Faculty of Forest and Environment

Bachelor thesis

To gain the Bachelor of Science degree (BSc) in International Forest Ecosystem Management at the University of Applied Sciences in Eberswalde, Germany

A food forest design process

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for the showcase food forest "Den Food Bosch" on Bleijendijk, Vught (NL)

presented by

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“Nature does not hurry, yet everything is accomplished.”

Lao Tzu

Abstract

This paper deals with the subject of agricultural transition and explores a way of creating an agro-ecological system that functions like a natural ecosystem. It is briefly looking into different approaches of multistrata agroforestry systems and then describing and analysing a design process of a showcase food forest. The permaculture SADIMET-design tool is used as a general frame. The small-scale food forest Den Food Bosch will be established by end of the year 2017 on the Bleijendijk Estate, Vught (NL). The results of the presented paper are two designs, one future scenario design which illustrates the food forest after 20 years and one establishment design after 3 years.

The design process of a multi-layered system is a complex task, but useful background information and pioneer projects already do exist. Now, the time has come that the number of food forest projects increases. This paper and the project Den Food Bosch are one contribution.

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Acknowledgement

When I joined the group, the food forest design process was about to start. Ernst Götsch was invited to ‘s-Hertogenbosch for a week of “syntropic farming” in the Netherlands. Since I just had done an internship with Ernst Götsch in Brazil, I came to Den Bosch and met up with a very beautiful bunch of people who were organising his stay with love and fun. During that time we agreed upon working together on the design and the establishment of the food forest. I am really glad to be here, now.

Special thanks I want to address towards Wouter van Eck, Malika Cieremans and Floris Komen who helped a lot with their experiences of food forest systems and growing trees. It is beautiful to see, which power a trans-generational network can have, where all the different people and groups support each other. Let us show, that cooperation is stronger than competition. I am grateful that Karst Kooistra and Herma Winnemuller chose to integrate Den Food Bosch on the Bleijendijk Estate. It is such a beautiful and peaceful place and the love of more dedicated people can even “put the Estate on a whole new level”, as Karst said. The interview and the conversations with Karst and Herma helped to realize what potential lies within the synergetic relation between Den Food Bosch and the Estate.

The Waterschap turned out to be a great partner in the shared vision to establish further food forests for research programs. The support of the AgriFood Capital is outstanding – without their financial support Den Food Bosch would probably not be in the same situation, right now. Also the HAS university and the consultancy of some professors like Erwin Bouwmans, Frederike Praasterink an PJ Beers is well appreciated.

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Foreword – A call for future food systems

“The ultimate goal of farming is not the growing of crops, but the cultivation and perfection of human beings”
Masanobu Fukuoka (1975)

Looking at agroforestry systems or even more explicit at food forest systems worldwide, there is quite a broad spectrum of approaches to be seen. All of them address the threat of global ecosystems destruction, while seeking solutions for a growing world population. “Syntropic farming”, “restoration agriculture”, “analog forestry”, “carbon farming” and other agroforestry methods are showing several similarities. Working with natural succession, recovering the soil and building up permanent agricultural systems, which do not (mainly) rely upon annual crops but instead cultivate numerous perennial plants, are basics of all these farming methods. Naturally, they are all planting trees.

On the contrary, the conversion of forests to agricultural land is one main driver of deforestation. An estimation in the FAO-report “State of the World’s Forests” (2016) states that about 80% of the forest cover loss is related to agricultural impact, especially caused by large-scale agriculture[1]. While depletion of natural ecosystems, which are the fundament of life on earth, goes on, greenhouse gas emissions are rising, causing climate change and thus endangering the world’s population. Annual agriculture alone, including agricultural production, deforestation, the food system and the production of waste is responsible for half of all greenhouse gas emissions.[2]

To realize the necessary global transition in agriculture, the cooperation between farmers is a crucial step for creating sustainable land use techniques. Next to a worldwide grassroot movement, a political and financial support for sustainable agricultural techniques is needed. Many different movements such as “organic agriculture”, “demeter”, “permaculture”, “multistrata-agroforestry systems”, “forest gardening”, “water retention landscapes” and dozens of other orientations need to be included into this bigger picture. They are actually all working on the same question: how can

1 FAO, 2016: “State of the World’s Forest”, quoted from: (Kissinger, Herold and De Sy, 2012)
2 Grain: “Food, climate change and healthy soils: The forgotten link.” in Wake Up Before It Is Too Late: Make Agriculture Truly Sustainable Now for Food Security in a Changing Climate, UNCTAD)

agriculture be a source of high quality food, while supporting ecosystem health and resilience? This is the base to create a sustainable system for future generations.

One of the key messages of the UN Trade and Environment Review (UNCTAD, 2013) “Wake Up Before It’s Too Late” states, that the world needs a paradigm shift “from conventional, monoculture-based and high external-input-dependent industrial production towards mosaics of sustainable, regenerative productions systems […] [where] the farmer is not only a producer of agricultural goods, but also a manager of an agro-ecological system”[3]. The main capitalistic driving force of competition taken by itself will only lead to increasing scarcity. However, when using one of the main driving forces in nature, which is the key for a functioning ecosystem, we can succeed: By cooperation, we can go far beyond the imagination of an individual. There lies a great potential within the combination of different solutions.

The question of “how we can feed the world” in a life-enhancing rather than a life-destroying manner, is a task of humanity to be resolved within these generations. Those are big words. Though, the steps are small. They are being taken everywhere. Having the advantage of world wide connectedness and living in the era of information, we do have the possibility to easily share knowledge and experiences. Still, next to all the information available, our teacher really is nature. Here, energy is being structured and organized and natural evolution creates ever new forms of life.

So far, modernisation has taken place on the cost of natural resources. This is not the only possible way - by using our skills of observation and adaptation wisely, we can de facto create a world of abundance. There are farming systems existing, which are highly productive and recover devastated landscapes *meanwhile* they nourish the people. These systems are sprouting, all over the planet. To be part of this worldwide movement, to create one more permanent food system, is the will of a handful of people in the Den Bosch (NL).

– Be the change you wish to see in the world.

3 UNCAD (2013): “Wake Up Before It’s Too Late”

1. Introduction

1.1 Framework and aims

A food forest (syn. for 'multistrata agroforestry system') is a productive low-input farming system mimicking a forest ecosystem. It follows the driving forces of natural succession, uses species diversity for ecosystem resilience and works with existing niches for an efficient capturing of sunlight energy. The species are selected to create a functioning agro-ecological ecosystem, that at the same time fulfils human needs. In a food forest system a wide range of products such as fruits, nuts, berries, perennial vegetables, seeds, herbs, mushrooms and other useful plant material like green manure, wood and medicinal plants can be grown. This list is by far not complete, the integration of livestock, bees, fish and further animals, adds another layer to the diverse range of possibilities.

Food forest farming is not a new invention but has a long historical background in many parts of the world. The Amazon rainforest is a great example, scientists have estimated that around 21mio ha of the Amazon rain forest river basin has anthropogenic background with “varying degrees of multistrata agroforest featuring 69 species domesticated native Amazonian trees”.[4] Some of these food forest systems still exist. Even though diverse food forests are mostly found in the tropics, this farming method is not only valid for warmer climates. Yet, diverse multistrata agroforestry systems in temperate climates currently consist only of a few pioneers. However, the interest and number of projects is rising. The principles of succession, nutrient and water cycles and the differentiation of niches remain the same in all natural ecosystems.

A worldwide call for further research projects on food forest systems can be noticed as their efficiency has not yet scientifically been proven for different climates and crops. Nevertheless, amongst others, the Fazenda Olhos da Água in Bahia, Brazil (Ernst Götsch) and the New Forest Farm in Massachusetts, US (Mark Shepard) indicate the huge potential lying within these farming approaches – in tropical and temperate climate.

Inspired by these multilayered and multifunctional agro-ecological systems, a group of students of the HAS university started Den Food Bosch (du.: “The Food Forest”).

4 Toensmeier, Eric (2016): “The Carbon Farming Solution. A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security.” (p. 113)

In September 2016, when helping to plant a temperate food forest in Dronten (NL), the students envisioned a showcase project in Den Bosch (NL). As a result the group was formed and a network built up.

In the process of land acquisition, contact was made with Karst Kooistra and Herma Winnemuller from the Bleijendijk Estate (Vught), who were interested in supporting the young entrepreneurs. The AgriFood Capital Noord-Brabant decided to provide funding for a project period of two years, covering the establishment of the food forest system and the development of an up-scalable business model. In the fund proposal, the project aims were described as follows: “The design of the plot will be realized with focus on the production of high quality, nutritious food, while being liberal of inputs such as agrochemicals or big machinery. The abandonment of chemicals and tillage practices will allow biodiversity to regenerate, making the system more resilient season after season. […] The end result of this project will be a low-input / high-output food forest farm that is designed to do research and prove the efficiency of this alternative farming method as well as being an educational module for students of young and older age [...].”[5]

This paper is especially focussing on the design process of Den Food Bosch, with the goal of inspiring and motivating further people to create food forest systems. The idea is to give a well documented example, of how designing a food forest can look like. If it clarifies the underlying decision-process and if it helps with the development of other food forest projects, this paper has fulfilled its purpose. As the target group is not entirely scientific - farmers and interested people are addressed likewise - a balance between scientific profoundness and an enjoyable text without too many exhausting repetitions and square brackets of numerous quotes, was aimed for.

5 Extract from: Den Food Bosch – Project description, February 2017. (Unpublished paper)

1.2 Fundamental ideas and sources of information

"With the help of trees, at least three quarters of the earth could supply human needs for food, fuel, shelter, clothing and other basic needs. At the same time the wild-life could be conserved, pollution decreased, and the beauty of many landscapes enhanced, with consequent moral, spiritual and cultural benefits. Forest farming can make a very substantial contribution to human well-being and its applicability to many situations where agriculture or forestry alone, in enforced separation, would not make a difference"
J. Sholto Douglas and Robert A.de J. Hart (1985)

Since there is a great variety of approaches in the field of food forestry, every new intent to plant a food forest has the possibility to relate to different guidelines and sources of inspiration for establishing and maintaining this permanent agricultural system. The advice to study literature and to visit actual food forests is emphasized so that an individual choice of how to design and manage the respective food forest, can be made.

In the case of Den Food Bosch, several main sources of knowledge can be distinguished. Some group members did internships in food forests, wrote assignments and papers on specific topics and got to know experts personally. Also a fair amount of literature and internet research has been part of the process. As different agricultural approaches have influenced the design process, a brief overview with backgrounds and fundamental ideas is presented below.

Syntropic farming

Several group members experienced the working methods of syntropic agriculture during workshops and internships with Ernst Götsch. This inspiration and the practical work in food forest systems had a great influence on the ideas of how food forest systems can be managed. These experiences involve activities as pruning trees and chopping branches for enhanced tree growth and soil fertility, doing selective weeding and harvesting fruits. Ernst Götsch is teaching how to create ideal circumstances for vigorous plant growth by giving each plant the necessary gap in time and space to fulfil its function within the food forest ecosystem.

As this thesis does not have the capacity to give a full explanation of syntropic farming, only a brief principal description is given. The impression of the food forest on the Fazenda Olhos da Água can be described as a thriving ecosystem which is producing human resources in abundance. Plant growth, vitality and amounts of yield especially benefit from pruning and selective weeding. Principally, the soil always is to be covered with biomass and/or vegetation - constantly doing this, is a bless for the soil. Around 30 years ago, farmers were fleeing from this land, because of the "poor" and dry soil. After planting trees of different successional stages and reforesting all of the 500 ha of degraded land, including around 110 ha of food forestry with cacao as main crop, the situation has changed. It was done without big machinery, artificial fertilizers or agrochemicals. Ernst Götsch describes his way of planting as "an attempt at finding for each plant those conditions in which it best develops, [by] approximating our agricultural systems in any given situation as near as possible to the natural ecosystem to be intervened."[6]. Later on in his paper "Break-through in Agriculture"(1994), he points out that the natural regeneration of vegetation which is well adapted for the given soil conditions, is a key factor for rehabilitation of soil life. By removing "those grasses, herbaceous species and vines which had matured" and allowing all the "other native herbs, trees and palm trees […] to grow and fulfil their important function in soil-improving", the cultivated species are performing well, even on "poor soil". From his longterm observations, he realized that natural succession is giving a specific order of plants with longer life cycles being raised in the shelter of species with shorter life cycles. Even with the same light conditions, a plant would not grow well underneath of later successional species, while performing well underneath earlier successional species. Götsch summarizes that "the critical factor for the establishment and development of a plant which makes part of a given system is not as much the factor of light but the order and timing of its introduction in the natural succession." Nowadays the food forest of the Fazenda Olhos da Água does not even loose the harvest in years of severe droughts, while farms in the surrounding countryside are suffering from low yields due to the missing precipitation.

Starting simple by using deep rooting, nitrogen fixing and biomass producing plants, while nursing the future crop trees and shrubs, the system is going to become more and

6 Götsch, Ernst (1994): Breakthrough in Agriculture. (Fazenda Três Colinas, Bahia).

more complex over time. The natural driving force to generate complex and specialized life forms while organizing sunlight energy into natural, organic structures is defined as syntropy.

Ernst Götsch originates from Switzerland and also has experiences with temperate climate food forests. He emphasizes, that this kind of successional planting is not only suitable for the tropics, "but the principles of the method would be the same, wherever crops can be cultivated on our planet".[7] Combining the cultivation of annual crops in the first years of food forest establishment closes the gap, before trees and shrubs start producing fruits, nuts and berries. "All salads, that you buy in a supermarket, should have nursed a growing tree", Ernst said in April 2017, when he was visiting the Netherlands.

Restoration Agriculture

Mark Shepard's New Forest Farm (Massachusetts, US) is a very productive and profitable food forest ecosystem. In his book "Restoration Agriculture: Real-world permaculture *for* farmers"(2013) he explains his farming approach. Among the main principles of his work is the mass-selection of species. This means to plant "way too many seeds and select the plants that behave the way we want them to."[8] Also working with the natural succession is a crucial part of restoration agriculture. As Shepard describes "like gravity, the process of natural succession is unstoppable" and "weeds are a natural step of succession, that reveal the status of the soil". Still, there are differences to the successional planting of syntropic farming, which uses the successional driving force in a more organized way.

The use of "over-yielding polycultures" is an important factor Shepard emphasises in his book. He includes a large number of different plants and animals into his system, and the net gain of nutritional value is by far outreaching the mono-cropped corn field that was previously cultivated on the land. Looking at the way the New Forest Farm is planted with a key-line design, a very organic structure is to be seen, that really fits into the naturally given topography.

7 Götsch, Ernst (1994): "Breakthrough in Agriculture." (Fazenda Três Colinas, Bahia).
8 Shepard, Mark (2013): "Restoration Agriculture – Real-world permaculture *for* farmers" (p.111)

Lazy Farming

In contrast to the working methods of the previously mentioned agroforestry approaches, Wouter van Eck refers to his way of managing the food forest as lazy farming. In his opinion, nature does the work. Instead of pruning, weeding and mulching, he lets the system to do "automulching" by the natural processes of root starvation and foliage loss in autumn. Natural succession fills remaining niches between the planted crops, resulting in a well adapted species community for the given environmental circumstances. For example, in case of compacted soil, naturally those species occur that are best suited for these conditions and will change the soil structure over time.

Most important in this way of farming is an initially well designed system, with a high species variety for ecosystem resilience. Wouter van Eck points out that "in nature, diversity creates stability."[9] Looking at his Voedselbos Ketelbroek, indeed the plants are healthy and it is a beautiful diverse place. To reveal, whether a food forest is more productive with our without human intervention like intensive pruning, still needs further research. Certainly, instead of acting carelessly or unwisely cutting down everything which is unknown or misunderstood, leaving things to natural succession is the better option. Another important feature of the food forest Ketelbroek is the research on new species which perform well in the given climate region. Wouter van Eck gives the advice not to be afraid of non native species, as changes of species compositions in ecosystems are happening already for billions of years - with and without human aid.

Permaculture

The word permaculture was mainly coined by Bill Mollison in the mid 1970th and since then became a worldwide movement. Next to the agricultural aspect, permaculture includes the idea of a permanent and sustainable human culture in general. Many useful methods, tools and sources of information are available within the worldwide permaculture network. One of these tools are the 12 permaculture design principles [see illustration 1].

9 Limareva, Anastasia (2014), "Natural Temperate Forest Ecosystems Relevant for Productive Food Forests – Lessons Learned from Food Forest Ketelbroek, the Netherlands", (p. 68, quote: Wouter von Eck, 2014).

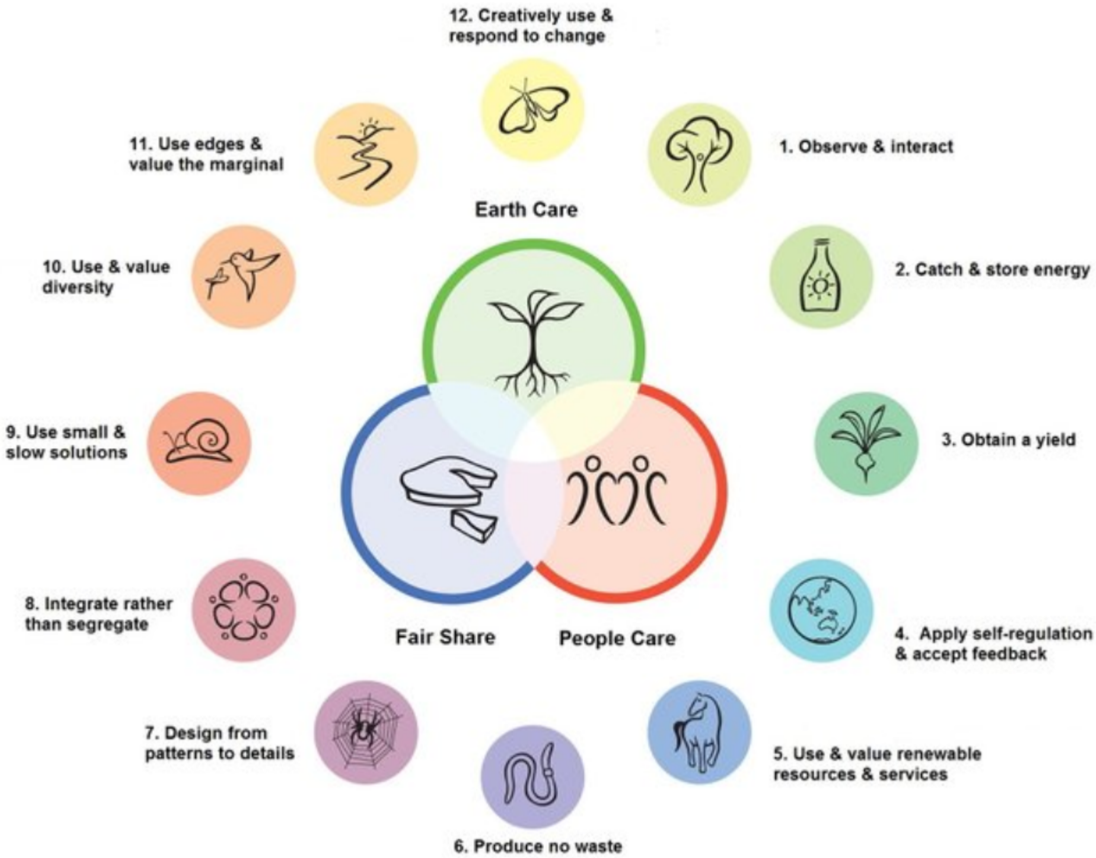

Illustration 1: Permaculture Principles. (Source: http://directoryofpermaculture.com/what-is-permaculture/)

The highest principle of permaculture is to actively carry out responsibility for the own existence and that of your children. “Make it now.” is one of the first messages Bill Mollison writes in his book “Permaculture – A designer’s Manual”. In his vision, everybody is able to become an active part of a worldwide sustainable transition. Cooperation and not competition is seen as “the very basis of existing life systems and future survival”.[10] Furthermore, Bill Mollison announces three ethical basics of permaculture, which are abbreviated to “Earth Care, Fair Share and People Care” in the image above. In his original text, they are called “Care of the earth”, “Care of the people” and “setting limits to population and consumption”. To be able to work with, rather than against nature, the 12 design principles can be used to guide and evaluate permaculture designs.

10 Mollison, Bill (1988): “Permaculture. A Designers’ Manual.” (Tagari)

Carbon farming

Facing the global reality of human induced climate change, Eric Toensmeier presents in his book "The Carbon Farming Solution" (2016) a worldwide analysis of perennial staple crops for the different climatic regions of our planet. For agricultural carbon sequestration, he defines the most promising crops as Non-Destructively Harvested Perennial (NDHP) Crops. Meaning that the plants are not killed when harvested. Toensmeier describes perennial staple crops as "trees and other long-lived perennial plants that provide […] basic proteins, carbohydrates, and fats."[11] In combination with no-till and soil-recovery farming methods, NDHP crops can help storing carbon and restoring soil life. In his book he presents a comparison between different farming methods and their (possible) ability of climate change mitigation. The highest potential of carbon farming lies within multistrata agroforestry, as it "has by far the best carbon sequestration rates of any food producing systems, between 10 and 40 times higher than typical improved annual crop production and managed grazing."[12]. In this context, he points out the need "for development of multistrata production systems for non-tropical climates"[13]

Next to the analysis of the perennial staple and industrial crops, Toensmeier gives a global species matrix, presenting promising agricultural practices and describes different breeding efforts. Additionally he gives a "Road Map to Implementation", addressing the different actors, being farmers, politicians and individuals/consumers. The three main points to scale up carbon farming practices are "support for farmers and farming organizations to make the transition", "effectively finance carbon farming" and "remove national and international policy barriers". It is a very recommendable book for anyone interested in agriculture.

11 Toensmeier, Eric (2016): "The Carbon Farming Solution. A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security." (p. 129)
12 Toensmeier, Eric (2016): "The Carbon Farming Solution. A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security." (p. 100)
13 Toensmeier, Eric (2016): "The Carbon Farming Solution. A Global Toolkit of Perennial Crops and Regenerative Agriculture Practices for Climate Change Mitigation and Food Security." (p. 323)

1.3 Research questions

This paper deals with and responds to the following research questions:

→ How does the process of designing a multistrata food forest look like, which is fulfilling the purpose of being

- site-adopted
- fertility-increasing
- manageable
- income-generating
- a source of inspiration for other farmers?

→ How can a group of people effectively agree upon decisions on the sensible subject of creating a permanent food forest system?

→ What kind of monitoring will efficiently reveal the ecological and economical outputs of this agricultural system?

→ How can the experience of this project be used as a guide for further food forest design processes?

2. Methodology

2.1 "SADIMET-design tool"

It is helpful to have a clear structure and organisation of the process and in the beginning, an adequate methodology was sought. After some research amongst different approaches, the SADIMET-design tool felt most suitable for our purpose, as it is simple and yet summarizes well the single steps towards the design and its implementation. The book "Permaculture Design. A step-by-step guide." by ARANYA gives an introduction on different permaculture design process tools. The illustration 2 summarizes the different design

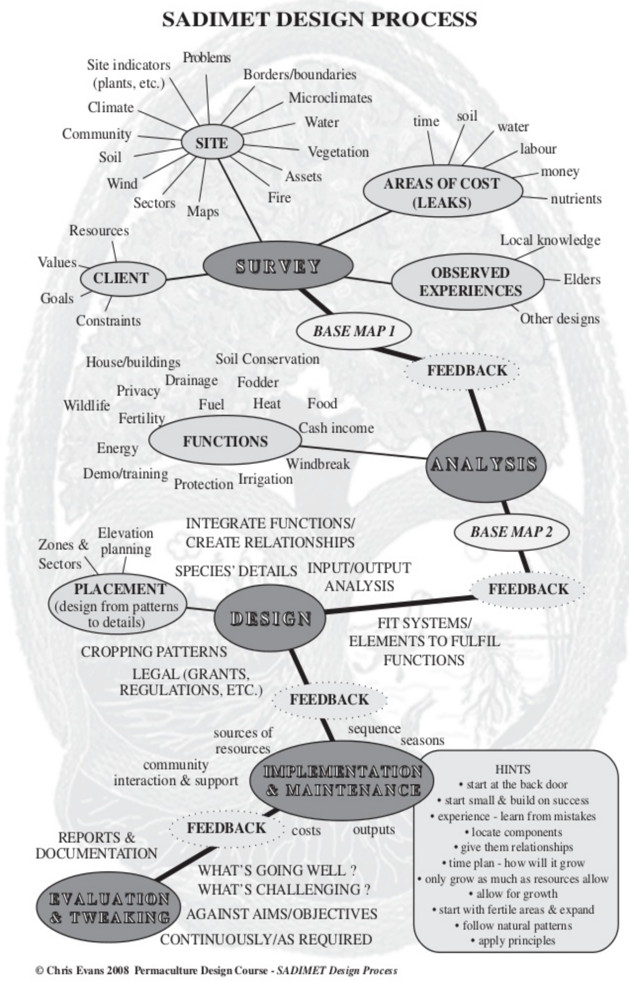

Illustration 2: SADIMET-design tool. (Source: http://www.sector39.co.uk/permaculture/resources/sadimet.pdf)

2.4 Design process in a group

Focus groups

Currently 8 core members are responsible for Den Food Bosch and due to the number of people and the individual time frames it was not possible to decide upon all the design details within the main group. As a result, smaller focus groups to work on topics like the food forest design, networking, infrastructure and founding of an association were formed. In this way, the work could be done more efficiently and still, the focus groups would always reflect their working process within the general group meetings. One of these focus groups was the “design group”, including Jonas Steinfeld, Marc Leiber, Paul Müller and myself, Janine Raabe. For the design process, regular meetings were arranged.

Stakeholder interviews

To understand the interests and ideas of the different stakeholders several interviews were conducted. Personal interviews were carried out with Herma W. and Karst K., the owners of the Bleijendijk Estate, Wouter v. Eck, a food forest expert and Floris K. who has an organic tree nursery. The Den Food Bosch group and some professors from the HAS university filled in written interviews via email.

In the context of the design, the results of the stakeholder interviews will be discussed in chapter 3.1.4 [p. 23 ff.].

Accumulating knowledge about food forests

Different sources of information about multistrata agricultural systems had an influence on the design process, some of them being already previously mentioned [see chapter 1.2, p. 3 ff.]. The combination of internships, food forest courses, personal contacts, practical work, literature and internet research as well as in-depth exchange of experiences was creating a basic comprehension about the topic. And yet, it is a life-long learning task to deepen the understanding of nature and to find out agricultural techniques that work in harmony with man and nature.

Species selection

One major question when designing a food forest is the species selection. Looking for those species appropriate to the hardiness zone, adapted to site conditions and useful for human needs and/or wildlife, are the first considerations to narrow down the possibilities. Of course, the people involved in the design process always have preferences and ideas on the species composition as well.

To simplify the decision making, a pre-selection of suitable plants was prepared by literature and internet research, exchanging ideas and visiting other food forests. Afterwards, having about 100 species of trees and shrubs selected (including the different zones of the food forest system), the evaluation of the pre-selection was done by giving a presentation, where the whole group and the specialists Floris Komen, Wouter van Eck and Malika Cieremans came together. The audience could evaluate the presented species on their suitability and give additional remarks. This presentation can be found online [www.denfoodbosch.org]. The evaluation sheet is added in the appendix [see appendix 1, p. X ff.].

The process of species selection is very crucial in a long living system and should be done without any rush. Only after the site survey has been done and the main decisions about the goals, the focus and the ways of managing the food forest are agreed upon, a species selection is reasonable. The website PFAF.org as well as the books “Creating a forest garden” written by Martin Crawford (2010), “555 Obstsorten für den Permakulturgarten und -balkon” (“555 fruit species for the permaculture garden and -balcony”) written by Siegfried Tatschl (2015) and “Edible Forest Gardens. Vol. 2: Ecological Design and Practice for Temperate-Climate Permaculture” by Dave Jacke and Eric Toensmeier (2005), were some of the main sources for the pre-selection.

Moreover, the existing vegetation of trees and shrubs in the surrounding neighbourhood was taken into account as a reference for some species and their performance in the given growing conditions. The full list of intended species to be planted is given in chapter 3.3 [p. 49 ff.]. The given species are chosen to be suitable for the environmental conditions of a forest edge.

Design by hand

Due to personal preference, the design was done by hand. By using different layers of transparent paper on one base map, several functional food forest layers could be illustrated. Since drawing is a creative process and a skill to be developed over time, my recommendations for other design processes would be, that enjoying the work most likely will lead to better results. Whether to design the system by hand or with computer programs like Auto-CAD or GIS remains an individual question of skill and preference. As the design changes in time, one design after 3 years including trees and shrubs and another design after 20 years, illustrating only the trees and their estimated crown diameters, is provided [see chapter 3.3.3 and 3.3.4, p. 45 ff.]. On the given scale it would be confusing if all the different food forest layers would be pictured. While the trees form the core structure of the food forest, all the other perennial plants can be exchanged more easily, so illustrating only the trees seemed sufficient. While the design has been done manually, Den Food Bosch will most likely use programs such as GIS to create a digital map of the research plots when working out a monitoring plan in autumn 2017.

Monitoring Plan

One of Den Food Bosch's aims, to become a place for research and reveal more data on future faming systems, will be realized together with the Waterschap, the HAS university and Wageningen UR. The organisation Rich Forest is developing a set of worldwide monitoring indicators for food forests and in the context of a meeting with the DFB group, an unpublished version of the report was shared. Hence, it was already possible to choose a set of indicators for future monitoring [see chapter 3.5.2, p. 60 ff.], data on social, ecological and economical aspects will be gathered on site. These information will be used to test the Rich Forest database, but also collected and supplied for long-term research.

Advisedly the monitoring system is agreed upon before implementing the food forest, since it might be interesting to create a reference point of soil and ecosystem conditions before things have changed.

2.5 Research on soil conditions

To acquire data on geography and climate of the region, an internet research was done. The Waterschap (water office North-Brabant) helpfully provided maps of the water tables. Since the land property rights were not transcribed yet, we faced the difficulty of not being able to do research on-site. As a result, information about soil quality were mainly derived from a vegetational analysis of species surrounding the field. To evaluate soil conditions, the Ellenberg values were used [see chapter 3.1.3, p. 19 f.]. The vegetational survey is added in the appendix [see appendix 2, p.XIV ff.] and can be used as a basis for further analysis in the coming years. To gain a small insight in soil structure, organic matter content and pH-value, one soil sample of the upper 20 cm soil horizon was examined. By using the facilities of the HAS university, some soil qualities could be analysed. For the determination of soil structure, an analysis of the granule size division was conducted by dividing the dried soil into various sub-fractions using a sieving device. 100 g of the dried soil was placed into a shaker for 30 minutes with stacked sieves of 2 mm, 1 mm, 600 µm, 425 µm, 212 µm, 150 µm and 53 µm hole-size and afterwards, the weight of the different fractions was measured. The organic matter content was derived by heating 2 samples of 5 g in an oven with 800°C for one hour and measuring the weight loss, as the organic matter is burned. For the pH, 10 g of the dried soil were filled into an Erlenmeyer flask and diffused in 25 ml of demineralised water by being placed onto a shaker for two hours. The results of the soil testing are presented in chapter 3.1.3 [p. 19 ff.]. Because only one soil sample was taken, these measurements are very punctual and not scientifically viable. However, they give a general idea of the soil conditions. A more in-depth research will follow when the leasing contract has been signed.

3. Main Part

3.1 Survey

The area of interest is allocated in North-Brabant, which is a state of southern Netherlands [see illustration 4]. This chapter explores the given site conditions from a broader climatic perspective to a local and site-related investigation.

Illustration 3: Map of divisions (NL). (Source: https://commons.wikimedia.org/wiki/Atlas_of_the_Netherlands)

3.1.1 Geography and climate

The respected 0.8 ha piece of land (51°63’60,79’’N; 5°32’41,96’’E) is part of the municipality of Sint-Michielsgestel in the federal land of North-Brabant (NL). It is situated within the watershed basin of the Dommel, the Esschestroom and the draining system of ‘s-Hertogenbosch-Drongelen. While most of the Netherlands is beneath sea level and formerly has regularly been flooded by the sea and the rivers, this area is about 4-5 m above sea level. Still, the groundwater tables are very high, which will further be examined in chapter 3.1.3 [p. 23 f.].

Most of North-Brabant is covered by eolian sands. The “younger cover sands” were deposited within the Late Glacial and Early Holocene, forming subtle dunes.
The high amounts of sand and finest sand particles are analysed more detailed in chapter 3.1.3 [p. 24f].

The region is located within the zone of oceanic climate (“marine west coast climate”) however has slightly warmer summer and colder winter temperatures than the coastal part of the Netherlands. In winter, there is normally no long lasting snow cover because of the mild daytime temperatures. Occasionally, late frosts can occur until end of May, which is a limiting factor for many frost tender crops.

Hardiness zones, Western Europe

The hardiness zones for Western Europe are referring to the U.S. Department of Agriculture's hardiness zones and are based upon the average annual minimum temperature of any given area. This differentiation of climatic zones is an useful indicator for the choice of suitable non-native species. The food forest will be allocated in the hardiness zone 7/8 which means that minimum temperatures lie within the range of -6.7°C to -17.7°C. However, this zoning does not give all necessary information, as it does not include warmest

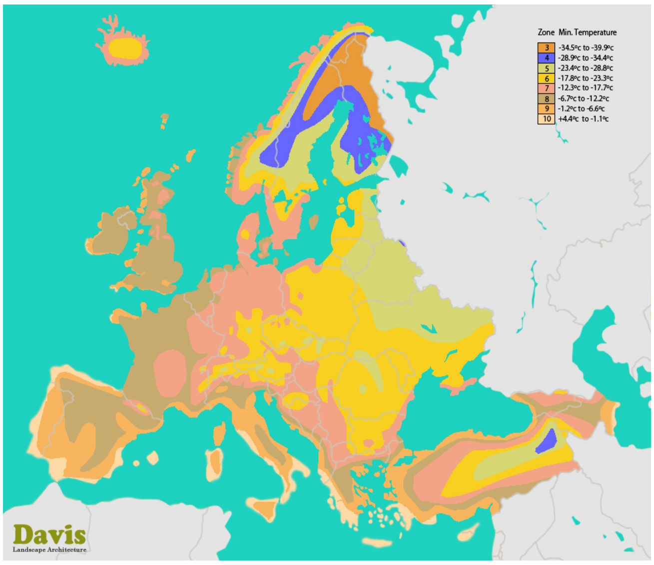

Illustration 4: Europe Hardiness Map. (Source: https://davisla.wordpress.com/plant-zones/europe-plant-hardiness-zone-map/)

temperatures, amount and patterns of precipitation, soil conditions nor types of biomes. Nevertheless, for a first verification if the specific plant could possibly grow within the given climatic region, the hardiness zone can be a useful indicator. Generally speaking, it is easier to transfer a plant from a lower hardiness zone to a higher one, than vice versa. Though, chilling requirements for fructification need to be considered in that case.

Köppen-Geiger Climate Classification

Another useful climate classification system is given with the world map of the Köppen-Geiger Climate Classification, where the present situation of climate regions can be seen. The world map is divided into defined areas of similar growing conditions.The climatic region of western and central Europe is classified as warm temperate, fully humid climate with warm summers.

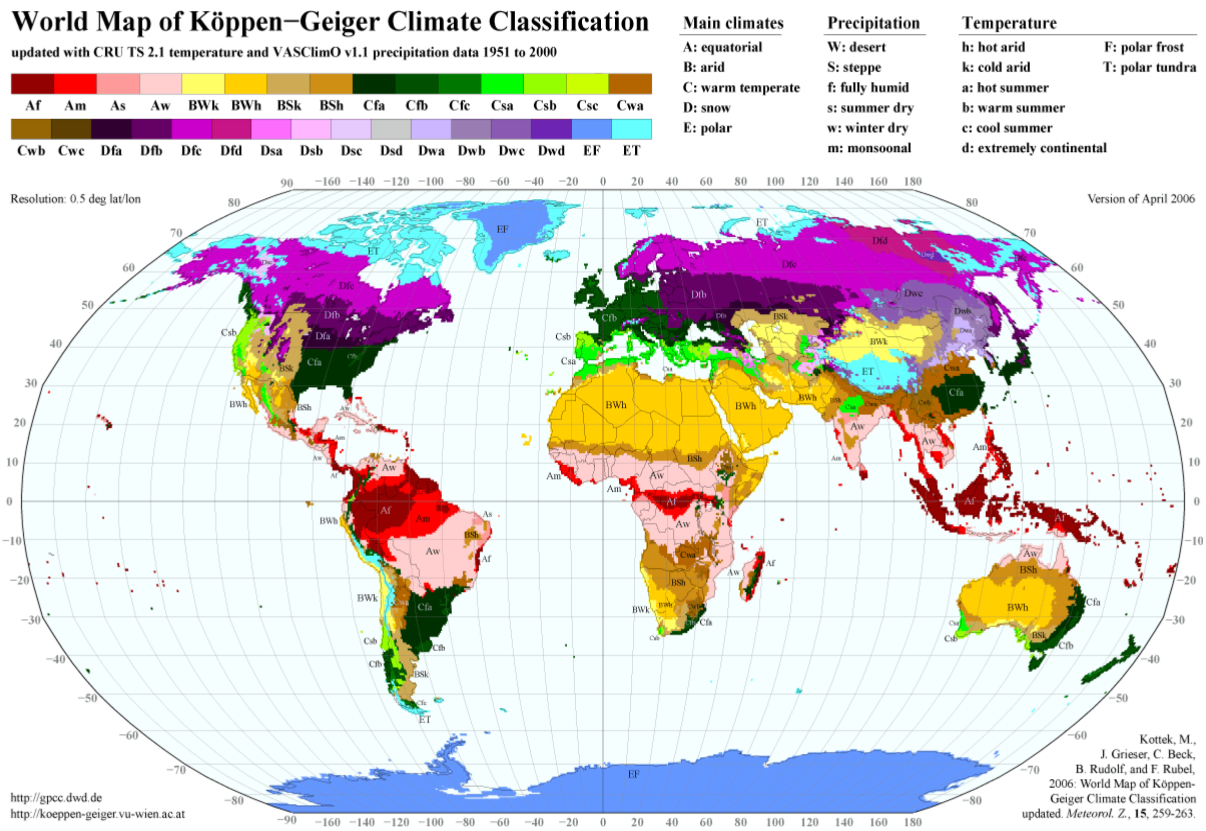

Illustration 5: World Map of Köppen-Geiger Climate Classification. (Source: http://koeppen-geiger.vu-wien.ac.at/present.htm)

Similar climates can be found in small parts of northwestern and eastern North America, southeastern South America, eastern China and southeastern Australia [see illustration 5]. From these regions, possible new crop species could be introduced. Geographic differences like mountain ranges within the same climate region of course have additional effects on species adaption to climate conditions.

Today, many agricultural crops technically are exotic species that have been introduced worldwide due to their high yield potentials and the demand, corn being one example. The selection of possible new species for food forest systems should not be restricted merely to the regional natural vegetation. When looking for new systems to “feed the world”, the opportunities for genetical exchange should be open likewise for sustainable agriculture. But still, precaution is necessary, as many carelessly planted exotics from agricultural and forestry trials already have impacts on local ecosystems. For minimizing the possibility of introducing invasive species, it is very advisable to only plant species without known weeding-hazard. On top of that, new species should always be limited to a small area first to observe their behaviour in the respective new growing situation.

Rainfall patterns, sunshine and temperatures

As illustrated in the diagram below, the amount of rainfall is lowest in February, March, April, August and September [see illustration 6]. Generally, there is no month with a real drought situation, the precipitation is quite evenly distributed throughout the year. The average yearly rainfall is about 750 mm.

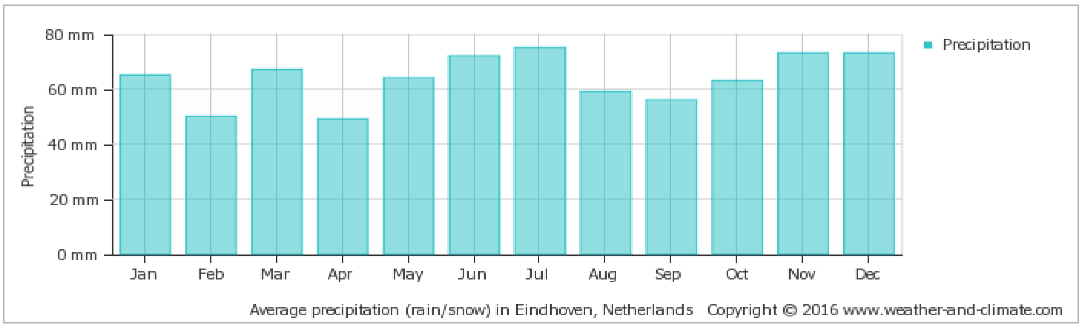

Illustration 6: Average Monthly Precipitation (of Rainfall/Snow). (Source:https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,vught-noord-brabant-nl,Netherlands)

The average monthly sun hours are peaking in May and again in July / August [see illustration 7]. On average there are about 1600 hours of sunshine per year.

Illustration 7: Average Monthly Hours of Sunshine. (Source: same as previous)

As visible in the diagram below, the hottest months of the year are July and August, the coolest month is January [see illustration 8]. The average winter temperatures do not fall below 0°, even though the lowest temperatures are beneath that. The record low of about -21°C was in January 1968, while the record high was 36.6°C in August 2009. The growing season with 24h average temperatures being higher than 5°C is from March to November. The annual average temperature is about 10°C.

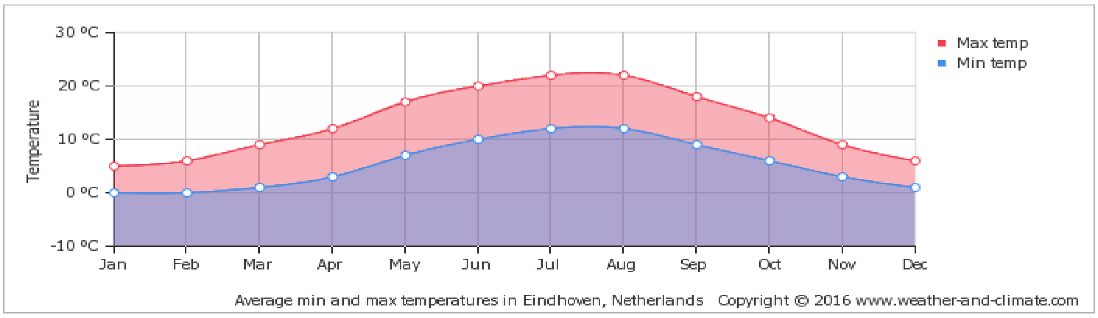

Illustration 8: Average Minimum and Maximum Temperature over the Year. (Source: same as previous)

The wind rose [see illustration 9] shows that the main and strongest winds are coming from Southwest, while winds from Southeast are most rare. This information is especially important for the design of a windbreak/hedge to protect the main crops [see chapter 3.3.7, p. 53].

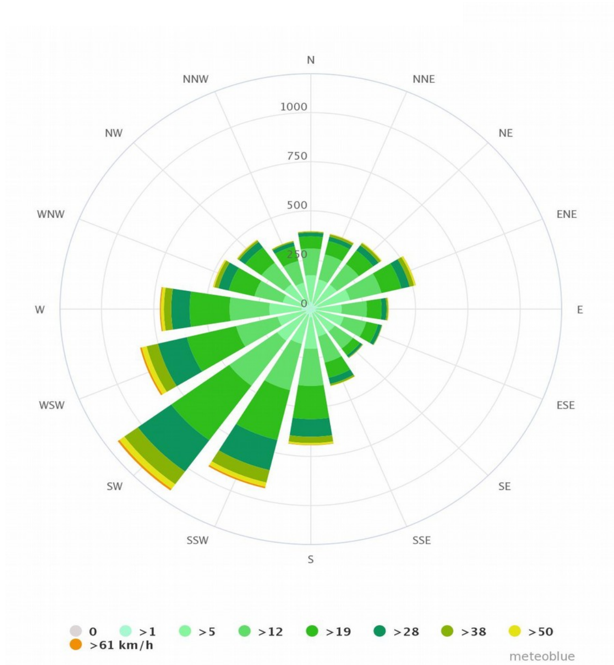

Illustration 9: Wind rose. (Source: https://www.meteoblue.com/en/weather/forecast/modelclimate/%27s-hertogenbosch_netherlands_2747351)

3.1.2 Base Map and photo of "Ground Zero"

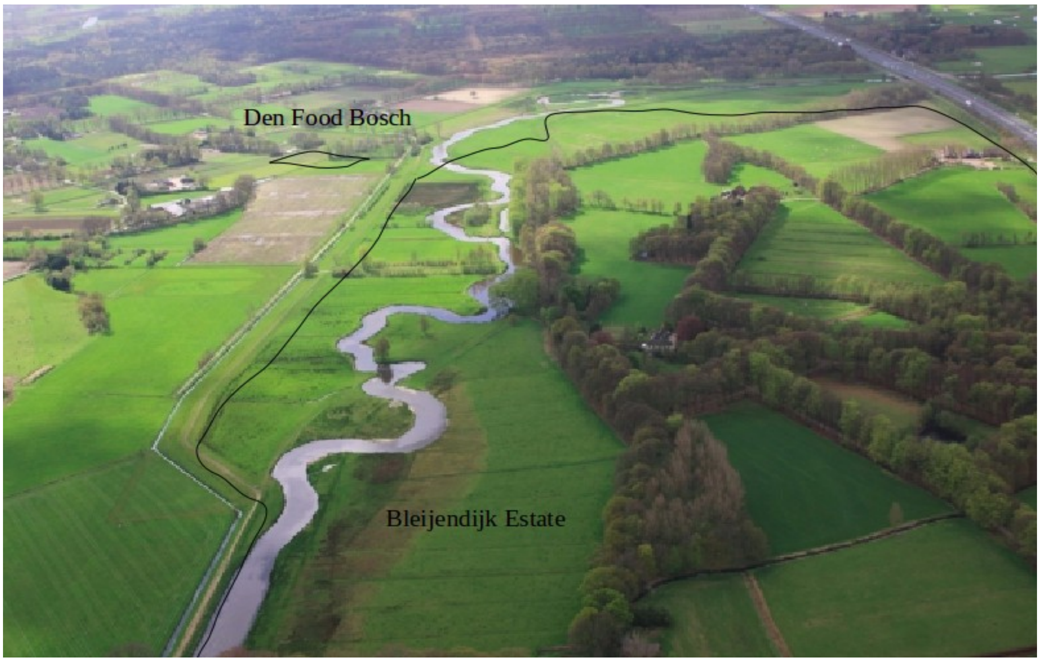

Illustration 10: Aerial photo - Bleijendijk. (Source: https://www.esschestroom.nl/index.php?pid=7&info=16)

On this photo, the river Esschestroom, which is embracing the Bleijendijk Estate, can be seen from a bird's-eye perspective. The Esschestroom was re-naturalized some years ago and now is winding its way through the landscape.

Illustration 11: Aerial picture - Den Food Bosch. (Source: Google Maps)

This aerial photo shows the respective land where the food forest will be established [illustration 12].

Illustration 8: Area of Interest, May 2017. (Photo by Janine Raabe)

The photo on the left hand side shows the recent state of the land. Soon, the dry soil will most likely turn into fertile ground and where now only one single species is allowed to grow, an assembly of trees and various life-forms will be growing together.

3.1.3 Site indicators

Soil Conditions – General approach

As the land was not owned by Bleijendijk within the time period of the food forest design, a proper scientific soil analysis could not be done. For this reason, a vegetational analysis of the species surrounding the field is replacing an in-depth laboratory soil testing. The full list of species naturally occurring around the field is added to the appendix [see appendix 2, p. XIV ff.]. To seek information about soil conditions the Ellenberg indicators were utilised. Additionally to the vegetational survey, one soil sample of the upmost 20 cm soil layer was investigated on granule size division, pH-value and organic matter content. To reveal information on soil depth, water table and topography, maps of the area provided by the water office (Waterschap) were used.

Generally it is advisable to do a detailed soil analysis and talk to the previous farmer about the conditions on any given side, however, in this case patience was required. Nevertheless, with the research that has been done and using common sense, a basic understanding of soil conditions could be created and enabled the following steps of the design process to be taken. Still, it is planned to do a more in-depth analysis of the status quo, later on. This will be useful to have a reference point for longterm monitoring on site. For further information on research and monitoring see chapter 3.5.2 [p. 60 f.].

Surrounding vegetational cover

In order to analyse soil conditions based on vegetational cover, the Ellenberg values can be of great help in Western Europe. The values show the occurrence of species in natural environments, with all limiting factors included; they do not show the species' preferences on soil conditions in monoculture. For the following analysis, the data on vegetational indicators was derived from the revised edition of the ecological indication values from Ellenberg (1979), “Vegetation Mitteleuropas mit den Alpen” (germ.: “Vegetation of Middle Europe including the Alps”) (Ellenberg et al. 2001).

The ecological reaction towards a certain environmental factor is expressed in a number between 1 and 9. The number 0 is used only to describe a very low tolerance towards salinity. The indicators are divided into Light (L), Temperature (T), Continent (K), Humidity (F), Reaction (R), Nitrogen (N) and Salinity (S).

Due to the frame of this thesis, the results are briefly presented below, while a more detailed procedure of deriving the information is given in the appendix [see appendix 2, p. XIV ff.]. The identified species indicate the following soil conditions:

Humidity:

In all the different zones the species indicate humidity values between 5.1 – 6.4. This means the land is generally quite wet. Especially close to the canals the values indicate high humidity, which is an obvious result. In the Water (Wa) the value 9.5 indicates water plants.

Reaction:

The results for soil reaction are in between 6.2 – 7. This means the pH is not significantly high or low - apparently the soil is neither very acidic, nor very alkaline.

Nitrogen:

The values for nitrogen indicating plants lie within the range of 6.3-7, which means the soil is rich in nitrogen. Within the drainage canal the water plants even indicate an oversupply of nitrogen (8.5). If the water indeed is polluted with high amounts of nitrogen, water tests will reveal when monitored.

The further results of the Ellenberg indicators do not have any significant impact on the design process. The soil does not seem to be very saline which is favourable for most plants. Further, most plants indicate relatively high values of light intensity (6,4 – 8), logically, as they are growing on an open field.

Soil Conditions – Laboratory results

In this chapter, the laboratory results are presented. For the methodology of the soil analysis, see chapter 2.5 [p. 12]. As only one soil sample was taken, these results are not scientifically viable. However, they give a general idea of the soil structure; further research will reveal more detailed soil conditions.

a) Granule size division

Granule size	Weight [g]*	Percentage [%]	Soil particle classification
> 2 mm	2	2.01	Gravel
> 1 mm	0.84	0.85	Coarse sand
> 600 µm	0.96	0.97	Coarse sand
> 425 µm	1.22	1.23	Medium sand
> 212 µm	**22.94**	**23.11**	**Medium sand**
> 150 µm	**33.9**	**34.15**	**Fine sand**
> 53 µm	**34.33**	**34.58**	**Fine sand**
< 53 µm	3.09	3.11	Clay, Fine/Medium/Coarse Silt

Table 1: Granule Size Division.

(*The difference between the 100 g of the initial sample weight and the total weight of 99.28 g after the granule size devision is a result of soil particles being lost in the fine net of the sieving device during the process.)

Name				Size range (mm)
Very coarse soil		Large boulder	LBo	>630
		Boulder	Bo	200–630
		Cobble	Co	63–200
Coarse soil	Gravel	Coarse gravel	CGr	20–63
		Medium gravel	MGr	6.3–20
		Fine gravel	FGr	2.0–6.3
	Sand	Coarse sand	CSa	0.63–2.0
		Medium sand	MSa	0.2–0.63
		Fine sand	FSa	0.063–0.2
Fine soil	Silt	Coarse silt	CSi	0.02–0.063
		Medium silt	MSi	0.0063–0.02
		Fine silt	FSi	0.002–0.0063
	Clay		Cl	≤0.002

Illustration 9: Grain Size - International Scale. (source: https://en.wikipedia.org/wiki/Grain_size)

The soil particle classification is derived from the ISO 14688-1:2002 [see illustration 13].

As the sieves from the HAS laboratory do not have the exact granule devision as classified in the ISO 14688-1:2002, the ranges are put into the classification of most overlap. For example, Msa (Medium sand) is defined as granule sizes between 0.2-0.63 mm. The section of 600 µm to 1 mm in the given results is partly overlapping with this classification, but most of it is within the range of 0.63-2.00 mm, which defines Csa (Coarse sand). For simplification, it is classified as Csa in the table [see table 1].

The classification shows a very sandy soil structure, with a small portion of 2.01% gravel and 1.82 % Csa (Coarse sand), medium amounts of Msa (Medium sand) with 24.34 % and a very high amount of Fsa (Fine sands) with 68.73%, last but not least a small part of silt/clay with 3.11%. These results reflect the situation of most parts in the region of North-Brabant, as the eolian sands mostly consist of fine sand particles [see chapter 3.1.1, p. 13 f.].

b) pH-value

The mean of the two soil samples tested, is a pH-value of 4.89. This indeed is more acidic than expected when looking at the results of the vegetational cover surrounding the field. But as the soil is more compacted on the field itself, where big machinery has been used for long, the soil compaction might contribute to more acidic conditions on the field in comparison to the surrounding edges.

c) Organic matter content

The two samples put into the oven revealed an average organic matter content of 3.07%.

Water table

Facing the obstacle of not being able to do research on the land, maps of the highest and lowest water tables were used to gain information about the depth to water table [see appendix 3, p. XVII]. The two maps provided by the Waterschap give a picture of the 3 highest and lowest water tables in a measurement period of the last 8 years. In times of the lowest water tables, the distance of the water table lies between 80 cm to 140 cm below ground, while the highest water tables show to be 0-20 cm below ground. These results are not very delightful as many deep rooting plants and even most fruit trees do not appreciate “wet feet” and struggle or even die off with the occurrence of rising water tables. Yet, looking around in the neighbourhood, some very healthy walnuts promise a better situation than expected. Another conversation with the Waterschap who provided the maps, revealed that they are not most accurate and the information about how long the periods of high water actually are, could not be determined.

3.1.4 Stakeholders

Currently most involved in the project are Herma W. and Karst K., owners of the Bleijendijk Estate, the Waterschap, currently owning the piece of land, and obviously Den Food Bosch. Since setting up a tenancy agreement and regulating land rights has highest priority for the current project development, these stakeholders are categorized as 'Main stakeholders', their interests on the food forest are observed individually. 'Secondary stakeholders' are the AgriFood Capital, funding the project, the HAS university and Floris K., owner of an organic tree nursery.

Main stakeholders:

“The name is a combination of the city's abbreviated name Den Bosch and the aim of the project to establish a food forest (Bosch is Dutch and translates into forest). → Den Food Bosch: A food forest for Den Bosch.”[14]

Den Food Bosch was formed in September 2016 by 4 students, soon it became a study club at the HAS. Possibilities of working on future agricultural systems and implementing a food forest near the university were discussed. This food forest should be a place to gain experiences and knowledge about temperate agroforestry as well as conducting research on the productivity of such a system. The vision was to establish an educational platform on the site, related to the local community, specially students and children, and whom else interested, enabling these people to study the topics of food forestry, permaculture and sustainability in a broader sense. Soon the number of interested people was rising. The connection with Bleijendijk was built up, a project proposal was written and finally Den Food Bosch realized to receive a funding from the AgriFood Capital.

In April 2017, Ernst Götsch was invited to the Netherlands by Den Food Bosch, who were organising a week of networking, presentations and inspiration.

14 Grimm, Katharina; Van Bemmel, Koert; Leiber, Marc; Müller, Paul; Villela, Felipe; Bremmers, Lowieke (2016): Den Food Bosch Proposal HAS (unpublished paper)

In this week I met, and soon afterwards joined the group, following inner motivation and indeed already looking out for the possibility to create temperate climate food forests. Currently, the core group consists of 8 members: Paul Müller, Marc Leiber, Felipe Villela, Katharina Grimm, Koert van Bemmel, Jonas Steinfeld, Malika Cieremans and Janine Raabe. The group is always open for interested people to join.

Bleijendijk

*"**Synergy** is the creation of a whole that is greater than the simple sum of its parts. The term synergy comes from the Attic Greek word συνεργία synergia from synergos, συνεργός, meaning "working together"."*[15]

The Bleijendijk Estate already exists since 1580 even though the cellar of the main house is the only remaining part of the estate from that time. It actually started with one small farm, which spread by time. The current land size is about 100 ha, being used as farmland, forest, nature reserve, place for mindfulness and residential property.

Illustration 10: Bleijendijk Map. (Provided by Herma Winnemuller)

15 Derived from: *https://en.wikipedia.org/wiki/Synergy*

The last owner of Bleijendijk was a woman, focussing on yoga and mindfulness who envisioned the estate to be a place for people to heal.
Bleijendijk actually got an international reputation as a place for mindfulness. When Herma Winnemuller and Karst Kooistra bought Bleijendijk in October 2015, their long term vision included a focus on a community of independent entrepreneurs working together synergistically. The integration of nature and people creates the umbrella within which Herma and Karst envision products such as organic meat, dairy, fruits & vegetables, honey, wood and processed food being produced and supplied locally. Social connectedness is crucial for this, including a daycare facility, nature education and several families living on the estate. At the moment the organic dairy farm Boerderij Bleijendijk with 60 cows, as well as an organic vegetable farm, the Tuinderij de Guit are part of this. Further there are 80 free range sheep on 8 ha, and 20 beehives all over the estate.

Into this vision, a food forest is interesting to be included as it is a natural way of farming and carries along recreational and educational values. Also a connection to the HAS university and the possibilities of research are interesting for Bleijendijk. The “middle generation” of young adults is missing at the moment, to create a cross-generational community.

The Waterschap

The Waterschap is a semi-governmental organisation responsible for water regulation and quality in North-Brabant. They have an interest in water protection and by this also in alternative agricultural land use without chemical fertilizers and toxics. Due to their responsibilities, they are keen on analysing soil and water quality changes after food forest implementation. Ineke Bartels and Annelies Balkema from the Waterschap expressed their interest that the regarded piece of land becomes a food forest. The idea is, in cooperation with the HAS, to set up a longterm monitoring program. Next to this project, the Waterschap is planning to establish further food forests on their proprietary land.

<u>Secondary stakeholders:</u>

AgriFood Capital

The project funding comes from the AgriFood Capital, they provide municipal as well as provincial money to innovative start-ups in the sectors of agriculture and food. To apply for the fund, a project proposal including a budget and a time plan along with the main aims and objectives was submitted to the AgriFood Capital. Besides building up the food forest, a focus was set upon creating an up-scalable business model. The project is also meant to be a showcase to catalyse the transition towards sustainable food production systems. They are funding the project for 2 years with a budget of 50,000€. For an overview on the budget see chapter 3.1.5 [p. 27].

HAS university

The relation to the HAS is an important part of Den Food Bosch, as students will be able to conduct internships or do research assignments in the food forest. For volunteer working days, students are always welcome, while workshops and guided tours for transmitting knowledge about the food forest system will be important, as well. On the other hand, Den Food Bosch is able to make use of the laboratory and research facilities as well as the greenhouse for activities such as propagation. The consultancy of the professors Erwin Bouwmans, Frederike Praasterink an PJ Beers is well appreciated.

In general, if research is going to be included into a food forest project, a connection to universities or other research facilities can be of great value.

Floris Natuurlijke Bomen

Floris Komen runs the organic tree nursery 'Floris Natuurlijke Bomen' nearby, in the township Den Dungen. Many of the trees and shrubs required for the land will originate from his nursery. This cooperation has a great potential, as he has a lot of knowledge about species and varieties that are suitable for this region. Looking out for local advise is always very helpful. In the species selection process of Den Food Bosch he already gave useful input.

3.1.5 Budget

For the project proposal, an initial investment of 100.000 € has been calculated. This covers soil preparation, the purchases of plants, necessary materials for land development and administration costs as well as some of the group's time that is put into the development along with consultancy from the HAS. The costs are split into 50.000€ out of pocket money coming from the AgriFood Capital, 40.000 € own investment in hours from the DFB group and consultancy worth 10.000 € from the HAS lectorship New Business Models. The budget will be transparent. The current budget plan of Den Food Bosch with the estimated expenses is given in table 2.

Budget Plan – Den Food Bosch	
Out of pocket money:	**Value**
Package 1: Establishment of productions system	
Planting materials (trees/shrubs/herbs/seeds)	18.000€
80 t wood chips	3.000€
Consultancy	2.000€
Package 2: Infrastructure	
Sea container with terrace	3.000€
Tools	2.000€
Wood for diverse constructions	1.600€
Costs for transport (fuel) / approx. 5000 km	1.000€
Package 3: Market research + processing unit	
Literature	2.000€
Processing unit & direct market research	10.000€
Package 4: Business model & networking	
Business model dev. & networking	4.000€
Package 5: Administration	
Office materials	2.000€
Land rent for 2 years	1.400€
In Total	50.000€
Internal Costs:	
Working hours of team members	40.000€
Working hours lecturer (HAS)	10.000€
In Total	50.000€

Table 2: Budget Plan - Den Food Bosch. (Made with LibreOffice Calc)

3.1.6 Land use governance

The subject of planting trees on agricultural land is a sensitive topic. Many farmers fear to loose the status of 'agricultural land' after planting trees - since 'nature land' is worth much less from the economical point of view. But farmers in the Netherlands do not need to be afraid of loosing their agricultural status anymore. Until recently, the agricultural system did not even know the term “food forest”. In the case of Ketelbroek, Wouter van Eck had to deal with some bureaucratic obstacles until his food forest was accepted as 'agricultural land' in 2016. Since then, a new agricultural system called “Voedselbos” (du.: “food forest”) officially exists. Due to this, food forest farmers are also able to get financial support from the government, which is 120 € /ha annually (Wouter v. Eck, 2017). The land of Den Food Bosch is currently registered as agricultural land and will keep this registration.

3.2 Analysis

"Through analysis, our challenge is to design and establish a system where the energy needed to maintain it decreases over time, while its outputs increase."[16]

Aranya (2012)

In this part of the design process, the specific goals of Den Food Bosch are presented. They were extracted by doing an initial interview with all the group members. Afterwards, concerns and priorities were collected and the specific aims of Den Food Bosch clarified. The agreement about the main functions to be incorporated and the elements to include into the system, is presented below.

Our group was concordant on integrating certain working principle, which embrace all the food forest functions and can be summarized as:

- increase photosynthesis
- restore soil conditions
- work with natural succession
- young forest (mid-succession-stage) mimicry[17]
- use disturbance
- approve syntropy
- unconditional love and cooperation
- peace farming

16 Aranya (2012): "Permaculture Design – A step-by-step guide." (p.92)

17 Martin Crawford explains in his book "Creating a Forest Garden - Working with Nature to grow Edible Crops" (2010), that the highest productivity is reached if a system is kept "in a state akin to a young or mid-succession-stage woodland". (p. 25) A young forest has an increased amount of light available in all layers and often contains nitrogen fixing species for soil improvement. In the book "Edible Forest Gardens Vol. 1 – Vision and theory" (2005), Dave Jacke and Eric Toensmeier also describe the mid-successional stage before the canopy closes as most productive in terms of biomass production, species diversity, nutrient flow, soil fertility improvement and ecosystem productivity in total (e.g.: p.33 or p. 267).

3.2.1 Main functions and elements

Main functions:

1. Functioning Ecosystem
   - Soil health
   - Self-fertilizing and self-regenerative ecosystem
   - Natural succession
   - Various microclimates for an increasing number of ecological niches
   - All year pollination and wildlife habitat
   - Longevity of the system
   - Natural water flow
2. Food production
   - Cash income (economically viable)
   - Finding out about new (NDHP) crops
   - New market creation
   - Up-scalability
   - Contributing to healthy and inspiring food supply (including food processing)
   - Own consumption and joy
3. Social interaction
   - Education, training, inspirational showcase
   - Research, experimenting
   - Gatherings, meeting point
   - Integrity of people dedicated to DFB and Bleijendijk community

Main elements:

- Windbreak/Hedge
- Sun catching system
- Main crops, secondary crops and special crops (for all forest layers)
- Diverse plants for biomass (accumulation system) and nitrogen fixing, as well as deep rooting plants and beneficial insect plants (plants for pest control and all year round pollination)
- Trees for water protection

- Picnic area
- Sea container (for tools) with green roof terrace
- Pathways (mulched)

Secondary elements:
- Outdoor kitchen, water supply, compost toilet
- Transparent business model
- Information tables

In permaculture it is advised that every element should fulfil at least 3 functions to create a resilient system, where every function is carried out by multiple elements and where the single elements are multifunctional. Mainly to sharpen the actual image of the design, it is very recommendable to reflect on the interconnection of the individual elements and their functions.

The list above is already summarized. After having had collected all the different functions and elements within the written interviews, the sum of individuals gave a quite broad picture of the place. Some elements as a open-air stage for speeches or a caravan containing a library were excluded after further consideration. We condensed the broad image to a list of decisions which everybody could agree upon.

<u>Following decisions were made:</u>

- We recognize our own responsibility and decide upon dedication to create a permanent food forest system.
- The consent is that our social connectedness within the group is very important.
- We feel belonging to the Bleijendijk community.
- The research is going to happen in cooperation with the HAS, future generations of students, Rich Forest and the Waterschap.
- We are looking for a way to integrate consent decision making.
- We, as a network of cooperating individuals, have the fire for creating large scale food producing ecosystems.

3.2.2 SMART-goals

Smart-goals have the aim to include the characteristics of being **S**pecific, **M**easurable, **A**greed upon, **R**ealistic and **T**ime-scaled. The mentioned goals do not include all of the goals of Den Food Bosch but give an overview of how smart-goals can be formulated.

Status June, 2017 (reviewed in July 2017):

- Until mid August 2017 the thesis of the design process will have been finalized. This means, we will have created the design of Den Food Bosch, including the different zones, the pathways and the list of species along with their placement. This design will consist of a future-scenario design which gives an idea of how the food forest will look in about 20 years, when it is well established. Further, for the implementation, there will be an intermediate design showing the status after 3 years. There will exist a general plan for longterm monitoring in cooperation with Rich Forest, the HAS and the Waterschap.

- Until September 2017, a rough structure for the workshops with Mark Shepard and Ernst Götsch will have been created and organized until End of 2017.

- Until November 2017, we will follow up doing the soil tests. The data will be included into the database of Rich Forest, so a longterm monitoring programme can be started. Other students will be part of this process.

- Within the year 2018 there will many species be growing and we will sell our first products in the newly opened Bleijendijk shop.

- Until the end of year 2018, the main structure of the site has been developed, we can go on a compost toilet and have the means to cook some food.

- Within the next 5-10 years we will level our financial inputs/outputs. A group of people has taken over constant responsibility for the land and crowd of consumers exists. Food forest products are being processed. There is a beneficial connection to Bleijendijk, products are sold under the common Bleijendijk label in the Bleijendijk shop. The food forest is part of the Bleijendijk community.

3.2.3 Species selection

Looking at different food forests already existing, a great biodiversity even here in temperate climate is often to be seen (Ketelbroek, Fruithof de Brand and others). Still there is a temptation to try to fit too many species into a small area. Finding the balance between a high diversity for ecosystem health and focussing on some main crops for economical income, is indeed one of the most sensitive topics and was discussed numerous times within the group. On a walk with John D. Liu on Bleijendijk in July 2017, he underlined that focussing on creating a functional ecosystem is of much greater value than focussing only on the economical aspect. An abundant and healthy agricultural system will derive economic income as one of the beneficial results. The "Principle of Functional Interconnection" is a term which Dave Jacke and Eric Toensmeier use in their book "Edible Forest Gardens Vol. 1 – Vision and Theory" to describe the web of cooperation and interdependence of the species. They determine that "healthy systems create no waste and generate no pollution because the inherent by-products of every living thing become food for some other living thing."[18] All the species within an ecosystem are correlated to each other and the sheer amount of tiniest life forms is the basis of the entire food web. The question of how many species and which species need to be integrated into a food forest system to function like a natural ecosystem, is interesting. According to Ernst Götsch species diversity is not the only clue for creating a healthy ecosystem, but most important is to meet all the different functions of a forest ecosystem. These functions (such as utilising the existing niches of all forest layers, improving soil conditions and covering soil surface and feeding the web of life, etc.) can also be fulfilled by fewer, well chosen species.

On the other hand, Mark Shepard declares that "consistently through decades of ecological research it has been shown that the greater the species diversity the greater the total side yield".[19] In addition, Martin Crawford writes in his book "Creating a Forest Garden" (2010), that "high diversity almost always increases ecosystem health".[20] More detailed, he explains that "the higher the diversity, the more resilient and productive the forest garden usually is. This is because different species rarely share the same pests and diseases, and different species utilise different ecological niches (e.g. root and aerial

18 Dave, Jacke and Toensmeier, Eric: "Edible Forest Gardens Vol. 1 – Vision and Theory" (2005) (p. 29)
19 M. SHEPARD: "Restoration Agriculture – Real-world permaculture *for* farmers" , (p.276)
20 Crawford, Martin (2010): "Creating a Forest Garden, Working with Nature to grow Edible Crops" (p.17)

space) to maximise the efficient use of available resources”.[21] His recommendation is that “larger gardens should easily be able to accommodate 100 species.” When looking at all the different layers and areas of Den Food Bosch, 100 species are achieved quite easily.

Generally speaking, every design needs to find its own balance in the very circumstance it is being done, as all these considerations also need to relate to the own necessities and wishes of how the harvest and management of the site should be. In the case of Den Food Bosch, several people who decided upon dedicating their time on the project for the following years, agreed upon having a long harvest period throughout the year would be good, as a shop is going to open on Bleijendijk, where the different fruits, nuts, berries, herbs, mushrooms, vegetables and other food forest products will be sold. Here, the reaction of the customers on the different food forest products can be surveyed. It is still an open question, whether in this case seasonal fresh berries and fruits have a higher demand and margin than processed food. The small area of 0.8 ha can be used to test consumer reactions and the most marketable and manageable species can be planted on bigger scale in the future. Next to the marketing of products, gaining experience which species are most adopted to the site conditions and to learn about useful companion plants is of high importance for Den Food Bosch as a research and educational project. By observing the food forest with the individual species and their performance throughout the years, a lot of experience and knowledge can be derived. By doing the work of maintenance and harvest manually, physical health is increased and experiences for suitable technology to improve efficiency will be gained. Without any question big machinery is not wanted, as soil life is the basis of an intact ecosystem.

There is a lack of information of suitable companion plants for fruit trees - research on this topic has only resulted in vague speculations in online forums. To try out different biomass trees in combination with fruit trees as well as a variety of shrubs, vines and herbs in different positions might lead to a better understanding of possibly beneficial companion plants, that can be reproduced in a more simplistic way on large scale. For now, it was not easy to narrow down the species consortium to a simple set of plants, knowing at the same time that all necessary functions to create a resilient ecosystem are present. Only working within the food forest, one is able to realize which plant

21 Crawford, Martin (2010): “Creating a Forest Garden, Working with Nature to grow Edible Crops” (p.27)

combinations are favourable and which work can be optimized. The aim is to create larger systems, but for this, a pathway of collecting experiences lies ahead. To enable findings about companion plants, some species of the same varieties will be planted in different combinations and light conditions.

During the species selection, 9 main cropping tree species were selected for the main area which has a size of about 0.5 ha. Next to this, 15 cropping shrub species were selected as well as 4 cropping climbing species [see chapter 3.3.5, P. 49]. For these main crops to thrive, sufficient biomass trees and nitrogen fixers need to be included. A rough calculation on the nitrogen budget is given in chapter 3.2.4 [see below]. Also, productivity is highest when all the different layers and niches above and below ground are used. Thus, for feeding the main crops with biomass (especially nitrogen and potassium), 11 biomass trees and 4 species of nitrogen fixing shrubs were selected [see chapter 3.3.5, p. 49]. Additionally, a perennial herbaceous layer with nitrogen fixers and deep rooting plants is planned to be introduced [see chapter 3.4.2, P. 58].

In regard of the changing climate, Martin Crawford points out that the choice of crops from warmer areas with less chilling hours in winter and higher temperatures / longer seasons in summer can help to create a resilient system in the long perspective. While mainly focussing on species which are commonly grown in middle Europe, some species like figs or almonds which are normally known from the Mediterranean region, are also part of the food forest design. They are situated in sheltered and warm parts of the farmland and climate adapted varieties are chosen.

Due to the high water tables, trees with long taproots were excluded. Most nut trees have a deep rooting system and suffer from high water tables because of a lack of oxygen for the fine roots. Now the design only integrates two sweet chestnuts (*Castanea sativa*), where initially at least one quarter of the food forest was supposed to consist of nut trees. These two sweet chestnuts will be planted on small dikes to ensure rooting space. Two healthy and fully grown walnuts are growing in the neighbourhood, but as water tables can locally differentiate and so far the only data available are the Waterschap maps, it felt risky to rely on nut trees. Also the land size is rather suitable for smaller trees and shrubs.

3.2.4 Nutrient budget

Having the aim to create a self-fertilizing system with low external inputs and a currently low organic matter content of about 3%, quite some biomass producing plants are required. Especially for long-term yields of heavy croppers, a steady supply of nitrogen is important. In various sources for conventional orchards it is recommended to use between 125 to 250 kg N per ha and year on “poor soil”. As Den Food Bosch does not want to use artificial fertilizers, a closer look on the nitrogen supply has been taken. Martin Crawford gives a detailed analysis about nitrogen demands of fruit trees and possibilities for natural supply[22]. As he states “ultimately no system of gardening or farming is sustainable if it relies heavily on the import of fertility.[23]” The main nutrients that that are looked at in traditional agricultural systems are nitrogen (N), phosphorus (P), potassium (K) and calcium (Ca). This chapter will focus on these basic elements. Of course, a healthy ecosystem contains a long list of micronutrients that are important for living organisms. To copy natural systems and steadily increase soil fertility while feeding all ecosystem dependent animals (and people), is the aim of a self-sufficient agricultural system. The tables below are derived from Martin Crawford's book “Creating a Forest Garden” and summarize a suitable strategy for a system inherent nutrient supply of Den Food Bosch.

To start with, it is good to investigate the different fertility demand categories of the selected species. This list includes only the main crops which are used for a rough calculation on the nutrient demand of the whole system. While most of the chosen fruit trees are within the category of “heavy croppers”, amongst the shrubs “heavy croppers”, “moderate croppers” as well as “undemanding” species can be found [see table 3].

Nitrogen (N)

The table below shows the amount of nitrogen required for the moderate and heavy croppers related to the plant area in square meters [see table 4]. For trees and shrubs, this area can be calculated with the equation $A=3.14*R^2$ (with A= crown area and R= radius of the crown). On the right side of the table there is a list of different nitrogen sources that will be used within the Den Food Bosch system.

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22 Crawford, Martin (2010): “Creating a Forest Garden, Working with Nature to grow Edible Crops” (p….?)
23 Crawford, Martin (2010): “Creating a Forest Garden, Working with Nature to grow Edible Crops” (p. 53)

FERTILITY CATEGORIES – Main Crops DFB (0.5 ha)			
	Heavy cropping	**Moderate cropping**	**Undemanding**
Trees	*Cydonia oblonga*	*Prunus avium*	*Ficus carica*
	Malus spp.		
	Mespilus germanica		
	Morus spp.		
	Prunus cerasifera		
	Prunus domestica		
	Pyrus spp.		
Shrubs	*Corylus spp.*	*Amelanchier spp.*	*Aronia aburtifolia*
	Ribes nigrum	*Ribes rubrum*	*Chaenomeles spp.*
	Ribes uva-crispa	*Rubus idaeus*	*Elaeagnus spp.*
	Rubus fruticosus	*Rubus phoenicolasius*	*Lonicera caerulea*
			Prunus tomentosa
			Rosa rugosa
			Sambucus nigra
Climbers	*Humulus lupulus*	*Actinidia spp.*	*Akebia quinata*
	Vitis vinifera		

Table 3: Fertility Categories - Main Crops DFB. (Source: "Creating a Forest Garden. Working with Nature to grow Edible Crops." Martin Crawford. Table modified.)

Next to nitrogen fixing and deep rooting plants, chicken manure – or generally speaking: bird manure is nitrogen rich resource. Next to pest control, another important job performed by wild life is to fertilize the ecosystem.

NITROGEN (N) SUPPLY TO SUSTAIN CROPPING			
Nitrogen demand		**Nitrogen supply**	
Moderate croppers	**Heavy croppers**	**Sources**	**Nitrogen content**
2g/m² per year	8g/m² per year	N-fixer in full light	10 g/m²
		N-fixer in part shade	5 g/m²
		Chicken-Manure	10.5-17.5 g/kg*
		Comfrey mulch	0.5 g per cut
			* source GRUDAF 2009

Table 4: Nitrogen Supply to Sustain Cropping. (Source: Same as previous)

The following table 5 deals with the production of fruits and berries in the main area (about 0.5ha). It estimates the amount of required nitrogen input on the base of the design after 20 years, when most trees are already well established and producing. The shrubby layer, which is for visibility reasons only shown in the design after 3 years, is also included into the calculation.

NITROGEN BUDGET (ANNUAL REQUIREMENTS)		
Amount needed	**Calculated Toral area**	**Required amount of N/a**
Heavy croppers	*2000 m²*	*16 kg*
Medium croppers	*670 m²*	*1.3 kg*
In Total		*17.3 kg*
Vegetational fertilizers	**Calculated Toral area**	**Supplied N/a**
N-fixer in full light	*800 m²*	*8 kg*
N-fixer in part shade	*350 m²*	*1.8 kg*
Comfrey – 4000 cuts	*800 m²*	*2 kg*
In Total		*11.8 kg*
Animal fertilizers	**Amount/a**	**Supplied N/a**
Chicken-Manure	*1350 kg*	*20.25 kg*

Table 5: Nitrogen Budget DFB. (Made with LibreOffice Calc)

In total, looking at the moderate and heavy croppers, an estimated annual amount of 17.3 kg of nitrogen for 2000 m² of heavy croppers and 800 m² of moderate croppers is required. While about half of the nitrogen can be accumulated by planting nitrogen fixing shrubs and trees (especially *Alnus glutinosa* and *Elaeagnus* spp.), the other half could be supplied by around 25 chicken living in the food forest. As 25 chicken would annually produce about 1350 kg manure, which is another 20.25 kg of plant available nitrogen. This means a surplus of 12.6 kg nitrogen for the main area, as the total land size available for the chicken would be 0.8 ha.

The general over-supply of nitrogen in the water bodies and within currently polluted air needs to be taken into account as well. This leaves the question, if a lack of nitrogen could actually occur in a vivid food forest system. The first approach will be to let nature do the work until research results might indicate that some further nitrogen supply could be useful.

Another verification on the amount of nitrogen needed “for a forest garden to be self-sufficient [...]”, Martin Crawford recommends to “aim for a total area of nitrogen fixing trees […] and shrubs […] of 10-30 per cent of the total canopy area.”[24] When most of the trees and shrubs are heavy croppers, the percentage should be at the higher end of the range. Calculating the estimated crown area of the medium and heavy croppers in addition to the nitrogen fixers and another approximate 1000 m² of further trees and shrubs with low nitrogen demand, the nitrogen fixing trees and shrubs account for about 24% of the total area. This is a pleasant result.

Phosphorus (P)

Worldwide phosphorus resources are coming closer to the end every year. Peak Phosphorus is a similar sign of overconsumption as Peak Oil. Industrialized agricultural systems however, are highly dependent on external P inputs. There are different approaches to close the phosphorus cycle as for example filtration of human urine. What is generally overseen in this discussion is the great efficiency with which natural ecosystems use and provide phosphorus amongst the living food web. By building up healthy soils, P levels will stabilize. If the plants show phosphorus deficiency though, two

24 Crawford, Martin (2010): “Creating a Forest Garden. Working with Nature to grow Edible Crops” (p. 150)

low cost sources are available, one being wood ash and one chicken (or wild bird) manure, with a phosphorus content of about 0.5%.

Potassium (K)

The same nutrient analysis can be done with potassium. Comfrey has a very high potassium content, cutting per year only one comfrey plant for mulch has a sufficient amount for one heavy cropping tree. Also the wild birds manure will be a source of potassium. In that sense, the supply is ensured.

POTASSIUM (K) SUPPLY TO SUSTAIN CROPPING			
Potassium demand		**Potassium supply**	
Moderate croppers	**Heavy croppers**	**Sources**	**Potassium content**
3g/m² per year	10g/m² per year	Chicken-Manure	8 g/kg
		Comfrey mulch	10g per cut

Table 6: Potassium Supply to Sustain Cropping. (Source: "Creating a Forest Garden. Working with Nature to grow Edible Crops." Martin Crawford. Table modified.)

POTASSIUM BUDGET (ANNUAL REQUIREMENTS)		
Amount needed	**Calculated Toral area**	**Required amount of K/a**
Heavy croppers	*2000 m²*	*20 kg*
Medium croppers	*670 m²*	*2 kg*
In Total		*22 kg*
Vegetational fertilizers	**Calculated Toral area**	**Supplied K/a**
Comfrey – 4000 cuts	*800 m²*	*40 kg*
Animal fertilizers	**Amount/a**	**Supplied K/a**
Chicken-Manure	*1350 kg*	*10.8 kg*

Table 7: Potassium Budget - DFB. (Made with LibreOffice Calc)

Calcium (Ca)

According to the first soil testings which show pH values of about 4.89 [see chapter 3.1.3, p. 21 f.], the calcium content seems to be low. The calcium content, which is related to the pH of a soil, also determines the availability of most nutrients (including nitrogen, phosphorus and potassium). A soil below 5.0 has a declining number of earthworms and is significantly reducing the uptake of nutrients, as the growth of root tips is dependent on the availability of calcium.[25] Commonly, our soils are acidifying, especially fast on agricultural land, which is why liming is a typical farming practice. Martin Crawford gives the advise that a food forest probably also needs liming in the beginning. But as it matures "nutrient cycling becomes more and more efficient"[26]. He observed that his

25 Crawford, Martin (2010): "Creating a Forest Garden. Working with Nature to grow Edible Crops" (p. 59)
26 Crawford, Martin (2010): "Creating a Forest Garden. Working with Nature to grow Edible Crops" (p. 59)

system was showing stabilised pH values after seven to eight years. An initial liming will probably also be part of establishing the Den Food Bosch system.

Further nutrients

To investigate the micro-nutritional changes of the soil after planting a diverse food forest system, is a very important topic and interesting for longterm research. The food we eat can only be as good as the soil it grows on. For human health, a balanced diet containing all the different micronutrients is required. While scarce resource derived artificial fertilizers are depleting over time, an agro-ecological system can actually feed itself with all the necessary nutrients in the long run.

3.3 Design

3.3.1 Design process

“The further your agricultural system is from woodland,
the more energy it takes to maintain and the more disturbed and distant the system is
from a long-term sustainable biological state.”
Martin Crawford (2010)

The design process was participatory in a sense, that the opinions of all group members were heard and respected. Still, for not having to discuss every detail within the whole team, a focus group of 4 group members concentrated especially on the design. In this chapter, the design process is explained for the reader to comprehend the underlying train of thought when looking at the resulting design.

To start off with, the design group discussed about the ways to create a functional ecosystem. It is crucial to think about all the niches in time, as succession is an ongoing process. In the beginning it is therefore useful to create a future scenario vision of the system and proceed with creating a design in time, heading towards the envisioned stage. Once reaching “the horizon”, a new perspective of the systems future development will have been created. Den Food Bosch uses one design of the food forest after 20 years as the temporarily stage aimed at and a design after 3 years as an intermediate pattern. The more detailed patches and polycultures to include are still in work.

The vision to establish a highly productive system incorporates to work with natural succession, as this is one main driving force in nature. While definitions on natural succession may differ, many ecologists do agree that the most productive stage of an ecosystem is before the mature forest with a closed canopy is reached. In this stage, “biomass gain, nutrient flow control, soil fertility improvement, species diversity, and ecosystem productivity all peak”[27].

Practically, we agreed upon rather planting way too many trees for biomass production in the beginning and cutting out the weaker plants. By doing this kind of “mass selection”, the food forest has better starting conditions to develop into a resilient and healthy ecosystem. All the biomass will contribute to soil improvement and the dense planting will give information of growth to the main crops. To reach a stage of intermediate succession after 20 years, where all different food forest layers are present, and keep this productive stage for a long time by pruning and rejuvenating the system will be a management task.

For the design, most important is the process to get the vision of the food forest as clear as possible. Questions like “who is going to sustain the food forest?”, “is it meant to be a source of income?”, “how much research will be done on site?”, “which products are marketable?”, along with other topics related to the future development of the land, need to be considered. Leaving the final choice of species selection until the basic questions have been answered requires some retention especially in the beginning, as this often is the first thing attracting the attention. Only when all main ideas have settled, the real design can be done. For this, the permaculture principles are a useful guideline [see chapter 1.2, p. 4 f.]. One is called “From patterns to details”. In our case we started with the Base Map and created the different zones that we felt necessary to integrate. Looking at the design principle “Use edges and value the marginal”, the food forest as one stretched forest edge mimicry can be linked to this. Forest edges are commonly very productive zones, with high species diversity due to good light conditions in a multi-layered biome that does not have closed canopy, while at the same time they have the beneficial connectedness to the forest ecosystem. Looking at the design after 20 years [see chapter 3.3.3, p. 45], the trees facing south are smallest, while the height is steadily

27 Jacke, Dave and Toensmeier, Eric (2005), “Edible Forest Gardens Vol. 1 – Vision and Theory” (p. 267)

increasing to the northern part of the system [see illustration 15], creating one big forest edge. In this design, the forest ecosystem is missing due to the size of the land.

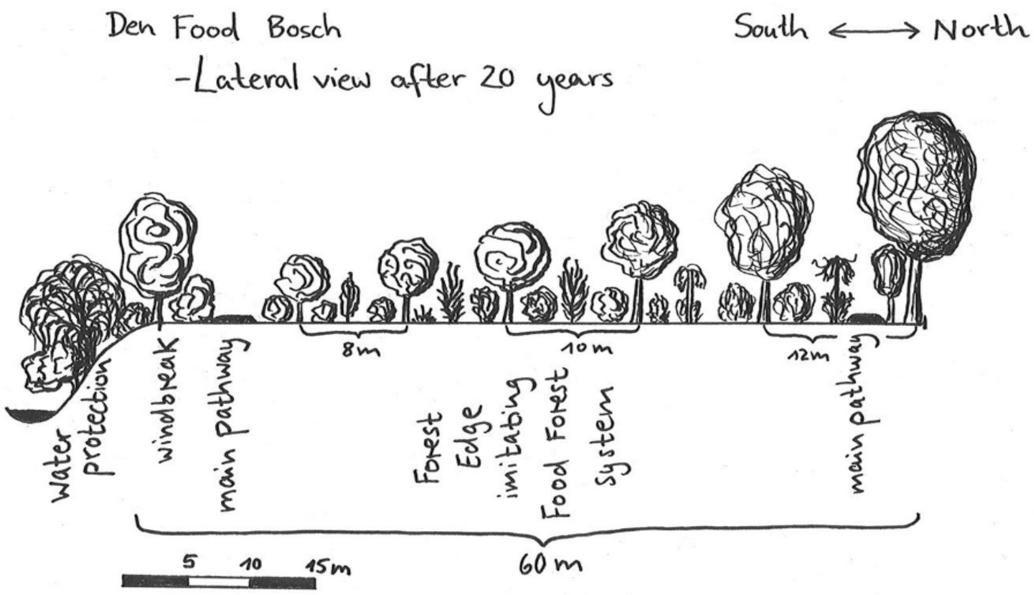


Illustration 11: Lateral View after 20 years - DFB. (Image by Janine Raabe)

The whole system is designed with two main half circles facing south. In this way, sunlight is assumed to be taken up most efficiently. If the trees are planted in east-west orientation, they get full sunlight on mid day, but this means that the rows would be shading out each other in the warm afternoon sun. On the other hand, by planting south-north, the trees shade out each other in the mid of the day and the rows in between will get less sunlight in the morning and afternoon. By planting them in a curve, the valuable afternoon sun is collected and the out-shading is minimized [see illustration 16].

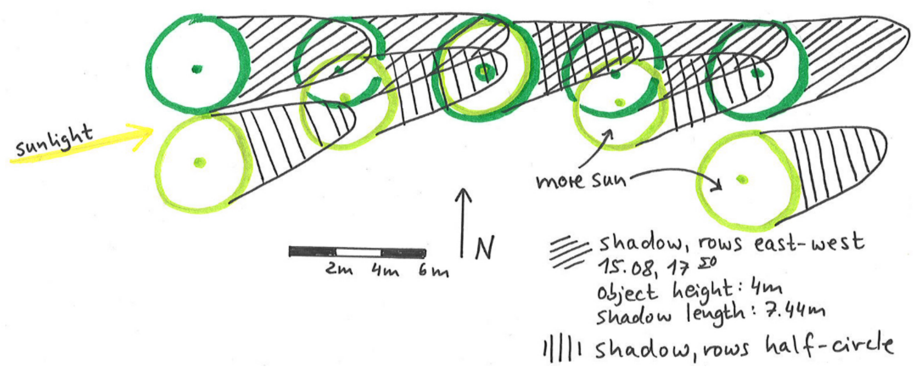


Illustration 12: Collecting sunlight by planting in half-circles. (Image by Janine Raabe)

On the website http://www.sonnenverlauf.de/, a very useful tool is given to calculate the sun course at any given time and date of the year. With the help of this page, it was possible to test in advance if the rows in between the trees will get afternoon sun. For instance, it became clear, that the grapes which will be growing on trellis in the second row, may not consist of late ripening varieties, as they will be shaded out end of September, when the system is established. Indeed, everything is an organic process meaning some sun loving species that grow well in the first years might be exchanged in the long run with more shade tolerant plants. By thinking about the system's development, some major mistakes can be avoided and additional costs for replacement of species saved.

As different species have different requirements on light quality and some prefer morning while others afternoon sun, this kind of sun catching system is useful to give ideal positions for all plants. The food forest can be seen as a trial for species performance in different light conditions. Some advices given by Ernst Götsch – for example, placing pears more in the middle part of the sun-catch and plums facing west – are included already into the design.

In general, the planting pattern is rather dependent on the topography of the landscape. On hillsides it is advisable to plant in contour-line to prevent erosion. But as Den Food Bosch is located on flat Dutch landscape, the orientation is somehow an individual choice. In principle, more organic forms in agriculture would be of high ecological value, when looking at natural water flow and other patterns in nature, straight lines and right angles are rarely found.

A detailed design including the exact placement of every species can be quite helpful for the implementation. Here, it is important to consider soil requirements and sun demand of the selected species. The soil is assumed to be roughly the same on the whole land of DFB. The shade tolerance is looked at individually. An overview on the height and width of the trees and shrubs and the respective shade tolerance was collected into a table [see appendix 4, p. XVII] and turned out very utile in the designing process. Next to the given potential species height and width derived from literature and internet research, an estimated pruned height and width is added. As nearly all the plants will be pruned to fit into the system harmonically, the design after 20 years [see chapter 3.3.3, p. 45] is working mainly with the pruned crown diameters.

To find the right placement for the individual trees, a very simple Base Map was used, including only a north arrow, the scale and the outline of the land to place different layers of transparent paper on top. If there are already other trees or obstacles on the land, which will remain, they should be illustrated on the Base Map as well. Some layers may include main wind directions, waterbodies, pathways or other contributing factors to be used while designing the system. With the list of species for the different zones and a ranking in which quantity the species will be growing, one way to deal with their actual placement is to draw the individual crowns on a paper in the same scale as the Base Map. For this, a scale of 1:100 or 1:200 is useful. A Tree of 6 m crown diameter has 3 cm diameter on the Den Food Bosch design, which is using the scale 1:200. By either using a legend and different styles or by writing the names on the trees themselves, they can be identified later on. After the individual trees have been cut out, they can be placed on a transparent layer of paper on top of the Base Map and different patterns can be tried out by replacing the trees. It is similar to a puzzle and ideas about distances and possible companion plants can be worked on. For the spacing of plants M. Crawford points out that "[a] temperate 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."[28] In his book "Creating a Forest Garden – Working with Nature to grow Edible Crops" he gives a detailed explanation about planting densities of fruit trees. In the design of Den Food Bosch some different spacings are used as a trial.

By doing the placement of trees digitally, one saves the work of cutting out the individual trees. On the other hand, it also is some work to get to know the program (f.e. AutoCad, GreenXpert, Adobe Illustrator and GIS). The designs presented, were done on transparent paper and then scanned and put together with Adobe Photoshop. In the end, it is important to do what feels right. It is good to work step by step and to take care to stay on scale.

28 Crawford, Martin (2010): "Creating a Forest Garden. Working with Nature to grow Edible Crops" (p. 45)

When the future scenario design is developed, a design for the establishment phase is useful. Over-yielding polycultures[29] can be designed in detail by using guilds which share available resources. In these plant guilds, “the most limiting resource will generate the greatest potential for competition”[30], so it is important to combine species with different physiology, root systems and seasonal growth to use the available niches. The patches to be cultivated in the first years are visible in the design after 3 years [see chapter 3.3.4, p. 48]. In temperate climates the shrubs should not be placed directly underneath the trees due to light conditions. Though below the dripping zone of the tree can be ideal. The exact map of the herbaceous layer and the rhizosphere will be designed in winter 2017. For now, only a rough idea of species for the ground cover is given [see chapter 3.4.2, p. 58].

The design can always be reflected in the perspective of the different permaculture design principles to assure that the different aspects of a functional ecosystem have been integrated. An in-depth description of all the principles included into the Den Food Bosch design will be left out in this context, still can be verified by the interested reader.

29 The term over-yielding abundance is used to describe the effect of higher yields of functional plant associations in comparison to monoculture.

30 Jacke, Dave and Toensmeier, Eric (2005), “Edible Forest Gardens Vol. 1 – Vision and Theory” (p. 164)

3.3.2 Map with zones

In the beginning the group decided to have 5 zones in the system: the main area, the experimental area, the windbreak/hedge, the water-protection area and the forest area. However, the size of the land is too small for the idea to have a closed-canopy area with a forest like environment and a productive food system next to each other. Due to this, the wild-life habitat was included more into a broader windbreak/hedge and the closed-canopy forest area was postponed for a bigger system.

Illustration 13: Map with Zones - DFB. (Source: Google Maps. Modified with LibreOffice Draw.)

3.3.3 Future scenario design – The food forest after 20 years

The design of the food forest after 20 years is illustrating a vision of how the system could look, when most of the trees are already well established and productive. In comparison to other agricultural methods where a 20 year perspective normally is not included, this type of long-term planning might seem very distant. But in relation to the lifespan of a permanent food forest which can be a productive farming system for as long as it is managed wisely, 20 years are nothing but a blink of an eye.

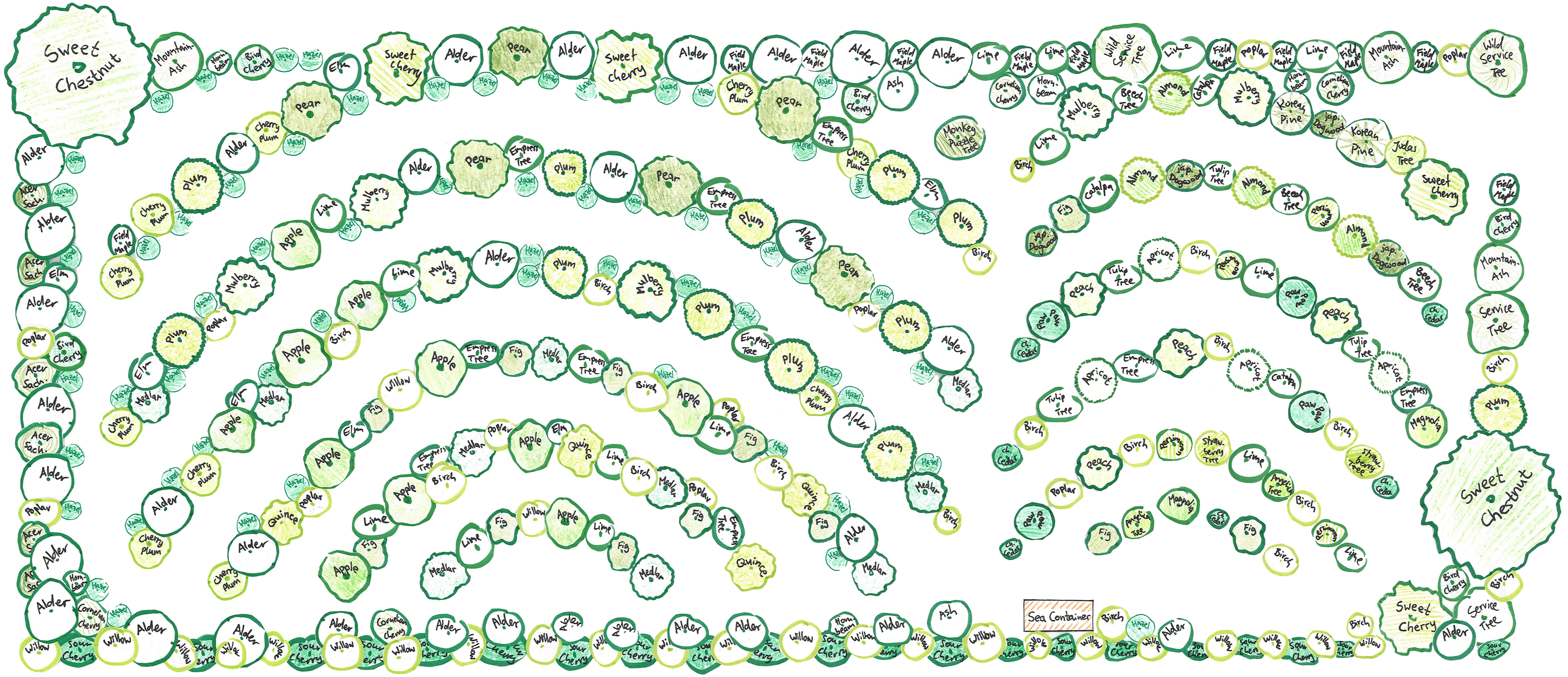
The names of the trees are written directly into the design, therefore a legend is not required. As one can see in the design after 20 years, the plants are smaller and closer together as they could potentially grow. This is because it is designed to be a well managed system, where the individual plants are going to be pruned, at times even intensely. Especially the biomass trees are included into the system for being pruned and increasing soil fertility by using their organic material to feed the soil life. All the cropping trees do have companion tree species to give information of growth, some shelter and accumulate biomass. The biomass trees such as common alder (*Alnus glutinosa*), lime tree (*Tilia* spp.), empress tree (*Paulownia tomentosa*), field maple (*Acer campestre*) or poplar (P*opulus* spp.), were chosen due to their fast growth rates and high ability to regenerate after pruning. In the case of *Alnus glutinosa* a nitrogen fixing species is included. In the experimental area, the biomass trees can be seen as trials, such as the tulip tree (*Liriodendron tulipifera*) or the trumpet tree (*Catalpa* spp.). The biomass trees will be pruned in such a way that the cropping trees get enough sunlight when their fruits are ripening. This period often overlaps with the growth peak and by cutting back the biomass trees in this stage, new growth information is added to the system.

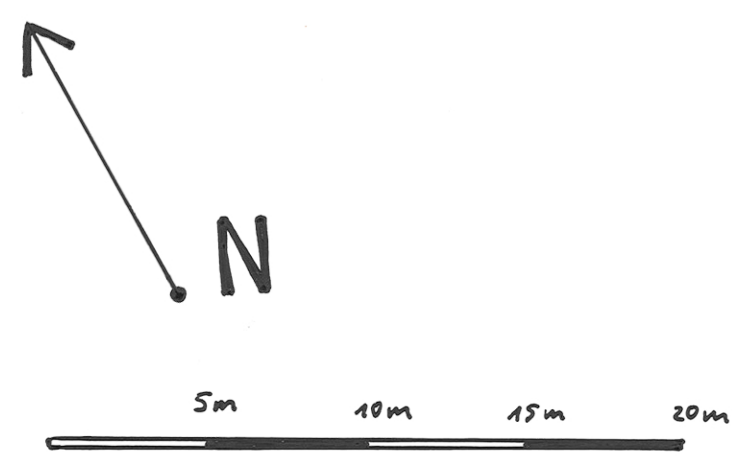
The fruit trees are generally placed in a sufficient distance, some space is left for smaller trees and shrubs to be included. On the design it might seem that the row distances between the trees are rather broad. However, when thinking about the missing shrub and herbaceous layer, the gaps actually will not remain blank. To have some space within the rows of trees, will increase the manageability and also leaves room for experiments in between. The main path will be in the southern part of the food forest, following the way along the windbreak/hedge, utilising the shade. The way back will be within the 12 m gap of the last two rows in the main area, leading through the system, also for visitors to have a look inside. The rows in between the trees will only be entered for maintenance and harvest, to reduce soil compaction. Between the last two rows of the experimental area a shortcut to the exit will be a main path, while another main path will lead back to the picnic area close to the sea container. Here a small outdoor kitchen and a compost toilet will be placed eventually, and of course there is room for social gatherings. The sea container will be used as tool shed, its green roof terrace will enable an overview onto the food forest system.

The windbreak/hedge surrounding the whole field will ensure a sheltered microclimate for the whole system.

Den Food Bosch

Design after 20 years





3.3.4 Establishment design – The food forest after 3 years

The design after 3 years shows not only the tree but also the shrub layer. All the fruit trees that are inside the future-scenario design are marked as filled green dots. As most of them need some more years to establish, this period can be used to build up soil fertility by planting biomass trees (marked as green circles with a green dot in the middle) in a high density and pruning them regularly, while cutting out the weakest ones. Soil fertility will be increased likewise by herbaceous plants such as comfrey (*Symphytum* spp.), lupins (*Lupinus* spp.), lucerne (*Medicago* spp.), clovers (*Trifolium* spp.) and others. Additionally productive grasses can be helpful in this stage of food forest development and also wild flowers for increased pollinator activity will be sowed. Next to all these site fertility increasing species, some annual crops will be included for harvest in the first years, though without tilling the ground.

The legends which are related to the main area and the experimental area show more detailed which kind of shrubs are to be introduced. The yellow dots are not further specified shrubs, as all the information about every individual shrub in the system would be overwhelming in this context. This is why the design has a focus on the space in between, where organized rows of berries, grapes, fruits and hop will be planted.

The design is printed in a way that enables to either look at the main area and use the related legend on the right hand side or investigate the experimental area and use the legend given on the left hand side.

Further explanation on the details of the different areas is presented in the following chapters.

3.3.5 Main Area

The two designs presented only consist of the canopy, the lower tree and shrub layer. To give an idea of the herbaceous layer, two sketches of the food forest after 15 years are added. In this stage, the amount of shrubs might be higher than illustrated. But to show the approximate use of space in the establishment phase of the food forest, the sketches include two rows of a cultivated herbaceous layer within the rows of canopy trees.

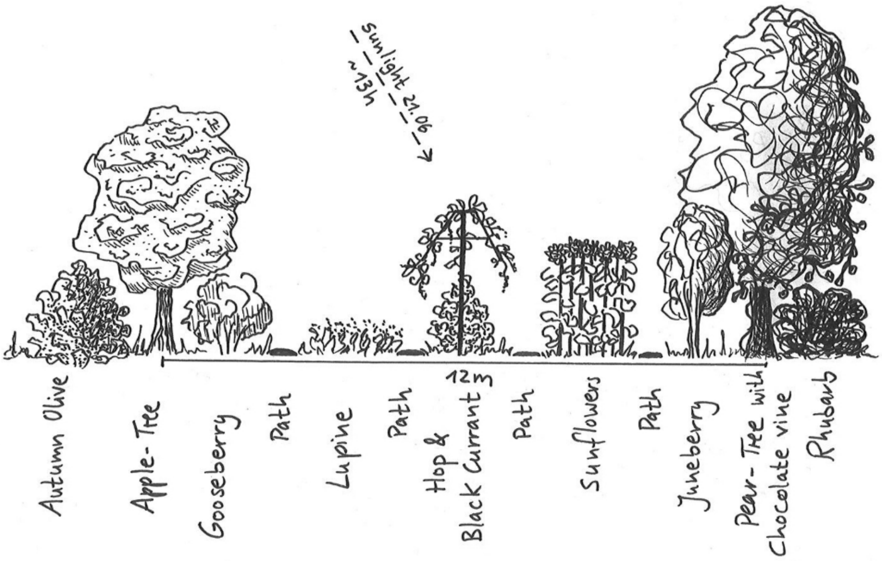


Illustration 14: Lateral View after 15 years - Row of 12 m. (Image by Janine Raabe)

The main crop species in the tree layer are pear (*Pyrus communis*), plum (*Prunus domestica*), cherry plum (*Prunus cerasifera),* apple (*Malus pumila*), medlar (Mespilus germanica) and fig (*Ficus carica*). In the shrub layer it is hazel (*Corylus avellana*), autumn olive (*Elaeagnus umbellata*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*), black currant (*Ribes nigrum*), red currant (*Ribes rubrum*), gooseberry (*Ribes uva-crispa*), cathay quince (*Chaenomeles cathayensis*),

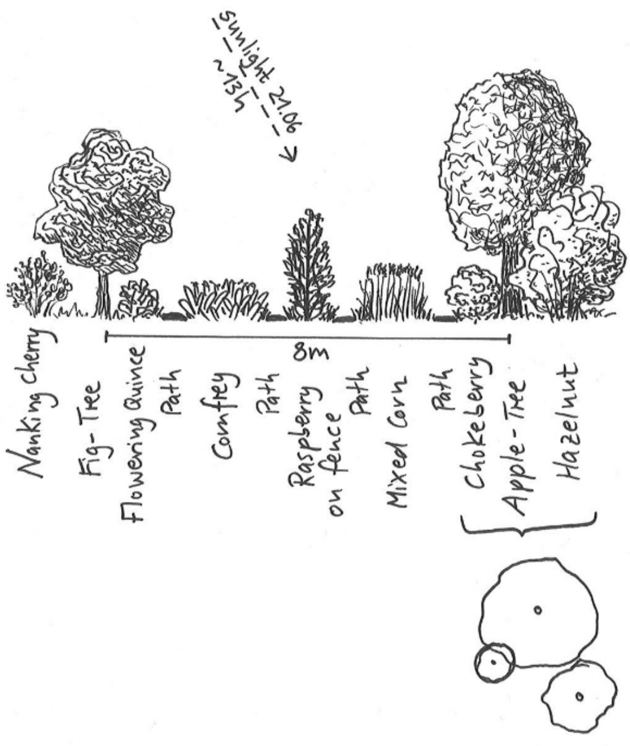
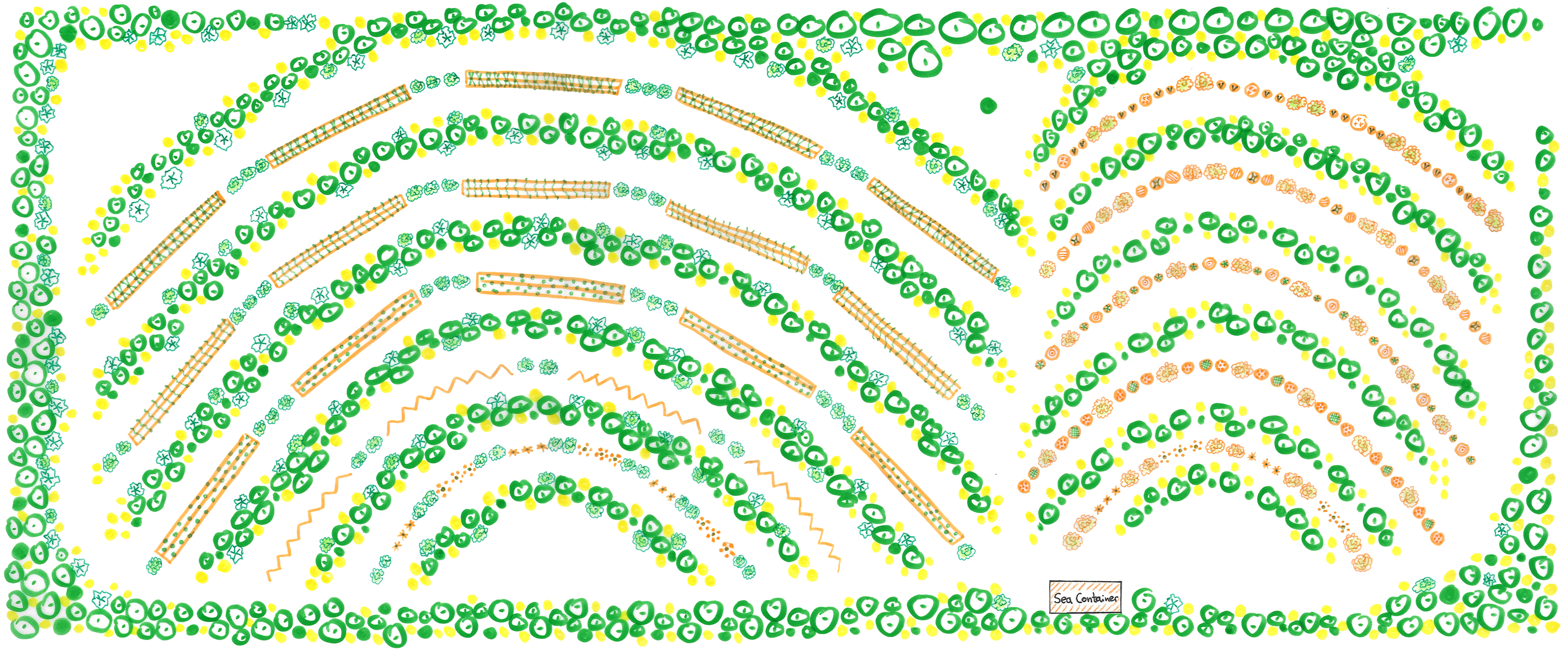
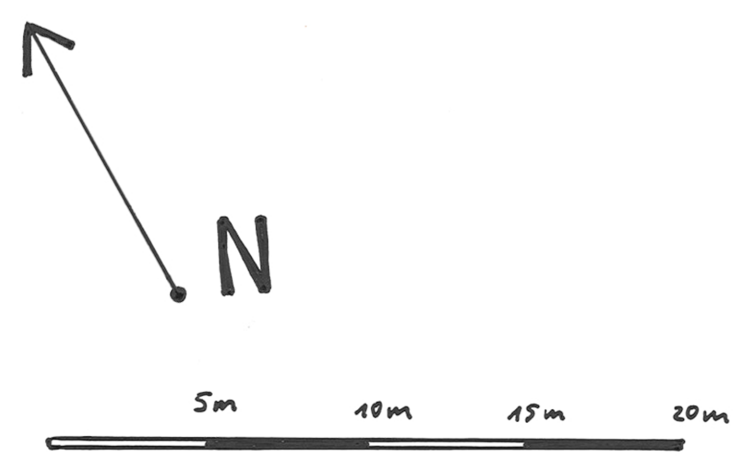


Illustration 15: Lateral View after 15 years - Row of 8 m. (Image by Janine Raabe)

Den Food Bosch

Design after 3 years





honeyberry (*Lonicera caerulea*) and nanking cherry (*Prunus tomentosa*). In the climbing layer, the main crops are grape (*Vitis vinifera*), kiwi (*Actinidia* spp.) and hop (*Humulus lupulus*). The species list [see table 8] presents the entire diversity of trees, shrubs and climbers which will grow in the main area.

While the higher fruiting trees are in the northern part of the system, smaller trees are placed towards the southern edge. In total, about 80 fruit trees are part of the 0.5 ha main area with another approximate 50 hazelnuts and 80 autumn olives next to numerous shrubs, climbers and ground cover plants as further crops. Adding the biomass trees, the image is complete. In comparison, fruit tree density in traditional orchards varies between 25 up to 260 trees per ha, depending on species variety and rootstock.[31] To be honest, these numbers cannot be compared, but are just standing for themselves.

Special attention is to be paid to the rows in between the fruit trees, which are 5 in total, one of 12 m, two of 10 m and 2 of 8 m width. In the centre of these intermediate rows, some species combinations of climbing plants on trellis, shade tolerant shrubs underneath and nitrogen fixing shrubs are assembled. For example, blackberry (thornless varieties and bound to a fence) and red

Type	Common name	Scientific name
Trees		
1st Main Crops	Common fig	*Ficus carica*
	Apple	*Malus domestica*
	Medlar	*Mespilus germanica*
	Cherry plum	*Prunus cerasifera*
	Pear	*Pyrus communis*
	European plum	*Prunus domestica*
2nd Main Crops	Quince	*Cydonia oblonga*
	Mulberry	*Morus (nigra, alba)*
	Sweet cherry	*Prunus avium*
Shrubs		
1st Main Crops	Juneberry	*Amelanchier spp.*
	Cathay quince	*Chaenomeles cathayensis*
	Hazelnut	*Corylus avellana*
	Autumn olive	*Elaeagnus umbellata*
	Honeyberry	*Lonicera caerulea*
	Nanking cherry	*Prunus tomentosa*
	Black currant	*Ribes nigrum*
	Red currant	*Ribes rubrum*
	Gooseberry	*Ribes uva-crispa*
	Blackberry	*Rubus fruticosus*
	Raspberry	*Rubus idaeus*
	Japanese wineberry	*Rubus phoenicolasius*
2nd Main Crops	Chokeberry	*Aronia arbutifolia*
	Oleaster	*Elaeagnus x ebbingei*
	Goumi	*Elaeagnus multiflora*
	Sea Buckthorn	*Hippophae rhamnoides*
	Romans rose	*Rosa rugosa*
	Black elder	*Sambucus nigra*
Climbers		
1st Main Crops	Hardy kiwi	*Actinidia arguta*
	Hop	*Humulus lupulus*
	Grape	*Vitis vinifera*
2nd Main Crops	Chocolate Vine	*Akebia quinata/trifoliata*
Biomass Trees	Field maple	*Acer campestre*
	Common alder	*Alnus glutinosa*
	Birch	*Betula pendula*
	Empress tree	*Paulownia tomentosa*
	Poplar	*Populus spp.*
	Willow	*Salix spp.*
	Lime tree	*Tilia spp.*
	Elm tree	*Ulmus spp.*

Table 8: Species List - Main Area DFB. (Made with LibreOffice Calc)

31 Derived from: "Traditional orchards: planting and establishing fruit trees", Natural England Technical Information Note TIN014 (Second edition, October 2010)

currant are placed underneath of hop growing on trellis. The individually combined blocks have a length of 15 m and grow in sequences with 6 m of autumn olives. For the harvesting, two mulched pathways on both sides are kept and and a stacked wooden ladder compound above of the trellis is already designed. The trellis of the hop will be 3 m high and 1.5 m wide to allow enough space for the shrub layer underneath.

Similarly, the next intermediate row combines climbers on trellis with an underneath growing layer of shrubs. Grapes on about 2.5 m high and 1.2 m wide trellis are positioned above black currant and gooseberry, again with autumn olives in between the blocks of 15 m length. Another row of kiwi on 2 m high and 1 m wide trellis with cathay quinces below is organized in the same way.

In general, the different blocks can be used for different varieties to ensure a long harvest period and to try out different varieties in this design. Furthermore one row with raspberry and wineberry and one with honeyberry combined with nanking cherry will fill the last two remaining gaps between the rows. Here again, autumn olives will be used as fruit bearing nitrogen fixers.

To reveal new favourable fruit and biomass species associations and positioning within the sun catching system, the fruit tree species might consist of one variety per row. This detail will be further discussed within the group in the following phase of choosing the appropriate varieties.

3.3.6 Experimental Area

The experimental area is structured in a similar way as the main area, with 6 main fruit rows and 5 intermediate rows with berry crops, the distance between the rows is smaller though, since the trees in that area will generally be smaller as well. Main focus in this area lies on almond (*Prunus dulcis*), peach (*Prunus persica*), apricot (*Prunus armeniaca*) and pawpaw (*Asimina triloba*) in the tree layer, sea buckthorn (*Hippophae rhamnoides*) and various other experimental shrubs [see table 9]. Possibly, some further climbers will be included but are not listed here.

The origins of the species included into this area vary a lot, they are introduced from different climates in the range of possibilities.

As the experimental area includes 46 sea buckthorns with one on seven being male, about 40 fruiting plants can each produce 5 kg, which means about 200 kg of fruits in total. This can be a great additional source of income derived from the experimental area, while fixing nitrogen for the surrounding species. Easy to pick varieties will be chosen.

Experimental Area – Den Food Bosch		
Type	**Scientific name**	**Common name**
Trees	*Aralia elata*	Angelica Tree
	Araucaria araucana	Monkey Puzzle Tree
	Arbutus unedo	Strawberry Tree
	Asimina triloba	Paw Paw
	Cercis siliquastrum	Judas Tree
	Cornus kousa	Japanese Dogwood
	Diospyrus spp.	Persimmon
	Magnolia spp.	Magnolia
	Pinus koraiensis	Korean Nut Pine
	Prunus armeniaca	Apricot
	Prunus dulcis	Almond
	Prunus persica	Peach
	Toona sinensis	Chinese cedar
Biomass-trees	*Betula pendula*	Birch
	Catalpa speciosa	Trumpet Tree / Catalpa
	Fagus sylvatica	Beech
	Liriodendron tulipifera	Tulip Tree
	Paulownia tomentosa	Empress Tree
	Populus spp.	Poplar
	Tilia spp.	Lime
Shrubs	*Aralia racemosa*	Spice berry
	Decaisnea fargesii	Blue bean
	Hippophae rhamnoides	Sea Buckthorn
	Hybiscus syriacus	Syrian ketmia
	Lycium barbarum	Goji berry
	Poncirus trifoliata	Trifoliate Orange
	Rhus spp.	Sumac
	Rosa rugosa	Romans rose
	Sheperdia canadensis	Buffalo berry
	Zanthoxylum spp.	Pepper Tree
Biomass-shrubs	*Robinia hispida*	Bristly Locust

Table 9: Species List - Experimental Area DFB. (Made with LibreOffice Calc)

The species composition is very interesting and Den Food Bosch is looking forward to observe the different species performances. While some trials might not work out, which is alright as this area has a focus on learning and education, speaking confident, probably most species will grow fine. Special plants such as the pepper tree (*Zanthoxylum* spp.), which might be a local substitute for black pepper, the goji berry (*Lycium barbarum*), known as superfood or the trifoliate orange (*Ponicirus trifoliata*) next to the cathay quince (*Chaenomeles cathayensis*) an interesting regionally grown lemon substitute, might become relevant crops in the future – if their quality and quantity reveal to be good.

3.3.7 Windbreak/Hedge

In general the windbreak/hedge is meant to reduce the amount and speed of wind within the food forest system. According to M. Crawford, the length of the quiet zone with about

50% wind speed reduction is 7-8 times the height of the windbreak and if there is another windbreak planted at the other side of the food forest, the protection zone even increases.[32] Eventually, the whole food forest should become a quite zone, with protection on each side. How the wind reacts to the planted system, will be observed in the following years and if necessary, adaptions will be made. One example is the western wind that could drop back into the system, as a result, another hedge between the main area and the experimental area could be planted.

To place alder trees (in this case *Alnus glutinosa*) in the western part of the windbreak has several advantages. Firstly, they grow very fast and thus will have an impact on the microclimate of the given side, soon. Secondly, their leaves stay long in autumn so the shelter will be given when autumn storms occur. And last but not least, their leaves rich in nitrogen will be blown into the system as winds from Southwest are the most frequent.

Windbreak/Hedge – Den Food Bosch		
Type	**Scientific name**	**Common name**
Trees	*Acer campestre*	Field maple
	Acer saccharum	Sugar maple
	Alnus glutinosa	Common alder
	Betula pendula	Birch
	Carpinus betulus	Common hornbeam
	Castanea sativa	Sweet chestnut
	Cornus mas	Cornelia cherry
	Fraxinus excelsior	European ash
	Populus spp.	Poplar
	Prunus padus	Bird cherry
	Rhamnus frangula	Alnus buckthorn
	Sorbus aucuparia	Mountain ash
	Sorbus domestica	Service tree
	Sorbus torminalis	Wild service tree
	Ulmus spp.	Elm tree
	Salix spp.	Willow
Shrubs	*Aronia arbutifolia*	Chokeberry
	Berberis vulgaris	Barberry
	Cornus sanguinea	Common dogwood
	Corylus avellana	Hazelnut
	Crataegus spp.	Hawthorn
	Eunymus europaeus	European spindle
	Mahonia aquifolium	Oregon grape
	Ribes nigrum	Black currant
	Ribes rubrum	Red currant
	Ribes uva-crispa	Gooseberry
	Sambucus nigra	Black elder
Climbers	*Actinidia spp.*	Kiwi
	Akebia quinata/trifoliata	Chocolate vine
	Humulus lupulus	Hop
	Schisandra chinensis	Wu Wei Zi

Table 10: Species List - Windbreak/Hedge DFB. (Made with LibreOffice Calc)

Even though not shown in the design, it is wise to consider placing early leave sprouting species in the eastern part of the windbreak, such as willow (*Salix* spp.). Especially for frost tender crops a shelter from the eastern sun in early spring is important as the morning sun falling on frozen flower tissues can cause great damage. Ideally, the whole design is surrounded by a windbreak/hedge to protect the crops from wind exposure and create a sheltered

32 Crawford, Martin (2010): "Creating a Forest Garden, Working with Nature to grow Edible Crops" (p. 101)

microclimate for pollination and optimal growth. The tallest species can be placed into the northern edge of the food forest, as there is no risk of shading out the other crops. As the northern neighbouring field is used for grazing horses, some shade for the animals in summer time might be welcome. Still, the ideas will be presented before the food forest is planted.

The main trees of the windbreak are common alder (*Alnus glutinosa*), poplar (*Populus* spp.), willow (*Salix* spp.), birch (*Betula pendula*), bird cherry (*Prunus padus*), different species from the sorbus genus and cornelian cherry (*Cornus mas*). Another detail is the northwestern edge where sugar maple (*Acer saccharum*) is included into the windbreak. Next to the higher trees, the shrub layer is very important to ensure the effect of a hedge. Chokeberry (*Aronia arbutifolia*), hazelnut (*Corylus avellana*), european spindle (*Eunymus europaeus*), black elder (*Sambucus nigra*) and some berries are going to be integrated into this shrub layer. Additionally, some beehives will be situated in the far north-western corner underneath of the sweet chestnut, here they have a sheltered spot and can fly into the food forest towards south.

3.3.8 Water protection Area

Water is is they key of life on earth and it should always be highest priority the keep it clean and alive. While the understanding of clean water nowadays has perverted into water being “cleaned” by chemicals, only natural water flow, including the big and the small water-cycle and natural riverbeds, really have the capacity to clean water. The vegetation in natural ecosystem always grows close to waterbodies and in the shelter of tree canopies the water cools down, while the roots of the riparian vegetation filter out a surplus of nutrients and induce small water turbulences which help cleaning the water. Ernst Götsch emphasizes that the natural vortex of water actually is the pulse of life and an active process of movement and cleaning. Further, some group members of Den Food Bosch went to the workshop “Learning from water” organized by the Spring College in April 2017, where they met Jörg Schauberger. He is the grandson of Viktor Schauberger[33] and gave further insights on how important natural water flow is for ecosystem health.

33 Viktor Schauberger (1885-1958) was a forester, natural scientist, discoverer and inventor from Austria. In his life he studied especially the natural water flow and put his observations into practice by inventing new technologies which are based on his profound understanding of the water inherent energies.

In the Netherlands the water regime is very special as most of the land needs to constantly be drained to prevent flooding. Higher water infiltration rates into the ground reduce the pressure of heavy rain events, this mainly is reached by perennial, multilayered systems such as natural forests or food forests. By planting more of this multilayered systems, flooding can be prevented and the landscape has a higher potential to absorb rainfall. The water contamination with agrochemicals and fertilizers often is problematic, too. Here again nature is the best partner. Low cost water filtration can be achieved with water plants such as bulrush (*Typha* spp.) and other reeds. These plants potentially have multipurpose uses such as biomaterials for constructions and energy, livestock fodder, some species can even be used for human consumption – as a byproduct from cleaning canals, rivers and other waterbodies.

Water Area – Den Food Bosch		
Type	Scientific name	Common name
Trees	*Alnus glutinosa*	Common alder
	Betula pendula	Birch
	Populus spp.	Poplar
	Prunus cerasus	Sour cherry
	Salix spp.	Willow
Shrubs	*Myrica spp.*	Bayberry
	Ribes nigrum	Black currant
	Ribes rubrum	Red currant
	Ribes uva-crispa	Gooseberry
	Sambucus nigra	Black elder
	Vaccinum macrocarpum	Cranberry
	Viburnum lentago	Nannyberry
Climbers	*Actinidia spp.*	Kiwi

Table 11: Species List - Water-Protection Area DFB. (Made with LibreOffice Calc.)

It still has to be clarified whether Den Food Bosch will be able to plant right down to the canal, since the Waterschap usually cleans the canals twice a year from vegetation and other materials. For this maintenance some space is required. However, the integration of water into the system is crucial for ecological restoration and the interest for that is mutual. The ideal case would be Den Food Bosch being fully responsible for that section of the canal.

When Ernst Götsch visited the Netherlands in April 2017 his first input for the design of the land was to grow different species of willow (*Salix* spp.) all along the canal and sour cherry (*Prunus cerasus*) as the lower tree layer. Planting about 30 sour cherries each producing 30 kg of fruits already results in 900 kg sour cherries, which is a great yield for protecting the water and sheltering the food forest at the same time. Some shrubs like nannyberry (*Viburnum lentago*), bayberry (*Myrica* spp.) and cranberry (*Vaccinum macrocarpum*) might be interesting additional crops. As kiwi grows well in moist conditions, some trials will be done to grow kiwi on coppiced willows. In the herbaceous layer especially wild garlic and mints will be introduced.

3.4 Implementation

To overcome the period of low yield in the first 3-4 years until the trees start producing well, planting annual crops in polyculture can be a very suitable way to generate income and use the space effectively until the shading of the trees and shrubs is increasing to a level, where sun loving annual plants will be replaced by more shade tolerant perennials. Of course, a food forest can also be planned in such a way as to always include annual plants, spacing the rows between the trees in a bigger distance. But Den Food Bosch is aiming for a permanent system which does not rely on annual sowing or planting and as a result leave the longterm maintenance of the system to pruning, selective weeding and harvesting. Planting annual crops will be "filling the gaps" - ecologically and economically - for the first years.

Indeed, this opens a new chapter of the design, as it is important to plan the annual cropping system more detailed. For this, further literature research needs to be done, to create a "design in time" and come up with a 5-year design plan. This plan will be created in winter 2017/18 and used as a general guide for the following years. Certainly, it is a organic process and changes will most likely occur as the time goes by.

Another important question is whether to plant by seed or to plant young trees and shrubs. Mark Shepard recommends to do mass selection by planting huge amounts of seeds and selecting the best individuals afterwards – also by natural selection. This way of planting will lead to well site adapted and healthy plants. It is less time consuming than planting all the trees and shrubs individually – and of course the costs to establish the food forest are much lower. However, as some years of plant growth already make a difference in terms of human lifespans, and to show how the food forest is meant to look like, in a shorter time period, it is an advantage to plant nursed trees and shrubs. Den Food Bosch is meant to inspire other farmers and individuals to integrate more perennial plants into agricultural systems and to think about creating healthy ecosystems for human food supply. To have positive results after just some years might be convincing. Generally, mass selection of species in a way Mark Shepard and Ernst Götsch plant their food forests, can especially be very useful to plant large scale systems. In further food forest systems this might be the way to go. Yet, for planting an organized system right now, to inspire for change rather sooner than later, it seems more appropriate to use nursed plants.

3.4.1 Planting

For the planting itself, a well organized volunteer weekend will take place. Small groups will carry out precisely defined tasks in certain areas. For easy access and reduction of soil compaction the main pathways will already be mulched. Some tonnes of woodchips will be used as mulch, which are locally derived from a poplar alley on Bleijendijk, that needs to be replaced due to high age. As poplar (Populus spp.) is a fast composing and not acidifying biomass, it is a very useful resource for this purpose.

The rows of trees as well as the positions of the main crops will be marked with sticks. Some earthworks will also be done for tall growing trees in the northern area to give them more rooting space which is advisable when having higher water tables. While the main area, the windbreak/hedge and the water protection area should be planted in winter, it might be smart to plant some frost tender trees of the experimental area in late spring to avoid cold temperatures. Most trees are getting more hardy throughout the years and planting tender trees after the late frost period is over, gives them another season without danger of dying back. When planting the trees and shrubs, they need to be watered very well to ensure that the roots are not within bigger pores of air but all have a good soil contact.

If the field needs to be limed, further soil testing will reveal. To protect the soil from erosion, exposition to direct sunlight and raindrops, the entire land is either being covered by vegetation or mulch. Natural occurring species are welcome to help restoring soil fertility and will be managed if they are invasive or in direct competition with the crop species.

3.4.2 Introduction of herbaceous layer

To plan species guilds and crop rotation schemes, especially deep rooting herbaceous plants for loosening of compacted soil, nitrogen fixing and pollination plants as well as edible crops will be used. In the beginning some winter cover crops are going to be sowed into the bare soil of the previously mono-cropped cornfield after the trees and shrubs have been planted, followed by more sowing of annuals and perennials in springtime. A high priority is to introduce NDHP-crops [see chapter 1.2, p. 8]. Annuals such as sunflowers, potatoes, squash and beans will be planted in the first years with no-till techniques.

The table right hand side gives an overview on a pre-selection list of herbaceous plants. This list is not finalized and only includes species that might stay in the food forest for a while. Plants for natural pest management have a high priority. Jacke and Toensmeier use the term of "aromatic pest control"[34] for the method of introducing species like mint, garlic and onion to confuse the chemical signals that pests use to find their host plants, which are in some cases human desired crops.

The high value of comfreys (*Symphytum* spp.) just can be highlighted another time, as they "accumulate six different minerals (including N, K and Ca) to higher than average levels, they produce abundant biomass and their leaves decompose rapidly."[35]

Pre-Selection of Herbaceous Layer	
Scientific name	**Common name**
Alchemilla mollis	Lady's mantle
Allium neapolitanum	Daffodil garlic
Aralia cordata	Udo
Borago officinalis	Borage
Calendula spp.	Calendula
Fagopyrum esculentum	Buckwheat
Foeniculum vulgare	Fennel
Fuchsia spp.	Fuchsia
Hosta spp.	Hostas
Lilium lancifolium	Tiger lily
Hemerocallis spp.	Day lilies
Lupinus spp.	Lupin
Malva spp.	Mallows
Matteuccia struthiopteris	Ostrich fern
Medicago lupulina	Black medick
Medicago sativa	Lucerne/Alfalfa
Mentha spp.	Mint
Myoga spp.	Japanese ginger
Myrrhis odorata	Sweet Cicely
Origanum vulgare	Oregano
Petasites japonicus	Giant butterbur
Phacelia tanacetifolia	Phacelia
Polygonatum spp.	Solomon's Seal
Pulmonaria officinalis	Lungwort
Raphanus sativus	Fodder radish
Rheum spp.	Rhubarbs
Sassafras albidum	Sassafras
Scorozonera hispanica	Black Oyster Plant
Sinapis alba	White mustard
Symphytum spp.	Comfreys
Trifolium spp.	Clover
Tropaeolum spp.	Nasturtium

Table 12: Pre-Selection List of Herbaceous Layer DFB. (Made with LibreOffice Calc.)

3.5 Maintenance

3.5.1 Management

The management practices of pruning and selective weeding will be the main tools to harmonize the growth of the system. The task of identifying the optimal growth conditions for each species, creating disturbances when needed and selecting the most vigorous plants, is the fundament to create a highly productive and healthy food forest. It is important to see the development of the system as an organic process, where changes occur constantly and we, one part of the system, constantly have to adapt and by the time will learn how to play with it. By pruning it is for example possible to "harvest sunlight" where and when it is needed. The planted species will grow together with the natural vegetation, the food forest farmer can observe, interact with and direct the process.

34 Jacke, Dave and Toensmeier, Eric (2005), "Edible Forest Gardens Vol. 1 – Vision and Theory" (p. 151)
35 Jacke, Dave and Toensmeier, Eric (2005), "Edible Forest Gardens Vol. 1 – Vision and Theory" (p. 187)

The main objective to keep the system functional in all ecological, economical and social aspects will help to decide upon given situations. There is a range of open questions to observe while managing the system, for example it is interesting to find out whether vines do better on trellis or on coppiced trees in regards to total work and harvest input/output. Also Den Food Bosch wants to find out, if the soil fertility will increase faster when only introducing perennial plants in comparison to cultivation of annuals with no-till techniques. Furthermore it is open if certain combinations will stand out, if the sun catching system really creates a warmer microclimate in the front and which row distances are most suitable for the given species. Assumably, a well designed system does not need external inputs once established – let us see if this is the case.

As a broader vision, the use of “shifting mosaic mimics”[36] for large scale projects possibly following in the future is a very efficient approach, where ecosystem management and human food production come together. This method is also described by Jacke and Toensmeier, who suggest that on bigger scale, a majority of the agro-ecological systems could be in the stage of highly productive mid-succession, while some smaller patches are within early-succession and about a third could be already mature, created to be in a constant flux of rejuvenation while keeping some mature areas to fulfil their important role of grand-parenting.

3.5.2 Monitoring

To monitor the food forest, a set of indicators was chosen from the indicator list of “Sustainable Food Forests – A multi-layered approach to monitoring and evaluation” which is a so far unpublished report conducted on the behalf of Both ENDS and Rich Forest[37]. As the research programme is still under development in cooperation with Rich Forest, the HAS university, the Waterschap and Den Food Bosch, and will not be finalized until the end of this thesis, an approximate list of indicators to be surveyed, is presented.

36 Jacke, Dave and Toensmeier, Eric (2005), “Edible Forest Gardens Vol. 1 – Vision and Theory” (p. 267)
37 Huijsoon, Marlies; De Leeuw, Pieter; Mooij, Marjolein, Mens, Lotte (2017): “Sustainable Food Forests – A multi-layered approach to monitoring and evaluation” (unpublished report, students of Wageningen university on behalf of the NGO Rich Forest and Bastiaan Rooduijn)

Indicator list - Pre-selection of possible indicators for long-term monitoring		
Ecological indicators	**Soil quality**	- Organic matter content - Top soil depth - Soil texture - Soil structure - Infiltration rate - Water holding capacity - pH - Soil respiration rate - Extractable NPK - Nitrate - Pollutants - Amount of earthworms - Plant growth - Percentage of soil cover
	Nutrient balance	- Quantity of external input - Quantity of yield
	Biodiversity	- Plant species richness - Amount of layers - Quantity of pest controlling organisms - Key species
	Carbon sequestration	- Above ground biomass - Soil carbon
Socio-economical indicators	**Economic inputs**	- Mechanical input - Planting material - Workforce - Hired labor - Planting density
	Economic outputs	- Yield - Tree productivity - Total output - Profit
	Market resilience	- Subsidies - Loans - Yield stability
	Entrepreneurship	- Non-food income sources - Tourism - Business model
Socio-cultural indicators	**Social capital**	- Working hours volunteers - Number of visitors
	Education	- Guided tours offered - Number of school field trips

Table 13: Indicator list - Pre-selection for long-term monitoring DFB. (Made with LibreOffice Calc)

3.6 Evaluation and Tweaking

3.6.1 Scheme of future self-evaluation

To do reflection rounds within the group and look upon recent development of the project in the perspective of the individual group members is very important. It can be the base for learning from difficulties that arose within the process. These reflection rounds where everybody has time to speak about personal feelings and points of view, are often an integral part of the group meetings. Probably it would be of great value to have a bigger meeting once every year, where the past year and all the main developments can be reflected together and also celebrated. The method of Dragon Dreaming[38] uses the "Celebration" as en ending-phase of every project cycle. Celebrating what has been accomplished is a strong source of new inspiration and motivation for the following project cycle. Therefore, a day of celebration after the main harvesting period, can be a good point for self-evaluation.

As important, research on soil improvement, plant growth and biodiversity will reveal the status of ecosystem health. Keeping track of inputs and outputs, yields and costumer satisfaction will show the economical development of Den Food Bosch, while the number of courses and guided tours indicates the educational value of the project.

3.6.2 Outlook

In the upcoming time period, the Den Food Bosch group will buy planting material, required tools, a sea container for tool storage and further necessary materials to set up the food forest this winter. When the main structure has been planted, in early spring some annuals will be introduced with no-till techniques (using mulch and combined harvesting-sowing strategies). Further, the first perennial herbaceous species will be planted during 2018. Next to the process on the land, the Bleijendijk shop will be opened. In the next years, experiences with working on the land will increase, likewise the amount of harvested and sold food forest products. To promote longterm profitability it can be wise to have own processing facilities and increase the profit by adding value internally.

38 Dragon Dreaming was created by the GAIA Foundation in Western Australia and consists mainly of the cycle "Dream, Plan, Action, Celebration". For further research see http://www.dragondreaming.org/.

A research programme will be worked out this year, and students from the HAS, Wageningen UR and other institutes are welcome to participate gathering data and analysing results. Den Food Bosch can be seen as an outdoor school. Pruning courses and food forest management lessons will be offered for small groups along with volunteer working days, workshops and guided tours for bigger groups. In spring 2018 two workshops with Mark Shepard and Ernst Götsch are being organized.

A connection and team up with other food forest projects is important, as a strong network can have a greater impact on politics and the broader public.

Den Food Bosch is looking forward to experience how productive a food forest system in temperate climates can be.

4. Discussion

4.1 Reflection

Looking back at the overall design process, several helpful key points can be highlighted. The chosen literature turned out to be a useful source for the process and is very recommendable when planning to establish a food forest system. Moreover, it was very beneficial that the different stakeholders shared a mutual interest on the success of this project and all discussions aimed for the best outcome. It became clear, that by moving on slowly and integrating all the stakeholders, the results turn out best. And after all the basic work had been done, it felt like the system designed itself.

Although, some difficulties occurred on the way. For example, sometimes the different time schedules of the group members made it challenging, that everybody was "up to date" with the progress of Den Food Bosch. Also, inaccessibility of the land made the task of research and monitoring quite hard. In general, the size of the land was actually a bit small for the ambitions of the group.

As this paper deals with a real project and is not only a theoretical scientific work, the separation between the "real process" and the thesis required some reflection on what is important for the project development and vice versa for the paper.

For the time management, it was helpful to have a self-made time schedule, with different objectives and working tasks. Even though in the end it felt like a marathon, which could have been avoided by starting the literature research and the site survey before the three month time period for the thesis, I am glad to be able to present this paper.

Den Food Bosch can be proud of the way of communication amongst the group members, as everybody is learning and growing. Although sometimes it might be difficult and a bit exhausting, the group can look back at a great process and forward to a future with plentiful growing trees.

If this paper can be useful for other projects is out of the range of own perception. Hopefully, the given literature and the step by step process description will contribute to further developments of food forest systems.

Otherwise, for further interest, nothing is left but saying: “come and visit”.

4.2 Further research questions

Within the design process, several questions for further research arose. Some of them will be listed below for whom interested.

- Which biomass trees are especially doing well in the western European climate?
- Which tree and shrub species are especially good companion plants to create productive over-yielding polyculture guilds?
- For a longterm research program: Are multistrata agroforestry systems more productive when planted by seeds vs. by nursed trees?
- Is the NPP (Net Primary Production) of a system higher when intensely pruned or when using the “automulching-technique”? Related to this: Which systems yield higher when comparing input/output (work, harvest, etc.)
- How can policies be changed to be more supportive for agro-ecological farming systems?
- What are the interests of farmers on changing the current agricultural system into an agro-ecological and diversified system?
- [...]

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Interviews were conducted with the following persons:

Erwin Bouwmans – Lecturer at the HAS university.

Erwin van Woudenberg – Lecturer at the HAS university.

Floris Komen – Owner of tree nursery, Den Dungen.

Ineke Bartels – Employee at the Waterschap.

Karst Kooistra and Herma Winnemuller – Owners of the Bleijendijk Estate.

Malika Cieremans – Food forest expert, Wageningen.

Paul Müller, Felipe Villela, Marc Leiber, Jonas Steinfeld, Koert van Bemmel, Katharina Grimm, Malika Cieremans – Members of Den Food Bosch.

Wouter van Eck – Food forest farmer / expert, Ketelbroek, Nijmegen.

Appendix 1 – Evaluation-sheet of species selection

Den Food Bosch – Species selection

These are the results of meeting on the 3rd of July, 2017.

The **rating** is as follows:
1 = “very suitable”
2 = “That’s fine”
3 = “Unsuitable”
4 = “I don’t know”

Colouring means:

Selected Main Trees
Selected Main Shrubs
Selected Main Climbers
Secondary (Less individuals)

Main Area – Tree (9):

Scientific name	Common name	1	2	3	4	Further remarks	Known recommended Varieties
Cydonia oblonga	Quince	IIIIIII	IIIII			- easy growing - “very good, drawback is that you have to cook it” - nice shade plant - “probably really likes pear/apple” - “Maybe in smaller amounts, very new for most costumers”	
Ficus carica	Fig	IIII				- warm place, protected from frost (when young)	- Brown turkey (as main crop?) / cold hardiest variety
Malus pumila	Apple	IIIIIIII	I		I	- cider? (special varieties) - plenty of possibilities - “spread the varieties” - “apple juice, apple cake, apple trees!”	- pectine rich varieties - check with old heirloom variety / orchards and associations - please no Elstar - “Sunset” (Robert Hart) + crab apples aswell (M. baccata)? - something fancy, special - red fleshed varieties?
Morus spp.	Mulberry	IIIIIIII	II	I		- young leaves edible - morus nigra is young less hardy (but has bigger fruiting var.) - morus alba is good for dried fruits and leaves (fast growth) - possible to coppice - “Probably nice under nut tree” - Nigra is more difficult to store	- hybrids like Capsrum, Ivory

Mespilus germanica	Medlar	IIIIIIII	IIII	I		- very easy tree/shub - “needs market development” - “nice winter crop” - “maybe nice to make processed food” - jam - “was a long term cultivated fruit, let’s bringt it back!” - “Maybe difficult to sell in large amounts”	- Bredase reus - Westerveld - varieties have bigger fruits, the wild medlar also has a great taste - Canadian?
Prunus avium	Sweet cherry	IIII	III	II		- “difficult pitching” - likes a lot of water, but no wet feet - “we can share with birds”	- “also the morel is very nice” - “saw a variety with dark red leaves hiding the fruits from birds”
Prunus cerasifera	Cherry plum	IIIII	IIIII	I	I	- good for hedging - “very good, excellent in our climate” - small prunes, tree is bigger than p. domestica - “lower layer, shade tolerant” - “Fruiting early”	
Prunus domestica	European plum	IIIIIII	II		I	- “very good, excellent in our climate” - “choose a number of varieties for fresh use and processing + ripening early/late” - “tasty, good value, marketable”	- “Mirabelle” - “Czar” (early, big yields, black) - “Marjorie’s seedling” (very late ripening, until december if no frosts, self-fertile) - “Opal”, swedish variety, early, sweet - “Purple Pershore”, very nice, fleshy and firm
Pyrus communis	Pear	IIIIII	IIIII			- “don’t forget shoot prevention” - strong root stock - “nice canopy tree with cherries” - “Nashi, please”	- Pyrus pyrifolia = Nashi - Brederode, Conference - Doyenne du Comice (- “Seckel” / Sugar pear) (- “Winter Nelis” / very late ripening)

Main crops – Shrubs (15):

Scientific name	Common name	1	2	3	4	Further remarks	Known recommended Varieties
Amelanchier spp.	Juneberry	IIIIII	III	I	I	- grows easy - shade tolerant - “great taste” - “I like it” - “I don’t think, it’s marketable”	- Prince Charks - Ballerina
Aronia arbutifolia	Chokeberry	II	II	I	II	- juice / marmelade - “promissing, try it”	- “no specific varieties needed” - “try the varieties”

		I I I				- “raw not great” - dried as superfood - “seems suitable”	
Chaenomeles spp.	Flowering Quinces	I I I	I	I		- grows quite easy, lots of fruits	- C. cathayensis
Corylus avellana	Hazelnut	I I I I I I I				- “sure bet!” - great product, many uses - “defenitely” - paste, nut, flour, biomass - “try make pure hazel butter, it is insanely good!” - “a must have”	- “never ever use seedling” - “lots of varieties available” - “there is higher tree varieties too”
Elaeagnus spp.	Oleaster, Autumn olive	I I I I I I I		I		- “umbellata is the good one” - “great crop” - “beware grazing by deer (rabbits, hare?)” - “more for nitrogen, than for fruits / intercrop”	- umbellata → amber, red cascade, sweet ‘n’ tart - “both decidous and evergreen varieties existing” - ebengeii is completely shade tolerant
Lonicera caerulea	Honeyberry	I I I I	I I I			- grows well and easy - very sun demanding... - “Cool, that it fruits early”	- Blue velvet - Atut
Prunus tomentosa	Nanking cherry	I I I I	I			- easy picking - bears a lot of fruits	
Ribes nigrum	Black currant	I I I I	I I			- very hardy plant - “Cannot be missed!” - “I love these!”	- Titan
Ribes rubrum	Red currant	I I I I I I I	I I I			- “good” - traditionally grown with plums	- Jonkheer van tets - incude white berries as well - (Ben Sarek: very big and sweet berries) - (Consort: resistant to white pine blister rust) - Jostaberry (miy with gooseberry) of dutch origin (*Ribes nidigrolaria*)
Ribes uva-crispa	Gooseberry	I I I I I I I	I I I I			- shade tolerant - “good cash-crop” - stays low - both colors - traditionally grown in orchards - “I love these”	- Invicta - Whinhan’s industry (very shade tolerant)
Rosa rugosa	Romans Rose	I I	I I	I	I	- Thick skin - needs sun	

		II	I				
Rubus fruticosus	Blackberry	IIIIIII	I	I		- "not the native one, spreading too much" - "important for mycorrhizae" - "thornless please!" - "organized on a fence" - "there exists less invasive varieties"	- Dormans red? - ask Taco Blom what he has
Rubus idaeus	Raspberry	IIIIII				- "important for mycorrhizae" - "include early and autumn, red and white varieties" - "favorite berry!" - "on a fence or wild?" - "needs trellis"	- several - Autumn bliss (very late!) - Glen clover (Robert Hart)
Rubus Phoenicolasius	Japanese Wineberry	II				- same treatment as blackberry/raspberry	
Sambucus nigra	Black Elder	IIIIII	IIIII			- as a hedge and in between other trees - "very nice, especially because they are quite common on Bleijendijk" - syrup and juice	- black beauty - korsor - Sambucus canadensis (American Elderberry)

Main crops – climbers (4):

Scientific name	Common name	1	2	3	4	Further remarks	Known recommended Varieties
Actinidia arguta	Hardy Kiwi	IIIIII	I	I		- easy grown - "try it!" - " think it's nice, also type of 'trend' right now in NL" - "grow it on coppiced lime-trees"	
Akebia quinata/trifoliata	Chocolate Vine	III				- on willow?	
Humulus lupulus	Hop	IIII				- produces better in sun - "sell to home beermakers also sell plant material"	- "Use good bitter varieties and visit the hop grower in Wijbosch (Schijndel)"
Vitis vinifera	Grape	IIIIIIII	I			- good, easy grown - with Tilia - "I am not so sure"	- Lakemount - Bianca - use good varieties, german varieties - Brand vine? (cold hardy) - There is a Demeter farmer growing table grape, old Dutch varieties

Due to the amount of information, only the evaluation of the main crop area is given.

Appendix 2 – Analysing of the field-surrounding vegetational cover

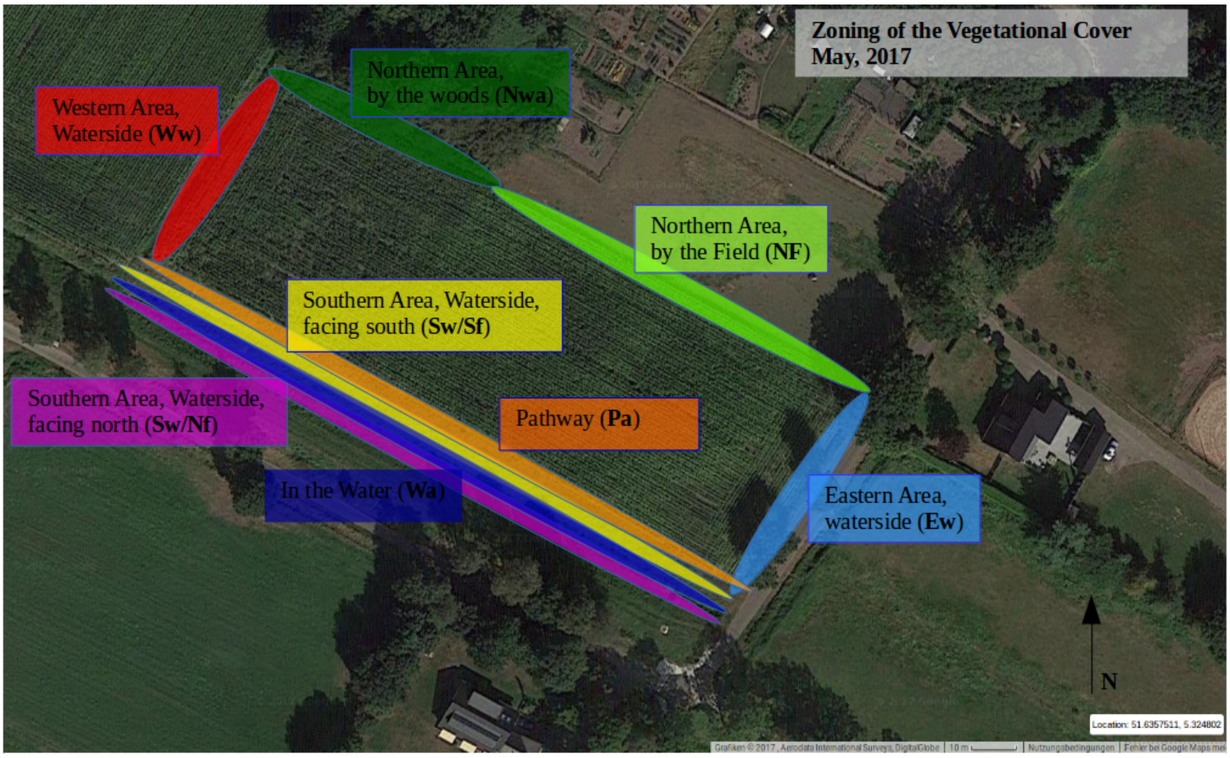

Illustration 16: Zoning of the Vegetational Survey, May 2017 - DFB. (Source: Google Maps. Modified with LibreOffice Calc.)

The illustration 20 shows the zoning of the vegetational research that has been conducted in May 2017. Because of the different growing conditions the respected species associations differ in the regarded zones. In the table below [table 14] the findings of the occurring species are listed. This database can be used as a basis for observing changes of the vegetational cover in the coming years. The species were identified with the help of the Schmeil-Fitschen book “Die Flora Deutschlands und angrenzender Länder” (Quelle&Meyer, 96. Auflage) as well as a basic knowledge on species identification.

The table includes the different Ellenberg values for a vegetational analysis of soil conditions. The analysis of the Ellenberg values is presented below, including the significance of the different values [see table 15]. Due to the high amount of information, not the entire list of species is presented. For comprehension, an extract of four zones is given.

The english translation of the Ellenberg values is derived from the “Ecological Factors controlling biodiversity in the British countryside (ECOFACT)” by Mark Hill.

Month	Zones	Identified Species	Occurence	Englisch Name	Deutscher Name	L	T	K	F	R	N	S	LF	LF_B	Not identified surely
MAY	Nf	Achillea millefolium	xx	Common Yarrow	Schafgarbe	8	x	x	4	x	5	1	H,C	W	
	Nf	Arrhenaterum elatius	x	False Oat Grass	Glatthafer	8	5	3	x	7	7	0	G	S	
	Nf	Cerastium holosteoides	xxx(x)	Mouse-Ear Chickweed	Gewöhnliches Hornkraut	6	x	x	5	x	5	1	C,H	W	
	Nf	Claytonia perfoliata	xx	Indian Lettuce	Gewöhnliches Tellerkraut	6	6	4	5	7	7	0	T	S	
	Nf	Convolvulus arvensis	xx	Field Bindweed	Ackerwinde	7	6	x	4	7	x	0	Gvp	S	
	Nf	Crepis cappilaris	xx	Smooth hawksbeard	Pippau	7	6	2	5	6	4	0	T,H	S	
	Nf	Festuca pratensis	x	Medow Fescue	Wiesenschwingel	8	x	3	6	x	6	0	H	S	
	Nf	Geraniaceae	xx	Cranesbills	"Storchschnäbel"										*
	Nf	Holcus lanatus	x(x)	Meadow Soft Grass	Wolliges Honiggras	7	6	3	6	x	5	1	H	W	
	Nf	Myosotis arvensis	xxx	Fiel-Foregt-Me-Not	Vergissmeinnicht	6	6	5	5	x	6	0	H	W	
	Nf	Papaver rhoeas	xxx	Common Poppy	Klatschmohn	6	6	3	5	7	6	9	T	W	
	Nf	Poa trivialis	xxxx	Rough Meadow-Grass	Gewöhnliches Rispengras	6	x	3	7	x	7	1	H,C	W	
	Nf	Ranunculus repens	x	Creeping Buttercup	Kriechender Hahnenfuß	6	x	x	7~	x	7	1	H	S	
	Nf	Rumex acetosa	x	Common Sorrel	Sauerampfer	8	x	x	x	x	6	Ob	H	W	
	Nf	Rumex obtusifolius	x	Bitter Dock	Stumpfblättriger Ampfer	7	5	3	6	x	9	0	H	W	
	Nf	Taraxacum officinale agg.	xx	Common Dandelion	Gewöhnlicher Löwenzahn	7	x	x	5	x	8	1	H	W	
	Nf	Trifolium repens	xx(x)	White Clover	Weiß-Klee	8	x	x	5	6	6	1	C,H	W	
	Nf	Urtica dioica	xx	Common Nettle	Große Brennessel	x	x	x	6	7	9	0	H	S	
	Nf		x		"Kamille"?										*
	Nwa	Acer pseudoplatanus	x	Sycamore maple	Bergahorn	[4]	x	4	6	x	7	0	P	S	
	Nwa	Aesculus hippocastanum	x	Horse-Chestnut	Gewöhnliche Rosskastanie										
	Nwa	Betula pendula	xxx	Birch	Birke	[7]	x	x	x	x	x	0	P	S	
	Nwa	Corylus avellana	xxx	Common Hazel	Haselnuss	6	5	3	x	x	5	0	n	S	
	Nwa	Galium aparine	x	Cleavers	Kletten-Labkraut	7	6	3	x	6	8	0	Tli	V	
	Nwa	Glechoma hederaceae	xx	Ground-Ivy	Gundermann	6	6	3	6	x	7	0	G,H	W	
	Nwa	Holcus lanatus	xxxx	Meadow Soft Grass	Wolliges Honiggras	7	6	3	6	x	5	1	H	W	
	Nwa	Lamium purpureum	xx	Red Dead-Nettle	Purpurrote Taubnessel	7	5	3	5	7	7	0	T,H	W	
	Nwa	Prunus serotina	xx(x)	Black cherry	Spätblühende Traubenkirsche	[6]	6	x	5	x	?	0	N,P	S	
	Nwa	Quercus robur	xxx	Penduncculate oak	Stieleiche	[7]	6	6	x	x	x	0	P	S	
	Nwa	Rubus idaeus	xxx(x)	Red Raspberry	Himbeere	7	x	x	x	x	6	0	n	S	
	Nwa	Salix caprea	xx	Goat Willow	Salweide?	7	x	3	6	7	7	0	N,P	S	
	Nwa	Stellaria media	xx(x)	Chick Weed	Vogelmiere	6	x	x	x	7	8	0	T	W	
	Nwa	Urtica dioica	x	Common Nettle	Große Brennessel	x	x	x	6	7	9	0	H	S	
	Ew	"Vicia"	xx(x)	Vetch	"Wicke"										*
	Ew	/	xxx	Bryophyta	"Sphagnum Moos"										*
	Ew	Cerastium holosteoides	xx	Mouse-Ear Chickweed	Gewöhnliches Hornkraut	6	x	x	5	x	5	1	C,H	W	
	Ew	Equisetum arvense	xxx	Common Horsetail	Ackerschachtelhalm	6	x	x	x~	x	3	0	G	S	
	Ew	Galium aparine	x	Cleavers	Kletten-Labkraut	7	6	3	x	6	8	0	Tli	V	
	Ew	Lamium album	x	White Nettle	Weiße Taubnessel	7	x	3	5	x	9	0	H	S	
	Ew	Poa trivialis	xx	Rough Meadow-Grass	Gewöhnliches Rispengras	6	x	3	7~	x	7	1	H,C	W	
	Ew	Prunus serotina	xx	Black cherry	Spätblühende Traubenkirsche?	[6]	6	x	5	x	?	0	N,P	S	
	Ew	Quercus robur	xxx	Penduncculate oak	Stieleiche	[7]	6	6	x	x	x	0	P	S	
	Ew	Ranunculus repens	x	Creeping Buttercup	Kriechender Hahnenfuß	6	x	x	7~	x	7	1	H	S	
	Ew	Rubus idaeus	x	Red Raspberry	Himbeere	7	x	x	x	x	6	0	n	S	
	Ew	Rumex longifolius	xx	Dooryard Dock	Langblättriger Ampfer	8	6	?	5	?	8	0	H	W	
	Ew	Stellaria media	xxx	Chick Weed	Vogelmiere	6	x	x	x	7	8	0	T	W	
	Ew	Urtica dioica	x	Common Nettle	Große Brennessel	x	x	x	6	7	9	0	H	S	
	Ew	Viola tricolor arvensis	x	Field Pansy	Acker-Stiefmütterchen	6	5	x	x	x	x	0	T	W	
	Ew		x		"Kamille"?										*
	Pa	Capsella bursa-pastoris	x	Sheperd's Purse	Gewöhnliches Hirtentäschel	7	x	x	5	x	6	Ob	T	W	
	Pa	Cerastium holosteoides	xxxx	Mouse-Ear Chickweed	Gewöhnliches Hornkraut	6	x	x	5	x	5	1	C,H	W	
	Pa	Cirsium arvense	xx	Creeping Thistle	Acker-Kratzdiestel	8	5	x	x	x	7	1	G	S	
	Pa	Claytonia perfoliata	xxx	Indian Lettuce	Gewöhnliches Tellerkraut	6	6	4	5	7	7	0	T	S	
	Pa	Convolvulus arvensis	xxx	Field Bindweed	Ackerwinde	7	6	x	4	7	x	0	Gvp	S	
	Pa	Crepis cappilaris	x	Smooth hawksbeard	"Pippau"	7	6	2	5	6	4	0	T,H	S	
	Pa	Erucastrum nasturtiifolium	xxx	Dogmustard	"Stumpfkantige Hundsrauke"	8	6	2	6=	8	3	0	H,T	W	
	Pa	Holcus lanatus	xxx	Meadow Soft Grass	Wolliges Honiggras	7	6	3	6	x	5	1	H	W	
	Pa	Taraxacum officinale	xx	Common Dandelion	Gewöhnlicher Löwenzahn	7	x	x	5	x	8	1	H	W	
	Pa	Trifolium repens	xx	White Clover	Weiß-Klee	8	x	x	5	6	6	1	C,H	W	
	Pa		xx		"Kamille"?										*

Table 14: Vegetational Cover DFB - Survey May, 2017 with Ellenberg Values. (Made with LibreOffice Calc.)

Northern Area, by the field (NF)

	L	T	K	F	R	N	S	LF	LF_B
Claytonia perfoliata	6	6	4	5	7	7	0	T	S
Convolvulus arvensis	7	6	x	4	7	x	0	Gvp	S
Holcus lanatus	7	6	3	6	x	5	1	H	W
Myosotis arvensis	6	6	5	5	x	6	0	H	W
Papaver rhoeas	6	6	3	5	7	6	9	T	W
Poa trivialis	6	x	3	7	x	7	1	H,C	W
Taraxacum officinale agg.	7	x	x	5	x	8	1	H	W
Trifolium repens	8	x	x	5	6	6	1	C,H	W
Urtica dioica	x	x	x	6	7	9	0	H	S

Mean Values	Significance
Light: 6,6	Plant generally in well lit places, but also occurring in partial shade
Temperature: 6	Semi warm to warm (planar to collin)
Continent: 5,5	Intermediate to sub-coninental
Humidity: 5,6	Between 5 and 7 (5: see below, 7: Dampness indicator, mainly on constantly moist or damb, but not on wet soils)
Reaction: 6,8	Indicator of weakly acid to weakly basic conditions, never found on very acid soils
Nitrogen: 7	Plant often found in richly fertile places
Salt: 1,3	Slightly salt-tolerant species
Livingform:	2 Therophyta, 6 Hemikryptophyta, 1 Geophyt
Leaves:	2/3 evergreen, 1/3 deciduous

(Occurence: xx, xxx, xxx)

Northern Area, by the woods (Nwa)

	L	T	K	F	R	N	S	LF	LF_B
Betula pendula	[7]	x	x	x	x	x	0	P	S
Corylus avellana	6	5	3	x	x	5	0	n	S
Glechoma hederaceae	6	6	3	6	x	7	0	G,H	W
Holcus lanatus	7	6	3	6	x	5	1	H	W
Lamium purpureum	7	5	3	5	7	7	0	T,H	W
Prunus serotina	6	6	x	5	x	?	0	N,P	S
Rubus idaeus	7	x	x	x	x	6	0	n	S
Stellaria media	6	x	x	x	7	8	0	T	W

Mean Values	Significance
Light: 6,5	Plant generally in well lit places, but also occurring in partial shade
Temperature: 5,6	Semi warm to warm (planar to collin)
Continent: 3	Marine to sub marine (big parts of middle Europe)
Humidity: 5,5	Between 5 and 7
Reaction: 7	Indicator of weakly acid to weakly basic conditions, never found on very acid soils
Nitrogen: 6,3	Between 5 and 7 (5: Indicator of sites of intermediate fertility, 7: see above)
Salt: 0,1	Absent from saline sites
Livingform:	2 Therophyta, 3 Hemikryptophyta, 3 Nanophanaerophyta, 2 Phanaerophyta, 1 Geophyt
Leaves:	50% deciduous, 50% evergreen

(Occurence: xx, xxx, xxx)

Eastern Area, waterside (Ew)

	L	T	K	F	R	N	S	LF	LF_B
Equisetum arvense	6	x	x	x~	x	3	0	G	S
Poa trivialis	6	x	3	7~	x	7	1	H,C	W
Prunus serotina	6	6	x	5	x	?	0	N,P	S
Rumex longifolius	8	6	?	5	?	8	0	H	W
Stellaria media	6	x	x	x	7	8	0	T	W

Mean Values	Significance
Light: 6,4	Between 5 and 7 (5: semi-shade)
Temperature: 6	Semi warm to warm (planar to collin)
Continent: 3	Marine to sub marine (big parts of middle Europe)
Humidity: 5,6	Between 5 and 7
Reaction: 7	Indicator of weakly acid to weakly basic conditions, never found on very acid soils
Nitrogen: 6,3	Between 5 and 7
Salt: 0,2	Absent from saline sites
Livingform:	1 Therophyt, 2 Hemikryptophyta, 1 Nanophanaerophyt, 1 Phanaerophyt, 1 Geophyt
Leaves:	2/5 deciduous, 3/5 evergreen

(Occurence: xx, xxx, xxx)

Pathway (Pa)

	L	T	K	F	R	N	S	LF	LF_B
Cirsium arvense	8	5	x	x	x	7	1	G	S
Claytonia perfoliata	6	6	4	5	7	7	0	T	S
Convolvulus arvensis	7	6	x	4	7	x	0	Gvp	S
Erucastrum nasturtiifolium	8	6	2	6=	8	3	0	H,T	W
Holcus lanatus	7	6	3	6	x	5	1	H	W
Taraxacum officinale	7	x	x	5	x	8	1	H	W
Trifolium repens	8	x	x	5	6	6	1	C,H	W

Mean Values	Significance
Light: 7,2	Plant generally in well lit places, but also occurring in partial shade
Temperature: 5,8	Semi warm to warm (planar to collin)
Continent: 3	Marine to sub marine (big parts of middle Europe)
Humidity: 5,1	Moist-indicator, mainly on fresh soils of average dampness
Reaction: 7	Indicator of weakly acid to weakly basic conditions, never found on very acid soils
Nitrogen: 6	Between 5 and 7
Salt: 0,5	Slightly salt-tolerant species
Livingform:	2 Therophyta, 4 Hemikryptophyta, 2 Geophyta, 1 parasite
Leaves:	3/7 deciduous, 4/7 evergreen

(Occurence: xx, xxx, xxx)

Table 15: Analysis of Ellenberg Values May 2017. (Made with LibreOffice Calc.)

Appendix 3 – Watertables

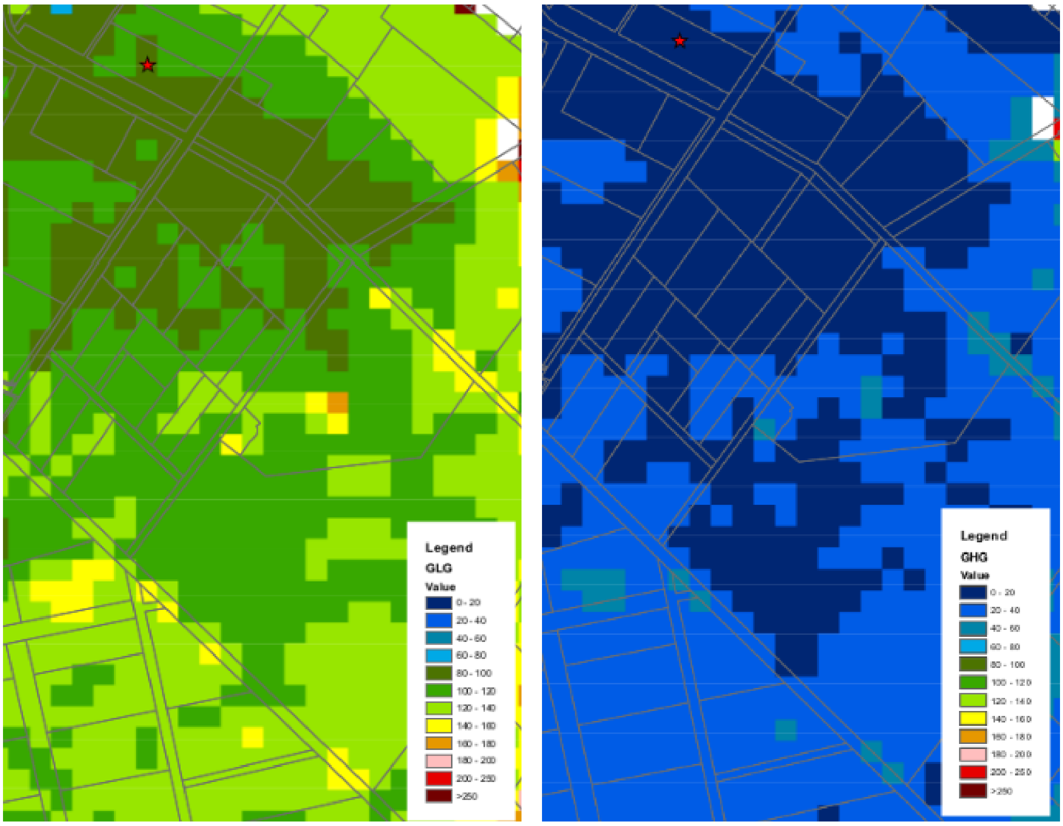

Table 16: Water tables - highest and lowest levels. (Source: Provided by Waterschap.)

The two tables presented were provided by the water office North-Brabant. The area of interest is marked with a red star. The tables illustrate the mean of the 3 highest and lowest water tables within the last 8 years. The green figure shows the lowest water tables. For the regarded land, water table values between 80 to 140 cm below ground level are given. The blue figure shows the deepest highest water tables with values between 0 to 20 cm below ground.

Appendix 4 – Useful Species information

On the following page the gathered information in the individual tree species in the main area of Den Food Bosch is presented as an example. The given information on pruned height and width, pollination, shade tolerance and growth rate are important for the exact placement of the individual plants with the food forest design.

Main Area (Trees, Shrubs, Climbers and Species for Biomass-accumulation)											
Type	**Common name**	**Scientific name**	**Hard. Zone**	**Pot. Height**	**Pot. Width**	**Pruned Height**	**Pruned Width**	**Pollinating**	**Shade Tolerance**	**Growth rate**	**Main Food forest services**
Trees											
1st Main Crops	Common Fig	*Ficus carica*	6	3-6 m	2-4 m	3-4 m	2-3 m	Self-fertile	Full sunlight	medium	crop
	Apple	*Malus domestica*	3	4-7 m	4-7 m	4-5 m	4-5 m	Cross-pollination	Sunlight, semi-shade	medium	crop
	Medlar	*Mespilus germanica*	6	4-6 m	3-5 m	4-5 m	3-4 m	Self-fertile	Semi-shade	medium	crop, bee plant
	Cherry plum	*Prunus cerasifera*	4	3.5-9 m	3.5-9 m	3-5 m	3-4 m	Cross-pollination	Semi-shade	medium	crop
	Pear	*Pyrus communis*	4	4-20 m	4-8 m	4-10 m	4-6 m	Cross-pollination	Semi-shade/sunlight	fast	crop, bee plant
	European plum	*Prunus domestica*	5	12 m	10 m	6-10 m	4-5 m	Cross-pollination	Semi-shade	medium	crop
2nd Main Crops	Quince	*Cydonia oblonga*	4	3-5 m	3-5 m	3-4 m	3-4 m	Self-fertile	Semi shade	medium	crop, bee plant
	Mulberry	*Morus (nigra, alba)*	5	10 m	15 m	4-6 m	4-5 m	Self-fertile	Semi-shade	fast	crop
	Sweet cherry	*Prunus avium*	3	18 m	7 m	3-6 m (dwarf)	3-4 (dwarf)	Cross-pollination	shady/sunlight	fast	crop, bee plant
Shrubs											
1st Main Crops	Juneberry	*Amelanchier spp.*	4	5-6 m	3-4 m	4-5 m	2-3 m	Self-fertile	Semi-shade	medium	crop
	Cathay Quince	*Chaenomeles cathayensis*	5	1.5-3 m	1.5-5 m	1.5 m	1.5 m	Cross-pollination	Full/Semi-shade	medium	crop, bee plant
	Hazelnut	*Corylus avellana*	4 to 5	5-6 m	3-6 m	3-4 m	3-4 m	Windp., not self-fertile	Semi-shade	fast	crop
	Autumn olive	*Elaeagnus umbellata*	3	5 m	5 m	3 m	3 m	Cross-pollination	sunlight/semi-shade	medium	crop, n-fixing, bee plant
	Honeyberry	*Lonicera caerulea*	2	2 m	2 m	1.5 m	1.5 m	Cross-pollination	Full sunlight	medium	crop
	Nanking cherry	*Prunus tomentosa*	2	1.5 m	2 m	1.5 m	1.5 m	Cross-pollination	Semi-shade	medium	crop, bee plant
	Black currant	*Ribes nigrum*	5	2 m	1-1.5 m	1.5 m	1 m	Self-fertile	Semi-shade	medium	crop, bee plant
	Red currant	*Ribes rubrum*	6	1.5-2 m	1.5 m	1.5 m	1 m	Self-fertile	Semi-shade/full shade	meidum	crop, bee plant
	Gooseberry	*Ribes uva-crispa*	5	1-1.5 m	1-1.5 m	-	-	Self-fertile	Semi-shade	medium	crop, bee plant
	Blackberry	*Rubus fruticosus*	6	2-4 m	2-4 m	2 m	1.5-2 m	Self-fertile	Full/semi shade	fast	crop
	Raspberry	*Rubus idaeus*	3	2 m	1.5 m	-	-	Self-fertile	Semi-shade	medium	crop
	Japanese Wineberry	*Rubus Phoenicolasius*	5	1.5-3 m	1-2 m	1.5 m	1.5 m	Cross-pollination	Semi-shade	medium	crop
2nd Main Crops	Chokeberry	*Aronia arbutifolia*	4	3 m	3 m	2m	2m	Self-fertile	Semi-shade	medium	crop, bee plant
	Oleaster	*Elaeagnus x ebbingei*	6	4 m	4 m	3 m	3 m	Cross-pollination	Full shade	medium	crop, n-fixing, bee plant
	Goumi	*Elaeagnus multiflora*	6	2-3 m	2-3 m	2 m	2 m	Cross-pollination	Semi shade	medium	crop, n-fixing, bee plant
	Sea Buckthorn	*Elaeagnus rhamnoides*	3 to 7	3-6 m	2-6 m	3 m	2 m	Windp., not self-fertile	Sunlight	medium	crop, n-fixing, bee plant
	Romans Rose	*Rosa rugosa*	2	1.5-2 m	1.5-2 m	1.5 m	1.5 m	Self-fertile	Semi-shade	medium	crop, bee plant
	Black Elder	*Sambucus nigra*	5	4-6 m	4-6 m	3-4 m	2-3 m	Cross-pollination	Semi-shade	fast	crop
Climbers											
1st Main Crops	Hardy Kiwi	*Actinidia arguta*	2 to 7	15 m	-	4-7 m	-	Cross-pollination	Semi-shade	medium	crop
	Hop	*Humulus lupulus*	5	6 m	-	4-6 m	-	Windp., not self-fertile	Semi-shade	fast	crop
	Grape	*Vitis vinifera*	5	15 m	-	3-7 m	-	Cross-pollination	Semi-shade	fast	crop
2nd Main Crops	Chocolate Vine	*Akebia quinata/trifoliata*	5	12 m	-	4-7 m	-	Cross-pollination	Semi-/Full shade	medium	crop
Biomass Trees	Field maple	*Acer campestre*	4	15 m	8 m	4-5 m	2-3 m	Cross-pollination	Semi-shade	fast	biomass, trellie
	Common alder	*Alnus glutinosa*	3 to 6	20-25 m	10-15 m	4-10 m	3-4 m	Windpollination	Semi-shade	fast	N-fixing, biomass
	Birch	*Betula pendula*	3 to 5	20 m	10 m	4-10 m	3-4 m	Windpollination	Full sunlight	fast	biomass
	Empress Tree	*Paulownia tomentosa*	6	15 m	10 m	4-10 m	3-4 m	Self-fertile	Sunlight	fast	biomass
	Poplar	*Populus spp.*	3	30 m	20 m	4-10 m	3-4 m	Windp., not self-fertile	Full sunlight	fast	biomass
	Willow	*Salix spp.*	4	25 m	10 m	2-4 m	2-4 m	Cross-pollination	Full sunlight	fast	biomass
	Lime Tree	*Tilia spp.*	2 to 5	30 m	12 m	2-4 m	2-4 m	Cross-pollination	Semi-shade	medium	biomass, bee plant, edible leaves
	Elm Tree	*Ulmus spp.*	5	30 m	25 m	4-10 m	3-4 m	Windpollination	Semi-shade	fast	biomass

Table 17: Main Area DFB - Useful Species Information. (Made With LibreOffice Calc.)

Declaration of independent work on Bachelor Thesis

With this statement, I declare that this Bachelor thesis was prepared by me, only using the given references in this paper. The connections with companies, governmental organizations and similar was only made with the agreement of my Bachelor thesis adviser.

Janine Raabe

s' Hertogenbosch, 10th of August, 2017