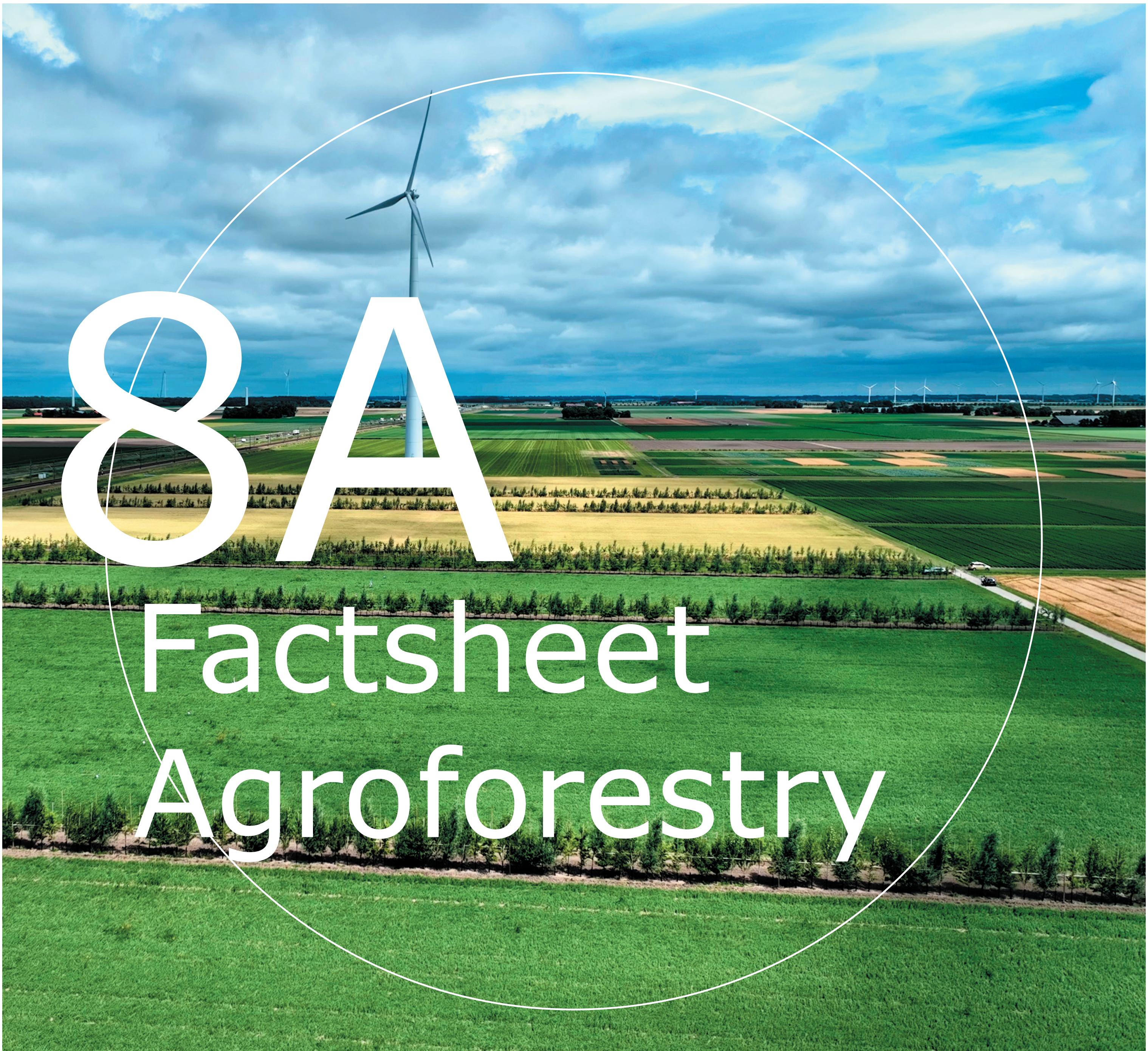

8A Factsheet Agroforestry

The long-term agroforestry research facility for Dutch arable farming: the experimental design and monitoring choices

WAGENINGEN
UNIVERSITY & RESEARCH

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1| About this factsheet

Agroforestry, the combination of woody perennials with arable farming, vegetable cultivation or grassland, can offer multiple ecosystem services, while maintaining economic viability. It can play a major role in future proofing our farming systems and providing solutions to societal issues such as climate change and biodiversity loss. However, research on agroforestry in the Netherlands, especially in combination with Dutch cash crops like potato, onions and carrots, is lacking. There are still many questions regarding the optimal design of agroforestry systems and the effect of this on the different crops in the system and ecosystem services. Two long term agroforestry experiments were set up in 2021 on a sandy loam soil at the research facilities of Wageningen University & Research near Lelystad, NL. The aim is to test the hypothesis that agroforestry systems can be designed to be an economically viable farming system in a windy Dutch landscape and at the same time can serve other societal purposes such as supporting; biodiversity, carbon sequestration, microclimate and buffering against extreme weather events. These ecosystem services are monitored in addition to the yields in the tree and arable crops. Because the trade-offs and choices made in the design of the facility may also be of interest to other researchers (starting a new Long Term Experiment), we want to share and explain the background, design and data collection of the facility. With this, we hope to increase the understanding and interest in this trial and also to contribute to well-thought-out designs of agroforestry systems elsewhere.

2| Silvoarable agroforestry in the Netherlands

We speak of agroforestry when woody perennials (trees and shrubs) are deliberately combined with arable farming, vegetable cultivation or grassland, on the same plot. Agroforestry in combination with arable farming (silvoarable agroforestry) is still uncommon in the Netherlands. Historically, only the interweaving of hedgerows in the then small-scale landscape is a form which also falls under the definition of silvoarable agroforestry. A new form of agroforestry in combination with arable farming is alley cropping. This form of agroforestry fits the contemporary large-scale landscape and the current level of mechanization. In alley cropping systems, rows or strips of trees and/or shrubs are deliberately placed in, or around, arable fields in order to optimise tree and arable crop productions and support ecosystem services.. In addition to their influence on the agro-ecosystem and the arable crop, the trees themselves can also be a source of income for the arable farmer. This is the case if species are used that produce fruit, nuts, timber or biomass.

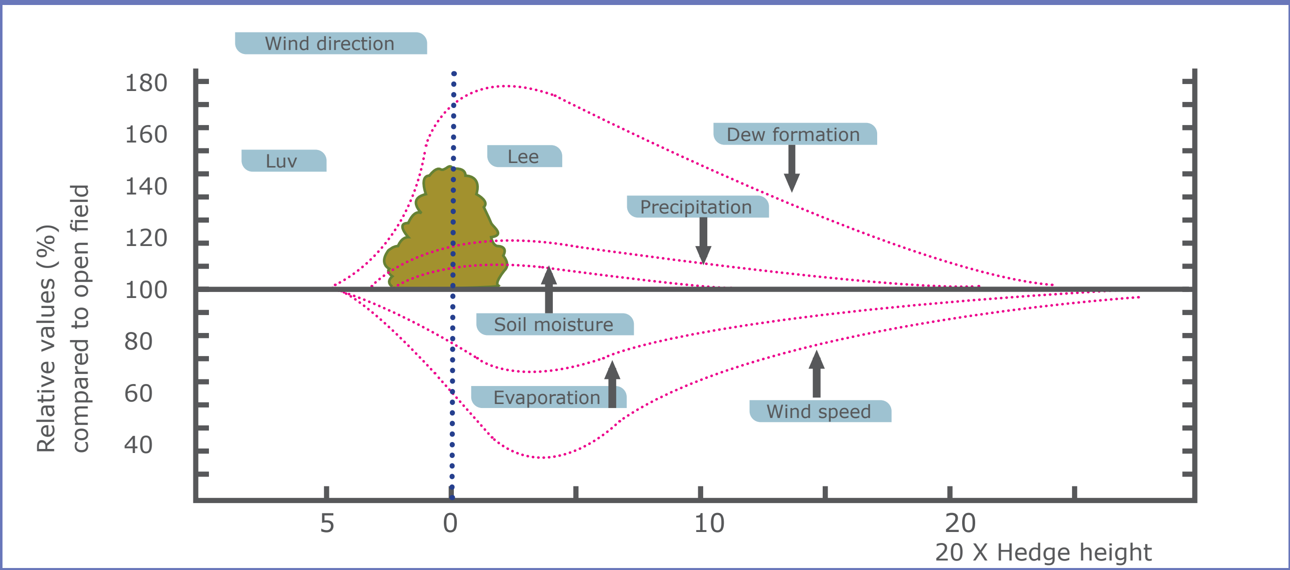
The possibilities for alley cropping agroforestry systems are also very interesting from a policy and social perspective to achieve various social goals. Climate mitigation through carbon sequestration, increasing biodiversity through a more varied landscape and climate adaptation through buffering against extreme weather events are all examples of how agroforestry could contribute to solutions to societal issues. Agroforestry also fits in well with the policy goals set out in, among others, the Dutch Forest Strategy (LNV, 2020), the Climate Agreement and the European Farm to Fork strategy. However, the challenge to the successful implementation of alley cropping agroforestry systems is that very little is known about how these systems work and how the system could be optimally designed to enhance the potential positive effects and minimise any negative effects. Also little is yet known about the economic viability of these systems. In order to maximise the potential of agroforestry for the foreseeable future, the development and research of generic and scalable system designs, that are interesting for both farmers and society, are necessary.

3| What are the opportunities for agroforestry in the Netherlands?

The high value of arable crops in the Netherlands makes it essential to find the optimal balance between tree-crop competition and facilitation. An important opportunity for the Netherlands is the effect of trees on the local microclimate. Because trees reduce wind speed, less moisture evaporates from the soil and crops. Also, erosion-sensitive soils are less likely to erode, or run off, and crops suffer less from wind stress and damage (eg Figure 1). The relatively strong and ever-present wind in the Dutch polders such as Zeeland and the Flevopolder, as well as the regionally important wind erosion in, for example, the Veenkoloniën and the sandy soil areas in Brabant, is a very important starting point for designing a generic agroforestry system. The challenges in these areas provide opportunities for silvoarable agroforestry. Additionally, the increase in weather extremes such as (extreme) heat and drought is an important starting point for almost all Dutch regions. At the same time, the arable crop is currently the most valuable product for arable farmers, so it is important to ensure the continued profitability of this crop. The experiment was designed to explore the optimisation of the microclimate (including temperature, radiation, humidity and wind) in order to minimize competition (light, water, nutrients) and increase positive interactions (microclimate). To achieve this the optimisation of tree row spacing was a logical next step.

Literature research shows interesting results that can be used to design an agroforestry system aimed at improving the microclimate. Trees appear to be able to influence crop yields over great distances, this effect is expected to be the result of an improved microclimate. In regions with prevailing strong winds, research has shown that in some crops, yields of between 10 and 40% or even higher can occur, due to shelterbelts (e.g. Kort, 1988). The size of this effect depends on the local climate, the size and form of the shelterbelt and the arable crop species (Mirck et al., 2016; Nuberg, 1988; Kanzler et al., 2019; Baker et al., 2018; Cleugh et al. al., 1998; Hodges et al., 2004; Zheng et al., 2016; Taksdal et al., 1992). However, for many relevant crop species, the effects of different types of tree rows and shelterbelts are still unknown. Recent research into alley cropping agroforestry systems and next to tree rows in arable plots shows that on average there is a negative effect on the crop yield close to the tree row (up to a distance of approximately 1.6 times the tree height) and a positive effect between 1.6 and 9.5 times the tree height, with an average additional yield of 7% in this zone (Figure 2) (Van Vooren et al., 2016). These distances and effects are reasonably similar to what was found in the study of wind hedges (Figure 3). The study by Van Vooren et al. (2016) is not focused on windy areas, so it is possible that the effect of agroforestry on crop yields can be greater in wind-sensitive areas and with a design specifically aimed at breaking the wind and minimising competition. If agroforestry has a positive effect on the arable crop yields it could be economically interesting independently of the yield of the tree crop. This also creates opportunities for agroforestry in areas with relatively high land and lease prices with regard to the area used for the trees.

Figure 1| The effects of a wind break hedge on the windspeed with a wind direction perpendicular to the hedge (Leuschner & Ellenberg, 2017).



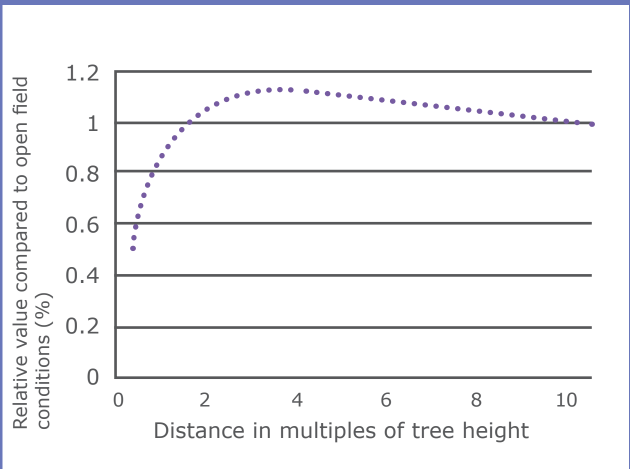


Figure 2| The relationship between the relative crop yield (y) plotted against the distance from the tree, expressed in number of tree heights (x). Yield loss is occurring up to 1.6 times the tree height and yield increase occurs between 1.6 and 9.5 times the tree height (based on Van Vooren et al., 2016).

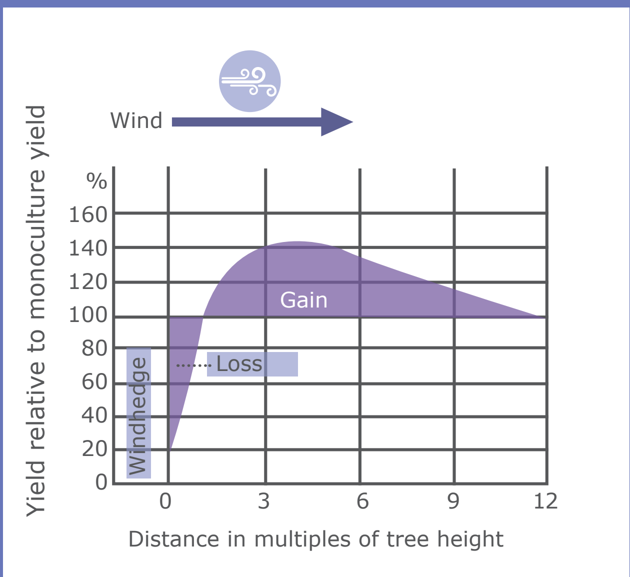


Figure 3| Summary graph of the influence of hedgerows on crop yields. With a yield loss of up to approximately 1.5 times the tree height and an increase in yield between 1.5 and 12 times the tree height (based on Voortman, 1977).

4| What was the initial starting point for the research?

The system design of the agroforestry facility was preceded by a lot of discussion between various experts. From these discussions, priorities were gradually ranked, design criteria formulated, the advantages and disadvantages of certain choices mapped out and weighed, and finally decisions were made. The discussions focused on site requirements for tree species, product marketing (niche vs. mainstream), impact on labour costs, years to full production, landscape incorporation, the trade-off between windbreak function and production function of the woody crop and the magnitude of all ecosystem services. The main question was: what kind of system can be designed which can provide valuable research for different purposes and target groups?

One of the first choices that was made is that the research should initially focus on the effect of tree rows on arable crops at different distances from the trees, whereby the optimization of microclimate effects has a priority. The following system criteria were formulated:

- Scalable up to 25,000 ha; a system that could become standard practice for arable farmers
- Good connection with the reality of the agricultural entrepreneur (market, labour and intrinsic motivation)
- Includes a productive woody crop with good market prospects
- Scientific set-up and international relevance
- Microclimate effects can be measured relatively quickly (6-10 years)
- A nature-based system in which ecosystem services can be investigated, such as; biodiversity, climate adaptation and carbon sequestration
- Consistent with design and cultural identity of the landscape (Fuchs et al., 2021)

Based on these criteria the common Hazel (*Corylus avellana*), in combination with (at least in the establishment phase) a fast-growing mixed (biodiverse) windbreak hedge have been chosen as woody crops in an alley cropping system on an organic farm with a standard organic arable crop rotation.

The reasoning behind these choices are as follows:

Choice for hazels

- Hazels are economically viable (although it is uncertain what will happen to the price when production is scaled up) (Reuler et al., 2020).

- Compared to fruit (apples, pears), nuts require less labour because the harvest can be mechanized. This is an important aspect as labour in agriculture is often difficult to find and can be a major expense.

- Hazels are a CAP subsidised crop, which makes the initiation phase of agroforestry easier.

Choice for the mixed hedge

- Hazels are quite sensitive to wind, and it is uncertain what windbreak effect hazels can have and how many years this takes after planting. In addition, it is unknown which tree form is suitable for this and producing nuts. To protect the hazel trees against wind and to quickly create a functioning wind hedge, it was decided to plant a mixed hedge next to the hazel row. The idea is to leave this mixed hedge at least in the establishment phase (the phase until the hazels produce and can take over the wind hedge function). A decision on this will be made during the course of the experiment. It may also be decided to only proceed with the mixed (biodiverse) hedge if the results give reason to do so.

- The mixed hedge has a value for biodiversity. The addition of the mixed hedge offers a better perspective for investigating the effects of agroforestry on biodiversity than with hazels alone.

In addition, it was decided to carry out the trial with organic management. Organic management allows for a better mapping of the full effect of the system on biodiversity and natural disease and pest control. This choice was somewhat at odds with scalability to common practice, as conventional farmers are the majority in the Netherlands. However the improved understanding of these elements were expected to be of value to both conventional and organic farmers.

A side note on the choice of hazel is that the controllability of the pest nut weevil (*Curculio nucum*) is uncertain. There are currently no authorized plant protection products to combat the nut weevil. The nut weevil is a pest that produces empty hazelnuts and whose numbers build up over time. The level of degradation can therefore increase over the years. Hazel growers are concerned about the possible movement of this pest and its advancement into new areas. Small-scale research is monitoring this weevil and exploring alternative prevention and control methods.

5| What are the research questions?

The research questions that will be answered with the agroforestry facility are:

1. What is the effect of the system on the cultivation, yield and quality of arable crops?
    a. When and how do these effects occur (looking in particular at the microclimate and aerodynamics)?
    b. What are the distances from the hedge at which these effects occur?
    c. How can these effects be translated and replicated in other agroforestry systems?

2. What is the effect of the system on soil quality, climate adaptation, carbon sequestration, biodiversity and farm economics?

3. Which tree form, pruning strategy and number of rows of hazel is most fitting in silvoarable agroforestry systems?
    a. What is the effect of tree form and pruning strategy on labour requirement?
    b. What is the effect of tree form, pruning strategy and number of rows on hazel productivity?
    c. What is the effect of the number of tree rows in the tree strip on the productivity of the hazel trees?

The design consists of two experiments; namely the 'distance' experiment and the 'tree form' experiment. The 'distance' experiment answers the first two research questions, and the 'tree form' experiment answers the last. Effects of the agroforestry system on hazel cannot be investigated in detail as no monoculture of hazel is available for scientific comparison. The conclusions from the research are specifically applicable to open areas, or landscapes that are comparable to the Flevopolder, in the Netherlands.

6| What does the 'distance' experiment look like?

6.1 *Experimental design*

Table 1 lists some properties of the 'distance' experiment. All tree rows have a similar design and consist of one row of mixed hedge and one row of hazel trees on the east side of the mixed hedge (sheltered from the prevailing wind). It is a dynamic design, which allows for the removal of either the hazels or hedgerows depending on the suitability of these elements. One option is that the mixed (biodiverse) hedge is removed after 5-10 years and the hazel row remains. This can be done when the hazel row is dense enough. Hazels can reach 4-6 m in height and are expected to provide a windbreak effect of up to 10 times the tree height. Consequently crop production is expected to be effected up to 40-60 m from the tree row. The 54 m and 108 m treatments are based on this assumption (and questions regarding the effect on the windward and leeward side). The direction of the tree rows is north-south, so that the light distribution on the crop is even on both sides, which is important for a homogeneous development of the arable crop (Dupraz et al., 2018). Additionally, the wind break effect in the growing season is expected to be high at this location with the north-south direction of the tree row (Figure 4). For the map of the experiment, see figure 5.

Table 1| Overview of the characteristics of the tree row distance experiment

Type of experiment	Randomized complete block design
Arable plots	2 (1 arable crop per plot per year)
Replications	2 (because of the size)
Plot dimensions	250 m x 300 m
Total surface	15 ha
Tree row orientation	North-South
Tree row length	1500 m
Tree row width	6 m
Amount of tree rows	6
Distance between hedge and hazel	4.5 m
Crops	1 in 8 rotation, organic management, with potato for human consumption, peas, seed onions, carrots, winter wheat, white cabbage, grass clover and spinach
Working width	3 m
Treatments	Three different tree row distances: 54 m, 108 m and Reference=no wind hedge

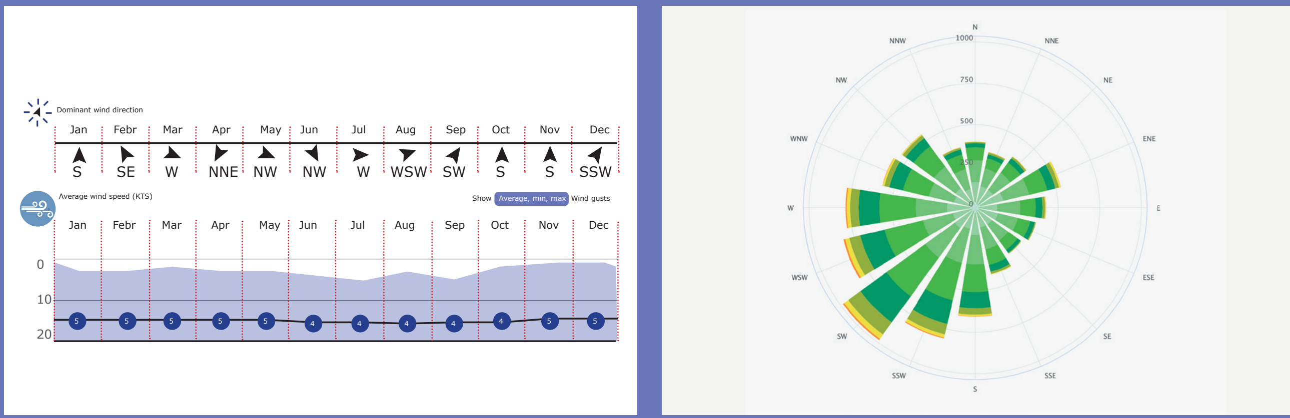


Figure 4| The wind direction and wind rose at the agroforestry research facility.

Figure 5| Map of the tree row distance experiment showing the treatments and the distances

6.2 ***Planting and management***

Table 2 lists some properties of the mixed hedge in the 'distance' experiment. A contract worker was hired for the planting. Bamboo canes and tree protectors were used. Tree species have been chosen that are suitable for a fast-growing mixed hedge that do not have fluff or fruit formation that could negatively impact the annual crop. The species are not expected to have any negative effects on disease and pests in the annual crops. Trees that died in the first year, 18 willows and 4 poplars were replaced with black alder and fluttering elm (or European white elm). The trees had their lowest branches removed in order to achieve sufficient aeration directly behind the hedge. With regard to the planting pattern, we ensured that no species would become too dominant, dominant, so fewer poplars and willows were planted, and more alders and elms.

Table 2| Overview of characteristics of the mixed hedge in the tree row distance experiment.

Year of planting	Beginning of 2021
Species	Black alder - *Alnus glutinosa*, white willow - *Salix alba* 'Belders' , fluttering elm- *Ulmus laevis* and black poplar - *Populus nigra* 'Vereecken'
Plant pattern	Repeated every 14th trees: poplar, 2x alder, willow, 2x elm, poplar, willow, 2x alder, poplar, 2x elm and willow
Planting material	150-200 cm
Planting distance	1 m in the row
Maximumtree height	Will be maintained at the maximum height of the hazels (estimated at 6-8 m?)
Hedge width	60-80 cm

Table 3 lists some properties of the hazels in the 'distance' experiment. It was decided to use varieties that are sufficiently known in the Netherlands as it is not known how new or introduced varieties will perform commercially. The three varieties Gunslebert, Gustav's Zeller and Corabel produce table nuts, can pollinate each other and fit well together in terms of flowering time (recommendation Herman Janssen, De Nootsaeck). They are grafted at a height of 20 cm on a rootstock of Coryllus colurna seedlings; the Turkish hazel. The planting material was one year old at the time of planting. The advantages of a Turkish hazel rootstock are that there are no suckering (shoots low on the trunk or from the roots) and that it may be more drought tolerant (personal communication, Bart van de Sluis, April 2021). The labour of pruning the suckers can normally be one day's work per acre, possibly twice a year. The Turkish hazel rootstock is therefore extremely suitable for agroforestry in arable farming, as labour availability is limited. However, some sources suggest that hazels on Turkish hazel rootstock could have a lower yield and smaller nuts.

When planting, all trees were supported with straps and bamboo cane at 1.5 m high. The tree rows also have drip irrigation, with a dripper at each tree. The drip irrigation is attached at a height of 30-40 cm to allow for mechanical weed control (finger weeder).

Planting year	The end of 2021
Varieties	*Corylus avellana* – 'Gunslebert', –'Gustav's Zellernuss', or 'Lang Tidlig Zeller' and –'*Corabel*'
Plant configuration	2:2:1 (of the 6 rows, 3.5 have Gustav's Zellernuss and 2.5 row have Lang Tidlig Zeller)
Plant distance	3 m
Tree height	6-8 m

Tabel 3| Overview of characteristics of the hazels in the tree row distance experiment

A strip of 100-150 cm bare soil is kept under the trees for the first two years of growth. A grass-herb mixture suitable for extensive mowing management is sown between the tree rows of approximately 3 m. With these dimensions at maturity a track width for pruning and other operations of 260 cm is possible and a working width of 300 cm is possible. The grass-herb mixture contains *Lolium perenne* – perennial ryegrass, Poa pratensis – smooth meadow grass and *Festuca rubra* – common red fescue. The herbal mixture contains: *Bellis perennis – Daisy, Cardamine pratensis* – cuckoo flower , *Crepis capillaris* – Smooth hawksbeard, *Erodium cicutarium* – Common stork's-bill , *Hypochaeris radicata* – Catsear, *Leontodon autumnale* – autumn hawkbit, *Lotus corniculatus* – Bird's-foot trefoil , *Medicago lupulina* – Black Medic , *Plantago lanceolata* – Narrow leaf plantain, *Prunella vulgaris* – common self-heal, *Ranunculus repens* – Creeping buttercup, *Rumex acetosella* – Sheep's sorrel, *Trifolium dubium* – lesser trefoil , *Trifolium pratense* – Red clover, *Trifolium repens* – White clover.

The mixed hedge and -hazel row are mechanically pruned when necessary to ensure they do not disrupt arable farming activities. It is essential to ensure that the hedge does not become too dense. The density is important because a hedge that is too dense displaces a strong wind current instead of slowing it down. The first 1 m of the trunks are also kept bare so that some air movement remains close to the hedgerows and the annual crops close to the hedges can dry sufficiently. In the beginning, the hazels need pruning, such as tying up side shoots and branches in the row direction, pruning the central leader and stimulating lateral branch formation. The hazels are allowed to develop freely in the direction of the row and the pruning is aimed at achieving a sufficient height and thickness (for windbreak function). The hazels will be pruned mechanically when they are larger, with minimal manual pruning.

6.3 ***Monitoring***

Microclimate

The 'distance' experiment is continuously monitored with a total of 22 soil stations and six weather stations. The soil stations measure soil moisture and temperature, while the weather stations record the microclimate: radiation, precipitation, air temperature, humidity, wind speed and direction.

It was decided to measure at the points where the greatest effect is expected on the basis of literature, or where no more effects are expected, or where effects cancel each other out (Figure 6). Using the model of Van Vooren et al. (2016) this resulted in: for the reference treatment one soil station at 75 m from the tree row, for the 108 m treatment seven soil stations at 1.5, 10, 23 and 56 m from the tree rows, and for the 54 m treatment three soil stations at a distance of 10 and 23 m (from the east and west side of the arable crop strip). The stations are placed at 130 m from the plot boundary, as the plot length is 260 m, this means in the middle of the plots.

The weather stations are placed as follows: one close to the tree row at a distance of 6 m, one at a distance of approx. 80 m and one at a distance of 27.5 m.

Crop, soil and biodiversity measurements

- All arable crops are sampled for **yield and quality**. This is done at the same distances from the trees as the soil stations. Yield sampling of the hazel will be done as soon as it starts producing.

- **Biodiversity** is measured between June and September on both plots at three different distances from the tree row (25, 50 and 75 metres) and in the tree row. The moths are caught eight times during the season using LED traps. Flying insects are caught with molasses traps three times in the season. Crawling insects are caught with pitfall traps three times per season.

- The **carbon sequestration** (and growth) of the above-ground parts of the trees is determined annually by calculating the tree volume from the length and perimeter of the trunk and the largest side branches. This volume is used to calculate the carbon sequestration.

- The **'Wind hedge rating'** assessed the extent to which the final wind reducing hedge attributes have been achieved: 100 cm wide, at least 5 m high and with optimal porosity. We are exploring different methods to measure this including digital methods for measuring the optical porosity of the hedge.

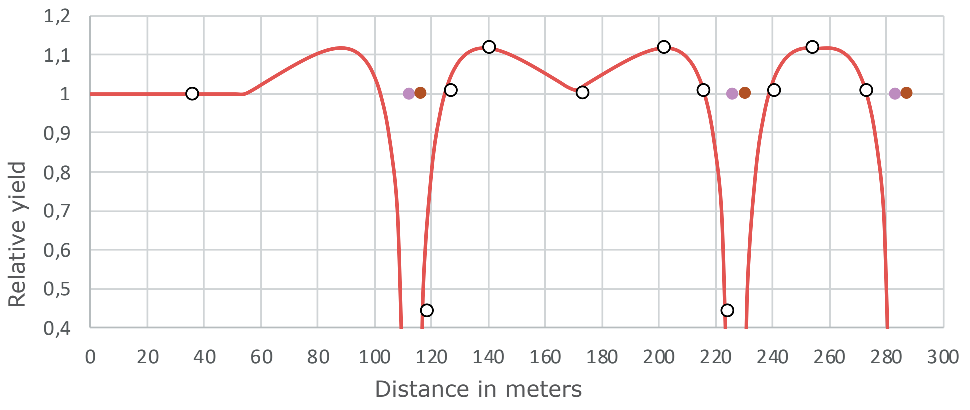


Figure 6| On the Y axis we see the estimated yield differences and on the X axis the distances from the tree row. The purple dot is the hedge row, the dark brown dot is the hazel row and the empty dots indicate the location of the sensors.

- For the LED traps and molasses traps there is one trap per sampling spot, while for the pitfall traps there are three traps per sampling spot. The presence of the nut weevil is also monitored in these traps.

- **Soil samples** are taken once a year outside the growing season at the three distances from the tree row and in the tree row and sent to a laboratory to determine soil quality, in addition to carbon sequestration. The bulk density of the soil is also determined to a depth of 30 cm at the spacing between tree rows and in the row to a depth of 30-60 cm. An extensive baseline survey of soil parameters was also made at 5 and 10 m from the tree row and also in the tree row.

7| What does the 'tree form' experiment look like?

7.1 *Experimental design*

The ideal tree form for hazels differs depending if the goal is nut production or microclimate control. It is therefore not clear what the best final tree form for hazels in agroforestry systems will be and what the consequences are for labour and nut yields. Pruning the hazel in a hedge form is expected to negatively influence the nut yield. Nevertheless, mechanical pruning reduces labour needs considerably. In the tree form experiment, different pruning strategies and tree forms are tested in single or multi-row hazel strips. The number of rows is expected to have an effect on the production in relation to the wind sensitivity of hazels and pollination.

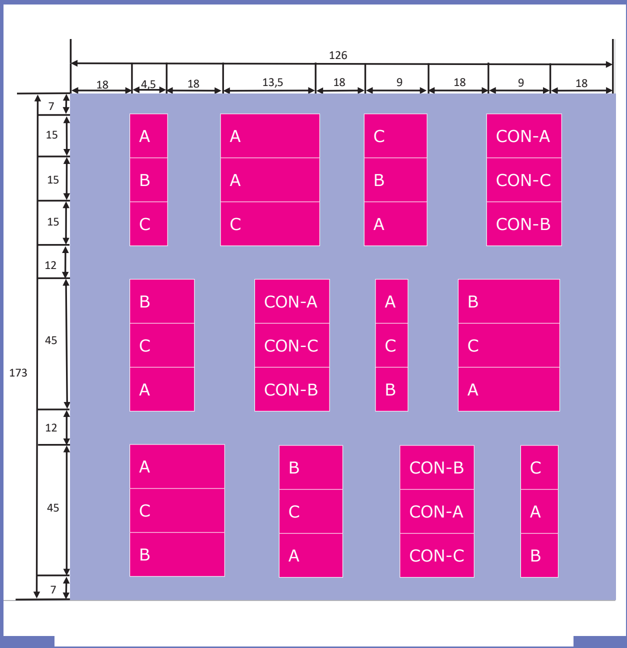


Figure 7| Map of the tree form experiment. Distances are indicated in metres. A=Spherical form, B=Wind hedge with mainly mechanical pruning, C= Wind hedge with hand pruning. CON stands for connection, which indicates that this treatment is the same as the treatment in the distance experiment, which means that the experiments are connected.

The spatial design of the experiment is shown in Figure 7. On each plot there are five hazels, the trees at the edge of each plot form a buffer between different treatments. There are a total of 12 treatments in the experiment, consisting of at least three pruning strategies and four plant configurations:

1. 1 row, common spherical form as in standard hazelnut cultivation (A)
2. 1 row, wind hedge model with mainly mechanical pruning (B)
3. 1 row, wind hedge model with hand pruning, and, if necessary, supplemented with mechanical pruning (C)
4. 2 rows, common spherical form as in standard hazelnut cultivation (A)
5. 2 row, wind hedge model with mainly mechanical pruning (B)
6. 2 rows, wind hedge model with hand pruning and, if necessary, supplemented with mechanical pruning (C)
7. 3 rows, common spherical form as in standard hazelnut cultivation (A)
8. 3 row, wind hedge model with mainly mechanical pruning (B)
9. 3 rows, wind hedge model with hand pruning and, if necessary, supplemented with mechanical pruning (C)
10. 1 row + wind hedge (CON-B), mainly mechanical pruning
11. 1 row + wind hedge (CON), alternative pruning 1
12. 1 row + wind hedge (CON), alternative pruning 2

CON stands for connection, which indicates that this planting is the same as the planting in the distance experiment, which means that the experiments are connected. The same pruning strategy is also applied in CON-B. The pruning strategy for the other CON treatments has not yet been decided.

7.2 *Planting and management*

Table 4 lists additional information on the tree form experiment. The trees are planted in the same way as the trees in the distance experiment and the trees and tree rows are managed in the same way as described for the distance experiment, with the exception of pruning. The rows are spaced 4.5 m apart to allow for mechanical pruning (3 m working width, 1 m tree width, 50 cm clearance).

Table 4| Overview of characteristics of the tree form experiment. Other properties of the experiment are the same as the tree row distance experiment.

Type of experiment	Randomized block design
Repetitions	3
Plot dimensions	126 x 173 m
Total area	1.84 ha
Length of tree rows	45 m
Arable crops	Various, organic management
Treatments	3*4 = 12 different treatments (see main text)
Planting year	End of 2021
Planting material mixed hedge	Spindles 200-250 cm
Varieties of hazel	*Corylus avellana* - 'Gunslebert', *Corylus avellana* - 'Gustav's Zeller' en *Corylus avellana* - 'Corabel'

7.3 *Monitoring*

The following aspects are monitored in the tree form experiment:

- The **labour requirement** for the hazel tree pruning strategies is recorded each year.
- The **growth of the hazels in terms of tree height**, is measured per individual tree each year in the autumn.
- **Yield of the hazels** is measured from three trees per plot. Starting when the trees begin production.
- '**Wind hedge rating**' for the extent to which the final desired hedge has been has been achieved: 100 cm wide, 500 cm high and closed. We are exploring the use of a digital method for measuring the optical porosity of the hedge.
- Extensive baseline surveys of **soil parameters** (not annually).
- **Carbon sequestration** in the trees (above ground), possibly using digital measurements (not annually).

8| Economics

Two farming systems will be compared for their economic viability. The reference farm is an organic arable farm with the same arable crops as in the distance experiment. The agroforestry farm is an organic arable farm with hazel as a woody crop. The agroforestry farm changes over the years to account for the growth of the trees and also the removal of the mixed hedge after a number of years.

The comparison includes any effects on the yields of the arable crops, as referred to in section 1.3 and both the costs and revenues of hazelnut production. Table 5 shows the key characteristics for the two farms, based on 15 hectares in production, with a 1 to 8 crop rotation plan. An average financial balance is drawn up for hazels from planting until removal, so that the costs and returns of hazels can be compared with an annual arable crop. This means that the costs of starting material and the planting costs (contract work) are divided equally over the calculation period of 25 years. This corresponds to the approach and principles as used in the Agroforestry Factsheet 4 – Economy. For the optimisation of this design in practice, we may explore various scenarios. For instance, if the costs for planting material were lower (relatively large planting material was used for the research facility in order to be able to measure effects more quickly), or if drip irrigation is omitted.

Within the project PPS Ontwikkkeling Businessmodellen Agroforestry (2022–2025) it will investigated which economically feasible designs exist within agroforestry, using the formula ((yield x price) + paid ecosystem services) – costs. The payment of ecosystem services refers to the (possible) financial compensation for providing ecosystem services, such as carbon sequestration. There may be instruments for commercialising ecosystem services that can increase the profitability of agroforestry systems. If this is also the case for the agroforestry experiment, this will be included as a scenario within the economic analysis.

Table 5| Overview of the defining farm characteristics for the economic comparison of an organic arable farm with an organic agroforestry farm.

Starting points	**Organic arable farming**	**Agroforestry system**
Crops	12.5% consumption potato, 12.5% peas, 25% winter wheat, 12.5% seed onions, 12.5% carrots, 12.5% white cabbage (industrial) and 12.5% spinach	11.5% consumption potato, 11 .5% peas, 23.1% winter wheat, 11.5% seed onions, 11.5% carrots, 11.5% white cabbage (industry) and 11.5% spinach, 1.03% Hazelnuts, 6.7% service row
Source data	KWIN-AGV 2022	KWIN-AGV 2022, Agroforestry factsheet 4 and data of the experiments
Calculation period hazels	-	25 years
Yield (full production)	-	2.500 kg/ha
Price hazelnuts	-	3.50 EUR/kg

9| **Closing remarks**

Some aspects of the trial are still under development; what is described in this factsheet is what is currently known (autumn ‘22). Protocols and treatments may change slightly over time. Familiarity with agroforestry and the developments within agroforestry (such as the emergence of regional networks and the emergence of consultancy firms) have increased enormously in recent years. However, agroforestry remains a 'long-term cultivation', trees take years to reach their full size and it will take years before the agroforestry facility, which was started in 2021, has matured and final conclusions can be drawn for this system. Nevertheless, the researchers expect that they will be able to report the first results on microclimate effects and describe trends within four years

The intention is that the agroforestry research facility will remain in existence for at least 15 years, and if the outcome is positive, it may be expanded and/or continued after those 15 years. It is possible that the monitoring of the distance and tree form experiments will be expanded over time, depending on the available funding. The agroforestry facility is also available to external parties to carry out research. Suggestions and collaborations are welcome.

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Authors | Isabella Selin-Norén & Maureen Schoutsen

Translation | Andrew Dawson
With the cooperation of | Dirk van Apeldoorn, Rien van der Maas, Maria-Franca Dekkers & Marcel Vijn

Design | Caroline Verhoeven

Front page | Joris van der Kamp | Future Farmers Film Productions. Agroforestry plot in Lelystad Wageningen University & Research

Contact |
Wageningen University & Research | Open Teelten
E | maureen.schoutsen@wur.nl T | +31(0)320 29 16 40
E | isabella.selinnoren@wur.nl T | +31(0)320 29 11 74

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