A food forest design

For farm estate De Koekkoek on behalf of the Farm Life project

A bachelor thesis report presented by
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Summary

The effects of climate change have resulted in more extreme weather events over the past decades, such as extended periods of drought and heavy rainfall. These extreme weather events have led to substantial crop damage and failed harvests. Current agricultural systems within the Netherlands, in where monocultures are often the standard, are often considered to contribute to this problem. Such systems are often based on environmentally unfriendly and unsustainable agricultural practices, such as the extensive use of herbicides and chemical fertilisers. More and more farmers recognise these problems and realise that there is a need for more environmentally beneficial and sustainable agricultural practices. Hereby, farming systems that are based on natural principles such as agroforestry are a possible solution. However, more knowledge is needed to explore the potential of such systems within temperate climates such as The Netherlands.

This report is written in behalf of the project Farm LIFE, part of the funding instrument of the European Union (EU) for environment and climate action. Within this project, University of Applied Sciences Van Hall Larenstein and other partners collaborate to develop sustainable and climate adaptive agroforestry systems for three farms in the Dutch province of Noord Brabant. Within this project, special attention was paid to the concept of food forests. Food forests are agroforestry systems that consist of multiple vegetation layers, containing a high number of edible perennial plants. These systems are known for having a high biodiversity, ecological resilience and productivity.

The objective of this report was to develop a food forest design plan for one of the farms that is included in the Farm LIFE project, of which farm estate 'De Koekkoek' in Drimmelen was selected for this purpose. The design was designed to be adopted to the given site conditions and to meet the objectives and needs of the farmer. Accordingly, the following main research question was assessed;

"How can a climate adaptive food forest design for farm estate De Koekkoek be developed that fulfils the purpose of being;

- Site adopted
- Adopted to the needs of the farm owner''

To answer this question, multiple steps were taken towards the final design. Initially, a survey was conducted, that focussed on the site conditions and the objectives and requirements of the farmer. These results were analysed and used to make decisions about the species that could be selected for the food forest. The selected species were selected based on their ability to grow on the circumstances of the farm site, the needs and requirements of the farmer and laws and regulations. The final step was to implement the selected species in a design layout, by using the design principles of a food forest as described in the book 'Creating a Forest Garden' by food forest expert Martin Crawford.

However the site conditions and needs of the farmer were taken into account seriously and decisions were taken based on related criteria, the food forest design presented in this report is just an example of how a food forest could be designed, and no rights can be derived from this report. The final decision to use this design or take other decisions is up to the farmer. At least, the result of this report will be a contribution to improved knowledge and inspiration within the Farm LIFE project and can be used as an inspiration for establishing a food forest.

Acknowledgements

This Bachelor thesis report cold have not been completed without the supervision and guidance of my supervisors Hans van den Dool, who always patiently gave me feedback during the whole process. I am very grateful to Matthijs Pleijter, who helped me when doing the soil sampling on the farm sites, and patiently answered all my questions during the sampling days. Special thanks I also want to address towards Valentina Secchi and Sieger Broers, who gave me valuable advice and feedback about how to process the data obtained from the soil analysis. I want to thank Euridicie Leyequin for giving me the opportunity to do my thesis on behalf of the Farm LIFE project and for providing all essential information. Of course, the farmers that I made the design for, Marc and Pipie Smits van Ooyen. should also be mentioned here. Their hospitality, friendliness and creative input made it a pleasure to work together within this project. To conclude with, I want to thank all the other interesting and enthusiastic people I met during the meetings of the Farm LIFE project. There were too many to mention them all, but their presence and valuable input was of a great importance during the whole process towards the finalisation of this report.

Signed,

Jip Jan Hulshof

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1. Introduction

1.1 Framework and aims

Since the start of the industrial revolution, climate change has led to an increase of the average world temperatures by 0,8 degrees Celsius, and within the North-western Europe region even with 1,5 degrees. The rapid increase in greenhouse gas emissions by human practices, such as Carbon dioxide (CO_2), are believed to be the main cause of this trend. (WUR, 2019). However, there is a certain margin of uncertainty, most future climate scenarios predict that these trends will continue or even increase, if no further action will be taken to reduce greenhouse emissions in the future. (Vonk, Vos, & Van der Hoek, 2010). Within the Netherlands, the effects of climate change have led to an increasingly unpredictable climate with more extreme wetter patterns, such as prolonged drought and extensive rainfall. A recent example of such extremes took place in the summer of 2018, in where prolonged drought and heat caused serious damage to crops on agricultural fields and lead to failed harvests on a large scale (INFRAM, 2019). The scale of this damage also needs to be seen in relation to agricultural and land use practices. Current agricultural practices are often focussed on large scale, input-oriented monoculture cropping systems. Unsustainable land use and the deployment of heavy machinery within such systems, has led to soil compaction and a gradual decline of organic matter. This has resulted in a decreasing soil life and an a decreasing water and nutrient retention capacity of the soil, which make crops more vulnerable for pests and extreme weather events (Hijbeek, 2017). Thereby, research in German nature reserves has indicated that the total biomass of flying insects had declined by around 75 percent between 1959 and 2016. There are strong indications that this rapid decline is partly the result of the extensive use of pesticides and chemical fertilisers, which is often common sense in traditional monoculture cropping systems (Kleijn et al, 2018).

In 2018, the Dutch government has presented a report in where a transition to more climate resilient, circular agriculture is advocated. Circular agriculture is a form of agriculture in where natural resources on agricultural lands will be managed sustainably, without external inputs such as chemical fertilisers or pesticides. The ambitious goal has set that The Netherlands should become a global leader in circular agriculture by 2030. To achieve this objective, some general criteria are mentioned. Accordingly, farmers should get a fair price for their products, by focussing on sustainable and diverse crop production. Also, the 'distance' between producers and consumers of agricultural products should be decreased, and the production of locally and organically produced food should be favoured. Therefore, it is essential to develop ago-ecological farming systems in which these criteria are implemented. (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2018).
One of the agro-ecological farming systems that are believed to have a high potential within the Dutch agriculture are food forests. A food forest is a climate resilient, agro-ecological farming system that is based on the principles of a natural forest ecosystem. Since this system builds up fertility by following the principles of natural succession, external inputs are not required (Raabe, 2017). Depending on the needs of the owner, there is a large variety of products that can be grown in a food forest. Food forests are very old farming systems, that were already in use by the Mayans between 8000 and 4000 before Christus (Ford & Nigh, 2009). Currently, most food forest systems are present in the tropics, but there are also possibilities to use them in temperate climates. Although food forests are not yet common in temperate climates, there recently is a growing interest in these systems within The Netherlands. In 2017, the Dutch government, policy makers and facilitating parties signed the agreement of the 'The Green Deal Voedselbossen' (Green Deal Food forests). The main objectives within this agreement is to optimally organize legislation and regulation for food forest establishment and to exchange practical knowledge about food forests in an efficient way with a professional knowledge structure. (WUR, 2018).

1.2 The farm LIFE project

This report will focus on the project Farm LIFE, which is part of the funding instrument of the European Union (EU) for environment and climate action (EU, 2018).

Within this project, Van Hall Larenstein University of Applied Sciences and other parties collaborate to develop and demonstrate innovative adaptation technologies and approaches for the transition of conventional agriculture towards climate resilient agro-ecological systems on 32 hectares of farmland, distributed over three different farms in the Dutch province of Noord Brabant. Besides of being climate resistant, these systems also need to be beneficial for socio- economic development and environment and biodiversity. The farms are in Drimmelen (Estate 'De Koekkoek'), Alphen (Kwaalburgse hoeve) and Sint Oedenrode (Bosboom B.V.). The farms were selected for the project because of the interest of their owners in sustainable farming systems such as food forests. The systems that will be developed will function as a test case for the farmers within the project and can also be used as a source of inspiration for other farmers.

1.3 Objective

The objective of this report is to present a food forest design plan for one of the farms that are part of the Farm LIFE project, whereby clarification about the underlying design process will be provided. Besides of being climate resilient, the food forest design should also fulfil the purposes of being site adopted and correspond to the objectives and needs of the farm owner. Of the three farm locations, farm estate 'De Koekkoek' in Drimmelen was selected for this purpose, since the owner of this farm had most concrete plans to realise a food forest on his land. The farmer has four potential farm sites available, of which the one with the best possibilities for the realisation of a food forest will be selected to make a design for.

1.4 Research questions

In line with the objective of this report, the following main research question was formulated:

"How can a climate adaptive food forest design for farm estate De Koekkoek be developed that fulfils the purpose of being;

- Site adopted
- Adopted to the objectives and needs of the farmer''

To answer the main research question, the following sub-questions were answered;

1. What are the main concepts of a food forest and its advantages compared to monocultures?

2. What are the site properties and site conditions of the farm sites?

3. What are the objectives and needs of the farmer?

4. What species will be selected for the selected farm site, that are adopted to the site conditions and the objectives and needs of the farmer?

5. How could the final design look like, while considering the site conditions, the requirements of the farmer, and the design principles of a food forest?

1.5 Reading guide

In **chapter 2** the methodology that is used to answer the research questions is described. **Chapter 3** describes the result of a literature study that will give a better understanding about food forests and their benefits. **Chapter 4** will discuss the site properties and site conditions of the farm sites, and **Chapter 5** will provide information about the objectives and needs of the farm owner. In **Chapter 6**, a selection of species will be presented that is based on the results of the site properties, site conditions and the objectives and needs of the farmer. The final design is described in **Chapter 7.** In chapter 8 a discussion is included, in which a critical reflection on the results is given. **Chapter 9** contains the conclusion and additional recommendations for further research.

2. Methodology

2.1 Focus area

The focus area of this report is estate 'De Koekoek', an organic farm located in the province of Noord-Brabant and owned by farmers Marc and Pipie Smits van Ooyen. In total, the farmer assigned a total area of 17,7 hectares for the Farm Life project, divided over four farm sites that range from 1,6 to 12,3 hectares. The sites are currently being used for various purposes, including forest, agriculture, and pasture. A map of the site locations is provided in Figure 1. Further information about site characteristics will be provided later in this report.

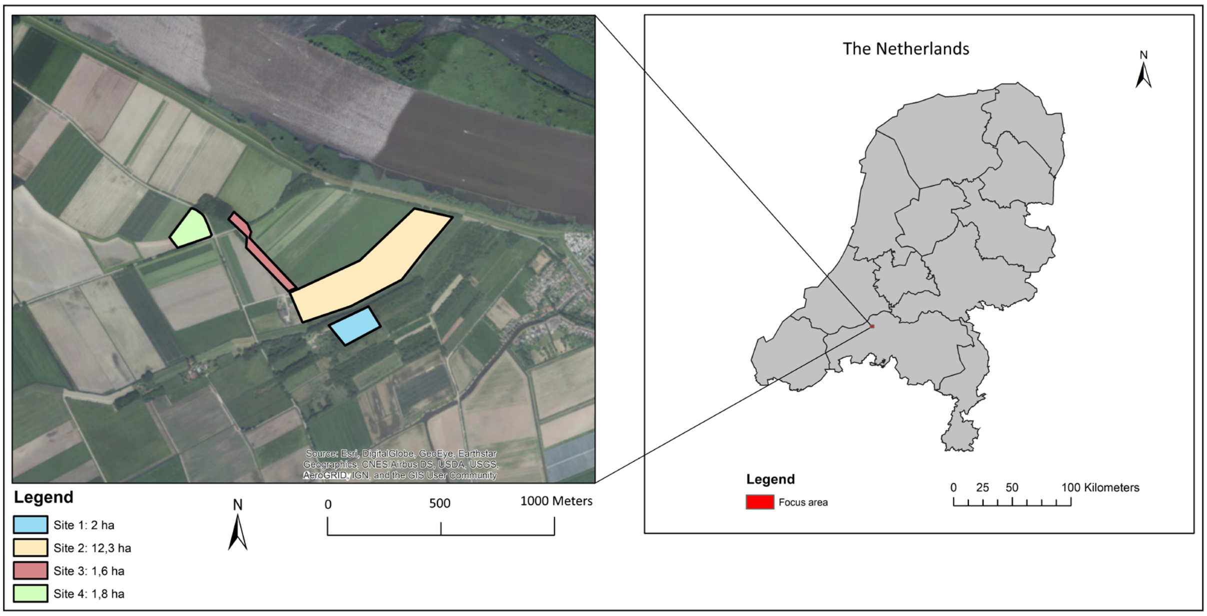

Figure 1: *Focus areas*

2.2 General approach

Designing a food forest is a comprehensive task and therefore it is essential to have a clear structure of the required steps taken to fulfil this objective. As being a common approach for designing agroforestry systems such as food forests, a clear approach was used that is based on four steps; <u>Survey</u>, <u>Analysis</u>, <u>Species selection</u> and <u>Design</u> (Whitefield, 2012). An overview is presented in Figure 2. The survey was the first step in this process, in were a literature study to food forests was conducted and information about the site conditions and client requirements of the four farm sites was collected. The results of this survey were analysed to decide what farm site would have the best possibilities for the realisation of a food forest, and to select suitable plant species for that location. Eventually, the selected plant species were used to make a food forest design for that farm site.

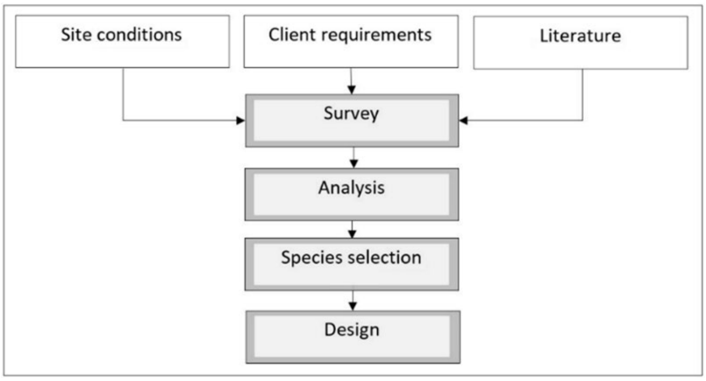

***Figure 2**: General design approach*

2.3 Literature survey

To provide insight in the subject of food forests and their benefits, a literature study was conducted. Although there is a lot of sources available about natural temperate ecosystems, it was not easy to find relevant scientific information about food forests. This is caused by the fact that not much scientific research has yet been conducted to food forests in temperate climates. Information was collected by doing internet research and reading books and articles. The key words that were used to find relevant information on the internet are ‘food forests’, ‘agroforestry’, ‘agroforestry systems’ and ‘permaculture’.

Even though there are lots of books about agro-ecological systems, there are just a view that are focussed on temperate food forests. The books that are most well-known on this topic are “Creating a Forest Garden” from Martin Crawford (Crawford, 2010), “Restoration Agriculture” from Mark Shephard (Shepard, 2013). Both authors are widely renowned on the field of food forestry in temperate climates. Therefore, these sources were considered most suitable for collecting information about this topic.

2.4 Site survey and analysis

The objective of a site survey is to collect information that gives insight in possibilities and limitations for plant growth. Requirements for plant growth are determined by two main factors; climate and soil conditions (Den Ouden et al., 2010, p. 134). In this chapter, the steps taken to collect and analyse the data for both of these factors will be described.

2.4.1 Climate

Regarding to climate, temperature and precipitation are the most important parameters for plant growth (Den Ouden et al., 2010, p. 135). To give an indication of temperature for plant growth, the USDA hardiness zone was used as a guideline. This system is developed by the U.S. Department of Agriculture and is based upon the average annual minimum temperature of a given area. (Raabe, A food forest design process for the showcase food forest “Den Food Bosch” on Bleijendijk, Vught, 2017). All farm sites in Drimmelen are allocated in the hardiness zone 8a, which means that the average annual minimum temperature lie within the range of -6.7°C to -17.7°C. The USDA hardiness zone does not give all climate information, as it does not include highest temperatures, and amount and patterns of precipitation. Nevertheless, it is considered suitable to provide a general indication of possibilities for plant growth.

2.4.2 Soil conditions

The most important criteria for plant selection regarding to soil conditions include soil moisture, soil texture, soil acidity and its availability of nutrients to support plant growth (Den Ouden et al., 2010, p. 136). Thereby, it is also important to gain insight in the overall condition of the soil. To gain insight in these indicators, both on site analysis and laboratory analysis were conducted. The corresponding methods used are described below.

Soil profile

The soil profile provides important information about soil formation, and soil properties as texture, moisture regime and soil richness. The soil map of the Netherlands (1:50.000) can be used as a global interpretation of the soil profiles within the sites. However, field sampling provides a more accurate insight. Therefore, soil profiles were taken in the field and classified by using the manual of "Bodemclassificatie van Nederland" developed by Bakker and Schelling (De Bakker & Schelling, 1966)

To get insight in the moisture regime, actual groundwater levels (GWS) were measured, and the mean highest groundwater level (GHG) and the mean lowest groundwater level (GLG) were estimated. Based on this data the ground water table (GWT) was determined (see Appendix I). Furthermore, the rootable depth for vegetation was estimated by using a penetrologger. At least one soil profile was taken at each site; the number of profiles taken varied per site and were estimated based on field size and heterogeneity. All samples were randomly taken at locations that were considered to be representative. Accordingly, samples were taken at a distance of at least 10 meters from the site border and driving tracks and other local deviations were avoided. For an overview of the sample locations, see Appendix II.

Soil condition

To determine the soil condition, the 'Bodemconditiescore' (Soil Condition Score) was used, this method was developed by Wageningen University and Boerenverstand to give farmers a better insight in the condition of their soil and how to improve it. It has been proven to be a very useful addition to chemical soil analysis (Koopmans, Zanen, & Ter Berg, 2005). An expert from Aequator was hired to improve the accuracy of the measurements in the field.

The method includes the following steps. Initially, a hole of 50 x 50 cm was dug, until a depth of 40 cm. Second, the soil was analysed by measuring eight criteria, including; soil acidity, soil structure, earthworms, symptoms of gley, rooting, soil colour, ploughing sole and crop cover. Each of these criteria were assessed (2 = good, 1 = moderate and 0 = poor). The method used to determine these criteria can be found in the manual of mijnbodemconditie.nl (mijnbodemconditie.nl, 2013). Eventually, the scores of all criteria were combined to calculate the overall soil condition score. The minimum score is 0 (very poor), and the maximum score 42 (very good), as shown by Figure 3. All the soil condition score samples were taken at the same locations as the soil profiles, in order to make it easier to correspond the soil profiles with their soil condition (see Appendix III).

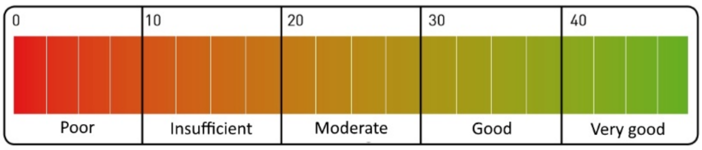

Figure 3: *Soil condition score range (mijnbodemconditie.nl, 2013)*

<u>Nutrient balance</u>

To gain more insight in the nutrient balance of the soil, field samples were collected and analysed in the laboratory by Eurofins. This company is leading in the field of soil analysis on agricultural fields.

Only samples of the upper 30 cm of the soil were taken, since this is where most nutrients and plant roots are present. At each site, 20 samples were taken randomly but well distributed over the area and were mixed into one sample for laboratory analysis. The results of this analysis can be found in Appendix IV. As one can see, this overview is very comprehensive. Therefore, the decision was taken to focus on the most important main soil parameters and nutrients when designing a food forest, as adopted from food forest expert Anastasia Limareva (Limareva, 2015).

- Main soil indicators

- Soil texture (% lutum, % silt, % sand)
- pH-value
- Organic matter (% organic matter, C/OS-ratio)
- CEC (Cation Exchange Capacity)

- Plant-available nutrients

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)

Except of soil texture and organic matter, Eurofins has included an optimal range for each of these soil parameters, which ranges from 'low, moderately low, good, high to 'very high'. A shortage (low – moderately low) or surplus (high – very high) may lead to reduced plant growth or even mortality. This optimal range is relevant for agriculture and horticulture and can therefore not be directly linked to requirements for individual species. However, it still be used as a useful indicator for overall soil conditions. Regarding to nutrient availability this report will mainly focus on those that are plant available nutrients rather than the part that is stocked in the soil, since nutrient stocks are rarely limiting and plant available nutrients determine the possibilities for plant growth (Ros, Reijneveld, Bussink, Abbink, & Van Rotterdam, 2014).

2.5 Client survey and analysis

A client survey was undertaken to get insight in the needs of the client, in this case the farmer. Within this survey, the following aspects were analysed;

- The objectives and limitations of the farmer
- The main focus of the farmer (commercial, environmental, social)
- Relevant regulations and subsidies that should be taken into account
- The main functions that should be included in the design according to the farmer

Information about the objectives and limitations, the main focus, and relevant regulations and subsidies was collected from a scoping report, and during various workshops organised by the Farm LIFE project. During all these meetings, the farmer and multiple experts in the field of agroforestry were present, depending on the topic that was discussed.

To decide on the main functions that should be included for each farm site, Marco Bijl from the Forest Service group (FSG) was invited for a special workshop with the farmer. Within this workshop a card game was used, in where each card shows a specific function that could be included. Altogether, the 49 functions were included, which each belong to one main focus group; commercial, environmental or social. Hereby ‘commercial’ was subdivided in ‘bioproducts’ and ‘ecoservices’. Bioproducts include functions that can deliver a direct profit, while ecoservices include functions that can indirectly deliver additional income sources trough ecosystem services. Environmental functions include functions that are directly linked to protect and improve natural values without the direct goal of making profit. Social functions deliver direct social benefits for the society, such as creating employment and working with disabled people. An overview of all 49 functions included the three focus groups including their definition is added in Appendix V. For each field, the farmer decided which functions would be potentially interesting and feasible for his farm sites by laying the corresponding cards on the table (see Figure 4). This process was supported by experts from the Farm LIFE project, including a biodiversity expert, a marketing expert and undersigned.

Figure 4: *Cards with functions selected by the farmer*

2.6 Species selection

The selection of suitable plant species is a major question when developing a food forest system. Hereby, it is important to select species that are adapted to the site conditions and also being useful for the farmer and the environment. To simplify this process, a database was created in excel that includes all plant species within the assortment of Arborealis, a grower specialised in food forest plant species. Additionally, species that were discussed during the meetings of the farm LIFE project were added. Altogether, 55 tree species, 46 shrub species and 30 perennial plant species were included in the database. Thereafter, species specific information was added regarding to site requirements, commercial functions and environmental functions. This information was obtained from pfaf.org, a large online plant database that contains relevant data from over 7000 plant species (Plants For A Future, 2019). Since the database with all species was too extensive to include in this report, an example is provided in Appendix VI.

The criteria for plant species selection were based on the results of the site conditions survey and the needs and objectives of the farmer. An explanation of the corresponding criteria used for both steps is given below.

Site requirements

The site requirements that were focussed on include climate and soil conditions. Since the Hardiness zone of the Netherlands is 8a, only species having a range within or below this zone were selected. Because climate conditions within the Netherlands are quite homogeneous, soil conditions are considered being the main limiting factor regarding to species selection (Den Ouden et al., 2010, p. 136).

As mentioned before, The most soil properties for species selection include texture, (chemical) soil fertility, soil acidity and moisture regime (Den Ouden et al., 2010, p. 136). To get insight in which species are suitable for the farm sites, plant soil requirements were linked to the results of the soil analysis. These plant soil requirements were obtained from pfaf.org and include four main criteria; soil texture (light, medium heavy), soil moisture (dry, moist, wet), soil acidity (acid, neutral, basic) and soil richness (poor, medium, rich). Weather and how these criteria were linked to the results of the soil analysis is explained below.

- Soil texture
  To match soil texture plant requirements to the sites soil texture, the results of Eurofins were used since those are considered to provide the most representative overview of the overall soil texture. The criteria 'light' was linked to sandy soils, the criteria 'medium' to loamy soils and the criteria 'heavy' to clay soils.
- Soil moisture
  The groundwater levels as measured in the field were used as an indication of soil moisture, as adopted from R. Bergevoet who has developed a plant selection tool for Sweco (Bergevoet, 2019). As an underground rooting space of 1 meter for most trees is preferred, groundwater levels from I – III were classified as 'wet'. Soils with a GHG of more than 80 cm (GWT VII and lower) were classified as 'dry'. The ground water levels in between were classified as 'moist'.
- Soil acidity
  Acid soils were classified as having a pH lower than 5,5, neutral soils between 5,5 and 6,5 and basic soils higher than 6,5. Accordingly, the criteria 'acid' include soils with a pH lower than 5,5, 'neutral' with a pH between 5,5 and 6,5 and 'basic' having a pH higher than 6,5.
- Soil richness
  Soil richness is based on nutrient availability, which is determined by processes such as the absorption of nutrients on the CEC complex (K, Ca, Mg, Na) and the conversion of organic matter (P, N, S) through soil life. Therefore, a simple measure to determine soil fertility does not exist. The target values for various nutrient levels provided by Eurofins do not provide information about plant-specific requirements. Therefore, these target values cannot be used as an indication for soil fertility and not be directly linked to the soil criteria obtained from pfaf.org. Thereby, soil acidity and soil texture already are good indicators of soil fertility (Bunemann, et al., 2016). For those reasons, the decision was taken to not include soil fertility as a criterion for species selection.

Client requirements

In order to select species that meet the farmers requirements, the commercial and environmental functions that were selected by the farm owner (see Chapter 2.5), were used as criteria for further preselection of site adapted species. Species were only selected when they support at least one function selected by the farmer. The collected species information at pfaf.org was used to find what functions are supported by each species, where after this information was linked to the functions that were selected by the farmer. Since pfaf.org did not contain species specific information about all the functions as described in Chapter 2.5., only the relevant functions that could be obtained by pfaf.org were used for selection (See appendix VI). Besides of being a contribution to the functions that the farm owner has selected, species were also analysed on possible risks. Species that are known to be very sensitive to pests and diseases were not selected, as well as species known for being invasive. This information was collected by literate research. Eventually, additional limitations that came up during the workshops were taken into account.

2.7 Design

In the design phase, the results of the site condition analysis, the client analysis and the species selection were used to develop and present a viable food forest design for the site that was selected for having has most potential for the establishment of a food forest.

Design principles

Food forest expert Martin Crawford points out that “a forest garden is not a closed canopy forest; it is more a young establishing forest, where there are plenty of gaps between trees and shrubs to allow light in.” (Crawford, 2010) According to this vision, the food forest design should preferably follow the ecological processes of natural succession within an ecosystem, which is a complex and comprehensive task. The selected species should be combined carefully so they do not negatively affect but complement each other. Furthermore, a design that is manageable for the farmer was aimed for, what means that harvesting and maintenance can take place effectively. The design principles within the book ‘Creating a Forest Garden’ from Martin Crawford (Crawford, 2010) gives a clear description of how to implement and combine these principles, and was therefore used as a guideline for decision making.

Design layout

Whether to design the design layout by hand or with software design programs is an individual question of skill and preference. In this report, the design was done by computer. The programme ‘Realtime Landscaping Architecture’ was used to make the layout, since it is easy in use and it includes functions to work on scale efficiently. Also, it is easy to make adjustments when needed. This is a main advantage, since designing a food forest is a creative process in where adjustments are often made. Initially, a base map of the existing situation was created. This map shows factors that should be taken into account while designing the system, such as existing vegetation and roads, the main wind direction, and differences in elevation. This map was taken as a basis to make the final design layout, which shows where the different vegetation layers and other important elements will be situated.

3. About food forests

This chapter provides a general introduction into the field of food forests. Initially, the definition of food forests will be explained, where after their advantages towards traditional systems based on monocultures will be further discussed.

3.1 What are food forests?

As already mentioned in the introduction, food forestry is a form of agroforestry. In its most basic form, agroforestry is defined as agriculture with trees. A more detailed definition is given by the Food and Agriculture Organization of the United Nations (FAO), which is the following;

"Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components". (FAO, 2015)

Accordingly, agroforestry systems can be roughly divided in three groups. Between those groups many combinations are possible.

- **Alley cropping:** These systems are known as silviculture in Europe. This is a system in where trees are planted in lanes combined with perennial or annual crops
- **Silvopasture:** These systems are also known as agrosilvopastoral agroforestry systems. These systems are based on trees combined with pasture and livestock
- **Forest farming**: Cultivation of crops crowing in a system with a forest overstory by which a suitable microclimate is created

Of these three groups, food forestry fits best within the field of forest farming. Since there is a large range of forest farming approaches, it is a challenge to obtain a more concrete view of what criteria a food forest should meet. One of the most common definitions was developed by Food forest pioneer Robert J. Hart. Based on personal observations of natural forests, he developed a framework for food forest structures that can be used as a guideline (Limareva, 2014). According to this framework, a food forest is based on seven vegetation layers, containing species that support each other to create a productive, resilient and healthy ecosystem (see Figure 5).

- **Canopy layer**
  - Medium to large canopy trees (> 10 meters high):
    These are large trees forming the upper layer of the food forest, such as walnuts.
  - Small trees and large shrubs (4-9 meters high):
    This layer contains lower trees and large shrubs such as small fruit trees.
- **Shrub layer** (max 3 meters high)
  This layer contains many shrubs that provide berries, nuts or other services. Examples include Hazelnuts, Red currants and Blueberries.
- **Herbaceous layer and ground cover layer** (0-3 meters high)
  These two layers merge with each other and includes shade tolerant perennials or low creeping shrubs.
- **Vertical layer**
  This layer includes perennial vines and climbers, which can be grown against trees.
- **Root layer**
  This layer includes root crops, which need to be dug up to harvest them.

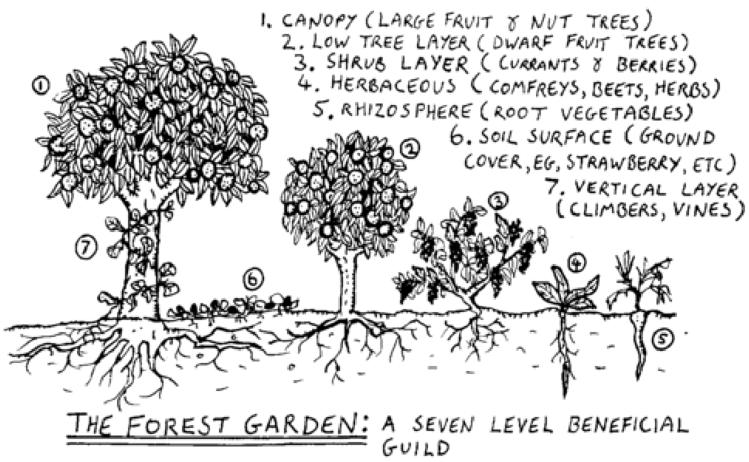

Figure 5: *The 7 layers within a food forest (Barth, 2019)*

However not all above mentioned layers need to be included in a food forest, including them all leads to a highest resilience and productivity within the system. The final choice of what layers will be included is dependent on the objectives of the user and present site conditions such as the size of the land, soil conditions and available budget (Limareva, 2014).

With the agreement of the Green deal of Voedselbossen (see Chapter 1.1), a more detailed definition was developed, which contains several criteria that a food forests system should meet. According to this definition, a food forest should meet the following criteria (WUR, 2018);

- A human designed productive ecosystem, based on a natural forest, with a high diversity of perennial and/or woody species, of which parts serve as food for humans.
- Presence of a crown layer or higher trees.
- Presence of a crown layer and at least three other vegetation layers
- No external inputs of chemical fertilisers
- No cultivation of annual crops and no livestock within the area
- Having a continuous area of at least 0,5 hectares

Since this is the most concrete and official definition of food forests that is available so far, it will be used as a guideline in this report.

3.2 What are the benefits of food forests?

Food forest systems provide multiple benefits compared to traditional forms of agriculture based on monoculture systems. Food forest pioneer Eric Toensmeijer has noted the main benefits that can be fulfilled by multistrata agroforestry systems such as food forests. (Jacke & Toensmeijer, 2005). These benefits include:

- Resilient and self-maintaining ecosystems
- Diverse production of high-nutritious foods and other useful products
- Ecosystem protection- and restoration
- Improving mental health
- Contributing to economical sustainability

Resilient and self-maintaining ecosystems

It is known that forest-based systems in where multiple species grow together have a much higher resilience to weather extremes than monocultures. Therefore, food forests can be considered as a response to the treats of climate change and contribute to food security in the future. Susceptibility for drought and flooding is minimised in a food forest, since the soil is permanently covered with plants which provide increasing levels of organic matter (Crawford, 2010). In food forest Ketelbroek, the oldest and most well-known food forest within The Netherlands, levels of organic matter increased from 2% to 9% in a time span of 15 years after it has been planted. Organic matter has a high capacity to absorb water and nutrients and is therefore important for plant growth and plant vitality. The rapid increase in organic matter within a food forest also leads to the capture of carbondioxide (CO_2), since roughly 50% of the organic matter consists of organic carbon (Lievense, 2019). In his book “The carbon farming solution”, Eric Toensmeijer claims that multistrata agroforestry systems such as food forests have the best carbon sequestration rates of all food producing systems, which are 10 to 40% higher than annual crop production systems and managed grazing systems (Toensmeier, 2016). According to this fact, food forests thus also have a great potential to contribute to climate mitigation.

Since the forest follows the processes of a natural forest ecosystem, it will take care of itself and no external inputs such as chemical fertilisers and pesticides are needed. If the ground cover layer of perennial plants in a food forest is well established, weeding is minimal since weeds do not have much opportunities to establish. Trees and shrubs need little maintenance apart from occasional pruning (Crawford, 2010).

Diverse production of high-nutritious foods and other useful products

Research has indicated that in the period of hunters and gatherers, people consumed around 200 and 1000 different plant species each year (Fern, 1997). A healthy diet for people contains a large variety of different food sources, which include proteins and carbohydrates. Besides that, it should contain nuts, berries, seeds and herbs, since they provide essential micronutrients. Currently, only 12 plant species provide 75% of our total plant based food supply as shown by the results of a study conducted by Harvard University (Chivian & Berstein, 2010). Since a food forest can potentially deliver a wide range of plant products that provide essential micronutrients, it could contribute to a more diverse diet and healthier diet.

Ecosystem protection- and restoration

An ecosystem can be defined as a group of biotic factors (plants, animals and other organisms) and abiotic factors such as soil, water and air that work together within a system. The health of an ecosystem can be defined as its resistance and its ability to recover after it has been damaged (Limareva, 2014). Since food forests are based on natural forest ecosystems, there are many ways of how food forests could contribute to create and improve healthy ecosystems. This is especially relevant in suburban and agricultural areas where ecosystem health is often relatively low. Some of the services of food forests towards ecosystem protection and restoration that are offered by are pointed out below (Leopold, 1966);

- Improving habitat functions for plants, insects and wildlife, in areas where ecosystems are under pressure
- Improving ecosystem services such as increased water holding capacity, the storage of biomass and nutrients, erosion control and increased abundance of soil life
- Food forests provide locally grown products, which have a lower impact on the environment since they do not need to be transported over large distances.

Since biodiversity increases when a system gets more complex, food forests usually have a higher biodiversity that agricultural field with monocultures. An interesting study conducted by students of Van Hall Larenstein in Velp in show that the biodiversity of insects and birds in food forest Ketelbroek is similar to nearby nature reserve “De Broek” (Breidenbach & Dijkgraaf, 2016). This underlines the fact that well designed food forests are healthy ecosystems with a high biodiversity.

Improving mental health

As food forest is a diverse natural system that contains many plants and wildlife, such an area could be a place for people to take a break from the crowded city life and bring them more in contact with nature. Research conducted by the University of Derby has shown that there was a scientifically significant increase in people’s health and happiness after they had conducted nature related activities such as feeding birds and planting flowers for trees, and that this effect even sustained for months after this activities took place (Richardson, Cormack, McRobert, & Underhill, 2016). A food forest could also be a place where such activities could be organised, as planting, harvesting and many more.

Contributing to economical sustainability

In the beginning, the initial investment of time and money is required to establish a food forest is much higher than that of a regular monoculture system. However, once it is established it is low in maintenance, and its productivity and economic value will only increase over the years. In his book "Restoration Agriculture", Mark Shepard claims that the average yield of corn fields per hectare is 1,5 times less than that of well managed food forest systems (Shepard, 2013). Besides this, well designed food forests have a high resistance against weather extremes as drought and heavy rainfall, which decreases the possibility of failed harvests. One of the advantages of food forests are that they can be designed around the requirements of their users, and since no pesticides are used in a food forest, everything is produced organically. Since there is a growing interest in organic products over the last years, this could be a market that is economically interesting.

4. Site conditions

In this chapter, an analysis of the site conditions will be presented. Since climate is already considered implicitly (see Chapter 2.4.1.), only the results of the soil conditions will be discussed. To provide a general introduction and better understanding of the soil conditions, geomorphology and land use will be discussed first. Consequently, the results of the soil field analysis and laboratory soil analysis will be focused on.

4.1 Geomorphology and Land use

Below, the geomorphology and land use of the farm sites will be discussed. This information was collected by desk research, field visits and personal communication with the farm owner.

Geomorphology

The geomorphological situation of the area is shown in Figure 7, and is obtained from the geomorphological map of the Netherlands downloaded from PDOK (pdok.nl, 2019). The different features of this map are explained below.

The geomorphological situation in where the four farm sites are situated is characterised by very young sediments of clay, and sabulous clay on degraded peat, known as the ‘’formation of Tiel en Duinkerke’’. Before the year 1421, are large part of the area was covered by extensive peat swamps, crossed by tidal creeks. A big flood in 1421, known as the “Elizabethsvloed” totally changed the landscape and its geomorphological processes. The influence of the rivers increased, causing degradation of the peat landscape and deposition of clay, sabulous clay and sand on the remaining peat layers. In this process, clay and sabulous clay were dominant. This process continued until human gradually reclaimed the land by building dams, regulating natural creeks and draining the land (Damoiseaux & Vos, 1987, p. 27). This process is shown by a timeline of historical maps obtained from Topotijdreis.nl (topotijdreis.nl, 2019), see Figure 8. On the elevation map (see Figure 6), it is visible that the whole area is low lying and quite flat, the only relief is formed by the dams that were constructed. After the land was reclaimed, it has been used for various purposes, which are discussed in the next paragraph under “landuse”.

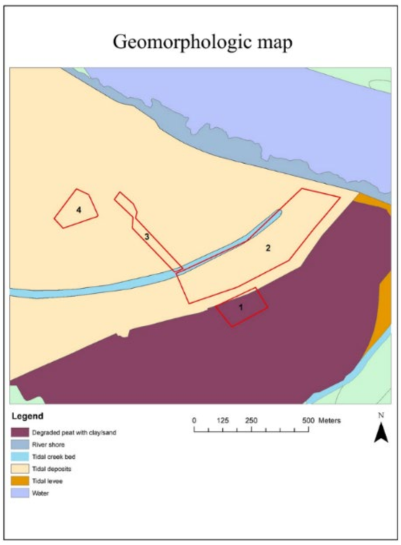

Figure 7: Geomorphological map (pdok.nl, 2019)

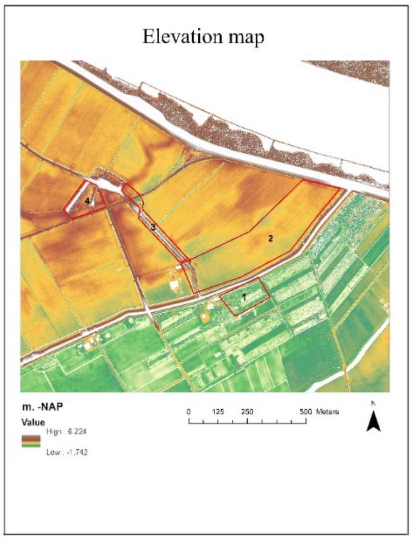

Figure 6: Elevation map (pdok.nl, 2019)

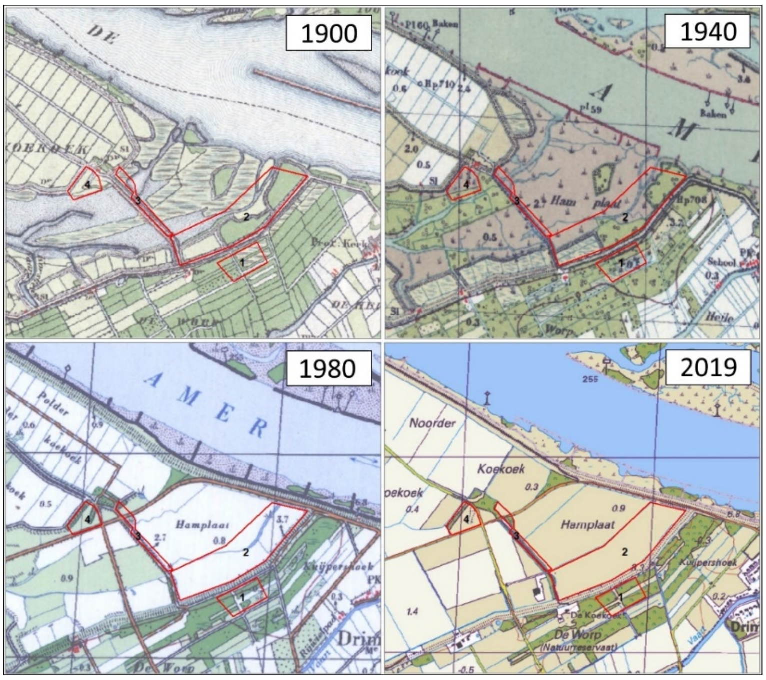

Figure 8: Timeline of historical maps (topotijdreis.nl, 2019)

Land use

Site 1 (see Figure 9) is situated on former peat swamp that has been degraded by prolonged flooding, where after is has been covered by tidal deposits. The area is still situated very low in the landscape and is the lowest lying of all sites, with an elevation between -1,3 and 0,21 m + NAP. As this area was not considered suitable for agriculture due to its wet conditions, the whole area had been completely planted with Poplar forest around the year 1950. The trees were planted on so called "rabatten". These are beds of soil dug out from both sides, serving the double purpose of drainage and deeper rooting trees. In 1998 half of the area was clear cut, but on the other half the poplars remain. The exploited part of the land was replanted by mixed broad-leafed trees, including oak, elder, and ash, which are still present.

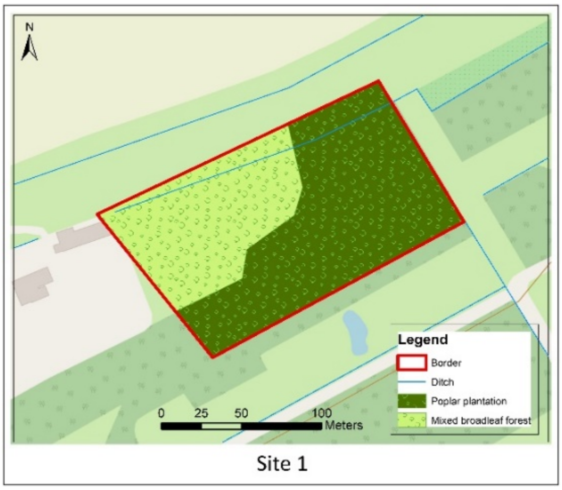

Figure 9: Landuse of site 1

Since **site 2** (see Figure 10) is situated adjacent to a former tidal creek it is also a low-lying area with very wet conditions. To make the site more suitable for agricultural purposes, the creek was drained by creating ditches, which are located at the borders of the site. From 2010, This site is used as a pasture for the cattle of the farm owner, by growing a mixture of grass and clover. In the past, maize (2007), and grass seed, (2008-2009) also were cultivated. In the year 2017 and 2018, the area was fertilised with liquid pig manure (around 20 m3/ha). In 2019, solid cow dung has been applied, of around 25 m3/ha. Since the land was changed to pasture, it has not been ploughed.

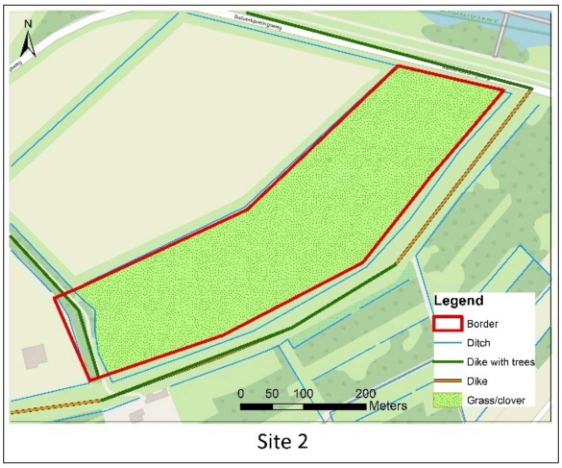

Figure 10: *Landuse of site 2*

The largest part of **site 3** (see Figure 11) is situated on a dike of around 2,5 meters higher than its surroundings, that has been established around 1950. The most northern part of the site is not part of this dike and has a much lower elevation, which is like the other sites. The soil that was used to establish this dike was collected from its surrounding area. Straight after its establishment, the dike was planted with ash and poplar. These trees are currently mature and still present. Underneath those trees, there is a rich undergrowth of native shrubs, such as hawthorn and elderberry. The most northern part of the site does not have tree cover and is partly in use for beekeeping; several beehives are present as well as a small flower garden in where bee-attracting plants are grown. The rest of the site has not been managed for a long time and is overgrown by native shrubs and weeds.

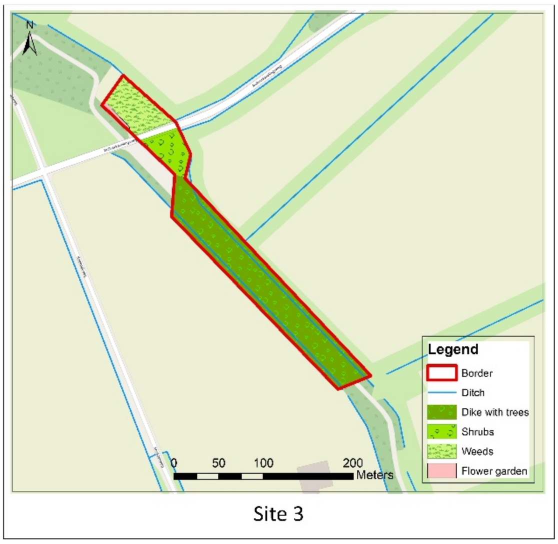

Figure 11: *Landuse of site 3*

In accordance with sites 1 and 2, **site 4** (see Figure 12) is a low-lying area. Because of its relatively small size and undesirable wet conditions it has never been used for agricultural purposes and has thus never been ploughed or fertilised. In the middle of the site there is a strip that has been raised by using soil form the rest of the site, on which willows are planted. The western border consists of a dike that is around 2,5 meters higher than the lowest parts of the site. This dike is planted by poplar trees, which are currently fully grown. Since the site has not been managed for a long time, it has been overgrown by weeds, mainly nettles.

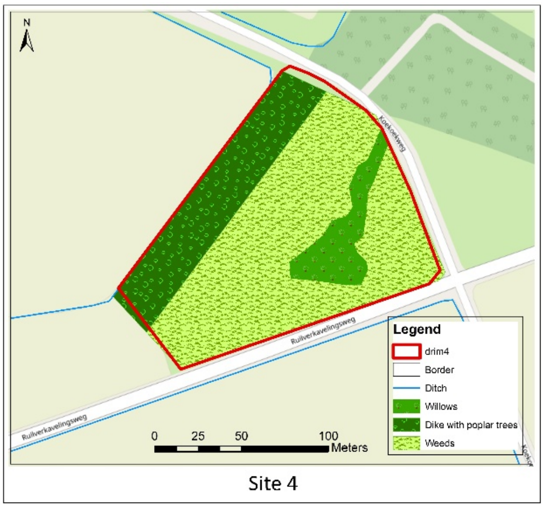

Figure 12: *Landuse of site 4*

4.2 Field soil analysis

In this part, the results of the field measurements are included. Hereby, the soil profiles and their characteristics will be presented and briefly discussed for each site, including ground water levels and rooting depth. Also, the corresponding soil condition score (BCS) will be discussed. For more detailed background information see Appendix II, (soil profiles) and Appendix III (soil condition score).

Site 1

Soil profile

Table 1 shows the soil profile of site 1 and its characteristics. As being located on a former peat swamp, peat soils are likely to be dominant. This expectation is proven by the fact that "Liedeerdgrond" was the most encountered soil type, as classified at 60% of the profiles taken. This soil type is characterised by the presence of deposits of sandy clay or sabulous clay on a peat layer. This peat layer starts from 80 cm below ground level (BGL). These soils are wet and poorly drained, as a GWT of IIIa and GHG levels ranging between 5 and 10 cm BGL were measured. Rooting depth is 30 cm. In the western site corner, a "Wiedeveengrond" is present. This soil type is very similar to the Liedeerdgrond, besides of the fact that the peat layer already begins within 40 cm BGL. In the western part of the area, a "Vlakvaaggrond" is encountered. This soil does not contain peat, has a sandier texture and is less rich in organic matter. At a depth of 40 cm, a very hard debris layer was encountered during the field work, which limits possibilities for rooting. This debris consists of the fundaments of an old side building house that is already gone.

Soil condition

The BCS of the Liedeerdgrond is relatively high, these soils gained the maximum score for all criteria, except for the presence of earthworms. The absence of earthworms could probably be caused by the wet conditions at the site, in which earthworms don't thrive well. The BSC of the Vlakvaaggrond is much lower, since it is low in organic matter, and soil compaction and rooting are poor since it is situated on the layer of debris that was mentioned earlier (see Table 1).

Table 1: *Overview of soil profiles and corresponding soil condition score (BCS) of site 1*

Sample	Soil type	GWT	GHG	GLG	GWS	Rootable depth	Soil Condition score (BCS)
1	Vlakvaaggrond	Vbo	35	120	30	40	20
2	Liedeerdgrond	IIIa	5	80	20	30	38
3	Liedeerdgrond	IIIa	5	100	10	30	35
4	Liedeerdgrond	IIIa	10	90	15	30	-
5	Weideveengrond	IIIa	5	85	5	30	-

Site 2

Soil profile

Table 2 shows the soil profile of site 2 and its characteristics. Site 2 was formed in a dynamic environment since it was formed by tidal deposits that left sand and clay, Hereby, the sandy material is usually present at a greater depth, since sandy material has a faster deposition rate than clay. This explains that the most encountered soil profile was “Leekeerdgrond”. This soil is characterised by the presence of a humus rich organic layer in light clay with a maximal depth of 30 cm, which gradually decreases in organic matter and clay content at a greater depth. Groundwater levels are high, with a GWT of IIIa and a GHG between 15 and 25 cm BGL. Rooting depth ranges from 70 – 100 cm below ground level. On the north-eastern corner of the site a Liedeerdgrond was found, indicating the presence of peat. This can be explained by the fact that a peat swamp was originally present at the sides of the creek. At the north-eastern corner a Vlakvaaggrond with a sandier was encountered, which is a sandy soil and indicates sandy deposits.

Soil condition

The BCS of the Leekeerdgrond is good, with a mean of 32. It obtained the maximum score for each criterium, except for soil structure and the presence of earthworms, which are both moderate. The BSC of the Liedeerdgrond is slightly lower. It has the same score for each criterion except of organic matter, which is moderate. The Vlakvaaggrond obtained the highest BSC of all soil types. It obtains the maximum score for each criteria except of soil structure, which is moderate (see Table 2 and Appendix III).

Table 2: *Overview of soil profiles and corresponding soil condition score (BCS) of site 2*

Sample	Soil type	GWT	GHG	GLG	GWS	Rootable depth	Soil Condition score (BCS)
1	Liedeerdgrond	Vao	20	125	55	80	31
2	Leekeerdgrond	IIIa	15	115	35	100	33
3	Leekeerdgrond	IIIa	15	110	95	90	30
4	Leekeerdgrond	IIIa	25	110	65	70	34
5	Vlakvaaggrond	IIIb	30	100	45	35	37

Site 3

Soil profile

Table 3 shows the soil profile of site 1 and its characteristics. As mentioned earlier, the largest part of site 3 is located on a dike and is drier than the other sites accordingly. Only a small part of this site in the upper north is not situated on this dike and has wetter conditions. In this location, a Leekeerdgrond was encountered, with a GWT of IIIb. On the dike, a Leekeerdgrond and a Liedeerdgrond were found, having a GWT ranging from VIId – VIIo and a GHG from 80 -120 cm respectively. Rooting depth was found to be quite similar all over the site and ranges from 80 – 100 cm below ground level.

Soil condition

The soil condition of the low-lying part of the area is much lower than the part that is situated on the dike. This was mainly caused by the presence of soil compaction and waterlogging. The samples on the dike obtained the maximum score for all criterea, except of the presence of earthworms (see Table 3 and Appendix III).

Table 3: *Overview of soil profiles and corresponding soil condition score (BCS) of site 3*

Sample	Soil type	GWT	GHG	GLG	GWS	Rootable depth	Soil condition score (BCS)
1	Leekeerdgrond	IIIb	35	110	65	80	27
2	Leekeerdgrond	VIId	120	180	>120	100	37
3	Liedeerdgrond	VIIo	80	160	>120	100	34

Site 4

Soil profile

Table 4 shows the soil profile of site 4 and its characteristics. As shown by the geomorphological map in appendix 3, site 4 was formed by similar processes as site 2. This is underlined by the result that all encountered soils profiles are Leekeerdgrond, which is also the dominant soil profile at site 2. Ground water levels are a bit lower than site 2, however overall drainage is still quite poor with a GWT of IIIb and a GHG ranging from 30 – 35 cm below ground level.

Soil condition

The soil condition score of this site has obtained the highest overall score of all sites, since all samples resulted in a high score (see Table 4 and Appendix III). One of the samples taken even obtained the maximum score for each criterion, resulting in the maximum overall score of 42. A possible explanation for this is that this area was not used for agriculture for a long time and is covered by natural vegetation, which is beneficial for soil structure and soil life.

Table 4: *Overview of soil profile and corresponding soil condition score (BCS) of site 4*

Sample	Soil type	GWT	GHG	GLG	GWS	Rootable depth	Soil condition score (BCS)
1	Leekeerdgrond	Vbo	35	120	70	80	42
2	Leekeerdgrond	IIIb	35	110	105	80	38
3	Leekeerdgrond	IIIb	30	95	55	65	35

4.3 Laboratory soil analysis

In this chapter, the results of the laboratory analysis by Eurofins are presented and analysed. Only the main soil indicators (soil texture, Cation Exchange Capacity, and pH), and the most common plant available nutrients (Nitrogen (N), Phosphorus (P), Potassium (K) and Calcium (Ca)) within the top soil (0-30 cm) are discussed since those parameters are most often looked at to determine soil fertility (Den Ouden et al., 2010, p. 136). A total overview of measured soil parameters can be found in Appendix IV. Initially, the definition and importance of each parameter will be explained where after implications for plant growth will be discussed.

Main soil indicators

Table 5 shows an overview of the main soil indicators of the four farm sites, including the target range for agricultural crops from Eurofins. Each of these parameters will be described and analysed below.

Table 5: *Main soil indicators of the farm sites*

		Soil texture			pH	Organic matter		CEC	
		Lutum (%)	Silt (%)	Sand (%)		%	C/OS ratio	Occupation (%)	mmol/kg
Site 1	Result	3	19	75	6,4	3,3	0,52	99	77
	Target range	-	-	-	6 - 6,5	-	0,45 - 0,55	> 95	> 72
Site 2	Result	26	52	12	6,4	6,4	0,52	100	239
	Target range	-	-	-	6,4 - 6,7	-	0,45 - 0,55	> 95	208
Site 3	Result	21	36	28	6,9	9,5	0,55	99	233
	Target range	-	-	-	6,4 - 6,7	-	0,45 - 0,55	> 95	> 222
Site 4	Result	19	43	25	6,8	7,7	0,55	100	213
	Target range	-	-	-	6,4 - 6,7	-	0,45 - 0,55	> 95	> 193

Soil texture

Soil texture is determined by its content and composition of lutum, silt and sand.
In order of granular size, clay particles are the smallest (< 0,002µm, followed by silt (0,016 – 0,05µm) and sand (0,15 – 2µm***)***. The percentage of lutum is used to classify soils in sandy soils, loamy soil and clay soil. If the clay percentage is higher than 25% soil are classified as clay soil, between 8-26% as loamy soils and below 8% as sandy soil (Den Ouden et al., 2010, p. 137) The texture of a soil is important for a number of important soil properties. Sandy soils have a coarse texture and a large grain size, making them well drained and rich in oxygen. However, water and nutrients are poorly absorbed and washed out easily, making sandy soils susceptible for drought and nutrient depletion. Clay soils have a fine soil texture and a good water- and nutrient absorption capacity but are sensitive to soil compaction and waterlogging. Loamy soils are regarded as the most optimal soils for agriculture and forestry, since they have a higher capacity to absorb water and nutrients than sandy soils and have better drainage properties than clay soils (vruchtbarebodem.nl, 2019).

Because of the dynamic environment in where they are formed, there is quite a large variation in soil texture between the different sites. Site 1 has the sandiest texture of all soils, and is classified as loamy sand. Site 2 is classified as light clay and is the only clay soil of all sites. At 3 and 4 a loamy soil is present.

Organic matter

Organic matter is an essential part of the soil since it has a large influence on soil structure, moisture retention capacity and soil fertility. To sustain the organic matter content, the same amount of organic matter must be supplied as the amount that decomposes on a yearly basis. During the decomposition of organic matter trough soil life, nutrients (N, P and S) become available for plant growth. Thereby, organic matter availability improves the CEC as it absorbs cations as Potassium, Calcium and Magnesium. Nutrinorm indicates a minimum of 3% for sandy soils and 4% for clay soils for sufficient nutrient supply (Nutrinorm, 2019). At least as important as its quantity, however, is the quality and composition of organic matter. Hereby the carbon content within organic matter is very important, measured by the C/OS-ratio. The higher the carbon content, the more stable the organic matter and its water holding capacity, but the slower its decomposition rate and thus nutrient supply for plant growth. A good balance between stability and composition is thus very important. According to Eurofins, the optimal C/OS ratio lies between 0,45 and 0,55.

The organic matter content of site 1 is lower than the other sites, probably because it is formed in a sandy soil. However, it is still above the minimum value of 3%. The organic matter content of the zavel- and claysoil within sites 2, 3 and 4 ranges between 6,4 and 9,5%, which is clearly higher than the minimum required amount for clay soils that was mentioned earlier.
Thereby, the C/OS ratio of all sites fall within the range of 0,45 and 0,55, which indicates organic matter with good properties relating to nutrient supply and stability. Both organic matter content and proportions are thus positive for all sites. Thereby, the establishment the a food forest is expected to lead to an increase in organic matter; In food forest Ketelbroek organic matter levels increased from 2% to 9% 15 years after it was planted on an agricultural field (Lievense, 2019).

pH-value

The pH value is an important indicator of soil fertility; it has a large influence on the availability of nutrients since it effects chemical and biological processes. The optimum range for biological processes lies between 6 and 7. At low pH-levels (<5,5), the direct uptake of nutrients by plant roots will be negatively affected by the absorption of H+ ions at the CEC complex. Also, nutrients as nitrogen, phosphorus and sulphur are less available for plant growth because the mineralisation of organic matter decreases. At high pH-levels (>7), phosphorus will fixate to calcium which makes it inaccessible for plants (Nutrinorm, 2019). Optimal pH levels however are different for each plant species; some species are specially adapted to very acid or very basic soils.

The analysis results show that pH levels are quite high; site 1 has the lowest pH value (6,3) and site 3 the highest (6,9). This pH levels were expected knowing that tidal deposits of zavel and clay are usually rich in calcium. Since pH levels for all sites are neither too low (<5,5) or too high (<7), conditions for biological processes and decomposition of organic matter are favourable. Accordingly, the soil has a good potential to supply nutrients for plant growth.

CEC

The CEC (Cation Exchange Capacity) is a very important indicator of soil fertility, because it determines the adsorption capacity of cations, including nutrients as Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+}. Nutrients that are absorbed by the CEC-complex are available for plant growth. The CEC is determined by organic matter content and lutum content. Because the surface of lutum- and organic matter particles is negatively charged, it attracts and adsorbs cations that are positively charged. So, the higher the clay content and organic matter content, the higher the CEC. Sandy soils usually have a lower CEC than clay soil, since sand particles are not able to adsorb nutrients due to their positive charge. Therefore, the CEC of sandy soils mainly depends on its organic matter content (Nutrinorm, 2019).

The analysis results show that site 1 has a lower CEC than the other sites. This is probably caused by the fact that site 1 has a sandier texture and therefore a lower absorption capacity than the other sites, which consist of sabulous clay and clay soils. The CEC occupation rate of all sites is very high, which is probably the result of the neutral to basic pH levels of the soils; the higher the pH, the higher the adsorption capacity.

Plant-available nutrients

Table 6 shows an overview of the laboratory results of plant available nutrients for plant growth for the four farm sites, including the target range for agricultural crops from Eurofins. Each of these parameters will be described and analysed below.

Table 6: *Plant-available nutrients of the farm sites*

		N	C/N ratio	P	K	Ca
Site 1	Result	55	15	4,7	150	30
	Target range	95 - 145	13 -17	6,6 - 10,9	255 - 400	260 - 610
Site 2	Result	150	12	3,3	270	25
	Target range	95 - 145	13 -17	6 - 10	235 - 365	240 - 560
Site 3	Result	165	14	4,9	585	200
	Target range	95 - 145	13 -17	5,6 - 9,3	215 - 340	225 - 520
Site 4	Result	160	13	4,5	340	50
	Target range	95 - 145	13 -17	5,8 - 9,7	225 - 335	230 - 540

Nitrogen (N)

Of all nutrients, nitrogen has the biggest proportion within a plant. It supports photosynthesis and plant growth and is essential for the formation of proteins and DNA. A lack of nitrogen leads to reduced plant growth. However, a surplus is also undesirable since it leads to extensive growth of leaves with a weak structure. The largest part of Nitrogen is fixed to organic matter and comes available through the decomposition of organic matter trough soil life as Nitrate ($NO3^{-}$), and ammonium ($NH4^{+}$) The amount of plant available nitrogen is thus mainly determined by the organic matter content and its decomposition rate. Hereby, the C/N ratio of the organic matter can be used as a guideline. The lower the C/N ratio, the higher the decomposition rate and the N supplying capacity. Soils with young organic matter usually have a lower C/N ratio (5-15), and a higher decomposition rate than soils with old organic matter (Bokhorst, 2019).

The results of the soil analysis show that the C/N ratio of all sites fall within the target range of 13-17, except of site 2 where it is moderately low. This indicates a good supply of nitrogen from organic matter. This is underlined by analysing the plant-available nitrogen levels, which even show a light surplus for sites 2, 3 and 4. At site 1 however, there is a small deficit. Plant available Nitrogen levels of all sites are higher than the 80 kg N/ha that is required for good growth of heavy cropping trees and shrubs according to Martin Crawford (Crawford, 2010). Problems for crop growth related no nitrogen availability are thus not very likely. However, competition from weeds could be a potential problem since weed growth is more abundant when an oversupply of nitrogen is present.

Phosphorus (P)

Phosporus is essential for root growth and the formation of proteins and DNA. Plants can only use phosphorus in the form of phosphates $(PO_4)^{3-}$. Phosphates are only available for plants while being dissolved. Phosphates dissolve through the decomposition of organic matter by soil life and through acid substances that are excreted by plant roots and mycorrhiza. When phosphates dissolve plant-available, they are easily fixed by iron, calcium and aluminium. For that reason, the largest part of phosphorus in the soil is not plant-available (Nutrinorm, 2019). There are a broad range of measures to determine plant available phosphorus, of which the Pw value is one of the most common. According to this method, soils are considered poor in phosphate and P-fixating when the Pw-value is less than 25 (RVO, 2019).

The results show that even though none of the sites has a Pw value below 25, plant-available phosphorus is low to moderately low at all sites. This is somewhat unexpected, since all sites have a reasonable to high organic matter content and a favourable C/OS-ratio. The low availability is however not expected to be problematic for the development of a food forest, since most perennial plants and trees do not require high amounts of phosphate (Groen Kennisnet, 2018). Thereby, the level of plant available phosphorus is expected to increase whilst the food forest will develop, by the increased abundance of plant roots and soil life.

Potassium (K)

Potassium is important for a wide range of processes in plant growth, and its proportion in the plant is the highest of all nutrients after Nitrogen. A lack of potassium leads to reduced growth and drying out symptoms. A surplus of potassium however is also undesired since this causes problems with water uptake (salination). Potassium is very mobile and can easily re-occupy places with a low availability. Because of this ability however, it also sensitive for washing out. Since Potassium is bound by organic matter but mainly by the CEC complex, clay soils usually have a higher availability of potassium than sandy soils. However, If the lutum content is too high (heavy clay), Potassium will fixate to the inside of the CEC complex, which decreases availability for plant uptake.

There are quite large differences in plant-available Potassium between the sites. At site 1 levels are moderately low and at site 3 there is a high surplus. The levels of site 2 and 3 have an optimal content. The difference in plant-available Potassium between site 1 and the other sites is possibly caused by the fact that site 1 contains sandy soils, while the other sites contain zavel- and claysoils which have a higher capacity to absorb cations. However, Plant available Potassium levels of all sites are higher than the 80 kg N/ha that is required for good growth of heavy cropping trees and shrubs according to Martin Crawford (Crawford, 2010).

Calcium (Ca)

Calcium is important for the stability of plant cells and regulates the permeability of cell membranes. Thereby, calcium has a positive effect on soil structure. The availability of calcium depends on enough soil moisture, soil acidity (low pH prevents root growth and calcium uptake), and the ratio between other cations in the CEC complex as potassium and magnesium. A surplus of other cations in the CEC complex can lead to reduced calcium availability and uptake. Since calcium is absorbed by the CEC complex, clay soils usually have a higher calcium content than sandy soils. An optimum calcium range that counts for all crops does not exist, since every crop has its own calcium requirements. However, Eurofins claims that for apples a minimum amount of 80 kg Ca/ha/yr is required to meet optimal production levels (Eurofins Agro, 2019).

At all sites, plant-available calcium is low to moderately low. This is quite remarkable, since the soil is formed in river deposits that are usually rich in calcium. Thereby, the carbonated lime content is also high at all sites, except of site 1. A possible explanation for the low availability of calcium could be the surplus of plant-available magnesium that is present at all sites, which competes with plant-available calcium on the CEC complex. The low availability of calcium can also lead to soil compaction since enough levels of calcium are required for a good soil structure. Thereby, the quality and production levels of crops with a high calcium demand such as apples could decline (Eurofins Agro, 2009).

5. Client analysis

This chapter shows the results of the client survey and analysis as described in chapter 3.2. Initially, a general description of the farm is given, followed by objectives and limitations, the focus, relevant regulations and subsidies and the main functions that were selected by the farmer for each farm site.

5.1 General farm description

Estate 'De Koekoek' is an organic farm owned by farmers Marc and Pipie Smits-van Oyen. Ownership by the family dates back to 1838. De Koekoek is located on the edge of National Park De Biesbosch and includes 145 hectares of land. Of this land, 120 hectares are under own management and the remaining parts are leased out to the national forest agency (Staatsbosbeheer) and the Province of Noord Brabant. All the 17,7 hectares of the four farm sites that are used for the farm LIFE project are owned and managed by the farmer himself.

The farm has been organically certified (SKAL) since the year 2000, for all the products that are produced. Current products that are produced include pig meat, Aberdeen Angus cattle beef and vegetables. Vegetables are sold to Ecoplaza (organic food) and supermarkets Delhaize and Jumbo. The meat from the pigs and Aberdeen Angus cattle is home sold. Additionally, the farmer participates in a local food collective in Drimmelen, selling organic produce through their website. The farmer hires temporary workers, both from the Netherlands and from Romania. Ploughing and weeding is done by the farm owner himself, harvesting, sowing and planting is outsourced.

5.2 Objectives and limitations

The farmer has applied for the LIFE project because he aims to deviate from the traditional sharp distinction between nature and agricultural production and integrate both in their land use. The farm owner is interested to accomplish recycling of nutrients through mixed farming. He would like to have permanently grazing pigs and/or cattle under trees and to grow crops to feed them. He is also interested in establishing a food forest in where people can pick their own crops. The farmer has indicated that such systems need to be easy to manage, since he does not want to spend a lot of money to labor and does not have much time available himself.

5.3 Main focus

During one of the workshops, the farmer was asked to indicate his focus, by making a distribution based on percentage between commercial, environmental and social. Looking to the result (see Figure 13), the main focus of the farmer is commercial, followed by environmental and social. It is thus clear that systems that will be developed should be commercially profitable besides of taking the other criteria into account. The environmental aspect however still plays an important role, since it is the main objective of the Farm LIFE project to develop climate-adaptive farm plans. The main challenge thus will be to create a system that combines both functions. The social focus has just obtained a score of 5%, and thus does not have an important role according to the farm owner. Thereby, some social value will already be accomplished automatically, since employers will be needed to establish the farm systems on the site.

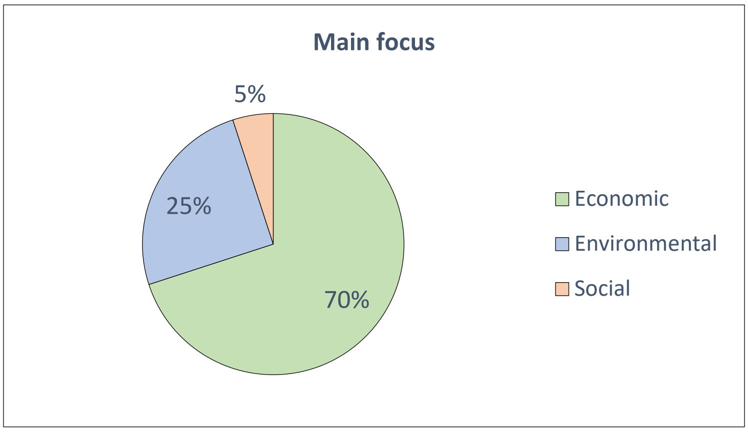

Figure 13: *Main functions selected by the farmer*

5.4 Regulations and subsidies

When establishing a food forest, a lot of laws of regulations have to be taken into account, as well as subsidies. Below, the most important ones are discussed.

<u>Laws and Regulations</u>

<u>Organic certification:</u>

The farmer is organically certified by Skal Biocontrole (SKAL), which is responsible to prove the reliability of organic products on behalf of the Dutch Ministry of Economic Affairs. Therefore, also obligated to buy organically certified planting material in order to maintain this certification (Poppens, 2018).

BRP crop registration:

The BRP crop registration system is a system used by the Dutch Government that determines what crop is grown on which agricultural farm site. All four farms sites currently meet the criteria of agricultural land, for which the farmers receive subsidy from the government. For nature and forest also subsidy can be received, but this is much less than for agriculture. To receive agricultural subsidy, the farmer is required to assign which crop he is growing on his sites within the BRP crop registration system. When establishing agroforestry systems on the farm sites this could cause problems, since in agroforestry systems multiple crops are grown and just one crop can be selected for registration. Accordingly, the sites could lose their status as agricultural land, which is obviously undesirable for the farmer. Since 2019 however, a special ‘food forest code’ is available, so farmers with a food forest can also receive agricultural subsidy (RVO, 2019). However, these food forests should meet the criteria as defined by the Green Deal Voedselbossen, as described earlier in Chapter 3.1.

The municipal land use plan

The future food forest design has to comply with the municipal land use plan, to obtain permits for planting trees. Signals from the neighborhood seem positive, since a nearby farmer already successfully obtained such a permit. The village council need to be involved in the project at an early stage, since he needs to agree with the future plans. Fortunately for this project, the village council has already favored land forestation. However, it is still important to sustain clear communication with the municipality throughout the process to prevent problems in the future (Poppens, 2018).

Subsidies

EU CAP pillar I subsidies

The farmer is receiving EU CAP pillar I subsidies for the four farm sites, which means that the way species will be used and planted should comply with the corresponding requirements. One of these requirements is that the use invasive species is not allowed. These species include all species that are included on a list of the Dutch Food Safety Authority (Nederlandse Voedsel- en Warenautoriteit) (NVWA, 2019).

Ondernemend Natuurnetwerk Brabant (ONB)

All project sites are subject to *Ondernemend Natuurnetwerk Brabant (ONB).* This fund supports ‘entrepreneurial nature’ within Noord-Brabant and co-financed the Farm LIFE proposal writing. In order to acquire ONB funding, farmers need to demonstrate a sound business plan involving sustainable production methods (Poppens, 2018).

5.5 Main functions

The outcome of the design day has resulted in a selection of functions that are of interest for the farmer. The list with all functions selected, including points being discussed is shown in Appendix VII. Below, the functions that were selected for each field (commercial and environmental) and each farm site are presented and discussed.

Site 1

As mentioned before, site 1 is currently covered with forest, that partly consists of poplar trees and partly of mixed broadleaf forest. Due to the current forest cover, the site already offers environmental services for wildlife, birds and insects. The farm owner has indicated that he wants to maintain and preferably improve these functions, in combination with small scale harvest of timber and firewood (see Table 7). For example, by harvesting the remaining popular trees and replacing them by native tree- and shrub species that are beneficial for wildlife, birds and insects in terms of shelter and/or food supply.

Table 7: *Selected functions for site 1*

Commercial (bioproducts)	Commercial (ecoservices)	Environmental
Timber and firewood	-	Wildlife protection Insect and bird shelter Re- and afforestation

Site 2

Site 2 is the largest of all sites and is currently in as pasture for the cattle of the farm owner. The farm owner would like to maintain this function in the future but supplement it with trees and shrubs that produce nuts, fruits, and berries in a sort of silvopastoral system (see Table 8 and Chapter 3.1). The nuts and fruits produced by the trees can be harvested for commercial purposes as well as being an additional food supply for the cattle that graze underneath the trees.

Table 8: *Selected functions for site 2*

Commercial (bioproducts)	Commercial (ecoservices)	Environmental
Berries Nuts Fruits Livestock Pasture	-	-

Site 3

Table 9: *Selected functions for site 3*

Commercial (bioproducts)	Commercial (ecoservices)	Environmental
Flowers & Bulbs Fodder & Bedding	-	Wildlife protection Insect and bird shelter Re- and afforestation Ecological corridor

Site 3 can be separated in two separate areas; the area that is situated on the dike and the low-lying small patch in the northern part. Since the part on the dike is totally covered with trees and shrubs, it contains environmental functions for wildlife, birds and insects. Therefore, it forms an ecological corridor that connects the other sites with each other. To improve this function, the farm owner aims to improve the structure and biodiversity of the current forest stand, by small scale harvesting and replacing biodiversity beneficial shrubs and trees in a more natural structure (see Table 9). The small patch in the north is currently used for bee keeping with beehives, and a small flower garden for the bees is present. This garden could be used for cutting flowers and bulbs. The other part that is mostly overgrown by weeds, and the farmer would like to use this area to create a fodder bank. Suitable species that can be used for this fodder bank include species as European alder and Willow, which can be used as an additional food sources for the cattle.

Site 4

The largest part of site 4 is of open area. It is crossed by a row of willows and a row of poplar trees is present at the north western border. The farm owner would like to transform this site to a food forest, in a system in where customers will pay by picking their own crops. Hereby, he would like to plant many tree and shrub species that produce nuts, fruits and berries are grown in combination with perennial vegetables (see Table 10). The species preferably need to be selected and planted in such a way that there is always something to pick in the different parts of the season. Since there are a lot of weeds on this site, selected vegetables need to be able to outgrow the weeds and preferably have large leaves to prevent them growing. The farm owner would like to maintain the rows of willows, which could function as a fodder bank. However, he would like to cut all the poplar trees since they already reached maturity, and replant new trees on their current location.

Table 10: *Selected functions for site 4*

Commercial (bioproducts)	Commercial (ecoservices)	Environmental
Fruits Berries Fodder & Bedding Fresh vegetables Nuts	Pick your own crops	-

6. Species selection

In this chapter, a selection of species will be presented and discussed for the farm site that has the best possibilities for the realisation of a food forest. Regarding to soil conditions, all sites are quite similar. They all have a high fertility and corresponding pH levels but are also poorly drained since high groundwater levels are present. An exception is site 3, which is situated on a dike and is therefore better drained. However, its current dense tree cover makes transformation to a food forest costly and time consuming, the farmer also indicated that he would like to use this site for other purposes. The same counts for site one. Site 2 does not have the problem of tree cover but was not selected since the farmer wants to use livestock in this system, and livestock is not allowed in a food forest according to the Green Deal of Food Forests (see Chapter 3.1). Eventually, site 4 was considered the most suitable option. This site has the advantage that it mostly consists of open area, and the farmer is eager to use it as pick you own crops system with many food producing species (see Chapter 5.3), what suits very well within the idea of a food forest.

As described in chapter 1, the farmer aims to make a food forest where customers can pick their own crops. As functions that this food forest should fulfil, he selected nuts, fruits, berries and fodder. Chapter 6.1. will discuss in how far this is possible while taking the site conditions into account, whereby the soil criteria described in Chapter 2.6 were used. In chapter 6.2., on overview of the selected species that are adopted to the site conditions as well as the functions chosen by the farmer is presented and discussed.

6.1 Site adaptivity

The site has a loamy texture, which is an optimal texture for agricultural purposes. Loamy soils usually have a high capacity to hold water and nutrients and have a good structure. For most plant species loamy soils are optimal, including heavy cropping species as nut- and fruit trees. The pH of the site (6,8) is also quite positive, since most fruit trees do well on neutral soils with a pH between 6,5 and 7 because under such conditions the availability of most nutrients is optimal.
(Limareva, 2015, p. 13). This was also underlined by the results of the chemical soil analysis, which show a high levels of plant available nutrients are available.

Besides from the dike with poplars, site 4 is very wet and poorly drained because of the high groundwater levels that are present. This is an important limiting factor, since many species do not grow well in such conditions, including nut- and fruit trees. It is known that especially nut trees suffer from high and fluctuating groundwater levels, because they have long taproots that need oxygen from the deeper soil layers. Also, fruit trees are not recommended to plant on wet sites, since they will be more sensitive to diseases and production levels will decrease. Especially cherries are very sensitive to waterlogging. For most fruit trees, a soil that is drained until a depth of at least 50 centimetres below ground level is recommended to prevent problems (Limareva, 2015, p. 15). This means that the GHG should be maximum 50 centimetres. Apples and plums are known to be less sensitive and can temporarily tolerate groundwater levels higher than 40 centimetres below ground level. Also, persimmons are relatively resistant for poorly drained soils (Hoffman & Hop, 2012). Berries are usually more resistant against waterlogging. For example, species as blackcurrant and European elder can grow very well in wet conditions. Regarding to fodder producing species, Alders and Willows are species that do very well on wet sites.

6.2 Selected species

Table 11 presents the species that are selected from the database for each site by having used the selection criteria for the species site requirements and the requirements of the farmer as described in Chapter 2.6. The column "Main functions" shows what function selected by the farmer the species fulfils, and the column "other functions" additional functions that were found. Thereby species that produce poisonous parts were also left outside this selection. This resulted in the selection of 6 tree species, 6 shrub species and 9 perennial plant species. To provide fodder and bedding, White willow and European alder were selected, since these trees grow well in the given site conditions and their fresh twigs can be used as a useful addition on the diet of de cattle of the farmer. They especially form a good supply of vitamins and minerals, that are often not present in grass species. (Whistance, 2018). However, no fruit trees were found that met the selection criteria of wet soils, Common Persimmon, Apple and Plum were added to the database since these fruit trees are best adapted to the wet soil conditions. Walnuts also do not meet that criteria but has been included since it could be planted on the dike were the poplars are currently standing. European elder, Sea buckthorn, Blackthorn, European blackcurrant and Red currant produce edible berries and are well adapted to wet soils. For most species. To make picking of the berries that are provided by the Sea buckthorn and Blackthorn easier, thorn less varieties could be selected.

Table 11: *Overview of selected species*

English name	Scientific name	Form	Main functions	Other functions
European Alder	Alnus glutinosa	Tree	Fodder and bedding	Biomass, timber, attracts wildlife, nitrogen fixing
Walnut	Juglans regia	Tree	Nuts	Timber
White willow	Salix alba	Tree	Fodder and bedding	Biomass, timber, attracts pollinators, attracts wildlife
Common persimmon	Diospyros virginiana (var.)	Tree	Fruits	Timber, attracts pollinators
Apple	Malus domestica (var.)	Tree	Fruits	Timber, attracts pollinators, attracts wildlife
Plum	Prunus domestica (var.)	Tree	Fruits	Attracts pollinators
Hawthorn	Crataegus spec. (var.)	Shrub	Berries	Attracts pollinators, attracts wildlife
European elder	Sambucus nigra	Shrub	Berries	Biomass, attracts pollinators, attracts wildlife
Sea buckthorn	Hippophae rhamnoides	Shrub	Berries	Biomass, timber, nitrogen fixing
Blackthorn	Prunus spinosa	Shrub	Berries	Attracts pollinators, attracts wildlife
European blackcurrant	Ribes nigrum	Shrub	Berries	Attracts pollinators
Red currant	Ribes rubrum	Shrub	Berries	Attracts pollinators
Welsh union	Allium fistulosum	Perennial	Fresh vegetables	Attracts pollinators, attracts wildlife
Horseradish	Armoracia rusticana	Perennial	Fresh vegetables	Attracts pollinators
Sea kale	Crambre maritima	Perennial	Fresh vegetables	-
Globe Artichoke	Cynara scolymus	Perennial	Fresh vegetables	Attracts pollinators
Daylily	Hemerocallis dumortieri	Perennial	Fresh vegetables	Attracts pollinators
August lily	Hosta plantaginae	Perennial	Fresh vegetables	Attracts pollinators
Lovage	Levisticum officinale	Perennial	Fresh vegetables	Attracts pollinators
Valerian	Valeriana officinalis	Perennial	Fresh vegetables	Attracts pollinators
Wild garlic	Allium ursinum	Perennial	Fresh vegetables	Attracts pollinators

7. Design

In this chapter, a potential design for the future food forest is presented and discussed.
Initially, the design process will be discussed. Hereafter, a possible food forest design layout will be presented as the result of this process. Eventually, advice for planting and implementation will be provided.

7.1 Design process

For the design, most important is the process to get the vision of the food forest as clear as possible. Only when all main ideas have settled, the real design can be done. As mentioned earlier, a food forest can contain up to seven different vegetation layers and should at least three different vegetation layers according to the definition of the Green Deal of food forests (see Chapter 3.1.). To keep the design clear and manageable, the decision was taken to only focus on these minimum three layers required, including a tree layer, a shrub layer and an herb layer. These layers were selected because these forms the main structure of a food forest. There are countless ways to use and implement and situate these layers within a food forest design, dependent on the site conditions and the objectives of the users. In many food forests, a dynamic design is used in where the plants are planted in organic patterns and structures. A well-known example is the oldest food forest in the Netherlands, Food forest Ketelbroek in Groesbeek, where over 450 species were planted in such a way (Breidenbach & Dijkgraaf, 2016). However, since ease of management is an important aspect for the farmer, a more rational design containing fewer species, in where the layers of the food forest are planted in rows was chosen.

After the planting patterns of the layers was decided on, attention was paid to the species that are included in each layer, and their exact placement within the design. Hereby the decision was made to include all species that were preselected in the previous chapter, since the farmer did not decide on specific species yet. Thereafter, choices were made how to implement these species in the design in a good way, in were the design principles described in the book "Creating a Forest Garden" from Martin Crawford were used (Crawford, 2010). These principles include;

- The maximum height and (crown) diameter of the selected plants.
- Each individual species requirement for light/shade and shelter.
- Aspect on site features, for example hills and slopes.
- Soil differences across the site.
- Pollination requirements: Species that are that need cross pollination need to be located fairly near (within a tree or two), because wind-blown pollen will not travel so far in a forest environment.
- The use and placement of nitrogen fixing trees and shrubs and other beneficial plants.
- Species mixing – plant species of the same family of species will not be placed adjacent to each other to prevent easy spreading of pest and diseases.
- Optimal root space use. The species known for their shallow root system were sought to be planted in complementarity with plants with deep roots to prevent competition.

Before the design was conducted, information relevant for these design principles for the selected species was collected from pfaf.org (Plants For A Future, 2019), and presented in a table (see Appendix VIII).

7.2 Design layout

In Figure 14, a map of the final design layout on scale is presented. Since this design shows the food forest in a mature state, the maximum height and diameter of the crops was used to represent them on the map.

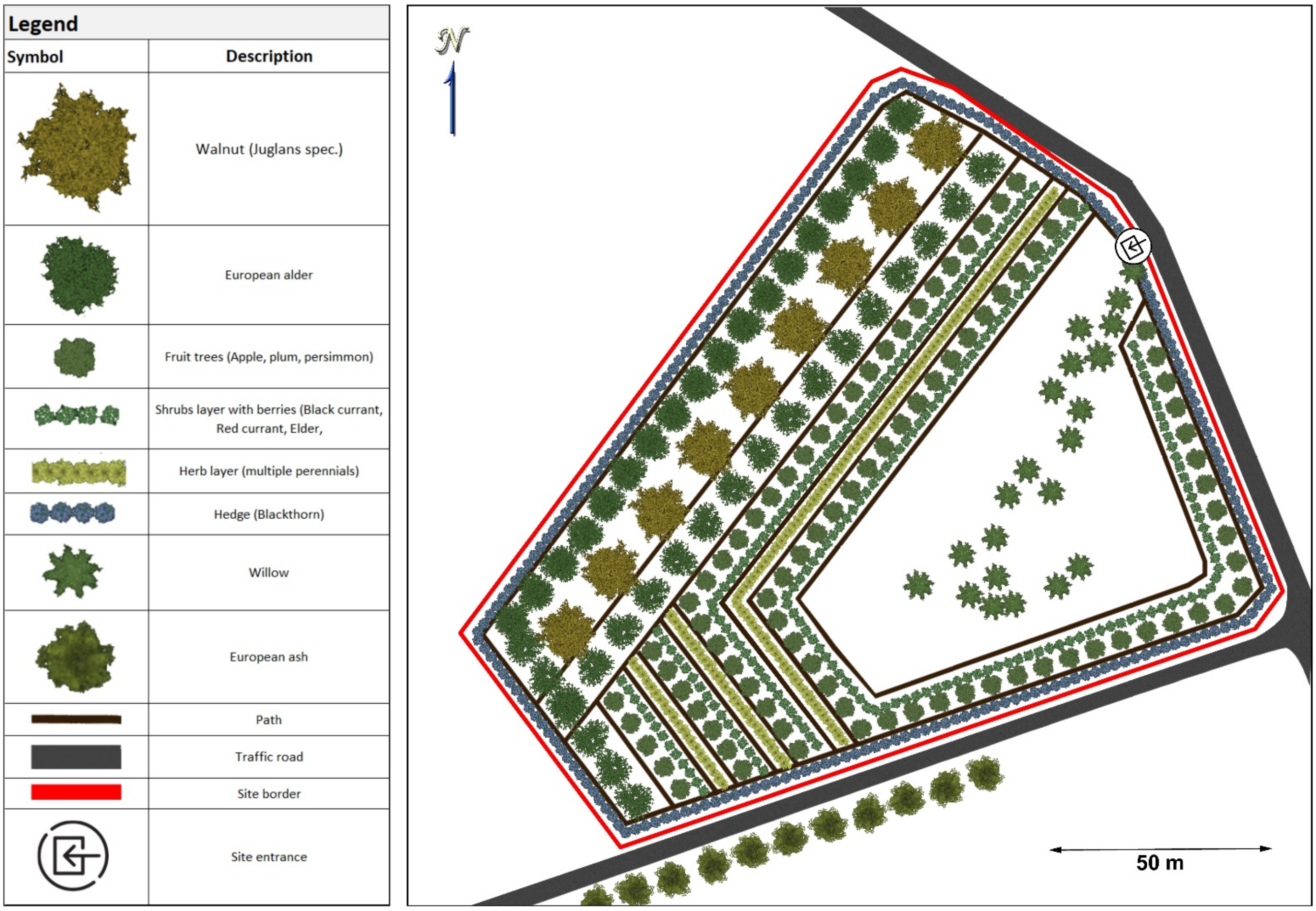

***Figure 14**: Food forest design layout (Image by Jip Jan Hulshof)*

In the design the following elements are included, which are further discussed below.

- Canopy layer
- Shrub layer
- Herb layer
- Hedges
- Paths
- Recreational area

Canopy layer

The design of the canopy layer is considered the most important step in designing a food forest, since tree placement and density is critical when crowing other crops beneath them. Therefore, the canopy layer should always be the first step taken when making a design (Crawford, 2010, p. 147).

On the dike where poplar trees are currently still present, walnut trees will be planted after these poplar trees are removed. This is considered the only suitable location to plant walnuts, since drainage properties are very poor at the rest of the site. Walnut trees are known to be quite sensitive for strong winds. Therefore, alders will be planted at the northern and eastern edge of the site to provide a natural windbreak, and also at the southern edge of the walnut trees. Besides wind protection, alders also provide benefits, such as nitrogen fixation it the soil and nesting opportunities for birds. Thereby, it is very tolerant of pruning and its branches can be used as fodder as an additional food source for the cattle of the farm owner.

The fruit trees are planted at the inner side of the alders, to give them a sheltered position in which they thrive well. The fruit trees that are planted next to the alder also benefit from the additional nitrogen that is fixed by the alders. The fruit trees are planted in multiple rows which all include apple, plum and persimmon. In these rows, fruit trees of the same species should not be placed adjacent to each other, to create a more diverse system that prevents easy spreading of pests and diseases. Persimmons have deep roots, and therefore will be always placed in between the plum and apple trees, that have a shallow root system. By doing this, root competition will be minimized.

Shrub layer

The position of the shrub layer shrubs was considered after the trees and their positions have been decided upon, since the shrubs are positioned next to the canopy layer. The shrub species used include European elder, Black currant and Red currant. All these species are shade tolerant and beneficial species for insects and deliver edible berries that can be harvested for various purposes. The shrub layer is situated adjacent to the inner-or outer side of the fruit trees. As recommended by Martin Crawford (Crawford, 2010, p. 196), the shrubs are planted just outside the dripline of the fruit trees, to prevent interference with the access to the fruit trees and to obtain sufficient light for their fruits to ripe (see Figure 15).

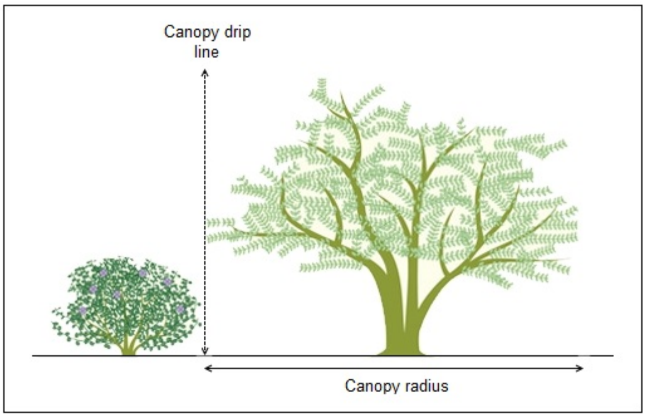

Figure 15: Shrub placement (Image by Jip Jan Hulshof)

Herb layer

The herbaceous layer is the last layer that is implemented in the design, because from all layer this layer can be adjusted most easily. This layer will be planted in between the shrubs and the fruit trees. The width will be 2 meters, so the herbs can be harvested without being tred upon. The presence of this layer provides the following advantages according to Martin Crawford (Crawford, 2010, p. 255);

- They provide soil cover, which prevents erosion on improves soil structure.
- They can accumulate minerals and make them available for nearby plants.
- Aromatic plants are believed to improve health of shrubs of where they are growing next to, since the ant bacterial- and fungal oils they produce prevents bacterial and fungal pests.
- Because an herb layer provides a good soil cover, unwanted weeds have less change to establish

Not all the plants in the ground cover layer need to be used for food production, species that support other functions as the ones mentioned above are just as important for a healthy ecosystem.

Hedges

As a natural barrier, a hedge with shrubs surrounding the whole circumference of the site will be planted. For this hedge sea buckthorn and blackthorn have been selected, since these species grow quickly to form a dense structure. Its dense structure and thorns will protect the site from undesired wildlife that can damage young trees and shrubs, such as the deer that are present in the area. Thereby, they provide nesting opportunities for birds and are important pollinator plants for insects. Furthermore, the hedge provides additional wind protection at each side of the food forest, making it a quit zone with a favourable microclimate for the crops inside its borders (Crawford, 2010). Sea buckthorns and blackthorns also both produce edible berries. Those of Sea buckthorn are especially interesting as their popularity of superfoods has been increasing over the last years.

Paths

The placement and properties of paths are important in the food forest, since the crops need to be harvested and managed efficiently. The crops need to be accessible by machinery as a indicated by the farm owner. Martin Crawford suggests that paths that need to be accessible for machinery should be at least 1 meters wide (Crawford, 2010, p. 303), so this width was adopted and used for all paths in the food forest design. Since the species that are growing in the hedge can have aggressive superficial roots, a path was created next to prevent it from spreading too much. Paths were also established between the alder and walnut trees, and between the alder trees and the fruit trees. This makes it possible to have easy access to the trees during harvesting and management tasks. Eventually, paths will also be created at both sides of the herb layer, to make picking from both sides possible without trampling them.

Recreational area

Since the future food forest aims to become a place where clients can pick their own crops, it would be an added value to create an open area within the food forest, where people can gather and relax while having a break from harvesting crops from the forest. This social aspect can be very important, since it will give potential customers the opportunity to develop a connection with the food forest and other people that use it. The open area will be created in the middle of the food forest, since it provides a sheltered environment and a great view on the surrounding food forest layers. Within this area, some tables or benches can be placed for this purpose.

7.3 Planting and management

In this chapter, advice will be given about how the design could be planted out best and what kind management within the food forest to keep it in an optimal condition to fulfil it desired functions.

7.3.1 Planting

Food forests can be established by planting all the layers and its species in only one year or dividing it over several years. Planting all the layers in only one year is most suitable for relatively small areas (<500 m2). This can be explained by the facts that this approach requires a lot of plants to be planted in a single season. Planting a food forest over multiple years is more common. Using this approach, the hedges and the canopy layer will be initially planted in the first years, followed by the shrub- and the herb layer. This has the advantage that the work and money needed can be spread over multiple years, and it allows an already sheltered environment when the shrub and the herb layer will be planted (Crawford, 2010, p. 95).

Before planting, it is important that the site should be free of undesired weeds. In this situation this is especially an important issue, since the site currently has a high presence of weeds since weeding or moving has not been done for three years. As a first step, the total site surface will be cleared from weeds by ploughing. Thereafter, a relatively long-lived green manure crop that covers the soil well will be sown, which will prevent the weeds from re- establishing. Suitable crops for this purpose are Lucern or White clover. This crop itself does not need any maintenance for several years, and can be replaced in sections by the layers of the food forest (Crawford, 2010, p. 95).

Regarding to plant material for tree and shrubs, bare rooted or pot grown plant material can be selected. Pot grown plants have the advantage that they can be planted in spring, in contrast to bare rooted trees. However, pot grown plants are more expensive and more susceptible to drought stress and diseases. It is recommended to plant trees and shrubs straight in late autumn or early winter just before the first frost occurs. Currently, the soil is still warm which makes it easier for the plant roots to establish. The planting material can best be purchased when being a few years old and has a size of at least be between 60-200 cm, depending on the species. Buying older trees has the advantage that they will come in production earlier but are more expensive and will have adapt less easy to the site conditions. When planting shrubs and trees, the planting hole should be large enough to prevent roots from being damaged (Crawford, 2010, p. 74).

7.3.2. Management

Within a food forest, the main management tasks, will be harvesting, weeding and pruning. Below, each of these management tasks will be described in relation to the food forest design as presented in this report.

Harvesting

Harvesting usually is the task that consumes most time and money when managing a food forest, also because a large variety of plant species need to be harvested. This makes it more complicated and time consuming than harvesting an agricultural system that only consist of one species (Crawford, 2010, p. 321). However, since the idea is to let customers pick their own crops in the food forest, the farm owner does not have to invest time and money for this purpose himself. The perennial crops that are planted in the herb layer will already provide harvestable production the first year after they are planted. After 2-3 years, the shrubs will give their first production, followed by the plums, apples and persimmons, which will start producing after three to four years. The walnuts come into production the latest, after around four to five years (Plants For A Future, 2019)

Pruning and coppicing

The need of pruning in a food forest system is always a point where is a lot of discussion about. Food forest expert Wouter van Eck claims that nature manages itself to be productive and humans do not need to make any effort for this (Limareva, 2014). However, the website of the Flemish institute for agriculture, fishing and nitration research (ILVO) states that pruning of the fruit trees (apple, plum and persimmon) is important to enhance the amount and quality of the crops, and to prevent the formation and spreading of diseases (ILVO, 2019).

Since the design is based on the maximum potential size of the trees, it is not necessary to use pruning to keep them on a certain size. Therefore, it is recommended to keep pruning to a minimum in this food forest, also since the farm owner does not have much time available for such tasks. In the first six years after the fruit trees have been planted this pruning should conducted the most frequent, which is once a year. Attention should be given to remove crossing branches, secondary stems, waterspouts and downward growth. After this period, pruning is barely required anymore and just need to conduct each two to three years, depending on the variety (ILVO, 2019). Pruning should be ideally conducted on dry sunny days around January-February, which is after the period of disease spores in the air. The shrubs and hedges can also be pruned during this time if required. And exception will be made for the plum trees, which are best pruned from late spring to summer to reduce the risk of silverleaf infection on branch cuts (Crawford, 2010, p. 330).

The willows on the small dike should be coppiced at least once in three years, to keep them in shape and to prevent large branches from tearing of. This must be done during winter, when the trees are in a dormant state (Caslin, Finnan, Johnston, McCracken, & Walsh, 2015).

Weeding

However, a food forest is a very low maintenance system, a system free of weeds does not exist. When weeding will not take place, the system turns slowly back into a forest in where species will dominate that are established closed by and will spread themselves through the system. Having said this, it should not be forgotten that weeds also have positive effects in a food forest garden, by covering the soil, providing biomass and improving biodiversity. Therefore it is not required to remove all weeds as rigorously as in a regular vegetable garden, as long if the food forest will stay well accessible (Crawford, 2010, p. 329). Since the paths are straight and are designed to be broad enough to be accessible for a mower, it is expected that weeding can be done quite efficiently and does not consume too much time. If a patch of the perennial layer gets too weedy and difficult to manage, it is recommended to replace that layer with another. This must be done by mulching off the existing plants first and replanting it with another species (Crawford, 2010, p. 335).

8. Discussion

In this chapter, a critical reflection will be given on the methodology that has been used, as well on the whole design process, and the contribution of food forests towards sustainability.

8.1. Methodological limitations

Site analysis

While conducting the field soil survey with Aequator, only a small number of soil profiles were taken at each site due to time limitations. However, these samples are considered to give a good indication and biased locations were avoided, a more detailed overview could be obtained if more time is available. This could be done by using raster of 5 x 5 meters over the site surface, in where in every square one soil profile will be taken. Afterwards, a soil map can be developed by analysing and processing this information.

The soil information that was used for the laboratory analysis was collected on the farm sites by Eurofins. Since no additional information about nutrients was collected, their results were used for further analysis in this report. In the method they used, 20 samples were randomly taken divided over the farm sites. Normally, this would provide a good representation of the average soil conditions. However, some sites were quite heterogeneous as mentioned earlies in this report. Differences in topography (dikes) were often present, as well as differences in vegetation cover. The results of Eurofins thus could be a generalisation, because they do not take the heterogeneity within the sites into account.

Stakeholder analysis

The method that has been used to make clear the functions within the food forest, worked out to be very useful. The main advantage of this method is that it was quite structured, which was important while there are so many options to choose from in a food forest. It also did not go too much in detail, which is an advantage since getting lost in detail was a main risk in discussing food forest systems. Additionally, the workshops organised by the Farm LIFE project worked out to be very useful to gain new insights and to develop a connection with the farm owner and the other members of the team.

Species selection

As mentioned before, the species selected were based on their ability to grow on the farm site, and their properties to contribute to the requirements of the farm owner. The method to link the species to the results of the site analysis was consciously done in a simple way, by just using the criteria soil moisture, soil texture and soil acidity (pH). However, information about nutrient levels was available, the choice was made to not directly use this for plant selection. This would have been very complicated since nutrient requirements for each species are different and soil fertility is dependent on many different factors. Thereby, the criteria mentioned above could be directly linked to information found in PFAF.org, which made it an accurate way to develop a database with reliable information.

The functions as selected by the farm owner were thereafter used to make decisions about species. Hereby, all species that support those functions were involved in the design. This decision was taken because the farm owner did not yet indicate which individual species, he would like to use in the food forest. It could be the case that some of the selected species will not be selected by the farmer, even though it supports his needs. Furthermore, a financial analysis of the selected species was not conducted, since this did not fit within the timeframe of this research.

8.2. Design process

The whole process towards the final design of the food forest was quite a challenge, since many factors were included and need to be combined. Since the farmer was not yet very concrete about his ideas for the farm sites, quite some time and discussion were required to make clear the vision, functions and objectives. Thereby, it was challenging to match the objectives with the farmers with the possibilities of the farm sites, especially related to soil conditions. During the meetings it became clear that this process should not be rushed since the development of a food forest is a complex task. Therefore, it was very beneficial to have several meetings within the project together within a group of people that share a mutual interest on the success of this project and all discussions aimed for the best outcome.

The design principles as described by Martin Crawford in his book 'Creating a Forest Garden' were very useful while make decisions on how to locate the previously selected plant species and how to combine them in an optimal way. However, the final design should not be looked at as the best and only possible design for a food forest, since these principles can be used on many ways depending on the creativity and personal view of the person who creates it. It is also important to take in mind that just three vegetation layers were used in the design, while a food forest can contain up to seven layers. Also, the design was well arranged in straight rows, to keep management easy. Thereby, it is good to take in mind that a food forest is not a fixed system in where unexpected chances always occur, even if such a system is well designed.

8.3. Reflection on sustainability

Within the Netherlands, there is still a sharp distinction between agriculture and nature. Food forest systems can be the missing link to connect those worlds, since food forests are productive farming systems that produce a wide range of edible products as well as environmental benefits. As mentioned before, traditional monoculture systems are not sustainable on the long term. These systems require high inputs of fertilisers and pesticides that are hazardous for the environment and also depend on high inputs of fossil fuels that will run out on the long term. Food forests follow the principles of natural succession, and do not require external inputs to remain productive. Thereby, there is evidence that systems in where a higher diversity of crops is grown has a better resilience against pests and diseases than monocultures. Food forests also provide social benefits, since nature is known to have beneficial effects on mental health and food forests often have a social function in where people come together and connect with each other.

However, there is no doubt that food forests are a promising sustainable alternative for traditional agriculture within the Netherlands, many farmers are not eager to transform their land to such a system. This has to do with the high initial investment costs that are required, and that it takes around 3-5 years until a food forest will reach its production phase. Thereby, there is not much knowledge available about how much profit can be made with a food forest system, since it is still a relatively new system in the Netherlands. Food forests are more complicated to design than monoculture systems and require deep knowledge of ecological processes. However, knowledge is rapidly increasing since a lot of research to food forests is currently undertaken. The results of this research could provide valuable insights that make it easier for farmers to switch to a food forest system in the future.

9. Conclusion and recommendations

In this chapter, a conclusion about the design process will be provided, as well as recommendations for the food forest and further research.

9.1. Conclusion

Food forests have a high potential for sustainable food production, while also being environmentally beneficial. The outcome of the whole design process has resulted in a food forest design that is both sites adopted, adopted to the needs of the farm owner and being environmentally beneficial. The site conditions and the client's objectives- and limitations are the main factors that should be taken into account to decide on what species can be selected and how the final design should look like. While making the final layout, the design principles as described by Martin Crawford are a useful guideline to place the species on the right location. Altogether, the final design is just one example of how a suitable food forest system could be developed. Within the criteria many other designs are possible. At least, this design can be used as an inspiration for the farm owner and other farmers and contribute to knowledge about food forest systems in the future.

9.2. Recommendations

As mentioned before, the design presented in this report is just an example how a suitable design could look like. Whether the food forest will be created and planted following the design as presented in this report, is up to the farm owner. After a food forest will be finally planted however, the following recommendations can be helpful;

- Since financial data about the selected species and their implementation and management is not provided in this report, it is recommended to do a market study in which these costs will be analysed. Hereby, the economic potential of the species and the way the food forest and it products will be marketed should also be taken into account.

- Once a food forest is established, it is important to monitor indicators that provide information about its development and functioning. It is recommended to start monitoring in the beginning of the process, since this makes it possible to monitor the food forest over time during its establishment. Attention could be paid to ecological indicators, socio-economic indicators and socio-cultural indicators. Examples of ecological indicators are soil quality, nutrient balance, biodiversity and carbon sequestration. Socio economic indicators could be financial inputs- and outputs. Socio-cultural indicators are the number of visitors, what the visitors appreciate about the food forest and what ideas they have to improve it.

- Once the food forest is planted, take in mind that it is a dynamic system. Even though the system is well designed, unexpected events can still happen. Trees and shrubs and shrubs can die when a diseases or other events occur. When something dies, it is recommended to not replant the same species at this location as the risk of reinfection is high.

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Appendix I: Ground water tables

Table 12: *Ground water tables*

Groundwater table (Gt)	Mean Highest Groundwater Level in cm Below Ground Level (GHG)	Mean Lowest Groundwater Level in cm Below Ground Level (GLG)
Ia	< 25	< 50
Ic	> 25	< 50
IIa	< 25	50 - 80
IIb	25 - 40	50 - 80
IIc	> 40	50 - 80
IIIa	< 25	80 - 120
IIIb	25 - 40	80 - 120
IVu	40 - 80	80 - 120
IVc	> 80	80 - 120
Va	< 25	> 120
Vao	< 25	120 - 180
Vad	< 25	> 180
Vb	25 - 40	> 120
Vbo	25 - 40	120 - 180
Vbd	25 - 40	> 180
VI	40 - 80	> 120
VIo	40 - 80	120 - 180
VId	40 - 80	> 180
VII	80 - 140	> 120
VIIo	80 - 140	120 - 180
VIId	80 - 140	> 180
VIII	> 140	> 120
VIIIo	> 140	120 - 180
VIIId	> 140	> 180

Appendix II: Soil profiles and their characteristics of all farm sites

***Table 13**: Soil profiles of the farm sites and their characteristics*

Farm	Site name	Sample nr	X	Y	Date	Soil type	Cultivation	GHG	GLG	Gt	GWS	Landuse	Rootable depth
Koekkoek	Site 1	1	113663	413233	8-3-2019	Vlakvaaggrond		35	120	Vbo	?		40
Koekkoek	Site 1	2	113768	413229	8-3-2019	Liedeerdgrond		5	80	IIIa	20		30
Koekkoek	Site 1	3	113785	413324	8-3-2019	Liedeerdgrond		5	100	IIIa	10		30
Koekkoek	Site 1	4	113705	413265	8-3-2019	Liedeerdgrond		10	90	IIIa	15		30
Koekkoek	Site 1	5	113667	413265	8-3-2019	Weideveengrond		5	85	IIIa	5		30
Koekkoek	Site 2	1	114128	413738	8-3-2019	Liedeerdgrond		20	125	Vao	55	GR	80
Koekkoek	Site 2	2	113922	413544	8-3-2019	Leekeerdgrond		15	115	IIIa	35	GR	100
Koekkoek	Site 2	3	113583	413427	8-3-2019	Leekeerdgrond		15	110	IIIa	95	GR	90
Koekkoek	Site 2	4	113785	413505	8-3-2019	Leekeerdgrond		25	110	IIIa	65	GR	70
Koekkoek	Site 2	5	113882	413624	8-3-2019	Vlakvaaggrond		30	100	IIIb	45	GR	35
Koekkoek	Site 3	1	113073	413683	8-3-2019	Leekeerdgrond		35	110	IIIb	65	AX	80
Koekkoek	Site 3	2	112992	413650	8-3-2019	Leekeerdgrond		120	181	VIId	>120	BL	100
Koekkoek	Site 3	3	113041	413710	8-3-2019	Liedeerdgrond		80	160	VIIo	>120	BL	100
Koekkoek	Site 4	1	113202	413728	8-3-2019	Leekeerdgrond		35	120	Vbo	70	AX	80
Koekkoek	Site 4	2	113369	413506	8-3-2019	Leekeerdgrond		35	110	IIIb	105	AX	80
Koekkoek	Site 4	3	113286	413586	8-3-2019	Leekeerdgrond		30	95	IIIb	55	AX	65

Appendix III: Soil condition of all farm sites

Table 14: *Soil condition scores of all farm sites*

Farm	Site name	Sample nr	x	y		Total	Crop cover	Rooting ability	Soil compaction	Earthworms	Soil structure	pH	Organic matter	Gley presence	Waterlogging	Cracks	Track formation
Koekkoek	Site 1	1	113663	413233		20	2	1	0	0	2	2	0	1	2	2	2
Koekkoek	Site 1	2	113768	413229		38	2	2	2	1	2	2	2	1	2	2	2
Koekkoek	Site 1	3	113785	413324		35	2	2	2	0	2	2	2	1	2	2	2
					Average	**31**	**2,0**	**1,7**	**1,3**	**0,3**	**2,0**	**2,0**	**1,3**	**1,0**	**2,0**	**2,0**	**2,0**
Koekkoek	Site 2	1	114128	413738		31	1	2	2	1	1	2	1	2	2	2	2
Koekkoek	Site 2	2	113922	413544		33	1	2	2	1	1	2	2	1	2	2	2
Koekkoek	Site 2	3	113583	413427		30	1	2	2	1	1	2	2	1	1	2	1
Koekkoek	Site 2	4	113785	413505		34	1	2	2	1	1	2	2	2	2	2	2
Koekkoek	Site 2	5	113882	413624		37	1	2	2	2	1	2	2	2	2	2	2
					Average	**33**	**1,0**	**2,0**	**2,0**	**1,2**	**1,0**	**2,0**	**1,8**	**1,6**	**1,8**	**2,0**	**1,8**
Koekkoek	Site 3	1	113073	413683		27	1	1	2	1	1	2	2	1	1	2	1
Koekkoek	Site 3	2	112992	413650		37	1	2	2	1	2	2	2	2	2	2	2
Koekkoek	Site 3	3	113041	413710		34	1	2	2	0	2	2	2	2	2	2	2
					Average	**33**	**1,0**	**1,7**	**2,0**	**0,7**	**1,7**	**2,0**	**2,0**	**1,7**	**1,7**	**2,0**	**1,7**
Koekkoek	Site 4	1	113202	413728		42	2	2	2	2	2	2	2	2	2	2	2
Koekkoek	Site 4	2	113369	413506		38	2	2	2	1	2	2	2	1	2	2	2
Koekkoek	Site 4	3	113286	413586		35	2	2	2	1	1	2	2	1	2	2	2
					Average	**38**	**2,0**	**2,0**	**2,0**	**1,3**	**1,7**	**2,0**	**2,0**	**1,3**	**2,0**	**2,0**	**2,0**

Appendix IV: Laboratory soil analysis results from Eurofins

Site 1

Table 15: *Laboratory soil analysis results from site 1*

Resultaat		Eenheid	Resultaat	Streeftraject	laag	vrij laag	goed	vrij hoog	hoog
Chemisch	N-totale bodemvoorraad	kg N/ha	4200	5250 - 8330					
	C/N-ratio		15	13 - 17					
	N-leverend vermogen	kg N/ha	55	95 - 145					
	S-plantbeschikbaar	kg S/ha	12	20 - 30					
	S-totale bodemvoorraad	kg S/ha	905	850 - 1450					
	C/S-ratio		68	50 - 75					
	S-leverend vermogen	kg S/ha	13	20 - 30					
	P-plantbeschikbaar	kg P/ha	4,7	6,5 - 10,9					
	P-bodemvoorraad	kg P/ha	585	380 - 585					
	K-plantbeschikbaar	kg K/ha	150	255 - 400					
	K-bodemvoorraad	kg K/ha	340	310 - 460					
	Ca-plantbeschikbaar	kg Ca/ha	30	260 - 610					
	Ca-bodemvoorraad	kg Ca/ha	4790	3675 - 5510					
	Mg-plantbeschikbaar	kg Mg/ha	220	180 - 310					
	Mg-bodemvoorraad	kg Mg/ha	330	185 - 495					
	Na-plantbeschikbaar	kg Na/ha	30	125 - 180					
	Na-bodemvoorraad	kg Na/ha	25	85 - 125					
	Si-plantbeschikbaar	g Si/ha	51880	21740 - 94200					
	Fe-plantbeschikbaar	g Fe/ha	< 7280	9060 - 16300					
	Zn-plantbeschikbaar	g Zn/ha	1200	1810 - 2720					
	Mn-plantbeschikbaar	g Mn/ha	3510	7250 - 11230					
	Cu-plantbeschikbaar	g Cu/ha	75	145 - 235					
	Co-plantbeschikbaar	g Co/ha	10	15 - 30					
	B-plantbeschikbaar	g B/ha	675	360 - 545					
	Mo-plantbeschikbaar	g Mo/ha	< 10	360 - 18110					
	Se-plantbeschikbaar	g Se/ha	< 7,7	13 - 16					
Fysisch	Zuurgraad (pH)		6,4	6,0 - 6,5					
	C-organisch	%	1,7						
	Organische stof	%	3,3						
	C/OS-ratio		0,52	0,45 - 0,55					
	Koolzure kalk	%	< 0,2	2,0 - 3,0					
	Klei (<2 µm)	%	3						
	Silt (2-50 µm)	%	19						
	Zand (>50 µm)	%	75						
	Slib (<16 µm)	%	9						
	Klei-humus (CEC)	mmol+/kg	77	> 72					
	CEC-bezetting	%	99	> 95					
	Ca-bezetting	%	86	80 - 90					
	Mg-bezetting	%	9,7	6,0 - 10					
	K-bezetting	%	3,1	2,0 - 5,0					
	Na-bezetting	%	0,4	1,0 - 1,5					
	H-bezetting	%	< 0,1	< 1,0					
	Al-bezetting	%	< 0,1	< 1,0					
		Eenheid	**Resultaat**	**Streeftraject**	**laag**	**vrij laag**	**goed**	**zeer goed**	
	Verkruimelbaarheid	rapportcijfer	10,0	6,0 - 8,0					
	Verslemping	rapportcijfer	7,7	6,0 - 8,0					
	Stuifgevoeligheid	rapportcijfer	7,5	6,0 - 8,0					
		Eenheid	**Resultaat**	**Streeftraject**	**laag**	**vrij laag**	**goed**	**vrij hoog**	**hoog**
Biologisch	Microbiële biomassa	mg C/kg	1	165 - 495					
	Microbiële activiteit	mg N/kg	32	60 - 80					
	Schimmel/bacterie-ratio		1,1	0,6 - 0,9					

Site 2

Table 16: *Laboratory soil analysis results from site 2*

Resultaat		Eenheid	Resultaat	Streeftraject
Chemisch	N-totale bodemvoorraad	kg N/ha	9280	4820 - 7650
	C/N-ratio		12	13 - 17
	N-leverend vermogen	kg N/ha	150	95 - 145
	S-plantbeschikbaar	kg S/ha	32	20 - 30
	S-totale bodemvoorraad	kg S/ha	3160	780 - 1330
	C/S-ratio		35	50 - 75
	S-leverend vermogen	kg S/ha	45	20 - 30
	P-plantbeschikbaar	kg P/ha	3,3	6,0 - 10,0
	P-bodemvoorraad	kg P/ha	625	350 - 535
	K-plantbeschikbaar	kg K/ha	270	235 - 365
	K-bodemvoorraad	kg K/ha	505	605 - 795
	Ca-plantbeschikbaar	kg Ca/ha	25	240 - 560
	Ca-bodemvoorraad	kg Ca/ha	14200	11405 - 17110
	Mg-plantbeschikbaar	kg Mg/ha	520	165 - 285
	Mg-bodemvoorraad	kg Mg/ha	835	465 - 820
	Na-plantbeschikbaar	kg Na/ha	60	115 - 165
	Na-bodemvoorraad	kg Na/ha	90	75 - 115
	Si-plantbeschikbaar	g Si/ha	176670	19960 - 86500
	Fe-plantbeschikbaar	g Fe/ha	< 6790	8320 - 14970
	Zn-plantbeschikbaar	g Zn/ha	2430	1660 - 2500
	Mn-plantbeschikbaar	g Mn/ha	1360	6650 - 10310
	Cu-plantbeschikbaar	g Cu/ha	385	135 - 215
	Co-plantbeschikbaar	g Co/ha	10	15 - 25
	B-plantbeschikbaar	g B/ha	785	335 - 500
	Mo-plantbeschikbaar	g Mo/ha	30	330 - 16640
	Se-plantbeschikbaar	g Se/ha	29	12 - 15
Fysisch	Zuurgraad (pH)		6,4	6,4 - 6,7
	C-organisch	%	3,3	
	Organische stof	%	6,4	
	C/OS-ratio		0,52	0,45 - 0,55
	Koolzure kalk	%	3,8	2,0 - 3,0
	Klei (<2 µm)	%	26	
	Silt (2-50 µm)	%	52	
	Zand (>50 µm)	%	12	
	Slib (<16 µm)	%	42	
	Klei-humus (CEC)	mmol+/kg	239	> 208
	CEC-bezetting	%	100	> 95
	Ca-bezetting	%	89	80 - 90
	Mg-bezetting	%	8,7	6,0 - 10
	K-bezetting	%	1,6	2,0 - 5,0
	Na-bezetting	%	0,5	1,0 - 1,5
	H-bezetting	%	< 0,1	< 1,0
	Al-bezetting	%	< 0,1	< 1,0

Bar scale columns: laag | vrij laag | goed | vrij hoog | hoog

	Eenheid	Resultaat	Streeftraject
Verkruimelbaarheid	rapportcijfer	6,3	6,0 - 8,0
Verslemping	rapportcijfer	5,8	6,0 - 8,0
Stuifgevoeligheid	rapportcijfer	9,1	6,0 - 8,0

Bar scale columns: laag | vrij laag | goed | zeer goed

Biologisch	Eenheid	Resultaat	Streeftraject
Microbiële biomassa	mg C/kg	19	320 - 960
Microbiële activiteit	mg N/kg	62	60 - 80
Schimmel/bacterie-ratio		0,7	0,6 - 0,9

Bar scale columns: laag | vrij laag | goed | vrij hoog | hoog

Site 3

Table 17: *Laboratory soil analyis results from site 3*

Resultaat		Eenheid	Resultaat	Streeftraject
Chemisch	N-totale bodemvoorraad	kg N/ha	11060	4480 - 7110
	C/N-ratio		14	13 - 17
	N-leverend vermogen	kg N/ha	165	95 - 145
	S-plantbeschikbaar	kg S/ha	31	20 - 30
	S-totale bodemvoorraad	kg S/ha	2935	725 - 1235
	C/S-ratio		54	50 - 75
	S-leverend vermogen	kg S/ha	45	20 - 30
	P-plantbeschikbaar	kg P/ha	4,9	5,6 - 9,3
	P-bodemvoorraad	kg P/ha	890	325 - 500
	K-plantbeschikbaar	kg K/ha	585	215 - 340
	K-bodemvoorraad	kg K/ha	495	550 - 725
	Ca-plantbeschikbaar	kg Ca/ha	200	225 - 520
	Ca-bodemvoorraad	kg Ca/ha	12630	11120 - 16680
	Mg-plantbeschikbaar	kg Mg/ha	260	155 - 265
	Mg-bodemvoorraad	kg Mg/ha	770	420 - 750
	Na-plantbeschikbaar	kg Na/ha	60	110 - 155
	Na-bodemvoorraad	kg Na/ha	90	70 - 105
	Si-plantbeschikbaar	g Si/ha	250480	18540 - 80330
	Fe-plantbeschikbaar	g Fe/ha	< 6300	7720 - 13900
	Zn-plantbeschikbaar	g Zn/ha	4600	1540 - 2320
	Mn-plantbeschikbaar	g Mn/ha	1170	3090 - 4020
	Cu-plantbeschikbaar	g Cu/ha	610	125 - 200
	Co-plantbeschikbaar	g Co/ha	< 10	15 - 25
	B-plantbeschikbaar	g B/ha	1115	310 - 465
	Mo-plantbeschikbaar	g Mo/ha	60	310 - 15450
	Se-plantbeschikbaar	g Se/ha	31	11 - 14
Fysisch	Zuurgraad (pH)		6,9	6,4 - 6,7
	C-organisch	%	5,2	
	Organische stof	%	9,5	
	C/OS-ratio		0,55	0,45 - 0,55
	Koolzure kalk	%	5,7	2,0 - 3,0
	Klei (<2 µm)	%	21	
	Silt (2-50 µm)	%	36	
	Zand (>50 µm)	%	28	
	Slib (<16 µm)	%	32	
	Klei-humus (CEC)	mmol+/kg	233	> 222
	CEC-bezetting	%	99	> 95
	Ca-bezetting	%	88	80 - 90
	Mg-bezetting	%	8,8	6,0 - 10
	K-bezetting	%	1,8	2,0 - 5,0
	Na-bezetting	%	0,6	1,0 - 1,5
	H-bezetting	%	< 0.1	< 1.0
	Al-bezetting	%	< 0,1	< 1,0

	Eenheid	Resultaat	Streeftraject
Verkruimelbaarheid	rapportcijfer	7,7	6,0 - 8,0
Verslemping	rapportcijfer	6,6	6,0 - 8,0
Stuifgevoeligheid	rapportcijfer	8,7	6,0 - 8,0

Resultaat		Eenheid	Resultaat	Streeftraject
Biologisch	Microbiële biomassa	mg C/kg	45	475 - 1425
	Microbiële activiteit	mg N/kg	68	60 - 80
	Schimmel/bacterie-ratio		1,0	0,6 - 0,9

Site 4

Table 18: *Laboratory soil analysis results from site 4*

Resultaat		Eenheid	Resultaat	Streeftraject	laag	vrij laag	goed	vrij hoog	hoog
Chemisch	N-totale bodemvoorraad	kg N/ha	10690	4670 - 7410					
	C/N-ratio		13	13 - 17					
	N-leverend vermogen	kg N/ha	160	95 - 145					
	S-plantbeschikbaar	kg S/ha	37	20 - 30					
	S-totale bodemvoorraad	kg S/ha	3285	755 - 1290					
	C/S-ratio		41	50 - 75					
	S-leverend vermogen	kg S/ha	45	20 - 30					
	P-plantbeschikbaar	kg P/ha	4,5	5,8 - 9,7					
	P-bodemvoorraad	kg P/ha	675	335 - 520					
	K-plantbeschikbaar	kg K/ha	340	225 - 355					
	K-bodemvoorraad	kg K/ha	490	535 - 710					
	Ca-plantbeschikbaar	kg Ca/ha	50	230 - 540					
	Ca-bodemvoorraad	kg Ca/ha	12200	10165 - 15245					
	Mg-plantbeschikbaar	kg Mg/ha	420	160 - 275					
	Mg-bodemvoorraad	kg Mg/ha	750	405 - 735					
	Na-plantbeschikbaar	kg Na/ha	60	115 - 160					
	Na-bodemvoorraad	kg Na/ha	80	75 - 110					
	Si-plantbeschikbaar	g Si/ha	208900	19320 - 83740					
	Fe-plantbeschikbaar	g Fe/ha	6920	8050 - 14490					
	Zn-plantbeschikbaar	g Zn/ha	7120	1610 - 2420					
	Mn-plantbeschikbaar	g Mn/ha	1460	3220 - 4190					
	Cu-plantbeschikbaar	g Cu/ha	565	130 - 210					
	Co-plantbeschikbaar	g Co/ha	10	15 - 25					
	B-plantbeschikbaar	g B/ha	1310	320 - 485					
	Mo-plantbeschikbaar	g Mo/ha	20	320 - 16100					
	Se-plantbeschikbaar	g Se/ha	32	11 - 14					
Fysisch	Zuurgraad (pH)		6,8	6,4 - 6,7					
	C-organisch	%	4,2						
	Organische stof	%	7,7						
	C/OS-ratio		0,55	0,45 - 0,55					
	Koolzure kalk	%	4,9	2,0 - 3,0					
	Klei (<2 µm)	%	19						
	Silt (2-50 µm)	%	43						
	Zand (>50 µm)	%	25						
	Slib (<16 µm)	%	32						
	Klei-humus (CEC)	mmol+/kg	213	> 193					
	CEC-bezetting	%	100	> 95					
	Ca-bezetting	%	89	80 - 90					
	Mg-bezetting	%	9,0	6,0 - 10					
	K-bezetting	%	1,8	2,0 - 5,0					
	Na-bezetting	%	0,5	1,0 - 1,5					
	H-bezetting	%	< 0,1	< 1,0					
	Al-bezetting	%	< 0,1	< 1,0					

	Eenheid	Resultaat	Streeftraject	laag	vrij laag	goed	zeer goed
Verkruimelbaarheid	rapportcijfer	7,8	6,0 - 8,0				
Verslemping	rapportcijfer	6,2	6,0 - 8,0				
Stuifgevoeligheid	rapportcijfer	8,8	6,0 - 8,0				

Biologisch	Eenheid	Resultaat	Streeftraject	laag	vrij laag	goed	vrij hoog	hoog
Microbiële biomassa	mg C/kg	58	385 - 1155					
Microbiële activiteit	mg N/kg	77	60 - 80					
Schimmel/bacterie-ratio		0,9	0,6 - 0,9					

Appendix V: Functions analysed during the stakeholder analysis

Table 19: *Functions analysed during the stakeholder analysis*

Focus group	Function nr	Function name	Explanation of function
Commercial (Bioproducts)	1	Aromatics & Herbs.	Non-woody plants with savory or aromatic properties that are used for flavoring and garnishing food, medicinal purposes, or for fragrances
	2	Annuals & Seeds	The use of annual plant species
	3	Biomass Crops	Plant species grown for energy production
	4	Livestock	The use of domestic animals in an agricultural setting
	5	Stimulants	Plants that have a stimulating effect after being consumed
	6	Cut flowers & Bulbs	Plant species grown for flowers
	7	Fruits	Trees and shrubs that produce large edible fruits
	8	Fish culture	Fish farming in using fish stock sytems
	9	Fodder & bedding	Plants species that are grown for fodder production
	10	Fresh vegetables	Plants that are known as vegetables
	11	Bee keeping	Owning and breeding bees for their honey
	12	Mushrooms/truffels	Growing mushrooms or truffels
	13	Natural fibres	Fibres that are produced by plants or animals
	14	Plant nursery	Propogation of plants
	15	Nuts	Trees and shrubs that produce edible nuts
	16	Oils & Resins	Plants that produce oil for commercial purposes
	17	Ornamental plants	Plants grown for decorative purposes
	18	Berries	Shrubs that produce edible berries
	19	Timber & Firewood	Trees that produce good quaility timber and firewood
	20	Pasture	Land covered with grass and other low plants suitable for grazing animals
Commercial (Ecoservices)	21	Pick your own crops	Farming system in where customers can pick their own crops
	22	Bee keeping rights	The right to keep bees in a certain area
	23	Carbon credits	Gaining money for the reduction of CO2 emissions
	24	Food self-sufficiency	Being self sufficient in terms of food requirements
	25	Campground/B&B	Offering accomodation for customers to stay overnight
	26	Recreational fishing	Getting paid for letting customers fish on your property
	27	Hiking trails	Specially designed routes for hikers to use
	28	MTB trail	Specially designed routes for mountainbikers to use
	29	Photo hunting	Offering tours for photographers
	30	Working at the farm.	Offering possibilities tocustomers work on the land and in the farm
	31	Grazing rights	The rights to let cattle graze in a certain area
	32	Test Area	A specific area assigned to test new species with a high potential value
	33	Payment Environmental Services.	Getting paid for taking action to improve ecological values
	34	Study & Research Facilities.	Offering study and reserach possibilities to schools and universities
	35	Study and guided tours.	Offering tours with the purpose of education
	36	Game hunting	Offering possibilities to hunt against payment
Environmental	37	Erosion control	Practices to prevent and control erosion
	38	Animal Feeding places.	Creating fouraging places for wildlife
	39	Wildlife protection.	Conducting measures to Improve habitat for wildlife

	40	Insect shelter	Conducting measures to improve habitat for insects
	41	Reforestation/Afforestation.	Planting or replanting trees in a non forested area
	42	Rivers & Open water.	Improving the environmental quality of rivers and open water
	43	Ecological Corridor	Creating a connection between two areas to improve their environmental functions
	44	Waste control	Taking measures to reduce or recycle waste
	45	Landscape Restoration	Taking measures to ecologically improve degraded landscapes
	46	Biodiversity promoting plants.	Using plants that are known to promote biodiversity
Social	47	Create employment	Offering paid work
	48	Work with disabled people.	Offer special working places for disabled people
	49	Provide social services	Promoting social benefits such as education and entertainment

Appendix VI: Example of database with relevant species information

Site requirements

Table 20: *Example of species database with relevant information regarding to site requirements*

English name	Scientific name	Form	USDA hardiness zone	Soil richness	Soil moisture	Soil texture	Soil pH
Crab apple	Malus sylvestris	Tree	4-8	M/R	D/M	L/M/H	N/B
Princesstree	Paulownia tomentosa	Tree	6-9	M/R	M	L/M/H	A/N
Chinese white pine	Pinus armandii	Tree	6-9	M/R	D/M	L/M	A/N
Chinese pinenut	Pinus koraiensis	Tree	4-7	M/R	D/M	L/M	A/N
Wild cherry	Prunus avium	Tree	3-7	M/R	D/M	L/M/H	A/N/B
Saskatoon	Amelanchier alnifolia	Shrub	4-6	P/M/R	D/M/W	L/M	A/N
Guelder rose	Viburnum opulus	Shrub	3-8	M/R	M/W	L/M/H	A/N/B
Black chokeberry	Aronia melanocarpa	Shrub	3-8	P/M/R	D/M/W	L/M/H	A/N
Butterfly bush	Buddleja davidii	Shrub	4-8	P/M/R	D/M	L/M/H	A/N/B
Carolina allspice	Calycanthus floridus	Shrub	5-10	M/R	M	L/M	A/N
Horseradish	Armoracia rusticana	Perennial	4-9	M/R	M	L/M/H	A/N/B
Arnica	Arnica montana	Perennial	5-9	P/M/R	D/M	L/M/H	A/N
Sea kale	Crambre maritima	Perennial	4-8	M/R	M	L/M	N/B
Cardoon	Cynara cardunculus	Perennial	5-9	P/M/R	D/M	L/M/H	A/N/B
Globe Artichoke	Cynara scolymus	Perennial	5-9	M/R	M	L/M/H	N/B

Soil richness		Soil texture	
Poor	P	Light	L
Moderate	M	Medium	M
Rich	R	Heavy	H
Soil moisture		**Soil pH**	
Dry	D	Acid	A
Mist	M	Neutral	N

Wet	W	Basic	B

Commercial functions and environmental functions

Table 21: *Example of species database with relevant information regarding to commercial and economical functions*

			Commercial function						Environmental functions		
English name	**Scientific name**	**Form**	**Edible fruits**	**Edible Berries**	**Herbs**	**Vegetables**	**Timber & firewood**	**Biomass crops**	**Fodder & bedding**	**Attracts pollinators**	**Attracts wildlife**
Crab apple	Malus sylvestris	Tree	+							+	+
Princesstree	Paulownia tomentosa	Tree					+			+	
Chinese white pine	Pinus armandii	Tree					+				
Chinese pinenut	Pinus koraiensis	Tree					+				
Scotch pine	Pinus sylvestris	Tree					+				+
Wild cherry	Prunus avium	Tree	+				+			+	+
Saskatoon	Amelanchier alnifolia	Shrub		+						+	+
Guelder rose	Viburnum opulus	Shrub		+						+	
Black chokeberry	Aronia melanocarpa	Shrub		+						+	
Butterfly bush	Buddleja davidii	Shrub								+	+
Carolina allspice	Calycanthus floridus	Shrub								+	
Horseradish	Armoracia rusticana	Perennial				+				+	
Arnica	Arnica montana	Perennial								+	
Sea kale	Crambre maritima	Perennial				+					
Cardoon	Cynara cardunculus	Perennial								+	
Globe Artichoke	Cynara scolymus	Perennial				+				+	

Appendix VII: Overview of selected functions with remarks and discussion points

***Table 22:** Overview of the selected functions with remarks and discussion points*

ILU focus group	Function nr	Function name	Remarks and discussions	Farm sites
Commercial (Bioproducts)	1	Aromatics & Herbs.	-	
	2	Annuals & Seeds	-	
	3	Biomass Crops	-	
	4	Livestock	When thinking about selling meats the story of Bio and 'free roaming' becomes more important all the time. This is a very good sales argument, besides being more healthier for the animals. The pigs in place could be roaming free. We should explore the options (landowner should answer). 1. If we leave the pigs on the bigger meadow, is rotation needed? 2. Can they held together with cows? 3. Do we need to adjust the fences? 4. What does that mean for feeding and bedding? It would help if we create more shadow, certainly when longer periods of high temperatures can be expected. This also counts for the cows in the same field. Shadow trees should be planted. Maybe a few in each compartment is enough? We will create a sort of 'Dehesa'.	2
	5	Stimulants	-	
	6	Cut flowers & Bulbs	Maybe some flowers near current bee hives location.	3
	7	Fruits	The trees/shrub rows or patches can include also some speciality fruit trees. Preferably fruits that are not easy to buy and produce in seasons that there is not much else available. This can also be low-stem fruits, growing in between the nut trees or other fruit trees. In this way the harvest and maintenance is easy. Added value may be an option (juices & cider). Certainly the mix of various juices is trendy: like vlierbes with apple. There are several options to explore when speaking about strips, rows or patches as this can be done in several ways, and maybe we should test all (please other experts, adjust the options where you think is best).	2 & 4

			1. Larger trees will stand in small square patches/islands. In each patch there is 1 tree and several other things (see other functions). Between the patches the annuals can grow and are harvested. 2. The trees are planted randomly in the field (or in rows). We create a Dehesa landscape. Around the trees annuals can grow. 3. We use strips where trees are planted in regular intervals. Between the trees we use the 'theory of abundance'. We put in so much seed and other smaller trees and shrubs that weeds will not be able to grow. We harvest, or thin out, whatever is needed in the future. 4. We use strips where trees are planted in regular intervals. Between the trees we use production species that have big leaves so as to avoid too much weeds. Like Artisjok, Rabarber. 5. We can also use many types of shrubs with berries and/or smaller fruit trees and these will overgrown the strip in the long run. This can also be combined with environmental functions.	
	8	Fish culture	-	
	9	Fodder & bedding	Fodder & bedding is both needed. Fodder: for this a fodderbank could be created. Either along the borders of the meadow (cattle eat over the fence when they are in a certain compartment) or in another place. In that case mowing, transporting and feeding the fodder is needed. Special species are needed. Bedding (stro) has to be come from outside. Thus preferably we grow something ourselves. Given the conditions of the soils this is not that easy.	3 & 4
	10	Fresh vegetables	Also as at test some speciality crops can be grown, preferable some crops that can outgrow the regular weeds and are perennials.	4
	11	Bee keeping	-	
	12	Mushrooms/truffels	-	
	13	Natural fibres	-	

	14	Plant nursery	-	
	15	Nuts	Nuts could take a substantial part of the system. The profit/kg is good enough and making oil out of it might not even be worthwhile. The soils are very wet so we have to be careful what to select. Maybe there are species on variety (local) level that are applicable.	2 & 4
	16	Oils & Resins	-	
	17	Ornamental plants	-	
	18	Berries	Some shrub species can be added to the fruit and nut tree areas, in the same rows or patches.	2 & 4
	19	Timber & Firewood	<u>Selected but no action required right now</u>. Timber will come from the new trees, but only after a long time.	3
	20	Pasture	We could improve pastures with new mixes of 'kruidenrijk mengsel'. We have to rethink the content of such a mix. We could also include a biodiversity goal, if possible. Could be tested first on small area.	2
Commercial (Ecoservices)	21	Pick your own crops	A part of the land will be converted to a food forest or pick yourself plantation. Many species will be planted in such a way that there is always something to pick in the different parts of the season. This can include flowers, fruits, nuts, berries etc. This area can function in a way that 'members' of the food forest may come, get the key of the gate, and pick things. Such has to be developed well off course. We could think about an annual paid subscription and maybe weekly alerts if something is ready for picking. Local economy is crucial here.	4
	22	Bee keeping rights	There is a beekeeper on the land. Better communication is required as to where to place what. Ask for bio honey in return to make part of the sales package. We should also think about the "Bloeiboog' to make sure the bees have always something to collect. Bloeiboog itself (planting special plants) are part of other functions. Starting with paardebloeme and ending with Klimop.	3
	23	Carbon credits	<u>No actions required at the moment.</u> This is already happening with a local initiative.	
	24	Food self-sufficiency	-	
	25	Campground/B&B	<u>No actions required at the moment.</u> This maybe possible in the future when the building is renovated.	
	26	Recreational fishing		
	27	Hiking trails	Yes, as part of 35 below. But some budget could be reserved for: Info panels on the small hiking trail. Small trail markers.	all

			Corresponding leaflet.	
	28	MTB trail	-	
	29	Photo hunting	Yes, as part of 35 below, no further action here.	all
	30	Working at the farm.	Yes, as part of 35 below, no further action here.	all
	31	Grazing rights	-	
	32	Test Area	Yes, areas will be included. It remains to be seen what else need testing, but this can be species and/or Adaptation Measures.	
	33	Payment Environmental Services.	No actions required at the moment. Already subsidies for vogelakkers, akkerranden, uitgesteld maaibeleid etc.	
	34	Study & Research Facilities.		
	35	Study and guided tours.	The general idea is to offer services to groups. These can be specialist groups of private people or companies. For this we should develop several 'packages'. And such packages could then be promoted on the website, and by the project. An annual program should be made (and who does what). Potential packages • Companies; meeting space + tour outside (walking the farm) + special lunch (either made by the participants while coordinated) or made by Horst. • Restaurants/hotel teams; collecting natural ingredients; + and cook learning day • Private people with specific interest: thematic farm walks: biodiversity (flora or fauna), photo hunting, collect your own food (and cook), historical/cultural walk. Coffee/thee and lunch included. • Special children or school class walk + do-it-yourself something. • Working at the farm. In special parts of the season this could take place. People (and children) could help with pruning, planting, seeding, harvesting etc..	all
	36	Game hunting		
Environmental	37	Erosion control		
	38	Animal Feeding places.		
	39	Wildlife protection.	Create more hiding places and create more stepping stones and connections with the surrounding landscape. This can be done by building more natural fences with	1 & 3

			shrub species with thorns that are also good for biodiversity and maybe produce berries that can be used. This also in relation to the Bloeiboog that need to be created.	
	40	Insect shelter	Yes, insect and bird shelter. Also useful for guided tours and information. Types of bird boxes to be decided by biodiversity experts (where there is a shortage of nesting capacity). For the rest we should aim to increase the natural nesting capacity by creating more rows or places with the remainings of prunings and branches. Dead wood should stay as much as possible.	1 & 3
	41	Reforestation/Affore station.	Renewing poplar stands. Maybe its an idea to convert a part of the poplar stand to a more native vegetation. We could remove some poplars that are its end of the rotation and replace them with more native species…or protect natural regeneration already in place. Species?	1 & 3
	42	Rivers & Open water.		
	43	Ecological Corridor	<u>No further action here.</u> The will be created by the natural fences as stated in 39 and the by the strip or patches of agroforestry under 7. Design in the field has to be made smartly. This while taking into account: • To take into account the local map of the 'ecologische hoofdstructuur'. • To connect existing larger vegetation plots. • Think about North-South and/or East-West importance. • Natuur Netwerk Brabant requirements (maybe for subsidies). • Any border should not need to be a straight line, the more structure and gradient the better. • To create a smooth connection between forest and open land.	3
	44	Waste control		
	45	Landscape Restoration		
	46	Biodiversity promoting plants.	<u>No further action taken here</u>. We will create a 'Bloeiboog ' throughout the project lands and this will include the use of more Biodiversity promoting plants.	
Social	47	Create employment	Automatic. <u>No further action required.</u>	all
	48	Work with disabled people.		

	49	Provide social services	No further action required. The landowner sees the entire project also as a service to the community (learning, education, demonstrating alternatives).	all

Appendix VIII: Relevant design principles for the selected species

Table 23: *Relevant design principles for the selected species*

Layer	English name	Scientific name	Max Height (m)	Max Diameter (m)	Roots	Pollination	Shade tolerance	Wind resistance	Main functions	Additional functions
Canopy	European Alder	Alnus glutinosa	20	10	deep	Self-fertile	sun/halfshade	high	Fodder and bedding	Biomass, timber, attracts wildlife, nitrogen fixing
	Walnut	Juglans regia	20	15	deep	Self-strerile	sun	low	Nut production,	Timber
	White willow	Salix alba	20	15	surface	Self-fertile	sun	high	Fodder and bedding	Biomass, timber, attracts pollinators, attracts wildlife
	Common persimmon	Diospyros virginiana (var.)	7	5	deep	Self-strerile	sun/halfshade	low	Fruits	Timber, attracts pollinators
	Apple	Malus domestica (var.)	6	5	surface	Self-fertile	sun/halfshade	low	Fruits	Timber, attracts pollinators, attracts wildlife
	Plum	Prunus domestica (var.)	6	5	surface	Self-fertile	sun/halfshade	low	Fruits	Attracts pollinators
Shrub	Hawthorn	Crataegus spec. (var.)	6	4	surface	Self-fertile	sun/halfshade	low	Berries	Attracts pollinators, attracts wildlife
	European elder	Sambucus nigra	4	3	surface	Self-fertile	sun/halfshade	high	Berries	Biomass, attracts pollinators, attracts wildlife
	Sea buckthorn	Hippophae rhamnoides	3	3	surface	Dioecious	sun	high	Berries	Biomass, timber, nitrogen fixing
	Blackthorn	Prunus spinosa	3	3	surface	Self-sterile	sun/halfshade	high	Berries	Attracts pollinators, attracts wildlife
	European blackcurrant	Ribes nigrum	2	2	unknown	Self-fertile	sun/halfshade	low	Berries	Attracts pollinators
	Red currant	Ribes rubrum	2	2	surface	Self-fertile	sun/halfshade	low	Berries	Attracts pollinators
Perennial	Welsh union	Allium fistulosum	0,6	0,2	surface	Self-fertile	sun	low	Fresh vegetables	Attracts pollinators, attracts wildlife
	Horseradish	Armoracia rusticana	0,7	0,8	surface	Self-fertile	sun/halfshade	low	Fresh vegetables	Attracts pollinators
	Sea kale	Crambre maritima	0,6	0,6	surface	Self-fertile	sun/halfshade	low	Fresh vegetables	-
	Globe Artichoke	Cynara scolymus	1,5	1	surface	Self-fertile	sun	low	Fresh vegetables	Attracts pollinators
	Daylily	Hemerocallis dumortieri	0,5	0,6	surface	Self-fertile	sun/halfshade	low	Fresh vegetables	Attracts pollinators
	August lily	Hosta plantaginae	0,6	1,2	surface	Self-fertile	sun/halfshade/shade	low	Fresh vegetables	Attracts pollinators
	Lovage	Levisticum officinale	1,8	1	deep	Self-fertile	sun/halfshade	low	Fresh vegetables	Attracts pollinators
	Valerian	Valeriana officinalis	1,5	1	surface	Self-fertile	sun	low	Fresh vegetables	Attracts pollinators
	Wild garlic	Allium ursinum	0,3	0,3	surface	Self-fertile	sun/halfshade/shade	low	Fresh vegetables	Attracts pollinators