the amount of additionally stored carbon (assuming the ration between SOM and SOC remains the same) could be calculated and accordingly a monetary value could be determined based on either the carbon price on the voluntary market or the ETS. An overview of the value of the additionally stored SOC can be found in table 5.

Table 5: Value of soil carbon sequestration per farm, based on the voluntary carbon market and the European emission trading system.

Farm	Increase in SOM (%)	Additionally stored SOC (t C/ha)	Area (ha)	Additionally stored SOC (t C)	Value voluntary market (€)	Value ETS (€)
1	34.4	31.0	4	124	€260.40	€2,971.80
2	51.5	46.4	2.5	116	€243.60	€2,784.35
3	7.4	6.7	1	6.7	€14.07	€160.82
4	-29.9	NA	0.5	NA	NA	NA
5	16.5	14.9	10	149	€312.90	€3,576.45
6	6.0	5.4	0.2	1.1	€2.31	€26.29

3.3.2 Reduction in ammonia emission and nitrogen runoff

The avoided costs method was used to value the environmental impact of nitrogen emissions and the use of artificial fertilizer (which is very nitrogen rich). The use of nitrogen in agriculture has a large ecological impact. For example, the emission of nitrogen can harm biodiversity and negatively affect human health, whereas the runoff of nitrogen into waterways can pollute drinking water (Guthrie et al., 2018; Zhang et al., 2018). All of the farms that were analysed in this study are biological farms and therefore do not use artificial fertilizers. This is, at least partly, possible due to the reintroduction of trees as the previous section already showed that agroforestry increased the SOM concentration in the soil and accordingly less artificial fertilizer is needed. To calculate how much costs were avoided by the agroforestry farmers due to nitrogen emission reductions (in the form of ammonia), data is needed on the actual reduction in ammonia emission by the farmers. As no farm specific data was available, the data on ammonia emission reduction of a group of biological farmers ("Landschapsboeren") in the province Noord-Brabant were used. Based on the data of the Landschapsboeren, nitrogen emission was reduced from 63 kg per hectare to a maximum of 45 kg per hectare (Landschapsboeren, n.d.).

In order to estimate the avoided costs by agroforestry as a result of a reduction in nitrogen emission and use, an indication of the economic impact of nitrogen emission is needed. In a recent study, Guthrie et al. (2018) estimated that the socio-economic impact of the emission of 1 kilogram of ammonia (NH_3) in the UK at €3. This value was based on an extensive literature review of both UK specific and EU wide studies, which analysed the impact of ammonia emission on both biodiversity and human health. Thus, each kilogram of ammonia emission that is reduced by agroforestry practices can be valued at €3, assuming that the impact is the same for the Netherlands as for the UK. Based on these numbers, there has been an 18 kg decrease in nitrogen emission per hectare by the farms and thus the average avoided costs are estimated at €54 per year per hectare.

Next to having an impact on biodiversity and human health, nitrogen can also pollute drinking water. Especially the surplus of nitrogen in the soil can potentially runoff into waterways and thereby pollute drinking water (Blokland, 2017). According to the data of the landschapboeren, ecological farming can reduce the nitrogen surplus of the soil from 121 kg N per hectare (for conventional farms in Noord-Brabant) to a maximum of 75 kg N per hectare (Landschapsboeren, n.d.). Thus, the nitrogen surplus was reduced by 46 kg N per hectare by ecological farming. According to a report of Ruijgrok and De Groot (2006), the costs of filtering nitrogen from drinking water by water treatments plants in the Netherlands is €2,20 per kg N. Thus, multiplying the reduction in potential nitrogen runoff (46 kg N/ha) by the filtering costs (€2,20) shows that €101,20 can be avoided per hectare. The potential revenues generated from avoided costs are summarized for each farm in table 6.

Table 6: Estimated annual value of the avoided costs of ammonia emission and nitrogen runoff per farm.

Farm	Avoided costs ammonia emission (€/ha/year)	Avoided costs nitrogen runoff (€/ha/year)	Area (ha)	Estimated economic value (€/year)
1	54	101.20	4	€620.80
2	54	101.20	2.5	€388.00
3	54	101.20	1	€101.20
4	54	101.20	0.5	€50.60
5	54	101.20	10	€1,012.00
6	54	101.20	0.5	€55.60

4. Results

4.1 Nut trees

4.1.1 Farm 1

The first farm is a conventional goat farm. The farm has a total area of 17.5 ha, and the largest share of this land is used to grow maize as fodder for the goats. In 2018, the farmer decided to implement agroforestry on 4 ha its farm, by planting walnut trees combined with a flower mixture. In total 360 walnut trees (90 trees/ha) were planted. The farmer received two subsidies to cover a part of the costs of the trees. Each tree was supported by two stakes each and fences were placed to prevent the trees from getting damaged by deer. As a result of the implementation of agroforestry, less land was available for the cultivation of maize and consequently additional fodder for the goats had to be imported. In table 7 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 7: Overview of the variable costs and revenues of farm 1, including their time intervals.

	Amount	Time interval
Revenues		
Subsidies	€ 6.200	Year 1
Walnuts	€ -	Year 1 - 7
(Yield will increase from 0 to 5 kg)	€ 1.224	Year 8 - 10
(Yield will increase from 5 to 10 kg)	€ 3.960	Year 11 - 20
(Yield will increase from 10 to 18 kg)	€ 7.776	Year 21 - 30
Timber	€ 144.000	Year 30

	Amount	Time interval
Variable costs		
1. Establishment		
a. Site preparation	€ -	Year 1
b. Planting		
Trees	€ 5.700	Year 1
Flower strips	€ 250	Year 1 - 5
Labour	€ -	
Equipment	€ -	
c. Physical protection		
Staking	€ 720	Year 1
Fence	€ 1.080	Year 1
e. Watering	€ -	
f. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
c. Pruning	€ -	
d. Watering	€ -	
e. Labour	€ -	
3. Harvesting		
a. Harvesting machine	€ 3.000	Year 8
4. Additional costs		
a. Fodder	€ 4.000	Year 1 - 30

Financial analysis

Based on these costs and revenues, a cash flow plan was made for farm 1 (Appendix C). With a discount rate of 4 percent, the NPV of the project is €44,629. The IRR of the project is 7,9%, thus considerably higher than the assumed discount rate of 4%. Due to the high costs of the additional feed that has to be imported for the goats (€4,000 per year), the project only reaches a positive net income after 12 years. The DPBT of the project is 30 years, as it is only in the last year of the project period (year of timber harvesting) that the farmer reaches a return on investment due to revenues from timber sales.

Sensitivity analysis

The calculation of the NPV is based on several assumptions, of which the most important ones are the yield of the walnuts, the selling price of the walnuts and the selling price of the timber. To quantify the effect of deviations in one of these variables, a sensitivity analysis was performed. For each of the variables the effect of an increase or decrease from the baseline value on the NPV and the IRR was calculated.

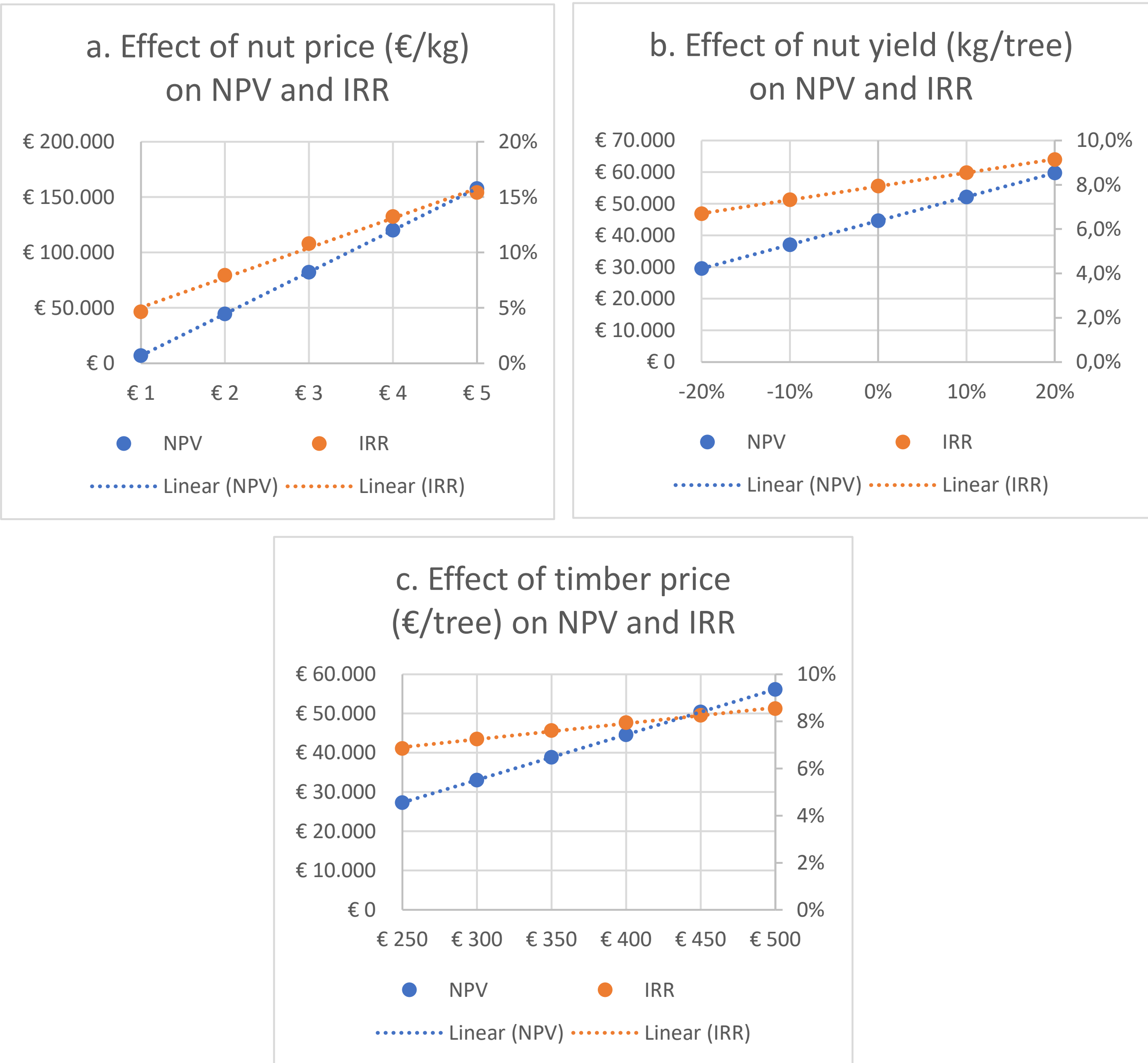


Figure 1: Sensitivity analyses of the effect of the nut price, nut yield and timber price on the NPV and IRR (farm 1). (a) Baseline: 2 €/kg. (b) Baseline: 0% increase in nut yield. (c) Baseline: €400/tree.

First of all, figure 1 shows that under all circumstances the NPV of the agroforestry project remains positive. The nut price has the biggest impact on the NPV and when the price of €2/kg, which was assumed by the interviewed farmers, decreases to €1/kg, the NPV decreases by approximately 85% from €44,629 to €6,964 (IRR: 5%). The other extreme is a nut price of €5/kg which has been used in previous studies (van Reuler et al., 2020), which results in a NPV of €157,925 with an IRR of 15%. The main reason that the impact of a reduction in the walnut price is so high is that the farmer has high yearly costs (€4,000) for additional fodder that he has to imported due to land clearance of maize for the introduction of walnut trees. Therefore, the revenues generated from walnut sales are necessary to compensate for the high yearly costs. If the selling price of walnuts is set at €1/kg this results in a negative cash flow until year 25, whereas at a selling price of €2/kg a positive cash flow is already reached after 12 years. The effect of the timber price on the NPV is less substantial as a decrease in the assumed timber price of €400 to €250 'only' reduces the NPV to €27,317 with an IRR of 7%. Deviations in the assumed nut yield can lead to an NPV of €29,523 in the worst scenario (20% decrease in nut yield) or €59,735 in the best scenario (20% increase in nut yield), decreasing or increasing the IRR approximately by 1%.

Worst-case scenario

For the worst-case scenario, the lowest value of each assumption was used in order to calculate the worst-case profitability of the farm. For the walnut farms, the variables for the worst-case scenario were set at €1 per kg walnut, €250 timber revenue per tree and a decrease of 20% nut yield compared with the baseline (Appendix B). Under these worst-case circumstances the NPV was -€18,004 with an IRR of 2%.

Socio-economic analysis

Lastly, the financial indicators for the farm were determined assuming that ecosystem services would be financially rewarded. The values of the different ecosystem services were included based on the calculations in section 3.3.2. Table 8 shows an overview of different scenarios and the values of the financial indicators. For the baseline scenario, the same values were used for the timber price (€400/tree), nut price (€2/kg) and the walnut yield (appendix B) as for the financial analysis.

Table 8: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow (farm 1). Baseline: 2 €/kg walnuts, 0% increase in nut yield, €400 timber revenue/tree.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€44,629	7%	30 years	12 years
Baseline, excl. subsidy	€38,429	7%	30 years	12 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€38,894	7%	30 years	12 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	€50,058	8%	29 years	10 years
Baseline excl. subsidy + carbon sequestration (carbon prices based on ETS)	€43,732	7%	30 years	11 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€54,895	9%	28 years	10 years

First of all, table 8 shows that a subsidy is not necessary for the agroforestry project to be profitable. Excluding the subsidy decreases the NPV by €6,200 (the amount of the subsidy) and results in a decrease of the IRR from 7,9% to 7,1%, which is still considerably higher than the assumed discount rate of 4%. Furthermore, the results indicate that the value of carbon sequestration does not have a substantial impact on the NPV when using the prices of the VCM. In contrast, including the value of the reduction of ammonia emission and nitrogen runoff as well does have a large impact on the NPV (€50,058), increasing it by 30% compared to the baseline excluding the subsidy (€38,894). Accordingly, the IRR increased when the nitrogen related ecosystem services were included (from 7% to 8%) and a positive cash flow was reached two years earlier compared to the baseline situation. Lastly, an increase of almost €5000 in the NPV was observed when using the carbon prices of the ETS instead of the VCM.

4.1.2 Farm 2

The second farm was a biological beef farm and has a total land area of roughly 2.5 ha. In 2019 the farmer started the implementation of agroforestry by planting rows of walnut trees on all the available grazing land, in total 120 trees were planted (48 trees/ha). The farmer received a subsidy once to cover a part of the purchasing costs of the walnut trees. Site preparation was performed in the first year in the form of digging holes and applying loam and compost. Around the trees, the farmer sowed Clover and Alfalfa seed, to feed the cows. Additionally, fences were placed to prevent the trees from getting damaged by the grazing of cows. Because of the fences, the farmer has to mow the clover and alfalfa for the cows for half an hour daily. Furthermore, stakes were attached on the young trees to support them. As this farm is located on a sandy soil, the pH is slightly lower and suboptimal for the walnut trees. Therefore, the farmer will need to apply chalk to the land on a yearly basis for the first seven years and then once every five years. In table 9 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 9: Overview of the variable costs and revenues of farm 2, including their time intervals.

	Amount	**Time interval**
Revenues		
Subsidies	€ 4.000	Year 1
Walnuts	€ 0	Year 1 - 7
(Yield will increase from 0 to 5 kg)	€ 408	Year 8 - 10
(Yield will increase from 5 to 10 kg)	€ 1.320	Year 11 - 20
(Yield will increase from 10 to 18 kg)	€ 2.592	Year 21 - 30
Timber	€ 48.000	Year 30

	Amount	**Time interval**
Variable costs		
1. Establishment		
a. Site preperation		
Mechanical	€ 5.000	Year 1
Chemical		
b. Planting		
Trees	€ 5.400	Year 1
Clover and Alfalfa seeds	€ 150	Year 1
Labour	€ -	
Equipment	€ -	
c. Physical protection		
Staking	€ 500	Year 1
Fences	€ 1.500	Year 1
e. Watering	€ -	
f. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
c. Liming		
Chalk	€ 350	Year 1 - 7
Chalk	€ 350	Every 5 years
d. Pruning	€ -	
e. Watering	€ -	
f. Labour	€ -	
3. Harvesting		
Harvesting machine	€ 3.000	Year 8

Financial analysis

Based on these revenues and costs, a cash flow plan was made for farm 2 (Appendix C). With a discount rate of 4 percent, the NPV of the project is € 31,860. The IRR of the project is 13%, thus considerably higher than the assumed discount rate of 4%. The project has a positive net income after 8 years. The DPBT of the project is 17 years, substantially sooner than farm 1. Due to the sand soil type (lower pH), liming is necessary for the first 7 years and then once every 5 years. If the farm was located at a more favourable soil (clay), and liming was not necessary, the NPV could have been 9% higher at € 34.738.

Sensitivity analysis

For the second farm sensitivity analyses were performed for the same variables as for the first walnut farm: nut price, nut yield and timber price. An overview of the results can be found in Figure 2.

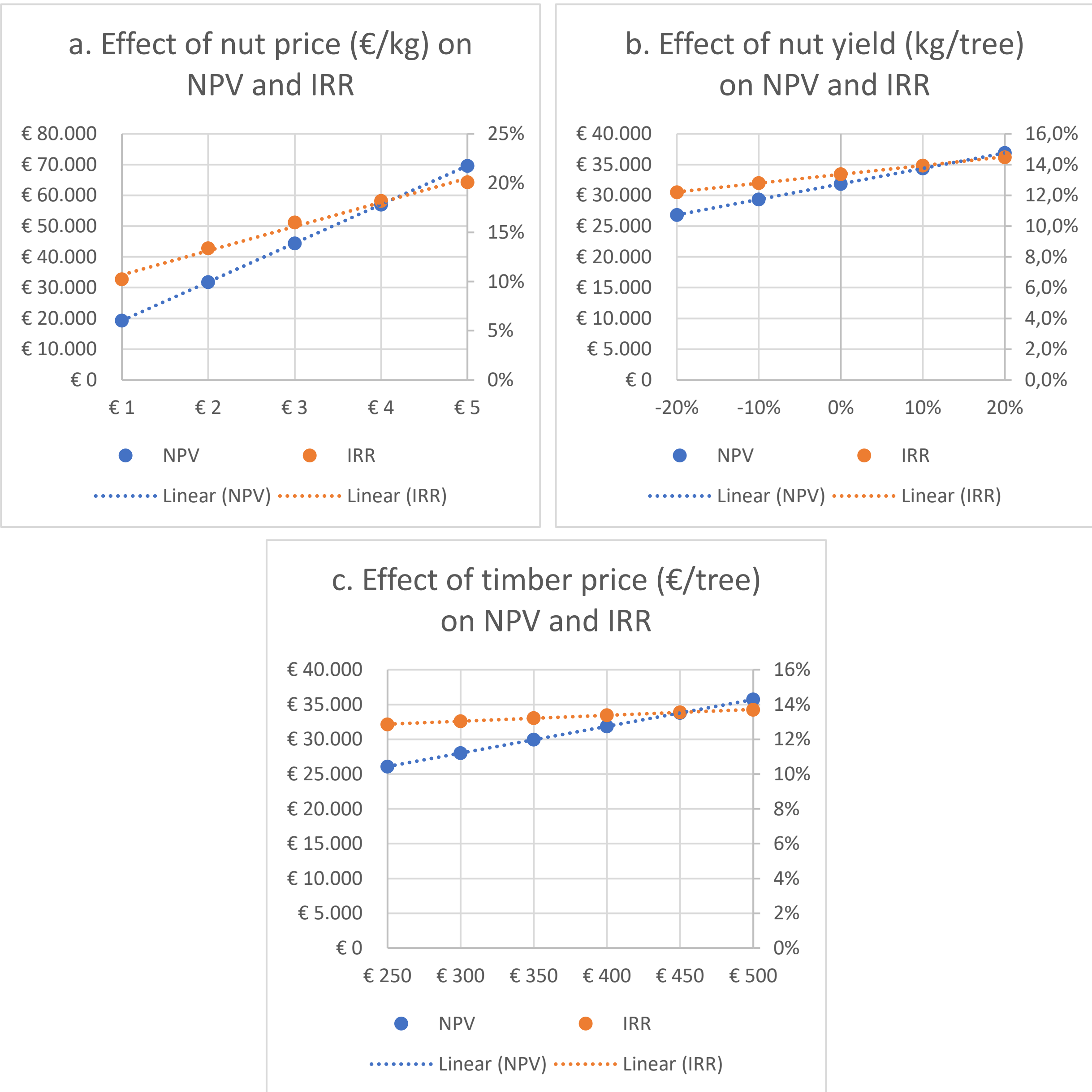


Figure 2: Sensitivity analyses of the effect of the nut price, nut yield and timber price on the NPV and IRR (farm 2). (a) Baseline: 2 €/kg. (b) Baseline: 0% increase in nut yield. (c) Baseline: €400/tree.

Figure 2 shows that, similar to farm 1, the nut price has the largest impact on the NPV. By reducing the nut price from €2/kg to €1/kg, the NPV drops by approximately 40% from €31,860 to €19,271. This decrease, however, is considerably smaller than the 85% decrease observed for the first farm. The main reason is that the second farmer does not have high yearly costs that need to be compensated and therefore the NPV is less dependent on the walnut sales. Accordingly, even at a nut price of €1/kg a positive cash flow is already reached after 9 years. Due to the same reason, the effect of the nut yield and the timber price are also less substantial for farm 2 compared to farm 1. A 20% decrease in nut yield leads to a roughly 15% reduction in the NPV from €31,860 to €26,824. A similar decrease can be observed when reducing the timber price from €400/tree to €250/tree.

The robustness of the business model of the second farm is further supported by the IRR, which remains high (above 10%) under all circumstances. In other words: even if future returns are highly discounted the project remains profitable. This is also explained by the fact that the second farmer has a really limited amount of costs associated with the walnut trees. For instance, no land had to be cleared for the walnut trees, the maintenance of the trees is taken care of by the farmer himself and chalking of the land only had to be done in the first 5 years after the introduction of the trees. Furthermore, the farmer sowed alfalfa and clover around the trees and therefore no additional fodder costs had to be made (Note: it might be that there will be additional costs in the future as no clover/alfalfa will be grown once the walnut trees yield walnuts, these costs were not taken into consideration). Hence, the only remaining investment is the purchase of the harvesting machine (€3,000) and therefore the project remains profitable, even under poor yield or selling price conditions.

Worst-case scenario

The lowest value of each assumption was used in order to calculate the worst-case profitability of the farm. The variables were set at €1 per kg walnut, €250 timber revenue per tree and a decrease of 20% nut yield compared with the baseline (Appendix B). Under these worst-case circumstances the NPV was still positive at €10,982 with an IRR of 8% and a DPBT of 28 years.

Socio-economic analysis

Lastly, the financial indicators for the farm were determined assuming that ecosystem services would be financially rewarded (Table 10). The values of the different ecosystem services were included based on the calculations in section 3.3.2. Again, the baseline calculation was based on the same values that were used for the timber price (€400/tree), nut price (€2/kg) and the walnut yield (appendix B) as in the financial analysis.

Table 10: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow (farm 2). Baseline: 2 €/kg walnuts, 0% increase in nut yield, €400 timber revenue/tree.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€31,860	13%	17 years	9 years
Baseline, excl. subsidy	€27,860	10%	21 years	9 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€28,171	11%	21 years	9 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	€35,149	13%	20 years	9 years
Baseline excl. subsidy + carbon sequestration (carbon prices based on ETS)	€31,421	13%	17 years	9 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€38,398	16%	14 years	2 years

First of all, table 10 shows that excluding the subsidy of €4,000 does not have a large impact on the profitability of the project. Excluding the subsidy decreases the NPV €4,000 and results in a decrease of the IRR from 13% to 10% and increases the DPBT from 17 to 21 years. Furthermore, the results indicate that compensating the carbon sequestration using the ETS prices results in a similar NPV (€31,421) compared to the baseline situation (€31,860), and thus shows that valuing carbon sequestration by the EU emissions trading system would be a viable alternative to the subsidy. Lastly, the results indicate that the NPV would increase approximately €7,000 when the value of the avoided nitrogen related costs are included.

4.1.3 Farm 3

The third farm is a biological dairy farm and has a total land area of 59 ha. In 2019, the farmer planted 45 walnut trees on 1 ha (45 trees/ha). The trees were strategically planted besides their milk tap to emphasize their nature inclusive approach to their customers. In the first year, the farmer received a subsidy to cover a part of the purchasing costs of the walnut trees. Stakes were used to support the young trees and fences were placed to protect the trees from the cows. In table 11 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 11: Overview of the variable costs and revenues of farm 3, including their time intervals.

	Amount	Time interval
Revenues		
Subsidies	€ 2.000	Year 1
Walnuts	€ 0	Year 1 - 7
(Yield will increase from 0 to 5 kg)	€ 153	Year 8 - 10
(Yield will increase from 5 to 10 kg)	€ 495	Year 11 - 20
(Yield will increase from 10 to 18 kg)	€ 972	Year 21 - 30
Timber	€ 18.000	Year 30

	Amount	Time interval
Variable costs		
1. Establishment		
a. Site preperation		
b. Planting		
Trees	€ 2.025	Year 1
Labour	€ -	
Equipment	€ -	
c. Physical protection	€ 405	Year 1
d. Watering	€ -	
e. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
c. Liming	€ -	
d. Pruning	€ -	
e. Labour	€ -	
f. Watering	€ -	
g. Labour	€ -	
3. Harvesting		
Harvesting machine	€ 3.000	Year 8

Financial analysis

Based on these revenues and costs, a cash flow plan was made for farm 3 (Appendix C). With a discount rate of 4%, the NPV of the project is € 12,503. The IRR of the project is 17%, thus considerably higher than the discount rate of 4%. The project has a positive net income after 9 years. The DPBT of the project is 16 years, also substantially sooner than farm 1, but comparable to farm 2 (17 years).

Sensitivity analysis

For the third walnut farm the sensitivity analyses were performed for the same variables as for the first two farms. An overview of the results can be found in Figure 3.

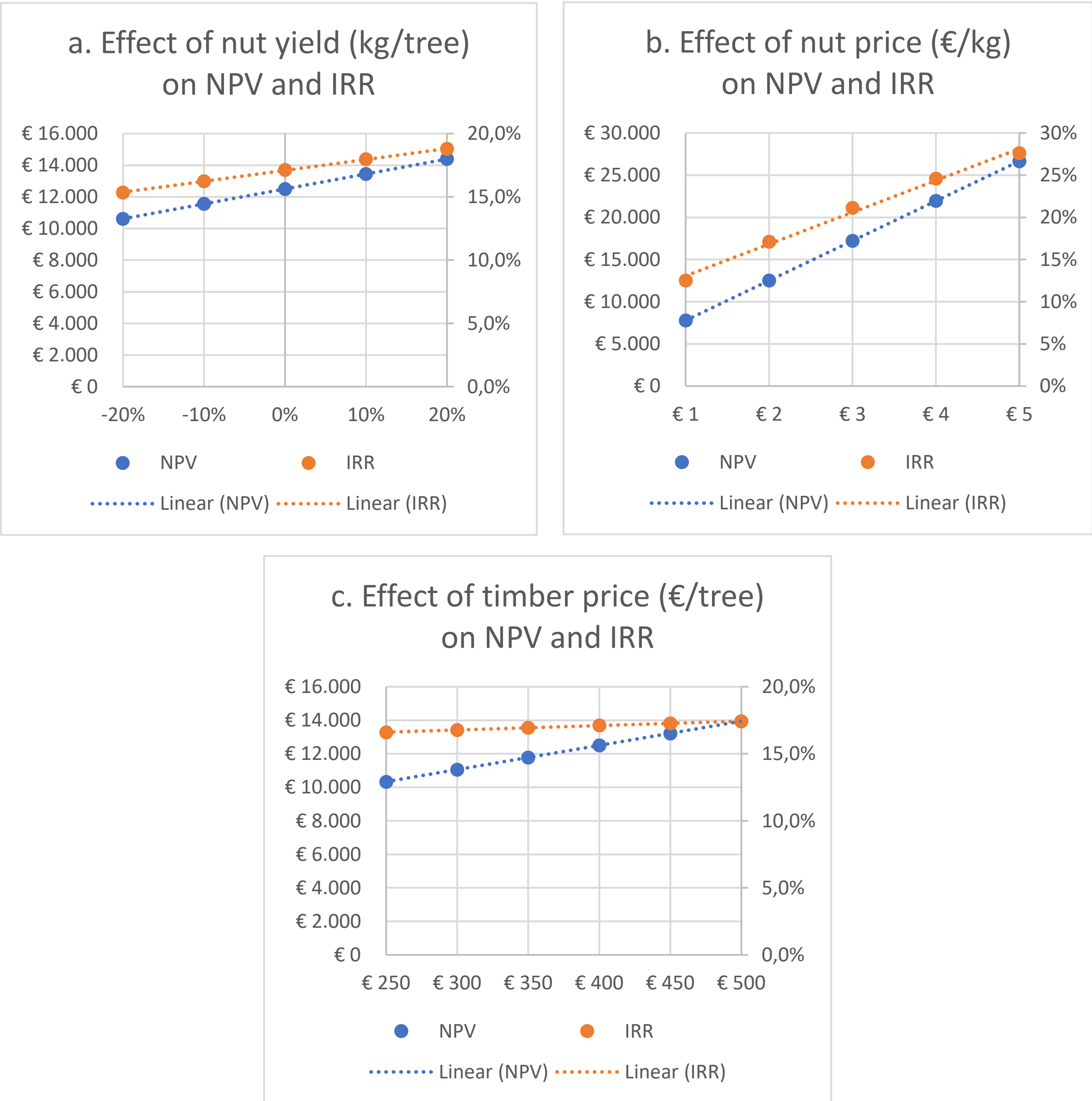


Figure 3: Sensitivity analyses of the effect of the nut price, nut yield and timber price on the NPV and IRR (farm 3). (a) Baseline: 2 €/kg. (b) Baseline: 0% increase in nut yield. (c) Baseline: €400/tree.

The patterns of the third farm are in line with the observations for the first two farms. Again, the nut price has the largest impact on the NPV, decreasing the baseline NPV of €12,503 to €7,783 at a nut price of €1/kg and increasing it to €26,665 at the maximum nut price of €5/kg. Of the three farms, the third farm has by far the lowest potential NPV as the maximum of €26,665 is still lower than the baseline values of the previous farms. This is mainly the result of the limited number of trees the farmer has planted (45), which also lowers the potential revenues. Nevertheless, the third farm does have the highest IRR, which is even at a nut price of €1/kg still 12,5%. The robust IRR is the result of the limited investment costs of the farmer, as the trees were subsidized, no land preparation was needed and the maintenance was done by the farmer himself. Thus, besides the costs for the stakes and fences (€400) and the harvesting machine (€3000), no investments were made and consequently, the project is almost always going to be profitable. This is also reflected by the limited impact of the timber price (NPV ranging between €10,399 and €13,946) and the walnut yield (NPV ranging between €10,615 and €14,392).

Worst-case scenario

For the worst-case scenario, the variables were set at €1 per kg walnut, €250 timber revenue per tree and a decrease of 20% nut yield compared with the baseline (Appendix B). Under these worst-case circumstances the NPV was still positive at €4,674 with an IRR of 10% and a DPBT of 25 years.

Socio-economic analysis

Lastly, the financial indicators for the farm were determined assuming that ecosystem services would be financially rewarded (Table 12). The values of the different ecosystem services were included based on the calculations in section 3.3.2. Again, the baseline calculation was based on the same values that were used for the timber price (€400/tree), nut price (€2/kg) and the walnut yield (appendix B) as in the financial analysis.

Table 12: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow (farm 3). Baseline: 2 €/kg walnuts, 0% increase in nut yield, €400 timber revenue/tree.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€12,503	17%	16 years	9 years
Baseline, excl. subsidy	€10,509	11%	21 years	9 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€10,540	11%	21 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	€12,303	13%	21 years	2 years
Baseline excl. subsidy + carbon sequestration (carbon prices based on ETS)	€10,923	11%	20 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€13,714	14%	16 years	2 years

For the third farm the subsidy is relatively more relevant, as excluding the subsidy reduces the NPV to €10,509, but more importantly it reduces the IRR to 11%, which is even lower than when the walnut price was set to €1/kg in the sensitivity analysis. Adding the value of carbon sequestration has little to no impact as the number of planted walnut trees is low (45) and thereby the tree carbon storage potential is limited (€1.26/year based on VCM prices, €14.40/year based on ETS prices). Additionally, only a limited increase in the SOM content was measured on the farm, which also made the value of additionally stored SOC limited. The fact that the cash flow is already positive after two years is a bit misleading, as the cash flow is very limited as a result of the low carbon storage potential. A NPV comparable to the baseline is only realised in the scenarios where the value of the avoided nitrogen related costs are included, similar to the first and second farm. Nevertheless, the IRR remains lower (13-14%) as the revenues of the avoided costs are discounted over the years, whereas the subsidy is received in the first year of the project and is therefore not discounted.

4.2 Fruit trees

4.2.1 Farm 4

The fourth farm that was studied was a biological pig farm. In 2016, the farmer decided to implement agroforestry at his farm. On about half a hectare, 30 fruit trees (15 standard apple trees; 15 standard pear trees) were planted to provide shade and fruit for his pigs. It was necessary to protect the trees against the rooting of the pigs with stakes and fences. To plant the trees and place the stakes and fences, two men were hired for 8 hours each. For the first years, no costs are expected for pruning. Only after 7 years, when the first yield can be harvested, costs for pruning are expected. Approximately, 8 hours of hired labour will be needed each year. For the time being the fruit serves as feed for the pigs. However, the farmer stated that no fodder costs were or will be saved because of the fruit. Its business model was based on the promotion of their meat sales (expecting that this form of nature inclusive agriculture will increase the meat value). In table 13 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 13: Overview of the variable costs and revenues of farm 4, including their time intervals.

	Amount	Time interval
Revenues		
Subsidies	€ 1.500	Year 0
Appels	€ -	
Pears	€ -	
Timber	€ -	

	Amount	Time interval
Variable costs		
1. Establishment		
a. Site preperation	€ -	
b. Planting		
Trees	€ 1.200	Year 0
Labour	€ 320	Year 0
Equipment	€ -	
c. Stakes and fences	€ 450	Year 0
e. Watering	€ -	
f. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
d. Pruning		
Labour	€ 160	Year 8 - 30
e. Watering	€ -	
f. Labour	€ -	
3. Harvesting	€ -	

Financial analysis

Based on these revenues and costs, a cash flow plan was made for farm 4 (Appendix C). Due to the fact that the farmer did not sell the products from the trees he did not receive any revenues from the trees. Only a subsidy was provided once. Without selling the fruit from the trees, the NPV of the project was -€2,347.

Assuming that the fruit will be sold, the NPV would be positive at €10,281, with an IRR of 27%. However, for this calculation no labour costs were included for harvesting the fruit. Due to the fact that the farmer used standard fruit trees, which can grow quite high, it is not very assumable that the farmer will harvest all the fruit himself. If not, costs for hired labour will increase and the NPV will decrease.

Sensitivity analysis

As said, the farmer does not intend to sell the fruits and therefore it was hard to perform a sensitivity analysis as there were no variables to analyse. Therefore, a sensitivity analysis was performed on the hypothetical scenario in which the farmer does sell the fruit. The two variables that were analysed are the fruit yield and the fruit price. As the selling price for fruits and apples differ, the average selling price was used to simplify the sensitivity analysis.

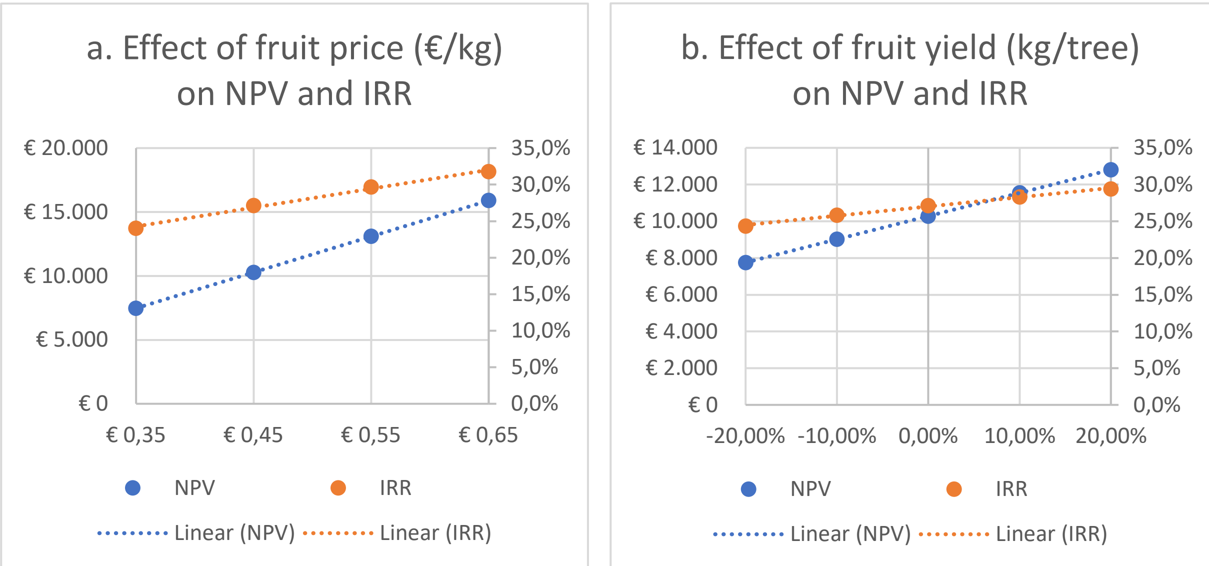


Figure 4: Sensitivity analysis of the effect of the fruit price and fruit yield on the NPV and IRR (Farm 4). (a) Baseline: 0,45 €/kg. (b) Baseline: 0% increase in fruit yield.

The sensitivity analyses first of all show that the NPV remains positive under all circumstances, ranging between €4,668 and €15,894 for the defences in fruit price, and between €7,755 and €12,804 for the differences in fruit yield. Also the IRR remains very high under the least favourable circumstances at 20% and 24% percent for the fruit price and fruit yield, respectively. The high IRRs are the result of the fact that costs of, for example, picking were not included in the analyses which leads to overestimation of the NPVs and IRRs.

Socio-economic analysis

Initially, a socio-economic analysis was performed on the situation in which the farmer does not sell his fruits (Table 14).

Table 14: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow, assuming that the fruit will not be sold (farm 4). Baseline: 0,45 €/kg fruit, 0% increase in fruit yield.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	-€2,349	NA	NA	NA
Baseline, excl. subsidy	-€3,849	NA	NA	NA
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	-€3,829	NA	NA	NA
Baseline excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	-€2,425	NA	NA	NA
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS)	-€2,129	NA	NA	NA
Baseline + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	-€629	NA	NA	NA

Table 14 shows that including the value of the ecosystem services was not sufficient to make the project profitable. Therefore, a second socio-economic analysis was performed on the scenario in which the farmer does sell his fruits (Table 15).

Table 15: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow, assuming that the fruit will be sold (farm 4). Baseline: 0,45 €/kg fruit, 0% increase in fruit yield.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€10,281	27%	10	2
Baseline, excl. subsidy	€8,781	15%	14	2
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€8,809	15%	14	2
Baseline excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	€9,809	17%	13	2
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS)	€9,108	15%	13	2
Baseline + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€10,094	17%	12	2

Table 15 shows that the subsidy is not necessary for the project to be profitable. However, excluding the subsidy of €1,500 drastically reduces the IRR from 27% to 15% and increases the DPBT from 10 to 14 years. The results furthermore show that the added financial value of the ecosystem services was highly limited. This can be explained by the fact that for farm 4 no increase in the SOM concentration was measured and the carbon storage capacity was limited as the farmer only planted 30 trees. These trees were only planted on a small area, which also makes the avoided costs of nitrogen runoff and the reduction in ammonia emission limited as these ecosystem services were measured on a per hectare basis. Only in the most optimistic scenario, in which the carbon prices are based on the ETS prices, and the avoided costs of the nitrogen reduction are valued, the NPV is comparable to the baseline situation. Thus, it can be concluded that for farm 4 the valuing of ecosystem services does not have a large positive impact on the financial performance of the farm.

4.3 Combination of nut and fruit trees

4.3.1 Farm 5

The fifth farm that was studied is a biological dairy and beef farm. In 2016, the farmer planted 400 trees on an area of 10 ha. Half of the trees (200) were walnut trees, and the other half were fruit trees (100 half-standard apple trees and 100 half-standard pear trees). This was the only farm that was not interviewed, so assumptions of costs and revenues of this farm were based on farm 1, 2, 3 and 4. In table 16 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 16: Overview of the variable costs and revenues of farm 5, including their time intervals.

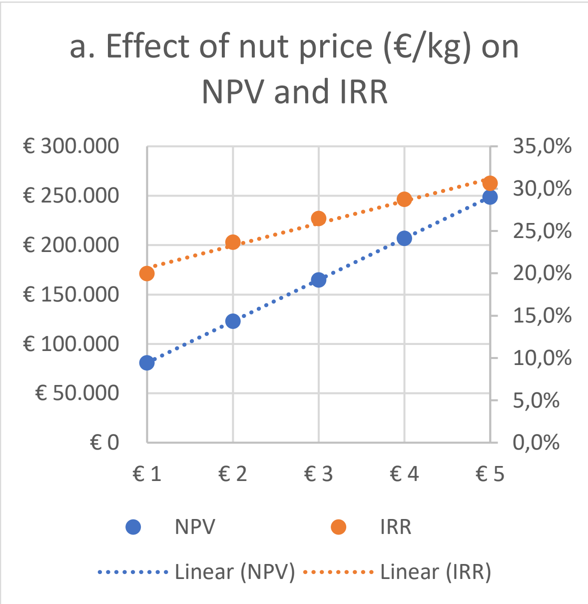
	Amount	Time interval
Revenues		
Subsidies	€ 8.000	Year 1
Appels	€ 0	Year 1
	€ 212	Year 2
	€ 384	Year 3
	€ 544	Year 4
	€ 572	Year 5 - 30
Pears	€ 0	Year 1 - 2
	€ 825	Year 3 - 30
Walnuts	€ 0	Year 0 - 7
(Yield will increase from 0 to 5 kg)	€ 1.360	Year 8 - 10
(Yield will increase from 5 to 10 kg)	€ 4.400	Year 11 - 20
(Yield will increase from 10 to 18 kg)	€ 8.640	Year 21 - 30
Walnut Timber	€ 80.000	Year 30

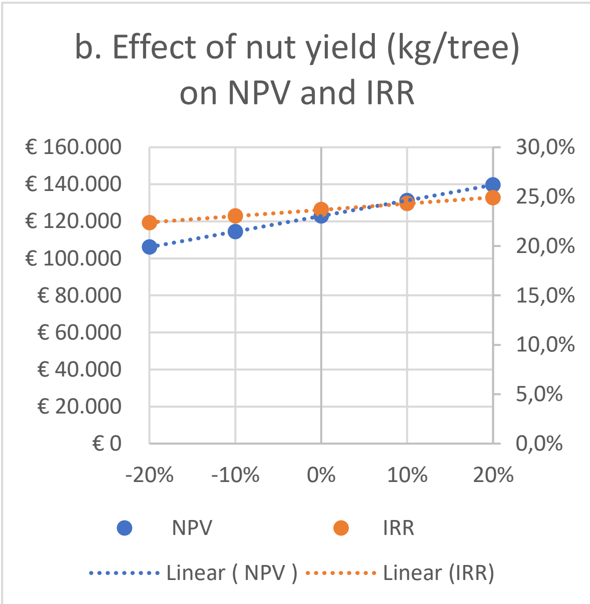
	Amount	Time interval
Variable costs		
1. Establishment		
a. Site preperation	€ -	
b. Planting		
Trees	€ 12.000	Year 1
Labour	€ -	Year 1
Equipment	€ -	
c. Staking	€ 4.000	Year 1
e. Watering	€ -	
f. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
c. Liming	€ -	
d. Pruning	€ -	
e. Watering	€ -	
f. Labour	€ -	
3. Harvesting		
Harvesting machine	€ 3.000	Year 8

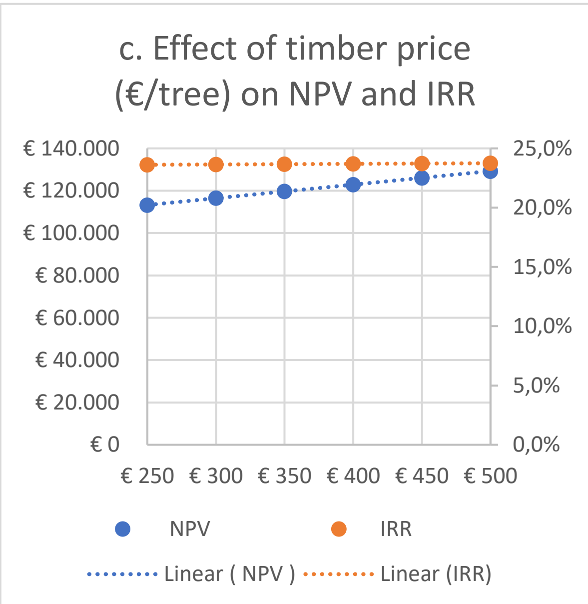
Financial analysis

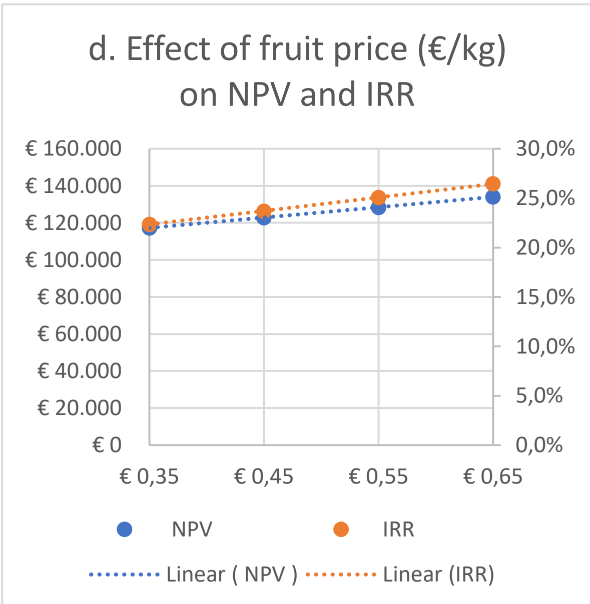
Based on these revenues and costs, a cash flow plan was made for farm 5 (Appendix B). With a discount rate of 4 percent, the NPV of the project is €122.872. The NPV is thus considerably higher than for the previously studied farms. Additionally, the IRR (24%), DPBT (10 years) and the positive cash flow (2 years) are also excellent and more in line with the fruit farm. Thus, farm 5 seems to combine the benefits of the business model of fruit trees and of walnut trees. As the fruit trees already reach their full yield potential and can thus be sold earlier than the walnut trees, the DPBT is low, and a positive cash flow is reached early in the project. Furthermore, the high timber value of the planted walnut trees and the walnut sales increase the potential financial benefits of the project reflected in the high NPV.

Sensitivity analysis









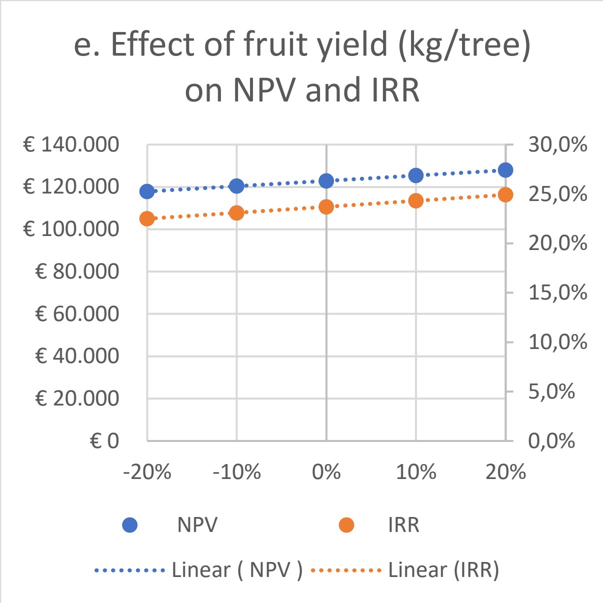


Figure 5: Sensitivity analysis of the effect of the fruit price and fruit yield on the NPV and IRR (Farm 5). (a) Baseline: €2/kg. (b) Baseline: 0% increase in nut yield. (c) Baseline: €400/tree. (d) Baseline: 0,45 €/kg. (e) Baseline: 0% increase in fruit yield

The results of the sensitivity analysis show that the business model of farm 5 is very robust as for all sensitivity analyses the project remains profitable. The lowest NPV is reached at a nut price of €1/kg, but even then, the NPV remains high at € 80.911 with an IRR of 20%. The robustness of the business model is further confirmed by the stable IRR which only remains relatively constant around 25%. This is most likely the result of the fact that several revenue streams are combined, and that fluctuations in one of the revenue streams can be compensated by others.

Worst-case scenario

For the worst-case scenario, the variables were set at €1 per kg walnut, €250 timber revenue per tree, €0,35 per kg fruit and a decrease of 20% in fruit and nut yield compared with the baseline (Appendix B). Under these worst-case circumstances the NPV was still positive at €53,425 with an IRR of 16% and a DPBT of 12 years.

Socio-economic analysis

The financial indicators for the farm were determined assuming that ecosystem services would be financially rewarded (Table 17). The values of the different ecosystem services were included based on the calculations in section 3.3.2. The baseline calculation was based on the same values that were used for the timber price (€400/tree), nut price (€2/kg) and the walnut yield (appendix B) as in the financial analysis.

Table 17: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow (farm 5). Baseline: 2 €/kg walnuts, 0% increase in nut yield, €400 timber revenue/tree, 0,45 €/kg and 0% increase in fruit yield.

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€122.872	26%	9 years	2 years
Baseline, excl. subsidy	€113,683	18%	11 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€114,168	18%	11 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM) + reduction ammonia/nitrogen	€141,639	25%	8 years	2 years
Baseline excl. subsidy + carbon sequestration (carbon prices based on ETS)	€120,367	21%	10 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€147,738	32%	6 years	2 years

4.4 Fodder trees

4.4.1 Farm 6

The last farm that was studied is a biological cow farm with ninety Jersey cows. In 2016, the farmer planted 500 fodder trees that can provide additional fodder for the cows, provide natural shade and naturally increase the nutrient intake of the cows. Eight different fodder tree species were planted (e.g., willow, alder, poplar, acer) on a strip of 500 by 3 meters. Fences were placed to prevent the cows from grazing the trees during the first five years. During these first five years, grass around the trees needed to be mowed to prevent the grass from overgrowing the trees. After five years, the fences were removed, and no more mowing was needed. The purchasing costs and maintenance costs for the first 5 years were covered by a subsidy that the farmer received. The farmer received all 500 trees for free as well as a total of €2,000 to cover the maintenance of the trees during the first 5 years. In table 18 an overview of the revenues and variable costs and their time interval can be found. The assumptions used for these revenues and costs can be found in Appendix B.

Table 18: Overview of the variable costs and revenues of farm 6, including their time intervals.

	Amount	Time interval
Revenues		
Subsidies	€ 2.000	Year 0

	Amount	Time interval
Variable costs		
1. Establishment		
a. Site preperation		
b. Planting		
Trees	€ 0	Year 0
Labour	€ 480	Year 0
Equipment	€ -	
c. Stakes and fences	€ 800	Year 0
e. Watering	€ -	
f. Fertilizer	€ -	
2. Maintenance		
a. Fertilization	€ -	
b. Pesti/fungi/herbicide	€ -	
c. Liming	€ -	
d. Pruning	€ -	
e. Labour	€ 160	Year 1 - 5
f. Watering	€ -	

Financial analysis

During the interview, the farmer indicated that there was no real business model developed for the introduction of the trees. The farmer planted the trees to improve the nutrient intake of the cows. Since all the costs were covered by the subsidy, no income was needed. Accordingly, the cash flow was already positive in the first year as the farmer received the subsidy for the maintenance of the trees and became slightly negative in the following years due to the maintenance costs (which were covered by the subsidy received in the first year) (Appendix C). The net cash flow became zero after 5 years as the farmer expected neither maintenance costs nor revenues. The lack of a real business model is also reflected by the NPV, which is only €139, with an internal rate of return of 4,55%.

Sensitivity analysis and worst-case scenario

As there are no yields or sales related to the fodder trees, it is not possible to perform a sensitivity analysis and worst-case scenario on these dimensions. Nevertheless, the effect of the subsidy on the profitability was studied. Removing the subsidy from the cash flow, assuming the farmer would pay for the trees (€10 per tree) and the maintenance himself, results in negative NPV of -€6,861. This shows the necessity of subsidies, as without these subsidies the introduction of fodder trees would only lead to costs, without many possibilities for returns.

Valuing ecosystem services

The business model of fodder trees would most likely be stronger if the ecosystem services that they provide would be valued. Following the calculations in the methodology section, the ecosystem services provided by the fodder trees were valued. Table 19 shows an overview of different scenarios and the values of the financial indicators.

Table 19: Overview of the effect of different combinations of subsidies, compensation for reduction of ammonia/nitrogen and compensation for carbon sequestration (based on both the voluntary carbon market (VCM) and the EU emission trading system (ETS)) on the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback time (DPBT) and years before a positive cash flow (farm 6).

Scenario	NPV	IRR	DPBT	Positive cash flow
Baseline	€139	5%	1 year	1 year
Baseline, excl. subsidy	-€1,861	NA	NA	6 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	-€1,292	NA	NA	6 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on VCM)	€127	5%	27 years	6 years
Baseline excl. subsidy + carbon sequestration (carbon prices based on ETS)	€4,639	28%	6 years	2 years
Baseline, excl. subsidy + carbon sequestration (carbon prices based on ETS) + reduction ammonia/nitrogen	€6,035	39%	5 years	2 years

The results show that the NPV becomes positive at €2,101 when the ecosystem services are valued using the prices on the voluntary carbon market. However, when the subsidies are excluded from the analysis the NPV becomes negative at -€4,899. Thus, when assuming that the stored carbon will be sold at the prices of the voluntary carbon market subsidies are still needed to make the introduction of fodder trees profitable. When assuming that carbon is sold at the ETS prices, the NPV becomes considerably higher at €8,009 and even remains positive when the subsidy was excluded from the analysis (€1,009).

5. Discussion

5.1 Discussion of results

Table 20 shows an overview of the financial indicators per farm, categorized based on the tree type. The table shows the baseline scenarios for which the initial financial analyses were performed as well as the scenario in which the ecosystem services (carbon sequestration based on VCM prices, reduction of ammonia emission and reduction of nitrogen runoff) are valued, but in which the received subsidies were excluded (indicated by baseline + ES).

Table 20: Overview of the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback Time (DPBT) and years before a positive cash flow based on a baseline scenario and a scenario in which the value of ecosystem services (ES) was included (carbon prices were based on the voluntary carbon market).

Tree type	Farm #	Scenario	NPV	IRR	DPBT	Positive cash flow
Nut	1	Baseline	€44,629	7,9%	30 years	12 years
		Baseline + ES (excl. subsidy)	€50,058	8,2%	29 years	10 years
	2	Baseline	€31,860	13%	17 years	9 years
		Baseline + ES (excl. subsidy)	€28,495	11%	20 years	9 years
	3	Baseline	€12,503	17%	16 years	9 years
		Baseline + ES (excl. subsidy)	€10,674	11%	21 years	2 years
Fruit	4*	Baseline	€10,281	27%	10 years	2 years
		Baseline + ES (excl. subsidy)	€9,809	17%	13 years	2 years
Nut + Fruit	5	Baseline	€121,683	26%	9 years	2 years
		Baseline + ES (excl. subsidy)	€141,639	25%	8 years	2 years
Fodder	6	Baseline	€139	5%	1 years	1 years
		Baseline + ES (excl. subsidy)	€127	5%	27 years	6 years

*For farm 4 it was assumed that the fruit was sold.

First of all, the overview in table 20 shows that the NPV of the nut farms is higher compared to the NPV of the fruit farm. This is in line with a previous study that also showed that agroforestry is more profitable when introducing 'high value trees' as walnuts compared to 'low value trees' as poplar or fruit trees (Palma, 2006). In contrast, the IRR of the fruit farm is higher than those of the nut farms. The high NPV of the nut farm can be explained based on the high value of walnut timber, for which return can only be expected in the last year of the project, increasing the DPBT. The high IRR of the fruit farm is the result of the lower investment cost, and therefore the project remains profitable, even if future returns are highly discounted.

Furthermore, the overview shows that the introduction of fodder farms is not financially attractive as the NPV is only marginally above zero. This is mainly the result of the fact that no real business model can be developed around the fodder trees as there are no products to be sold. Potentially the fodder trees can improve the health of animals, as they can provide natural sources of nutrients and medication. For instance, the bark and leaves of willows contain salicylic acid which is an active ingredient in paracetamol (Vlachojannis et al., 2011). Thereby, it can possibly reduce the health-related costs of the animals. Furthermore, the trees can provide shade for the livestock which also improves their wellbeing. The improved wellbeing of the animals and possible reductions in health costs were not considered in this research, but they are interesting to take into consideration in future research to get a better grasp of the potential socio-economic value of agroforestry systems based on fodder trees.

The farm that performs best from a financial perspective is the fifth farm, which combines fruit trees with walnuts. The baseline NPV of the fifth farm is high (€121,683), in line with the other nut farms, but it also has a high IRR, low DPBT and it reaches a positive cash flow after two years already, in line with the studied fruit farm. Thus, this farms seems to combine the benefits of the two different business models. A few aspect of the business model will be discussed to make the results more generalizable for agroforestry in temperate regions:

First of all, the introduction of walnut trees seems to be highly profitable and easily scalable. As there are almost no maintenance costs for walnut trees, the returns theoretically almost increase linearly with the number of trees. The first farm, however, demonstrated that the introduction of walnut trees can lead to high additional costs as maize land had to be cleared for walnut trees, which increased the fodder costs of the farmer. Therefore, it seems more profitable to combine walnut trees with pasture (farm two and three) as this trade-off between agricultural land and land for walnut trees is less of an issue according to the farmers. This is also reflected by the relatively higher NPVs and lower DPBT of farms two and three compared to the first farm. Yet, also for farms with pastures there is a maximum of walnut trees that can be introduced per hectare: the more walnut farms are introduced, the less land becomes available for the livestock and after a certain plantation size of the walnut trees less livestock can be held. Farms 2 and 3 both had a density of approximately 45 trees/ha, but the trade-off between livestock and trees was not yet reached.

Secondly, some aspects of the business model of the fruit trees will be discussed. This research has indicated that the introduction of fruit trees reduces the DPBT, which is mainly the result of the fact that fruit trees already reach their full yield potential after approximately 5 to 15 years (for half standard and standard trees respectively), whereas this is approximately 30 years for walnut trees (Ham, 2020; van Colen, 2019). Therefore, revenues in the first year of agroforestry can be substantially increased by the introduction of fruit trees and the DPBT can be shortened. However, the scaling of fruit trees comes at a cost. The growing of fruit trees and the harvesting of the fruits are severely more labour intensive compared to walnut trees. For instance, fruit trees have to be pruned every year and as the number of trees increase, the time needed for pruning does too. At a certain point it is not possible anymore for a farmer to perform the pruning himself and hired labour force is needed. The same goes for the picking of the fruit, which can be done at approximately 80kg/hour. This means that at 200 fruit trees the picking already takes up a full working week. Earlier studies on the profitability of apple and pear also showed that the profitability of large-scale fruit production in Belgium (3000 trees/ha) is only marginally profitable due to, among others, the high costs of labour and relatively low selling prices (Van der Straeten, 2016). Therefore, the number of trees should be determined based on the time a farmer is willing to invest into the maintenance, plucking and selling of fruits. If fruit trees are introduced, it is advisable to plant half or low standard instead of standard trees. The farmer of farm 4 indicated that the maintenance and plucking of fruits of standard trees most certainly needs to be performed by experts, as the size and height of the trees make it challenging for the farmer to perform these tasks himself. Thus, even the growing of a few standard trees will lead to considerable costs, limiting the profitability of the project. A potential advantage of standard trees is that they produce more timber, which can be sold at a higher price (Wood Database, n.d.). However, as the lifespan of these trees is roughly 60 - 100 years (Ham, 2020), this is not relevant for the current generation of farmers and is therefore not taken into consideration for this research.

The results of Table 20 furthermore show that the valuing of ecosystem services is a viable alternative for the subsidies that are currently given to farmers to initiate agroforestry projects. In all cases the NPV of the projects including the value of the ecosystem services (but without the subsidy) were close to or even higher compared to the baseline situation with the subsidy, even when using the more realistic carbon prices of the VCM. These results confirm the socio-economic potential that is often ascribed to agroforestry, even when only a limited amount of the potential ecosystem services of agroforestry are included in the analysis.

5.2 Theoretical and practical implications

As has become clear throughout this thesis, agroforestry is a promising example of an agricultural practice with lower environmental impacts. Despite the numerous ecological benefits of agroforestry compared to conventional agriculture, a limited number of farmers made the transition to agroforestry. The main reason being the financial insecurities as limited research has been performed on the financial aspect of agroforestry. By calculating the NPV, IRR and the DPBT of six Dutch agroforestry farms, this research provides empirical evidence on the profitability of agroforestry, at least in the Netherlands. As the research provided additional insight into the financial aspects of agroforestry, it also has strong practical implications for farmers considering a transition towards agroforestry. First of all, this research showed that a transition towards agroforestry can be profitable as the NPV was positive for all of the studied nut and fruit farms when the tree products were sold. Additionally, the sensitivity analyses showed that a decrease in the walnut price, walnut yield or timber price did substantially lower the NPV, but that the transition remained profitable under most circumstances. Thus, this research quantitatively shows that the transition towards agroforestry can be as profitable one and thereby reduces the financial uncertainty for Dutch farmers, which in turn can stimulate the uptake of agroforestry by farmers.

Furthermore, this research contributed to the research field of ecosystem service valuation. As has become clear in the theory section, valuing ecosystem services is highly complex. Two different methods were used to value the ecosystem services: the direct market valuation method and the avoided costs method. By analysing and calculating the increase in carbon storage as a result of the introduction of trees, a realistic value for the stored carbon could be determined based on the carbon price on the voluntary carbon market. Additionally, the avoided costs of the reduction in ammonia emission and nitrogen runoff were calculated. This research has shown that the effect of hypothetical returns for additional carbon storage on the NPV are substantial for most farms and can substitute the received subsidies of the farmers. Moreover, it has to be mentioned that in this study only two of the many ecosystem services that the reintroduction of trees provide, were included. Therefore, the potential socio-economic value of the trees might be even higher than found in this research.

5.3 Limitations and future research

Only recently farmers started the transition from conventional farming to agroforestry and therefore agroforestry is a relatively new practice. Consequently, little data is available on the costs and benefits of agroforestry and a lot of assumptions had to be made in this research. For instance, the farmers that participated in this research did not have their first nut harvest yet, so data on yield and sales were not available and had to be assumed by literature. To deal with these uncertainties in the data, sensitivity analyses were performed to improve the reliability and validity of the research. In the future, follow-up studies can be performed when more data on walnut yield and sales is available to verify whether the current projections are correct, and to make more accurate estimations of the NPV of the agroforestry projects.

In this research two ecosystem services were taken into consideration for the socio-economic analysis, namely carbon sequestration in the trees and in the soil (SOC). Whereas including these two ecosystem services in the socio-economic analysis already demonstrated the added socio-economic value of the reintroducing trees into the agricultural landscape, several other ecosystem services could not be included due to time and data constraints. Besides storing carbon and increasing soil organic matter concentrations, trees provide several other ecosystem services, such as reducing soil erosion, reducing particulate matter and community building that might be relevant to study. Interestingly, one of the farmers initiated the 'Landschapsboeren' which is a cooperative of Dutch dairy farmers with a focus on future-proof and nature inclusive agriculture. Both individuals and organizations can financially support farmers of this cooperative by 'buying' one or more ecosystem services that these farmers provide, for instance: improving water quality, increasing biodiversity, improving animal wellbeing and the sequestration of carbon (Landschapsboeren, n.d.). The initiator of the project indicated that currently a lot of research is performed (by the Louis Bolk institute) to quantify the ecosystem services that the farms provide, to be able to monetize them. Next to the fact that this project will result in a better quantification of the ecosystem services that agroforestry provides, it is also interesting to analyse the revenues that the project generates in future research. The financial contribution of both individuals and farmers can be interpreted as their 'willingness to pay' for the ecosystem services and can therefore give another perspective on the value of the ecosystem services provided by agroforestry. Also, potential negative effects of the introduction of trees could be researched. For instance, earlier studies indicated that the introduction of trees can increase light competition, reducing the yield of other crops in silvoarable systems or grass in silvopastoral systems (e.g., Dufour et al., 2013; Gao et al., 2013). In follow-up studies the light competition can be measured for the studied farms to estimate the potential yield reduction due to light competition.

Another limitation relates to the valuation of the reduction in ammonia emission and nitrogen runoff. In this study the reduction in ammonia emission and nitrogen runoff was assumed based on the area on which agroforestry was implemented. However, ideally the differences in nitrogen emission between conventional farming and agroforestry would be measured at the farms instead of relying on assumed values. Potentially, the reductions of ammonia emission of biological agroforestry farms could even be higher. A lot of ammonia is namely produced when manure and urine are mixed. Most of the farms that were studied are biological farms and therefore their livestock is grazing more than the livestock of conventional farms. If livestock is grazing, urine and manure do not mix, which can reduce nitrogen emission up to 75% according to research of the Wageningen University (Vellinga, 2019).

As time was limited, only a limited number of farms could be studied and consequently, the generalizability of the research is rather low. In future research, additional case studies can be performed to improve the generalizability of the research and provide a more thorough understanding of the profitability of agroforestry in the Netherlands or Europe. In this research multiple walnut farms have been studied, whereas for the other business models only a single farm was analyzed. Therefore, it would be especially relevant to study more farms involving fodder trees or fruit trees, or silvoarable agroforestry involving crops combined with trees. By this means a more comprehensive overview of the financial and socio-economic performance of agroforestry in temperate regions can be achieved.

Despite these limitations, this research provides valuable initial insight into the financial and socio-economic performance of silvopastoral agroforestry systems in the Netherlands. The case studies that have been performed already give interesting and new insights into the profitability of agroforestry in the Netherlands and show that agroforestry not only has a promising ecological future, but also a financial one. Furthermore, this research provides interesting directions for future research. For instance, future studies can build upon the findings of this research by extending the scope of the socio-economic analysis by including more ecosystem services. As a result, a more realistic socio-economic value of agroforestry can be calculated, which might be substantially higher than the value that was found in this research. By this means, the true potential value of agroforestry can be identified.

6. Summary and conclusion

Agriculture can be identified as the source of various problems, such as soil erosion, depletion of aquifers, eutrophication, climate forcing and biodiversity loss. Therefore, it is important to identify agricultural practices with lower negative environmental impacts. A promising example of an agricultural practice with lower environmental impacts is agroforestry. In previous research, the ecological benefits of agroforestry have been demonstrated, but little is known about the financial aspects of agroforestry. This makes the transition towards agroforestry uncertain for many farmers, which hampers its adoption. In this research, the financial and socio-economic aspects of agroforestry are studied in more detail, answering the following research question: 'What is the long-term financial and socio-economic performance of silvopastoral agroforestry practices in the Netherlands?'

To answer the research question, six case studies were performed, which were categorized into four categories based on the tree types they introduced: walnut trees, fruit trees, fodder trees or a combination of walnut and fruit trees. Interviews were used to get a better understanding of the farms and to acquire the necessary data on costs that were associated with the transition to agroforestry. Revenues were estimated based on desk research as the farms only recently transitioned towards agroforestry, and therefore data on yield and sales were not yet available.

Based on the acquired data, a financial analysis was performed for which the Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Payback Time (DPBT) and the first year of positive cash flow were calculated for the six agroforestry farms. A combination of different financial indicators was used to get a holistic and more thorough overview of the financial performance. Next to the financial analysis, a socio-economic analysis was performed in which the ecosystem services provided by agroforestry were valued. Two groups of ecosystem services were taken into consideration: carbon related ecosystem services (carbon sequestration by trees and the increase in soil organic carbon) and nitrogen related ecosystem services (reduction of ammonia emission and nitrogen runoff). The value of the carbon related ecosystem services was determined based on the value of carbon on the voluntary carbon market and the EU emission trading system, whereas for the valuation of the nitrogen related ecosystem services the avoided cost method was used.

The financial analysis indicated that especially nut farms have a high NPV, ranging between €12,503 and €44,629, benefiting from the high walnut timber values. The deviations in the NPV were mainly the result of the number of planted walnut trees: the research showed that for walnut trees the NPV increases almost linearly with the number of walnut trees and hence, the higher the number of trees, the higher the NPV. In contrast, the introduction of fodder trees was less profitable as no real business model could be developed around the fodder trees, resulting in an NPV approximately zero. The introduction of apple trees resulted in a lower NPV (€10,209), but a higher IRR compared to the walnut trees. This indicates that the introduction of apple trees is a less uncertain business model as it is even profitable at high discount rates. Furthermore, the introduction of apple trees reduced the DPBT and a positive cash flow was reached earlier compared to the farms that introduced walnut trees. Furthermore, this thesis showed that a combination of fruit and walnut trees results in the best financial performance, combining the benefits of both business models.

As the financial analysis was based on several assumptions (e.g., nut price/kg, nut yield, fruit price/kg and fruit yield), sensitivity analyses were performed to analyse the impact of deviations in these assumptions on the profitability of the agroforestry project. The results showed that especially the prices of either walnuts or fruits have a large impact on the profitability of the agroforestry projects, but the projects remained profitable under most conditions. Thus, these results demonstrate the financial robustness of the analysed agroforestry projects.

The socio-economic analysis demonstrated that the ecosystem services provided by agroforestry also hold a substantial financial value. The socio-economic value of the project was mainly dependent on the number of the planted trees and the area on which agroforestry was implemented, rather than on the tree density. For most farms, the value of carbon sequestration and avoided nitrogen related costs was equal (or even higher) than the value of the subsidy received in the first year of the project. These findings indicate that valuing ecosystem services is a viable alternative to the subsidy that is now received in the first year. In turn, valuing the ecosystem services, instead of providing a subsidy, can incentivize farmers to keep improving the nature-inclusiveness of their farms in the future.

Together, the results of the financial and socio-economic analysis are a first indication that agroforestry projects are profitable, robust and more nature-inclusive compared to conventional agriculture in the Netherlands. Thus, this research has shown that agroforestry not only has a promising ecological future, but also a financial one. Thereby, this research contributes to lowering the financial uncertainty of agroforestry projects for farmers, which can hopefully stimulate the adoption of agroforestry projects in the future.

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Appendix A – Interview guide

This interview guide shows a general overview of questions that were ask during the interviews. However, the questions were specified for the specific farms, based on their characteristics and business models.

- What were the reasons for you to start with agroforestry?

General farm information:

- In which year did you start with agroforestry?
- How many trees did you plant? And what species?
- What is the size of your land area? What part is dedicated to agroforestry?
- How many animals do you have on your farm? Did this number change because of the trees?

Revenues:

- Did you receive a subsidy for the implementation of agroforestry? What amount?
- Do you use less artificial fertilizer or pesticides now that you introduced trees?
- Do you plan to sell products from the trees?
- Do you have to import less fodder/medicine because of the trees? If yes, what are your savings?
- In addition to the possible sale of tree products, are there further income (directly or indirectly) linked to the trees (like guided tours or compensation for ecosystem services)?

Investment and variable costs:

- Did you have to prepare the land (mechanical or chemical) before planting the trees? If yes, what preparations and what were the costs?
- What did you pay for the trees?
- What were the costs of staking and fencing?
- Did you make use of fertilizer/pesticide specifically for the trees? If yes, what were the costs?
- Did you had to buy any material for planting or maintenance of the trees?
- By introducing the trees, is there less grass or crops available as fodder for the animals? If yes, what are the cost for importing additional fodder?
- How many hours were spent on planting the trees, including preparations?
- Did you do this all by yourself or did you have help of paid workers?
- How many hours do you think you will spend on maintenance of the trees? Are you planning to do this by yourself or by paid workers?
- Do you mow you pasture? Do you think to spend more time doing this because of the tree elements? If yes, how many time?
- Did the introduction of trees lead to other costs?

Appendix B – Assumptions

Assumption	Description	Source
Project lifespan	For all six farms a project lifespan of 30 years was chosen. It was preferred to use the same lifespan for each farm, to have a certain possibility for comparison. Also, most of the walnut farmers stated that they expected to harvest the timber after around 30 years.	NA
Nut price	During the interviews, the farmers with walnut trees indicated that they expected an average walnut price of 2 euros per kilo, but they mentioned that even lower prices between 1 and 2 euros are also common. However, literature shows considerably higher walnut prices. In a study of van Reuler et al. (2020) an average price of 4 euros per kilo was selected, with even the possibility of 5 euros. Factors like nut quality and the way of sales can have a great impact on this price. For this research 2 euros was picked as a baseline and the range that was selected for the sensitivity analysis was between 1 and 5 euros.	(van Reuler et al., 2020)
Nut yield	Van Colen (2019) stated that the walnut production starts (on average) in year 8 and that the nut yields are 5, 10 and 18 kg for 10-, 20- and 30-year-old trees, respectively. It was assumed that the nut yield increases linearly between these intervals. For the sensitivity analysis, the effect of an increase and decrease of 10 and 20 percent in yield was calculated.	(van Colen, 2019)
Walnut Timber yield and price	Van Veluw (2017) stated that the timber yield after 40 years would be 500 euros per tree. However, during the interviews the farmers indicated that they expected the timber harvest to occur in year 30. Van Colen (2017) stated that a full-grown tree yields on average 1 m^3 of timber and that prices vary from 250 to 500 euro/m^3. For this research, a baseline of 400 euros per tree (after 30 years) was selected. For the sensitivity analysis, the range of 250 to 500 euro/tree was picked.	(van Veluw, 2017; van Colen, 2019)
Fruit price	In order to estimate the fruit price per kilogram, the average apple and pear price was calculated over the years 2009 – 2014.	(Heijerman-Peppelman and Roelofs, 2010)
Fruit yield (standard fruit trees)	The apple production on standard fruit trees starts after 8 years. However, in a short amount of these trees can produce up to 100 kg fruit (apples and pears). It was assumed that the maximum production was reached in year 15	(Tuinadvies, n.d.)
Fruit yield (half standard fruit trees)	In a report of the KWIN ('Kwantitatieve Informatie Veehouderij') key numbers about fruit yield were determined. Apple yield (ton/ha) was based on a standard cultivation system of 3,000 trees per hectare, without artificial watering. Pear yield (ton/ha) was based on a standard cultivation system of 2,500 trees per hectare For this research the yield numbers (ton/ha) were divided by 3,000 and 2,500, for apples and pears respectively, to determine the fruit yield per tree. For the calculations, the average of the apple and pear yield was used.	(Heijerman-Peppelman and Roelofs, 2010)
Fruit tree timber	(Half) standard fruit trees can have a lifespan up to 100 years (Ham, 2020). Therefore, it was assumed that the timber of the standard fruit trees will not be harvested within 30 years. For the low standard	(Ham, 2020)
Maintenance costs fruit trees	In contrast to walnut trees, fruit trees have to be pruned each year. Farm 4 indicated that hired labour will be necessary each year to prune the standard fruit trees. However, for farm 5 it was assumed that no hired labour will be used to prune the half standard fruit trees as these trees are considerably lower and easier to maintain.	NA
Labour costs	In consultation with the farmers, labour costs for their own labour were not taken into consideration for this research. The costs of hired labour were set at 20 euros per hour, based on the research of van Reuler et al. (2020).	(van Reuler et al., 2020)
Nut harvesting machine	All farmers with walnut trees indicated that they would buy a harvesting machine in the future when nut harvest starts. They expected the costs to be around 15,000 euros. However, they all indicated to share the machine with college walnut farmers. It was assumed that the machine will be shared with 5 farmers, reducing the cost to 3,000 euros.	NA
Irrigation system	Two walnut farmers stated that they bought an irrigation system. One bought it specifically for the trees and the other would have bought it anyway. These costs were left out of the analysis because they are too specific. If the trees were planted after a less dry year, they probably would not have bought it.	NA

Appendix C – Cash flow Plans

Farm 1

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 6.200														
Walnuts	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 1.224	€ 2.376	€ 3.600	€ 3.960	€ 4.320	€ 4.680	€ 5.040	€ 5.400
Timber															
Total Revenues	€ 6.200	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 1.224	€ 2.376	€ 3.600	€ 3.960	€ 4.320	€ 4.680	€ 5.040	€ 5.400
Variable costs															
Trees	€ 5.700														
Flower strips	€ 250	€ 250	€ 250	€ 250	€ 250	€ 250	€ 250								
Stakes	€ 720														
Nets	€ 1.080														
Harvesting machine								€ 3.000							
Additional fodder	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000
Total variable costs	€ 11.750	€ 4.250	€ 4.250	€ 4.250	€ 4.250	€ 4.250	€ 4.250	€ 7.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000
Net income(/loss)	€ -5.550	€ -4.250	€ -4.250	€ -4.250	€ -4.250	€ -4.250	€ -4.250	€ -5.776	€ -1.624	€ -400	€ -40	€ 320	€ 680	€ 1.040	€ 1.400
Present Value	€ -5.550	€ -4.087	€ -3.929	€ -3.778	€ -3.633	€ -3.493	€ -3.359	€ -4.389	€ -1.187	€ -281	€ -27	€ 208	€ 425	€ 625	€ 808
Discounted cum. CF	€ -5.550	€ -9.637	€ -13.566	€ -17.344	€ -20.977	€ -24.470	€ -27.829	€ -32.218	€ -33.405	€ -33.686	€ -33.713	€ -33.505	€ -33.080	€ -32.456	€ -31.647

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Walnuts	€ 5.760	€ 6.120	€ 6.480	€ 6.840	€ 7.200	€ 7.776	€ 8.352	€ 8.928	€ 9.504	€ 10.080	€ 10.656	€ 11.232	€ 11.808	€ 12.384	€ 12.960
Timber															€ 144.000
Total Revenues	€ 5.760	€ 6.120	€ 6.480	€ 6.840	€ 7.200	€ 7.776	€ 8.352	€ 8.928	€ 9.504	€ 10.080	€ 10.656	€ 11.232	€ 11.808	€ 12.384	€ 156.960
Variable costs															
Trees															
Flower strips															
Stakes															
Nets															
Harvesting machine															
Additional fodder	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000
Total variable costs	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000	€ 4.000
Net income(/loss)	€ 1.760	€ 2.120	€ 2.480	€ 2.840	€ 3.200	€ 3.776	€ 4.352	€ 4.928	€ 5.504	€ 6.080	€ 6.656	€ 7.232	€ 7.808	€ 8.384	€ 152.960
Present Value	€ 977	€ 1.132	€ 1.273	€ 1.402	€ 1.519	€ 1.723	€ 1.910	€ 2.079	€ 2.233	€ 2.372	€ 2.497	€ 2.609	€ 2.708	€ 2.796	€ 49.047
Discounted cum. CF	-€ 30.670	-€ 29.538	-€ 28.265	-€ 26.863	-€ 25.344	-€ 23.621	-€ 21.711	-€ 19.632	-€ 17.399	-€ 15.027	-€ 12.530	-€ 9.921	-€ 7.214	-€ 4.418	€ 44.629

NPV @ 4%	€ 44.629
IRR	8%
DPBT	NA

Farm 2

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 4.000														
Walnuts	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 408	€ 792	€ 1.200	€ 1.320	€ 1.440	€ 1.560	€ 1.680	€ 1.800
Timber															
Total Revenues	€ 4.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 408	€ 792	€ 1.200	€ 1.320	€ 1.440	€ 1.560	€ 1.680	€ 1.800
Variable costs															
Trees	€ 5.400														
Clover and Alfalfa	€ 150														
Stakes	€ 500														
Fences	€ 1.500														
Chalk	€ 350	€ 350	€ 350	€ 350	€ 350	€ 350	€ 350					€ 350			
Harvesting machine								€ 3.000							
Total variable costs	€ 7.900	€ 350	€ 350	€ 350	€ 350	€ 350	€ 350	€ 3.000	€ 0	€ 0	€ 0	€ 350	€ 0	€ 0	€ 0
Net income(/loss)	€ -3.900	€ -350	€ -350	€ -350	€ -350	€ -350	€ -350	€ -2.592	€ 792	€ 1.200	€ 1.320	€ 1.090	€ 1.560	€ 1.680	€ 1.800
Present Value	€ -3.900	€ -337	€ -324	€ -311	€ -299	€ -288	€ -277	€ -1.970	€ 579	€ 843	€ 892	€ 708	€ 974	€ 1.009	€ 1.039
Discounted cum. CF	€ -3.900	€ -4.237	€ -4.560	€ -4.871	€ -5.170	€ -5.458	€ -5.735	€ -7.704	€ -7.126	€ -6.283	€ -5.391	€ -4.683	€ -3.708	€ -2.700	€ -1.660

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Walnuts	€ 1.920	€ 2.040	€ 2.160	€ 2.280	€ 2.400	€ 2.592	€ 2.784	€ 2.976	€ 3.168	€ 3.360	€ 3.552	€ 3.744	€ 3.936	€ 4.128	€ 4.320
Timber															€ 48.000
Total Revenues	€ 1.920	€ 2.040	€ 2.160	€ 2.280	€ 2.400	€ 2.592	€ 2.784	€ 2.976	€ 3.168	€ 3.360	€ 3.552	€ 3.744	€ 3.936	€ 4.128	€ 52.320
Variable costs															
Trees															
Flower strips															
Stakes															
Nets															
Harvesting machine		€ 350					€ 350					€ 350			
Additional fodder															
Total variable costs	€ 0	€ 350	€ 0	€ 0	€ 0	€ 0	€ 350	€ 0	€ 0	€ 0	€ 0	€ 350	€ 0	€ 0	€ 0
Net income(/loss)	€ 1.920	€ 1.690	€ 2.160	€ 2.280	€ 2.400	€ 2.592	€ 2.434	€ 2.976	€ 3.168	€ 3.360	€ 3.552	€ 3.394	€ 3.936	€ 4.128	€ 52.320
Present Value	€ 1.066	€ 902	€ 1.109	€ 1.125	€ 1.139	€ 1.183	€ 1.068	€ 1.256	€ 1.285	€ 1.311	€ 1.332	€ 1.224	€ 1.365	€ 1.377	€ 16.776
Discounted cum. CF	-€ 594	€ 308	€ 1.417	€ 2.543	€ 3.682	€ 4.865	€ 5.933	€ 7.189	€ 8.474	€ 9.785	€ 11.117	€ 12.341	€ 13.706	€ 15.083	€ 31.860

NPV @ 4%	€ 31.860
IRR	13%
DPBT	17

Farm 3

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 2.000														
Walnuts	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 153	€ 297	€ 450	€ 495	€ 540	€ 585	€ 630	€ 675
Timber															
Total Revenues	€ 2.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 153	€ 297	€ 450	€ 495	€ 540	€ 585	€ 630	€ 675
Variable costs															
Trees	€ 2.025														
Stakes and fences	€ 405														
Harvesting machine								€ 3.000							
Total variable costs	€ 2.430	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 3.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ -430	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ -2.847	€ 297	€ 450	€ 495	€ 540	€ 585	€ 630	€ 675
Present Value	€ -430	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ -2.163	€ 217	€ 316	€ 334	€ 351	€ 365	€ 378	€ 390
Discounted cum. CF	€ -430	€ -430	€ -430	€ -430	€ -430	€ -430	€ -430	€ -2.593	€ -2.376	€ -2.060	€ -1.726	€ -1.375	€ -1.010	€ -631	€ -242

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Walnuts	€ 720	€ 765	€ 810	€ 855	€ 900	€ 972	€ 1.044	€ 1.116	€ 1.188	€ 1.260	€ 1.332	€ 1.404	€ 1.476	€ 1.548	€ 1.620
Timber															€ 18.000
Total Revenues	€ 720	€ 765	€ 810	€ 855	€ 900	€ 972	€ 1.044	€ 1.116	€ 1.188	€ 1.260	€ 1.332	€ 1.404	€ 1.476	€ 1.548	€ 19.620
Variable costs															
Trees															
Stakes and fences															
Harvesting machine															
Total variable costs	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ 720	€ 765	€ 810	€ 855	€ 900	€ 972	€ 1.044	€ 1.116	€ 1.188	€ 1.260	€ 1.332	€ 1.404	€ 1.476	€ 1.548	€ 19.620
Present Value	€ 400	€ 408	€ 416	€ 422	€ 427	€ 444	€ 458	€ 471	€ 482	€ 492	€ 500	€ 506	€ 512	€ 516	€ 6.291
Discounted cum. CF	-€ 1.867	-€ 1.458	-€ 1.043	-€ 620	-€ 193	€ 250	€ 708	€ 1.179	€ 1.661	€ 2.153	€ 2.653	€ 3.159	€ 3.671	€ 4.187	€ 10.478

NPV @ 4%	€ 12.503
IRR	17%
DPBT	21

Farm 4 – Assuming that the fruit will be sold

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 1.500														
Fruit	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 203	€ 405	€ 608	€ 675	€ 878	€ 945	€ 1.148	€ 1.350
Total Revenues	€ 1.500	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 203	€ 405	€ 608	€ 675	€ 878	€ 945	€ 1.148	€ 1.350
Variable costs															
Trees	€ 1.200														
Stakes and fences	€ 450														
Labour	€ 320							€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160
Total variable costs	€ 1.970	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160
Net income(/loss)	€ -470	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 43	€ 245	€ 448	€ 515	€ 718	€ 785	€ 988	€ 1.190
Present Value	€ -470	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 32	€ 179	€ 314	€ 348	€ 466	€ 490	€ 593	€ 687
Discounted cum. CF	€ -470	€ -470	€ -470	€ -470	€ -470	€ -470	€ -470	€ -438	€ -259	€ 56	€ 404	€ 870	€ 1.360	€ 1.953	€ 2.640

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Fruit	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350
Total Revenues	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350	€ 1.350
Variable costs															
Trees															
Stakes and fences															
Labour	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160
Total variable costs	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160	€ 160
Net income(/loss)	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190	€ 1.190
Present Value	€ 661	€ 635	€ 611	€ 587	€ 565	€ 543	€ 522	€ 502	€ 483	€ 464	€ 446	€ 429	€ 413	€ 397	€ 382
Discounted cum. CF	€ 3.301	€ 3.936	€ 4.547	€ 5.135	€ 5.700	€ 6.243	€ 6.765	€ 7.267	€ 7.750	€ 8.214	€ 8.660	€ 9.090	€ 9.502	€ 9.899	€ 10.281

NPV @ 4%	€ 10.281
IRR	27%
DPBT	10

Farm 5

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 8.000														
Apple	€ 0	€ 212	€ 384	€ 544	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572
Pear	€ 0	€ 0	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825
Walnuts	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 1.360	€ 2.640	€ 4.000	€ 4.400	€ 4.800	€ 5.200	€ 5.600	€ 6.000
Timber															
Total Revenues	€ 8.000	€ 212	€ 1.209	€ 1.369	€ 1.397	€ 1.397	€ 1.397	€ 2.757	€ 4.037	€ 5.397	€ 5.797	€ 6.197	€ 6.597	€ 6.997	€ 7.397
Variable costs															
Trees	€ 12.000														
Stakes and fences	€ 4.000														
Harvesting machine								€ 3.000							
Total variable costs	€ 16.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 3.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ -8.000	€ 212	€ 1.209	€ 1.369	€ 1.397	€ 1.397	€ 1.397	€ -243	€ 4.037	€ 5.397	€ 5.797	€ 6.197	€ 6.597	€ 6.997	€ 7.397
Present Value	€ -8.000	€ 204	€ 1.118	€ 1.217	€ 1.194	€ 1.148	€ 1.104	€ -185	€ 2.950	€ 3.792	€ 3.916	€ 4.025	€ 4.120	€ 4.202	€ 4.272
Discounted cum. CF	€ -8.000	€ -7.796	€ -6.678	€ -5.461	€ -4.267	€ -3.119	€ -2.015	€ -2.200	€ 750	€ 4.542	€ 8.458	€ 12.484	€ 16.604	€ 20.807	€ 25.078

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Apple	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572	€ 572
Pear	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825	€ 825
Walnuts	€ 6.400	€ 6.800	€ 7.200	€ 7.600	€ 8.000	€ 8.640	€ 9.280	€ 9.920	€ 10.560	€ 11.200	€ 11.840	€ 12.480	€ 13.120	€ 13.760	€ 14.400
Timber															€ 80.000
Total Revenues	€ 7.797	€ 8.197	€ 8.597	€ 8.997	€ 9.397	€ 10.037	€ 10.677	€ 11.317	€ 11.957	€ 12.597	€ 13.237	€ 13.877	€ 14.517	€ 15.157	€ 95.797
Variable costs															
Trees															
Stakes and fences															
Harvesting machine															
Total variable costs	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ 7.797	€ 8.197	€ 8.597	€ 8.997	€ 9.397	€ 10.037	€ 10.677	€ 11.317	€ 11.957	€ 12.597	€ 13.237	€ 13.877	€ 14.517	€ 15.157	€ 95.797
Present Value	€ 4.329	€ 4.376	€ 4.413	€ 4.441	€ 4.460	€ 4.581	€ 4.685	€ 4.775	€ 4.851	€ 4.914	€ 4.965	€ 5.005	€ 5.035	€ 5.055	€ 30.717
Discounted cum. CF	€ 29.407	€ 33.784	€ 38.197	€ 42.639	€ 47.099	€ 51.680	€ 56.365	€ 61.140	€ 65.992	€ 70.906	€ 75.871	€ 80.877	€ 85.911	€ 90.966	€ 121.683

NPV @ 4%	€ 121.683
IRR	26%
DPBT	9

Farm 6

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Revenues															
Subsidies	€ 2.000														
Total Revenues	€ 2.000	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Variable costs															
Trees	€ 0														
Stakes and fences	€ 800														
Labour	€ 480	€ 160	€ 160	€ 160	€ 160										
Total variable costs	€ 1.280	€ 160	€ 160	€ 160	€ 160	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ 720	€ -160	€ -160	€ -160	€ -160	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Present Value	€ 720	€ -154	€ -148	€ -142	€ -137	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Discounted cum. CF	€ 720	€ 566	€ 418	€ 276	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139

Year	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Revenues															
Subsidies															
Total Revenues	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Variable costs															
Trees															
Stakes and fences															
Labour															
Total variable costs	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Net income(/loss)	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Present Value	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0	€ 0
Discounted cum. CF	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139	€ 139

NPV @ 4%	€ 139
IRR	4,55%
DPBT	0