Ecological Principles in Natural Temperate Forest Ecosystems Relevant for Productive Food Forests

Lessons Learned from

Food Forest Ketelbroek, the Netherlands

Anastasia Limareva

For my grandparents

Dear dedushka Vanja, babushka Alla and prababushka Vera, thank you for putting seeds of love and curiosity of Nature in my heart! I will always love you.

For Luca

Dear one, it was lovely to see you waiting for strawberries and raspberries in our garden, checking every other minute to see if they were ripe yet. You show papa and mama that we need to plant more of this delicious food.

Thesis

submitted in fulfilment of the requirements of the degree of

Bachelor of Environmental Sciences and Technology

by

Anastasia Limareva

Supervision Van Hall Larenstein University of Applied Sciences

Department Environmental Science and Technology

Mr. A. Baken

Mr. L. Bentvelzen

Mrs. A. Valent

Supervision Foodforestry Netherlands

Mr. W. van Eck

Mr. X. San Giorgi

Leeuwarden, The Netherlands

December 2014

First published as an e-book by Lucavera Publications on http://lucavera.wordpress.com in 2014.The author make no representation, express or implied with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for any errors or omissions that may be made.

About the author

My name is Anastasia Limareva. I was born on the 29 of April 1986 in the former Soviet Union, now Ukraine, in the small city of Dubno. It was on the third day after the Chernobyl disaster that I came into this world. My mother has told me stories about there being such strong white fog that day that she was scared and closed all the windows in the house. Afterwards, from her ecologist friends she heard that there had been an accident at the nuclear power plant just 400 km from our house.

My grandparents did not harvest any fruits or vegetables from their abundant organic garden. Through the summer and on beyond the next harvest we lived on home made canned food (my grandmother has the machinery to do this) and conserves bought from the shop. All the crops were huge in the summer of 1986: sunflowers, tomatoes, corn, greens, apples and mushrooms. That this was a negative consequence of radiation would only be discovered later.

I guess, care for this Earth and awareness of great consequences for the environment have been deeply rooted in me since my childhood as result of seeing lots of human science mistakes. Even now, finishing my study as an Environmental Scientist, I see that we lack holistic management in most areas considering environmental issues and problems. Propaganda for monoculture hailed it as a scientifically efficient and economically profitable form of agriculture. Scientists were pushing “proofs” that this is the only way to go if we want to feed the planet. Would they have advised the same if they would knew the ecological price that we are faced with today?

Permaculture and food forestry started to look beyond the economy, searching for holistic land management techniques all over the world. The holism of these movements brings us continually to a higher level of understanding of Nature and our interactions with her. For me, and for growing number of people, permaculture and food forestry are the best ways at the present moment to solve world hunger and many environmental problems.

The wise words of Mahatma Gandhi remind us that *“Earth provides enough to satisfy every man's needs, but not every man's greed”*.

You are welcome to follow my work at or contact me directly at

I wish you inspiring reading.

Anastasia Limareva

Personal

This work began and was completed during the period of rising conflict in my motherland Ukraine.

This work is finished now, but the conflict in Ukraine remains unsolved. The conflicts that started in Kiev later resulted in a power-shift towards an ultra-nationalistic government, which began to suppress Russian-speaking people in Donbass and in the Ukraine as a whole. The Dutch media continually failed to spread objective information on the situation in Ukraine, following manipulative advice of the EU, USA and NATO. Neither side is blameless in this, but it is hard for me to see these lies put about in my motherland and also here in the West

How and when the war in Donbass will end, no one knows. In the meantime, from the outbreak of air attacks and heavy bombardment carried out by the Ukrainian army on the Donbass region, hundreds of people there, adults, elderly and children, lost their lives or became invalids. Moreover, more than seven hundred thousand refuges from East Ukraine fled for their lives to the Russian Federation. The ones that stayed in Donbass are remain in constant danger, fighting for their freedom. International politics is blind to all of this.

My wish is to see peace and happiness in Donbass again, to see people come back home and restore in a sustainable way everything that has been destroyed without exploiting Nature. I wish that people after all the horrors of the war will understand the true meaning of life; to thrive we all need a kind and caring interaction with fellow humans and Nature. My wish is to return soon to Donbass to plant food forests and help to bring prosperity to both Nature and people there.

Preface

As far as possible, men are to be taught to become wise not only by books, but by the Heavens, the Earth, oaks and beeches

Comenius (1632)

A forest is like a beautiful poem about true Life. A forest world is one of the most spectacular performance scenes of Mother Nature.

My partner Alex told me a story about one wild, ancient forest in his home country Austria. The exact location of this forest is kept carefully hidden by scientists, because of their fear of potential disturbance by human activities. In this forest, the old fallen trees are lying everywhere, there are many albino snakes, and one hears amazing sounds of birds and insects. Such ancient forest where “human feet did not step” is incomparable to what we know as modern forest created in the industrialization period of the 19th century. Planting trees in rows, mainly in monoculture, provides fewer special eco-niches for biodiversity. Big mammals such as wolf and bear are no longer part of forest ecosystems in most parts of the Europe. Because of our needs and fears, we shape Nature to our perception of right and wrong. Unfortunately, our “creations” are not as sustainable as natural ones.

Natural wild forests are full of mystery. Animals, insects, plants and fungi find their way within. They know how and where to get food. Nature will always provide sufficient food and accommodation for them and for future generations, even when some creatures may die. Some of us see life on Earth as a never-ending battle for food and resources, but I see also balance, health and felicity in Nature, when it is not abused by the human race. Everything is interconnected and interrelated. Falling leaves from the tree immediately enter the next stage of life, providing the essential nutrients for tree growth. Nothing is lost and nothing is wasted. Life ends with death, which immediately feeds life again.

During reviewing of a draft version of this research, I received a comment of one of my teachers where he expressed some criticism on the fact that in this report I write Nature with capital letter instead of a small letter. Consciously or unconsciously in his comment he expressed the thinking of the most scientists of our time, where the term “nature” is defined as *the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations* (Oxforddictionaries, 2014)

What is the difference between “nature” and “Nature”, you would ask? In my opinion, mainstream economics and science use nature (written with small “n”) because they see it as a resources black box where different features and products are used simultaneously, leaving other, let’s say “no-money generating” aspects without great attention. Low-or-no-profit yield (in the eyes of western project developers) tropical rainforests makes way for agriculture that promises high profit. Natural oil and gas resources are extracted all over the world without necessary environmental considerations. High-yield monoculture, with incorporation of GMO-crops, intensive animal farming is considered the answer to the world hunger problem and is presented as the only practical solution by, among others, Bill Gates. But are we going the right way? The words of Herbert Girardet fit best for the answer: "Nature is our origin and our destination, even if technocrats try and persuade us *otherwise"*.

Caring for human life, we forget that Nature has an inherent value separated from the need of humans. We put names of humans, continents, countries, companies, all with capital letters to show respect. How much more respect deserves Nature, from whom we receive so many gifts and services? In this work, I will write Nature with capital N because even if we do not all realise it now, sooner or later we will do; *Nature can survive without us, but we cannot survive without Nature.*

Ecologist Paul Colinvaux gives us hope: *" There cannot be more individuals in a species population than there are opportunities to practice their niche"*. The greatest challenge for humanity is to find her niche within the natural ecosystem. May we all be successful in this challenge! Let's explore creative, Nature-friendly and sustainable ways that will transform our planet Earth into a beautiful place covered with unpolluted rivers and oceans, a pesticide-and-chemical-free environment, natural and food forests, and permaculture gardens. And may these words become reality in our lifetime and not a far off future.

Acknowledgment

I want to give thanks to my loved one, Alexander Kittenberger, for constant support during my research progress, and to our son Luca for his smiles, giving me a lovely reason to have a break. Dear ones, I cannot wait to find our dream spot surrounded with high mountains with crystal-clear water streams and never-ending forests. Together we will plant thousands trees which have some edible part (not necessarily the fruit) in food forests all over the world. This work leads us a step closer to make our dreams come true.

My deep respect and gratefulness goes also to my supervisor of the main research period, Ariën Baken. Thank you, dear Ariën for support and understanding, looking beyond the box and simply believing in me! With you Ariën, I could spread my wings on Van Hall Larenstein like never before. Thank you for being my friend.

My admiration goes to Wouter van Eck, my project leader at Foodforestry Netherlands. Wouter, you are an extraordinary man, who loves plants very much and knows the true value of Nature. Thank you for being my inspiration. I think you would be a great teacher at the University at faculty of Agriculture, Biology, Ecology, Environmental Science etc. It would be great if students could hear you in one of their first lectures, setting out your vision of food forestry.

Thank you Truus Rigters, in giving me advice on how to frame whole research and having time for help, even when you were not officially my supervisor.

Thank you too, Kevin de Bruin, for providing views from professional conventional gardener.

I am also grateful to my secondary supervisors Leo Bentvelzen and Astrid Valent for giving me space to be able to do research that I wanted to do so much, even if it was not considered usual at Van Hall Larenstein.

Great thanks to the employees of the Mediatheek of Van Hall Larenstein in Leeuwarden, Irma Abelskamp, Gerrie Koopman, Douwe van Randen and again Wouter van Eck, for providing me with great books for this research.

And last but not least, my special thanks go to David Cooper. David, I will always remember your great help with your elegant proofreading of my work. But the most, I am delighted to hear that afterwards you got excited enough about the idea to want to create your own food forest.

English Summary

This research describes the main ecological principles of the natural forests which can potentially influence productivity and the resilience of food forest ecosystems. The study methodology was based on literature research together with interviewing an expert on the subject of food forest in the Netherlands, Wouter van Eck. His experience in designing and planting the productive and successful Foodforest Ketelbroek forms a base for the advice about design and maintenance of food forests in the temperate climate given in this research.

Recent research in dietology has shown that before the dawn of agriculture, in the time of gatherers and hunters, somewhere between 200 and 1000 different species of plants would be eaten by a person in one year (Fern, 1997). New research in dietology indicates that a healthy human diet should contain a wide variety of foods based on sufficient carbohydrates and proteins, but also including different berries, herbs, nuts, seeds, etc. for supply of micronutrients. At the same time, researches of Harvard University showed that only 12 plant species provide approximately 75% of our total food supply, and only 15 mammal and bird species make up more than 90% of global domestic livestock production (Chivian, et al., 2010).

Jacke&Toensmeir (2005) in their book "Edible Forest Garden", Volume 2, give an overview of 626 plant species for possible growth within the food forest ecosystem in a temperate climate, that are considered as edible or having secondary values (fuel, timber, medicinal etc.). With all cultivars included, the plant list would be easily need to be multiplied by a factor of ten! That amount of 6000 plants for your temperate food forest sounds tempting, doesn't it?

Once established, the food forests will require no or little input in order to remain productive, because they are based on the ecological principles of natural forests. More than this, inputs of fertilizers, pesticides and herbicides will become redundant. The space in a food forest is used on multiple layers, so many different edible plants can be grown parallel to the trees. That is why food forests are a good example of one of the solutions to global hunger problems (Shepard, 2013). In food forests, the food production for humans is arranged in a more harmonious way with Nature compared to conventional and even to biological agriculture, which rely on huge monocultures. Instead of battling against Nature, the food forest works in harmony with it.

Food Forestry Pioneers

Robert J. Hart was the Englishman who had already in 1960 planted on his property a 500m² food forest prototype. With his food forest, Robert wanted to demonstrate a lifestyle that could help to provide more food and an improved standard of life for those areas of the world where starvation is growing (Burnett, 1997).

In the Netherlands, it is Wouter van Eck, together with his life companion Pieter Jansen, who both started the first Dutch food forest in 2009. Located near the city of Nijmegen, Groesbeek, on the former agricultural corn fields, the Foodforest Ketelbroek is an example and inspiration for a rising number of food forest initiatives throughout the Netherlands. The development of Foodforest Ketelbroek and many other projects can be followed by visiting the website **www.foodforestry.nl** and the Facebook page **www.facebook.com/FoodforestryNetherlands**

Layers of the Food Forest

It was Robert J.Hart, who observed "seven dimensions" in the natural forests, and used this concept to reshape his existing small orchard into an edible landscape (Burnett, 1997). By doing so, Robert built the framework for modern food forest structure. The seven layers are described as follows:

1. **Canopy layer (climax trees)** consisting of the original mature trees or new-planted walnuts, mulberries, limes etc.
2. **Understory (lower tree layer)** of smaller nut and fruit trees on dwarfing root stocks like apple, cherry, hazels etc.
3. **Shrub layer** of fruit bushes such as currants, raspberries, barberries etc.
4. **Herbaceous layer** of perennial vegetables and herbs
5. **Ground cover layer** of edible plants that spread horizontally
6. **Underground (root layer)** of plants grown for their roots and tubers
7. **Climbers (vertical layer)** of vines and climbers

In addition, John Kitsteiner described the 8th and 9th food forest layers as respectively aquatic and mushroom layers (Kitsteiner, 2013). Also, permaculture garden on the south side of the food forest, to have an annual and perennial vegetable harvest, can be counted as a separate layer, creating in total a 10-layer food forest. It does not mean that every food forest needs to have all layers included, but including them all can lead to the highest yields obtainable from a food forest. The choice of layers is dependent on design considerations and specified limiting factors, such as available surface, soil type, financial means, etc.

General Goals of Food Forestry

As described by Wouter van Eck, the level of initial work and financial investment is high and the level of harvest or profit is low in the initial phase of any food forest system, but as time goes on, the value and the yield rise while the work and investment decrease. If all goes well, the food forest in a temperate climate reaches its productive stage after 3-5 years.

Each person who starts to create a food forest has his/her own characteristic reason to start to plant trees. One of the first scientific research works on the theme of food forests, produced by D. Jacke and E. Toensmeier, summarizes the goals that are considered fundamental to food forest creators around the world (adapted from (Jacke, et al., 2005):

- Abundant diversity of delicious, high-nutritious food and other useful products
- Stable, resilient ecosystem that is largely self-maintained
- Protection and restoration of ecosystem health
- Embody beauty, elegance and spirit of the landscape
- Improving of economical sustainability
- New paradigm of human participation in the ecology of cultural and natural landscapes

Ecological Principles of Natural Forest Ecosystems Relevant for Productive Food Forests

In this work, a selection of the main ecological principles of natural forests, playing an essential role in food forest ecosystems, is presented, as it was conducted from theoretical research on food forestry (Hart, 1996; Whitefield, 2002; Jacke & Toensmeier, 2005; Crawford, 2010) and as it was practically observed during the past 5 years of development at Foodforest Ketelbroek by Wouter van Eck, followed by Xavier San Giorgi.

The main ecological principles of natural forests that are influencing productivity of food forest ecosystem are:

- Climate
- Forest structure
- Sunlight and shade
- Water
- Wind
- Soil
- Nutrient cycles
- Fungi
- Beneficial animal interactions
- Succession
- Native or exotic plants
- Nitrogen fixing plants
- Time for growth. Time for harvest

After recent research into ecological principles, conclusions were made concerning similarities and differences of the natural and food forest ecosystems. The similarities were aspects of climate, water, wind, soil, nutrient cycles, fungi, beneficial animal interactions and time for growth and harvest. What was different was the adjustment of forest structure within the food forest ecosystem where the open canopy lets in more sunlight and creates less shade compared to the natural mature grown forest which will, sooner or later, have a closed canopy. On the other hand, natural succession is speeded up in food forest ecosystems where the building up of fertile soil is stimulated by adding nitrogen fixing plants. Also the choice of plant species for food forests tends to include more “exotic” plants from similar climate regions. For the Netherlands it means that plants native to hardiness zone 6, 7 and 8, such as plants for example from Japan or North America, are suitable for productive growth under the Dutch climate.

Creation of Your Own Food Forest

The accessibility of knowledge needed for the creation of a food forest, is one of the major priorities of this work.

Before the design of a food forest system, the data needs to be obtained about the present situation. Therefore, the "Species Niche Analysis Worksheets" are available for download from **www.edibleforestgardens.com** (Jacke, et al., 2005).

The specific aspects of ecological principles used in the design of a food forest are listed below:

- Precise positions of the sun for the whole year round
- Good design of the canopy layer
- Total surface available for the forest
- Security of the biodiversity
- Providing sufficient space for the plant roots
- Usage of nitrogen fixing plants

Within this work, the selection of 21 species in Appendix I is presented in a seven-layer structure of the food forest, as an example of productive food forest ecosystem within a temperate climate.

Maintenance of the Food Forest

Because it mimics natural forest ecosystem succession, the maintenance level of a food forest is potentially very low. Wouter van Eck (Eck, 2014): *"You are welcome to do maintenance, but you actually do not need to do this. The ecosystem of a food forest comes very close to the idea of "the do-nothing-farming" introduced by Masanobu Fukuoka in 1975. Masanobu described it as: learning from Nature, you can create a system that is self-supporting, self-maintaining, self-balancing and self-nurturing. For the food forest ecosystem, it means: do not hoe, weed, use pesticides and insecticides (even organic), do not irrigate, and do not use manure. You do not need this in a natural forest, so you do not need this in a food forest"*. The food forest "do's" and "don'ts" are set out here again in a table:

Do	**Do not**
Regular observations and understanding the ecosystem	Use artificial and organic fertilization, pesticides, insecticides
Minimal watering Create place for dead wood	Prune, weed or hoe on regular basis Espalier trees and shrubs

Final remarks

The challenge of modern humanity is to find a way of completely sustainable interaction with our environment in meeting our human needs and at same time having respect for the inherent value of other creatures, plants and Nature as whole. Food forestry is one of the paths we must follow to meet this challenge.

”Obviously, few of us are in a position to restore the forests…
But tens of millions of us have gardens, or access to public land, where trees can be planted and new ‘city forests’
can arise…”

Robert A.de J. Hart (1991)

Dutch Summary

Dit onderzoek beschrijft de belangrijkste ecologische principes in natuurlijke bossen, welke de productiviteit en weerstand van voedselbos-ecosystemen zouden kunnen beïnvloeden. De onderzoek methodologie betreft literatuuronderzoek in combinatie met opname van interviews met een expert op gebied van voedselbossen in Nederland, Wouter van Eck. Ervaringen op door hem aangelegde productieve en succesvolle Voedselbos Ketelbroek vormen een base voor in dit onderzoek gegeven adviezen over het ontwerp en onderhoud van een voedsel bossen in gematigd klimaat.

Recent onderzoek in dieëtologie heeft laten zien, dat voor de opkomst van moderne landbouw, in de tijd van verzamelaars en jagers, mensen in een jaar ongeveer tussen 200 en 1000 verschillende soorten planten aten (Fern, 1997). Nieuw onderzoek in dieëtologie, wijst uit dat een gezond menselijk dieet zou moeten bestaan uit een brede variëteit van voedsel, gebaseerd op voldoende koolhydraten en eiwitten, maar ook verschillende soorten bessen, kruiden, noten, zaden etc. voor de voorziening van micronutriënten. Onderzoekers van Universiteit Harvard, lieten zien dat slechts 12 plantensoorten voorzien in ongeveer 75% van onze totale plantaardige voedselvoorziening en dat slechts 15 zoogdieren en vogelsoorten meer dan 90% van wereldwijde dierlijke productie voor hun rekening nemen (Chivian, et al., 2010).

Jacke&Toensmeir (2005) geven in hun boek “Edible Forest Garden”, Volume 2, een overzicht van 626 plantensoorten die beschikbaar zijn voor groei in gematigd klimaat zone en die eetbaar of verondersteld eetbar zijn en of verbonden zijn aan secundaire waarden (brandstof, bouwstof, medicinaal, etc.). Als rekening wordt gehouden met daarbij horende cultivars, dan kan deze lijst gemakkelijk met een factor 10 worden vermenigvuldigd.

Eénmaal aangelegde voedselbossen behoeven geen of nauwelijks input voor hun onderhoud en blijven toch productief. Dit doordat ze gebaseerd zijn op ecologische principes van natuurlijk bos. Meer dan dat, het toedienen door de mens van (kunst)meststoffen, pesticiden of herbiciden wordt overbodig. Omdat ruimte in voedselbossen op verschillende niveaus wordt gebruikt, kunnen vele verschillende eetbare planten parallel worden geteeld. Daarom, zijn de voedselbossen een goed voorbeeld van één van de oplossingen van het hongerprobleem op de wereld (Shepard, 2013).

In voedselbossen is de voedselproductie voor mensen, op een harmonieuze manier verbonden met de Natuur. Harmonieuzer verbonden dan het is in het geval van de conventionele en zelfs biologische landbouw, welke gebruik maken van grootschalige monoculturen. In plaats van tegen de Natuur te strijden, wordt in voedselbossen in harmonie met de Natuur gewerkt.

Voedselbospioniers

Robert J. Hart was een Engelsman, die al in 1960 op zijn erf van 500 m^2, een voedselbos prototype heeft geplant. Met dit voedselbos wilde Robert een leefwijze laten zien, die voor meer voedsel en verbeterde levensstandaard zou kunnen zorgen voor velen in hongersnood gebieden. Dat was de wens van Robert voor deze wereld (Burnett, 1997).

In Nederland, is het Wouter van Eck, samen met zijn levensgenoot Pieter Jansen, die in Groesbeek, nabij Nijmegen, in 2009 een eerste Nederlandse voedselbos hebben aangelegd. Het terrein van het voedselbos in Groesbeek was een voormalige landbouw maïsakker. Voedselbos Ketelbroek is een voorbeeld en inspiratiebron voor een groeiend aantal voedselbos initiatieven in heel Nederland. De ontwikkeling van voedselbos Ketelbroek, is net als vele andere projecten in het kader van het samenwerkingsverband met Xavier San Giorgi - Foodforestry Netherlands, te volgen op de website **www.foodforestry.nl** en Facebook pagina **www.facebook.com/FoodforestryNetherlands**

Lagen van het voedselbos

Het was Robert J. Hart, die zeven lagen systeem heeft waargenomen en gedefinieerd in natuurlijke bossen. Hij heeft dit concept toegepast om zijn kleine boomgaard tot een eetbaar landschap te herscheppen (Burnett, 1997). Op deze manier, heeft Robert een basis gelegd voor een moderne structuur van voedselbossen. De zeven lagen zijn als volgt te beschrijven:

1. ***Kroonlaag (climax bomen)*** bestaande uit originele volgroeide bomen of nieuw geplante walnoten, moerbei, lindes etc.
2. ***Lage bomen laag*** bestaande uit kleinere noten- of fruitbomen of halfstammen als appels, kersen, hazelnoten etc.
3. ***Struiklaag*** van fruit struiken zoals zwarte en aalbessen, frambozen, zuurbessen etc.
4. ***Kruidlaag*** van meerjarige groente en kruiden
5. ***Bodembedekkers laag*** van eetbare planten die zich horizontaal verspreiden
6. ***Ondergrondse- of wortellaag*** van planten met eetbare wortels of knollen
7. ***Klimmers (verticale laag)*** van klimmende planten

Als toevoeging, heeft John Kitsteiner (Kitsteiner, 2013) een 8ste en een 9de voedselbos laag beschreven als respectievelijk aquatische en paddenstoelen lagen. Ook een permacultuurtuin aan zuidzijde van een voedselbos voor een eenjarige of meerjarige oogst, kan worden gerekend als aparte laag, creërend in totaal een voedselbos met 10 lagen. Het betekent niet dat elke voedselbos alle lagen in zich zou moeten hebben. Het betrekken van alle lagen zal wel tot de hoogste productie kunnen lijden, die gehaald kan worden met het voedselbos in gematigd klimaat. De keuze van lagen is afhankelijk van ontwerp overwegingen en specifieke beperkende factoren, zoals beschikbare grond, bodemtype, financiële middelen, etc.

Algemene doelen van voedselbossen

Zoals beschreven door Wouter van Eck, zijn bij de start van een voedselbos de investeringen, zowel voor wat betreft arbeid als financieel, groot, terwijl de opbrengsten dan nog laag zijn. Maar, naarmate de tijd vordert, stijgen de waarden en opbrengsten en is er steeds minder investering en arbeid voor beheer nodig. Als alles goed vordert, bereikt een voedselbos in een gematigd klimaat zijn productieve fase al na 3-5 jaar. Elke persoon die een voedselbos zou willen aanleggen heeft zijn eigen karakteristieke reden om bomen te gaan planten. Eén van de eerste wetenschappelijke onderzoeken op het gebied van voedselbossen is gedaan is door D. Jacke en E. Toensmeier. Zij geven een lijst van doelen, die nu als fundamenteel worden beschouwd voor ontwerpers van voedselbossen wereldwijd (Jacke, et al., 2005).

- Overvloedig diversiteit van overheerlijke, hoog-voedzaam voedsel en andere nuttige producten
- Stabiele, veerkrachtige ecosystemen die grotendeels zelf-onderhoudend zijn
- Bescherming en restauratie van de kwaliteit van ecosystemen
- Belichamen van schoonheid en karakteristieke vorm en geest van het landschaap
- Verbetering van economische duurzaamheid
- Nieuw paradigma van menselijke participatie in de ecologie van cultuurrijke en natuurlijke landschappen

Ecologische principes van het natuurlijke bos ecosystemen relevante voor productieve voedselbossen

In dit rapport worden de belangrijkste ecologische aspecten en principes van natuurlijke voedselbossen gepresenteerd. Aspecten en principes die een essentiële rol spelen in het voedselbosecosystemen, zoals het is beschreven in het theoretisch onderzoek over voedselbossen (Hart,1996; Whitefield, 2002; Jacke& Toensmeier,2005; Crawford,2010) en die praktisch worden toegepast en gemonitord door Wouter van Eck en Xavier San Giorgi in de loop van laatste vijf jaar ontwikkeling van Voedselbos Ketelbroek.

Belangrijke ecologische aspecten en principes voor productieve natuurlijke voedselbosecosystemen zijn:

- Klimaat
- Bos structuur
- Zonlicht en schaduw
- Water
- Wind
- Bodem
- Nutriënten cycli
- Schimmels
- Gunstige dierlijke interacties
- Successie
- Inheemse en exotische planten
- Stikstof bindende planten
- Tijd voor groei. Tijd voor het oogst

Aan de hand van de ecologische aspecten en principes, zijn de verschillen tussen voedselbossen en natuurlijke bossen vergeleken. Gelijkenissen waren de aspecten klimaat, water, wind, bodem, nutriënten cycli, schimmels, gunstige dierlijke interacties en de tijdsperioden voor groei en oogst. Verschillend waren de aanpassingen van de structuur en natuurlijke successie van het bos binnen het voedselbos ecosysteem. In het voedselbos ecosysteem laat de kroon laag veel meer zonlicht door, in vergelijking tot natuurlijke volgroeide bossen (met vroeger of later een gesloten kroon laag). Aan de andere kant, natuurlijke opeenvolging in voedselbos ecosystemen gaat sneller in vergelijking tot successie in natuurlijke bossen. Dit komt doordat de opbouw van de vruchtbare bodem wordt gestimuleerd door addities van stikstof bindende planten. Ook de keuze van introductie van meer 'exotische' eetbare plantensoorten voor de voedselbossen zorgt voor verschillen met natuurlijke systemen. Voor Nederland betekent dit dat planten met een winterhardheid voor zones 6, 7 en 8, zoals planten uit bijvoorbeeld Japan of Noord Amerika, geschikt zijn voor productieve groei binnen het Nederlands klimaat.

Ontwerp van Je Eigen Voedselbos

Het toegankelijkheid van kennis die benodigd is voor aanleg van eigen voedselbos, is een van de prioriteiten van dit werk.

Voor het ontwerp van een voedselbos ecosysteem moeten gegevens worden verzameld over de huidige situatie. Daarvoor zijn werkbladen beschikbaar, die gratis kunnen worden gedownload, "Soorten Niche Analyse Werkbladen" op **www.edibleforestgardens.com** (Jacke, et al., 2005).

Hieronder volgen de specifieke aspecten die worden gebruikt bij het ontwerp van voedselbossen:

Precieze positie van de zon geheel jaar rond	Veiligstelling van biodiversiteit
Goed ontwerp van de kroon laag	Verstrekken van voldoende wortelruimte
Totale beschikbare oppervlak van het voedselbos	Gebruik van stikstof bindende planten

In dit rapport wordt een selectie van 21 plant soorten gepresenteerd in Appendix I en ingedeeld in een zeven lagen voedselbos ecosysteem, als een voorbeeld ontwerp van een productief voedselbos in gematigd klimaat.

Onderhoud van een Voedselbos

Door de mimicry van natuurlijk bos ecosysteem opeenvolging, is de behoefte aan onderhoud van het voedselbos potentieel heel gering. Wouter van Eck: *"Jij bent welkom om onderhoud te verrichten, maar eigenlijk hoef jij het niet te doen. Het ecosysteem van een voedselbos komt heel dicht bij het idee van "do- niks- landbouw " van Masanobu Fukuoka in 1975. "Masanobu heeft het beschreven als: door te leren van de*

natuur, kun jij een systeem ontwerpen, dat zelfdragend, zelfonderhoudend, zelf balancerend en zelf voedend is. Voor een voedselbosecosysteem betekent dit dat er niet gemaaid wordt en gewied en er geen gebruik wordt gemaakt van pesticiden en insecticiden (zelfs geen ecologische). Er wordt ook niet geïrrigeerd en bemest. Jij hebt het niet nodig in het natuurlijke bos, zo heb je het niet nodig in het voedselbos".
Hieronder is voor het onderhoud van een voedselbos een "Doen" & "Niet doen" lijstje gegeven:

Doen

Regelmatige observaties ter bevordering van begrip van ecosysteem werking
Minimale irrigatie
Plaats voor dood hout

Niet doen

Gebruik van kunstmatige en of organische bemesting, pesticiden, insecticiden etc.
Snoeien, wieden, maaien op reguliere basis
Leien van bomen en struiken

Slot opmerkingen

Uitdaging voor de moderne menselijke beschaving is een weg te vinden naar een complete duurzame interactie met onze milieu, waarbij voldaan kan worden aan menselijke consumptie behoeftes en waarbij karakteristieke waarde van andere wezens, planten en de natuur als geheel gerespecteerd kunnen worden. Aanleg van voedselbossen kan mogelijke een succesvol antwoord zijn op deze uitdaging.

"Uiteraard, weinig van ons zijn in de positie om bossen te herstellen. Maar tientallen miljoenen van ons hebben tuinen, of toegang tot publiek land, waar bomen geplant kunnen worden en nieuwe "stads bossen" kunnen ontstaan…"

Robert A.de J. Hart (1991)

Contents

1 Introduction

When I was a child in Ukraine, looking at the biological garden of my loved grandparents, full of orderly rows and separate places for flowers and vegetables, made me question if it is natural to garden this way. The garden was beyond words very beautiful, having delicious apricots, cherries, plums and apples, but at the same time it was quite labour-intensive.

One summer day looking at the lushness of the apricot tree and vegetables growing below, I was asking myself the question: "*Can you create a work-free garden where beauty and food production are combined, without the need to disturb Nature, just like in a natural forest? Can you harvest food just by taking a pleasant walk through the forest?"* Years on from there, having come to know permaculture and now also food forestry, I can say that I found the answer: "Yes, it is possible". In this work, I am trying to obtain scientific information on the processes taking place naturally in forest ecosystems, which are essential for food forest design and maintenance. You are invited to follow me on my journey.

2 Research methodology

This qualitative research has as its aim the creation of a public open source resource about food forests which contributes to worldwide theoretical and practical food forest knowledge.

2.1 Research questions

The audience for this research is made up of the people with practical and theoretical interest in food forest such as specialists in the subject of food forests in a temperate climate.

Research question: *Which ecological principles in natural temperate forest ecosystems are relevant for the design and maintenance of a temperate food forest, as conducted from the previous food forest research of others, as well as from practical experience at Foodforest Ketelbroek?*

Through the research process, the answer to this question was found through the triangulation method. With this method, different viewpoints are collected and observed for their converging into the same direction (Kumar, 2014). The most important ecological principles and factors that were taken into account were:

- Climate
- Forest structure
- Sunlight and shade
- Wind
- Water
- Soil
- Nutrient cycles
- Fungi
- Beneficial animal interactions
- Succession
- Native or exotic plants
- Nitrogen fixing plants
- Time for growth. Time for harvest

2.2 Research strategy

Qualitative studies are characterized by an emphasis on describing, understanding and exploring the phenomena using categorical and subjective measurement procedures, where construction of hypothesis is not significantly practiced (Kumar, 2014). The approach of this qualitative research was also open and flexible, taking the practical and theoretical perceptions into account (Verhoeven, 2004).

2.3 Research process

A research process is very similar to undertaking a journey. Kumar (2014) says that, the choice of the specific route within this journey depends on you. Within this research the following route was taken, divided into six logical steps, depicted in diagram 1:

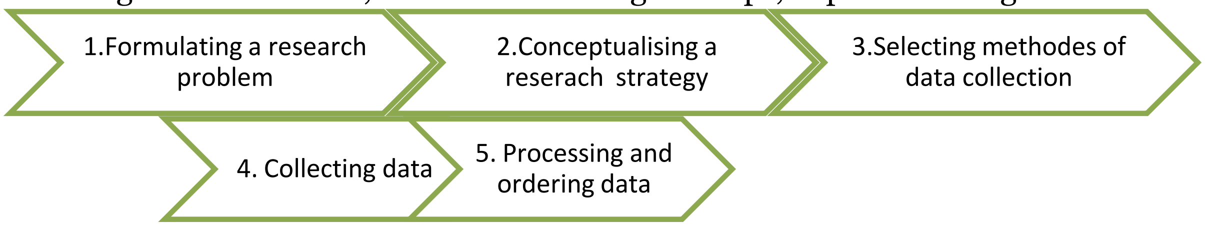


Diagram 1: Progress flow diagram of this research

In first place, the aim of the research question was defined. The research data was collected from literature, interviews and course recordings. The step-by step analysis and processing of the data was carried out, this leading to a written research report. This process in described in detail in following subchapters.

2.4 Selection of methods of data collection

Within this research, the choice of data collection methods was based on the following factors, leading the research into one direction. These factors are described below in detail.

1. ***Availability of literature resources***

The resources that were available to the author about food forests were limited in their theoretical and practical base. The research was based on as many relevant books as possible and other sources which were available to be freely used by the author. Therefore the Libraries of Van Hall Larenstein University and its librarian network anno 2014 were used to access the published works on natural and food forestry in a temperate climate. As the amount of available titles was limited, all information was used.

2. ***Choice of involved experts based on their practical experience in related subjects***

The choice of the expertise statements was limited during this research. Wouter van Eck appeared to be the only expert able or willing to cooperate within the time limits of the research period. For this reason, other experts on, for example, permaculture could not be used for this research.

3. *Choice of practical food forest pilot- project, based on its development grade*

The choice to put Foodforest Ketelbroek as the main pilot-case is based on the fact that this is the most developed food forest in the Netherlands. Other food forests, summarized in chapter 8, were created afterwards by Foodforestry Netherlands. The Foodforest Sualmana, was planted in 1995 near Swalmen in Limburg, the Netherlands, but is unfortunately far from being as productive as Foodforest Ketelbroek. The work on its regeneration was done during this research period, but due to tight time limits, a visit to this food forest was not planned for this research. Lessons learned on every stage of the development of Foodforest Ketelbroek is of potential interest for present and future food forests created in the Netherlands and scientific research on food forests in temperate climate.

2.5 Data collection methods

Data for this research were collected by literature research, open interviews with the expert on the subject of food forests for Dutch climate conditions, Wouter van Eck, and by participation in Basic Food Forests Design Course by Foodforestry Netherlands, taking place during the research period. These data collection methods were considered to be the most fitting for this research for several reasons, as described below.

Literature research

All applied sources within the literature research were divided according to their categories (Stebbins, 2006) as follows:

Internet data

This source considered different types, described in detail below:

1. *Information from relevant websites;*

Searches were made for relevant reports, journal articles etc. via Google and Google Scholar using terms such as: natural temperate forests, food forests, food forest gardens, temperate permaculture and agroforestry, and many more.

2. *Information from relevant scientific reports;*

A large amount of resources was found on natural temperate ecosystems, but relatively few were found on the subject of food forests. Because the term “food forests” is not common to all scientific sources, the terms “agroforestry” and “agroecology” were used for data search as well. The information that was found this way could, however, not always be applied within this research, as agroforestry and agro-ecological systems are working with less biodiversity of edible species per unit of land. Taking this into account, food forest ecosystems can be considered as systems where biodiversity, Nature value and aesthetic beauty and natural synergy play an important role. Further scientific research is necessary to explain all interactions and differences between typical agroforestry and food forest ecosystems.

3. *Information from personal websites, blogs, comments etc. of the people who for their work or as hobby are engaged in natural or food forests worldwide*

Expertise from people that are engaged in practical cases and have gained experiences in food forestry in their backyard, part of community projects of even commercial plots, provide a great source of knowledge that is not yet systematized and summarized, but has a great value.

Books

The search for books extended to relevant and recently published books about natural temperate forests, food forests, food forest gardens, temperate permaculture and agroforestry, etc. In the case of food forests, older books published in the last century were also useful. For information about natural forests, a great variety of books was found. In the case of temperate food forest ecosystems, the choice was limited

Interviews

Unstructured interviews, formed around open questions, were used for acquisition of information. It was chosen for this method because it offered great freedom. Within unstructured interviews, the questions and raised issues may be formulated on the spur of the moment, depending upon what occurs to you in the context of the discussion (Kumar, 2014). Therefore, the questions which were used here considered specific relevant research points at different stages of research progress. Received information was then ordered and filed in the relevant places within the research report.

Unstructured interviews with Wouter van Eck

The interviews with Wouter van Eck delivered a rich source of practical knowledge about food forests. Wouter van Eck is at the present moment the number one expert on the subject of food forests within the Netherlands. His expertise has until now not been documented in a book, besides this research. The interviews contained a range of questions about food forests, covering the research questions and moving on into the personal views of Wouter van Eck on agricultural themes. All interviews were audio-recorded and used for this report, but they are not available for public use. The author of this work personally held the interviews.

Participation in Basic course Food forests by Foodforestry Netherlands

A five-day Basic Food Forests Design Course was followed by the author (spring 2014), as a supporting part of this research. During the lectures of this course on Foodforestry

Netherlands, the main relevant research points were discussed. The lectures of this course were recorded and could be reviewed again during the research, but are not accessible to the public.

2.6 Analysis of the collected data

During the analysis of collected research data, all collected information about natural temperate forests was arranged by its relevance to temperate food forests. This research was growing by the so called “snowball effect”, where through the informing of relevant sources, new relevant sources were found (Baarda, et al., 2012). The information sources used are represented in totality in the Bibliography list at the end of this report.

3 Ancient Forests

According to modern scientific research, the first plants that developed lignified tissues (the xylem) on our planet, appeared around 400 million years ago, during the late Devonian, early Silurian geologic period, around 419.2 ± 3.2 million years ago (Nix, 2014)

Picture 1 Hypothetical image of first tree on Earth (Kazlev, 2002)

After examining newly collected pieces of tree fossils in Morocco, scientists propose that one of the first such plants was *Archaeopteris spp*. (progymnosperm). This fact makes the *Archaeopteris* the earliest known proto-tree with buds, reinforced branch joints, and branched trunks similar to today's modern tree. With trunks up to a meter wide, this tree grew perhaps 18 to 27 meters tall. Unlike modern trees, *Archaeopteris* reproduced by shedding spores instead of seeds. When it appeared, this tree very quickly became the dominant plant all over the Earth (Scheckler, 1999).

The extinct *Archaeopteris* developed the branches, leaves and flowers that we are used to seeing now, hundreds of thousands of years later. Therefore, together with *Aneurophytes spp.*, the *Archaeopteris* is considered as an ancestor of the modern seed-plant (UCMP, 2014)

From *Archaeopteris* trees, the development of the first forests on Earth emerged around 370 million years ago during the Devonian period. At one point *Archaeopteris* made up 90 percent of the forests and remained dominant for a very long time. Because *Archaeopteris* were so successful and abundant, they nourished life all around them. The decaying trunks and leaves and the altered carbon dioxide/oxygen atmosphere abruptly changed ecosystems all over the Earth (Murphy, 2005). A metaphoric description of Scheckler (1999) about *Archaeopteris* tree, concludes:

Picture 2 The fern-like leaves of Archaeopteris,spp. (UCMP, 2014)

"Its litter fed the streams and was a major factor in the evolution of freshwater fishes, whose numbers and varieties exploded in that time, and influenced the evolution of other marine ecosystems. It was the first plant to produce an extensive root system, so had a profound impact on soil chemistry. And once these ecosystem changes happened, they were changed for all

time. Archaeopteris made the world almost a modern world in terms of ecosystems that surround us now"

3.1 Edible Living Tree Fossils

Discoveries of modern representatives of a group long thought to be extinct, 'living fossils" as named by Charles Darwin, are considerable in our time too. At the present moment there are several discovered tree species that show no indication that they will change in another dozen million years. From these living fossils, several species have edible parts. This species are the monkey puzzle tree *(Araucaria araucana),* wollemi pine *(Wollemia nobilis),* horsetail *(Equisetum arvense)* and ginkgo *(Ginkgo biloba)* (Nix, 2014).

Figure 1 Nuts of Monkey puzzle tree *(Araucaria araucana)* (Havlis, 2014)

Figure 2 Nuts of Wollemi pine *(Wollemia nobilis)* (dangergarden.blogspot.nl, 2010)

Figure 3 Horsetail *(Equisetum arvense)* (www.interhort.com, 2008)

Figure 4 Nuts of gingko tree *(Ginkgo biloba)* (www.pinterest.com, 2013)

4 Humans and Forests

"I am a child of the forest; no roof covers the spot where I was born. Old oaks and beeches shade its solitude and grass grows upon it. The first song I heard was of the birds of the forest, my first surroundings were trees. Thus my birth determined my calling!"

Heinrich Cotta (1902)

"You betray yourself if you are against Nature. Because you are Nature"

Sepp Holzer (2013)

Forests are crucial to people everywhere in the world. Forests provide us with a range of resources we depend on in daily life in the modern world. The other name for forest is "Planet's Lungs" because trees produce oxygen needed for respiration of humans, animals and plants. Therefore, protection and enhancement of the forest biodiversity is an aim for present and future generations. But the reality is not always like this.

In modern scientific definitions, a forest is described as a resource for the human race. The FAO definition of a forest is considered as the basic one, for many scientists (2014): *"Forest includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10% and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m. Young stands that have not yet but are expected to reach a crown density of 10 percent and tree height of 5 m are included under forest, as are temporarily unused areas. The term includes forests used for purposes of production, protection, multiple-use or conservation (i.e. forest in national parks, nature reserves and other protected areas), as well as forest stands on agricultural lands (e.g. windbreaks and shelterbelts of trees with a width of more than 20 m), and rubber wood plantations and cork oak stands. The term specifically excludes stands of trees established primarily for agricultural production, for example, fruit tree plantations. It also excludes trees planted in agroforestry systems"*. Very surprisingly, trees planted in agroforestry do not have a right to be called forest, according to FAO committee.

After reading the forest definition from the FAO we understand the resource value of forests for the human race. But is this really everything that makes forest so precious?

Deep ecology gives an example of a different forest definition, for my part more corresponding with the truth: *The forest is a rich, diverse, holistic community that is self-sustaining. The forest's inherent richness and diversity has its own eccentric value besides human needs. We must learn that we visit the forest as visitors; it is not ours to exploit and to abuse. Human access to the forest is a privilege, not a right. We are obliged to restore it ensuring that it is valued and will survive and thrive (adapted* *from* (Naess, 2014). Another interesting fact is that many indigenous tribes do not separate animals from the forest. For them the animals are the higher expression of the forest (Lawton, 2014).

These words, while perhaps too poetic for some people, are at the same time in accord with recent scientific research done in Oxford (Chivian, et al., 2010).

"Most people experience the loss of other species and the disruption of ecosystems as intangible, abstract events, happening somewhere else, separate from themselves. In spite of this, they may feel these losses deeply—ethically, spiritually, and aesthetically—and may even understand some of the ecological and economic costs involved. Yet, it is still difficult for them to grasp what this impoverishment of Nature has to do with their daily lives. The challenge for those of us working to preserve biodiversity is to convince others, policy-makers and the public in particular, that we human beings are intimately connected with the animals, plants, and microbes we share this small planet with, and totally dependent on the goods and services they provide, and that we have no other choice but to preserve them" (Chivian, et al., 2010)

At present, forests cover 3.7 billion hectares of the planet's surface, or 30% of the global land area. Almost half of these forests are found in tropical areas (44% of the total area), about one-third in boreal (34%) and smaller amounts in temperate (13%) and subtropical (9%) domains. But whereas the amount of land under forest is growing in the boreal, temperate and sub-tropical zones, tropical forests are shrinking. Millions of hectares of forest in South America, Africa and Southeast Asia are cleared each year and converted to other uses by humans (FAO, 2011).

An estimated 1.6 billion of the world's poorest people (those surviving on less than $2 per day) rely daily on forests for their survival. About 300 million people depend on forests for their welfare and livelihood. These people include subsistence farmers, hunters, small-scale loggers, extractivists such as rubber-tappers, and harvesters of nuts, berries, fruits and medicinal plants (WBG, 2011).

According to the well-known forester, Richard St. Berbe Baker, for food safety a country should have about thirty percent of its surface covered with trees (Hart, 1996). In many countries, tree cover is far below this level.

4.1 The Effects of Deforestation

The German Heinrich Cotta (1763-1844) is called the "pioneer of forestry". Cotta studied forestry all his life and has had a profound influence on the profession of forestry and foresters in Europe. Several quotes from Cotta's Preface in "Anweisung zum Waldbau" (Cotta, 1902):

- ***"On the need for foresters: There would be no physicians, if there were no diseases, and no forestry science without deficiency in wood supplies"***
- ***"On why forestry is backward: The forester who practices much , writes but little, and he who writes much, practices but little"***
- ***"On the good forester: The good forester takes the highest yield from the forest without degenerating the soil, but preserves its fertility"***

It was a different forestry during the beginning of 18th century where forest ecosystems had been an integral and useful part of agriculture. Later, unfortunately, even if the views of Cotta and other forest pioneers were noble, the knowledge that they obtained was primary used for extracting timber and the useful resources from forests.

Eventually, "modern forest management" has led to creating massive cash crop tree monocultures, as we see now in most planted forests, and became in large part related to timber and firewood production. The consequences of such developments led to extensive environmental problems all over the world, such as soil erosion, frequent lowering of water tables and spread of plagues and epidemics.

It may not be directly visible to us, but the countries with the greatest grade of deforestation are largely dependent on agriculture in the form of small-holder farming. As seen in figure 5, step by step, deforestation influences different natural and cultural processes that eventually result in aggression and conflict of the affected people. Therefore it can also be considered that deforestation is directly related to the local poverty level in countries like, for example, those in South East Asia and South America.

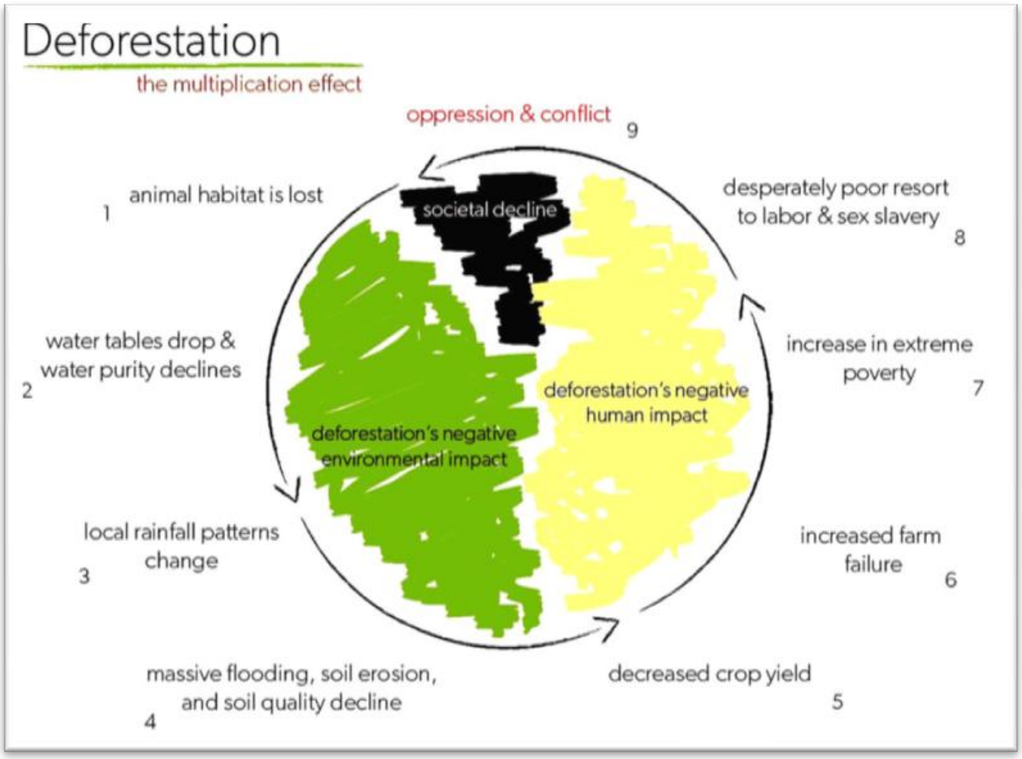


Figure 5 The multiplication effect for deforestation (Norton, 2012).

Into my mind comes the Native American saying (O'Toole, 2011):

"Only after the last tree has been cut down.
Only after the last river has been poisoned.
Only after the last fish has been caught.
Only then will you find that money cannot be eaten"

With destroying the Nature around us and putting the focus on earning money alone, we overlook the interconnectedness of things and destroy natural balances, and along with it our welfare.

4.2 The Price of Monocultures

"It is commonly supposed that neighbouring plants rob each other of sunlight, air, water and soil nutrients. Therefore the economic crops must be grown in isolation with potential competitors being eliminated"

Sholto Douglas and Robert A.J.de Hart (1985)

Our food from big supermarket stores comes from monocultures. Monoculture is the agricultural and forestry practice of cultivating a single crop over a whole farm or area. The conventional/productive agricultural system, also known as the industrial model of agriculture and forestry, is characterized by its preference for monocultures and large-scale agriculture, utilizing intensive production practices. These production practices rely heavily on the use of capital, technology and external petrochemical inputs. Conventional agriculture and forestry orients itself increasingly towards the global market, where the crops or trees grown in the developing world are transported to the developed world (Suárez, et al., 2009).

Intensive use of fertilizers and chemical pesticides is an essential part of monocultures that are acting as an incubator and magnet for different plagues. The danger of pest and pathogens is strongly dependent on site conditions. There is scientific evidence that species diversity minimizes pest outbreaks compared with their incidence among monocultures (Vouté, 1964). In the meantime, monoculture “essentials” (fertilizer and chemicals, etc.) not only provide a high-yield harvest, but at the same time destroy biodiversity, contaminate groundwater, lands, rivers and springs, and deplete freshwater in the short and long term.

In recent years, large energy consumers like the United States and the European Union have been greatly promoting the production of agro fuels in order to reduce their energy dependency from Middle East and Russia. Agro-fuels (biofuels), are presented as a form of clean energy that will reduce CO_2 emissions and pollution worldwide. Countries like Brazil, Malaysia, Indonesia and Colombia also promote the investment in agro-fuels on a regional and international level with great support from local and national government and scientific groups. A great number of such monocultures are using the genetically modified seeds that are associated with high risks to human health and the biodiversity (Suárez, et al., 2009). And also, agro fuel plantages are again planted in monocultures. But what is the price of these “sustainable” developments?

As result of such trends, huge pieces of virgin rainforests are transformed into the monoculture landscapes of the “cash crops” in no time. The rich people of this world, who invest the money to make more money, overlook small-scale farmers who are depending on natural forests for their primary supply of food and commodities. The protests of these poor people against the expansion of industrial agriculture were not heard for many years, until the attention of environmental activists from the West came.

But even when the problems are in clear view, the destruction of the world’s forests does not slow down. In the name of rural development, agricultural modernization and economical profits, millions of families have lost, are losing and will lose their land to make way for large industrial monocultures in the developing world.

The companies known for their ecocide practices can legally label their products as “sustainable” and “green”. A good example is Monsanto, which proclaims itself to be a “sustainable agricultural company”. So, despite growing criticism, the industrial agricultural system is still acting as a “modern”, “efficient”, and “safe” one and at the same time is considered essential in solving the growing worldwide problem of hunger and malnutrition.

5 Food Forestry as an Answer to Food Problems

"Our tool is knowledge
Yours the tools of steel
We feel the pulse of Earth
You do not feel"

Bill Mollison (1978)

"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)

Before the application of fertilizers and pesticides, wheat, growing in a temperate climate, produced on average 1,4 tones/hectare. With fertilizers the yield became 3 times as big (Curtis, 2014). At the same time, average annual yields obtainable from well managed plantations of good-quality trees show great yield too, but without input of fertilizers, as can be seen in table 2.

Table 1 Annual yields in tons/hectare of tree selection, producing edible yield (Sholto Douglas, et al., 1985).

Species	Botanical name	Annual Yield (tons/hectare)
Walnuts	Juglans spp.	4-6
Oaks	Quercus spp.	4-5
Hazelnuts	Corylus spp.	3,5 -5
Chestnuts	Castanea sativa	3-4,5
Mulberries	Morus spp.	3-4
Apples	Malus spp.	3

Design of low-maintenance productive ecosystems based on trees can greatly contribute to world food production. Once established, the food forests will require no or little input in order to remain productive because they are based on natural principles. More than this, inputs of fertilizers, pesticides and herbicides will become redundant. Food forests are a good example of one of the solutions of global hunger problems (Shepard, 2013).

As described by Wouter van Eck, the level of initial work and economical costs are high and the level of harvest or profit is low in the initial phase of any food forest system. But, as the time goes on the value and the yield rise and the work and investment decrease to minimal levels. While you wait for your food forest to enter it's high-yield phase (in temperate climate after 3-5 years), you can create a permaculture garden on the side of the food forest to have an annual vegetable harvest.

5.1 Food Biodiversity

"Chimps seem to be expert botanists, knowing exactly where and when the next crop of fruit will be. They use more than 150 species in their diet through the year. Some of the fruits the chimps eat are delicious and they can certainly teach us a great deal about balanced diet and preventive healthcare. But although a lot is known about the chimp's social behaviour, our understanding of their botanical knowledge and its significance to us, humans, is in its infancy".

Ken &Andy Fern (1997)

Research has shown that before the dawn of agriculture in the time of hunters and gatherers, somewhere between 200 and 1000 different species of plants would be eaten by a person in one year. Nowadays fewer than 20 species of plants supply about 90% of our plant foods (Fern, 1997).

New research in dietology tells us that the healthy human diet should contain a wide variety of foods, based on sufficient carbohydrates and proteins, but also including different berries, herbs, nuts and seeds, etc. for supply of micronutrients. But in our modern situation, in contrast to chimps, humans need to satisfy themselves with only limited food species. Researches of Harvard University showed that only some 12 plant species provide approximately 75% of our total food supply, and only 15 mammal and bird species make up more than 90% of global domestic livestock production (Chivian, et al., 2010)

According to other research in dietology, over three billion people worldwide are currently micronutrient (i.e. micronutrient elements and vitamins) deficient. This malnutrition results in increasing learning disabilities among children, morbidity and mortality rates, lower worker productivity, and high healthcare costs. As a result, the human potential and prosperity, as well the national economic development is diminished (Welch, et al., 2004). So what does it take for us to eat healthy? The answer will be: local, sustainable, safe, diverse and freshly picked food. Where can we get it? From the food forest ecosystems.

5.2 Look in the Conventional Garden

When you look at a conventional food garden, what you normally see are rows of vegetables, and in the best cases a few fruit trees or berry bushes in a separate area. In conventional gardens, the gardener is constantly engaged in a battle against the forces of Nature in the form of pests, diseases, drought, too much rain and eventually Nature itself. Therefore, garden work in the eyes of many people is intense and physically hard. With the aims of digging the ground every year, than fertilizing it with manure, and a constant battle to control the weeds - it is true warfare on a small scale (Fern, et al., 1996).

The food forest is a very different concept. Here everything grows together in a way that is very similar to natural woodland. However, instead of the usual forest plants where most of the plants are not edible, the trees and shrubs in food forests bear an incredible yield of edible crops. Moreover, the space in a food forest is used in multiple layers, so many different edible herbs and vegetables can be grown in parallel with the trees. In food forests the food production for humans is arranged in a more harmonious way with Nature; instead of battling against nature, the food forest works in harmony with it.

5.3 Food Forest Concept

"Obviously, few of us are in a position to restore the forests.. But tens of millions of us have gardens, or access to open spaces such as industrial wastelands, where trees can be planted. and if full advantage can be taken of the potentialities that are available even in heavily built up areas, new 'city forests' can arise..."

Robert A.de J. Hart (1991)

Robert J. Hart was the one who first put the basics of food forests on paper. At his residence in Wenlock Edge on the Welsh borders, Robert began the planting of his 500m² food forest around 1960. Robert's examinations of the interactions and relationships that take place between plants in natural systems, particularly in woodland, led him to evolve the concept of the food forest garden (Hart, 1996).

Based on the observation that the natural forest can be divided into distinct layers or 'storeys', Robert developed an existing small orchard into an edible landscape consisting of seven dimensions (Burnett, 1997), as also depicted in figure 2:

1. **Canopy layer (climax trees)** consisting of the original mature trees
2. **Understory (lower tree layer)** of smaller nut and fruit trees on dwarfing root stocks
3. **Shrub layer** of fruit bushes such as currants and raspberries
4. **Herbaceous layer** of perennial vegetables and herbs
5. **Ground cover layer** of edible plants that spread horizontally
6. **Underground (root layer)** of plants grown for their roots and tubers
7. **Climbers (vertical layer)** of vines and climbers

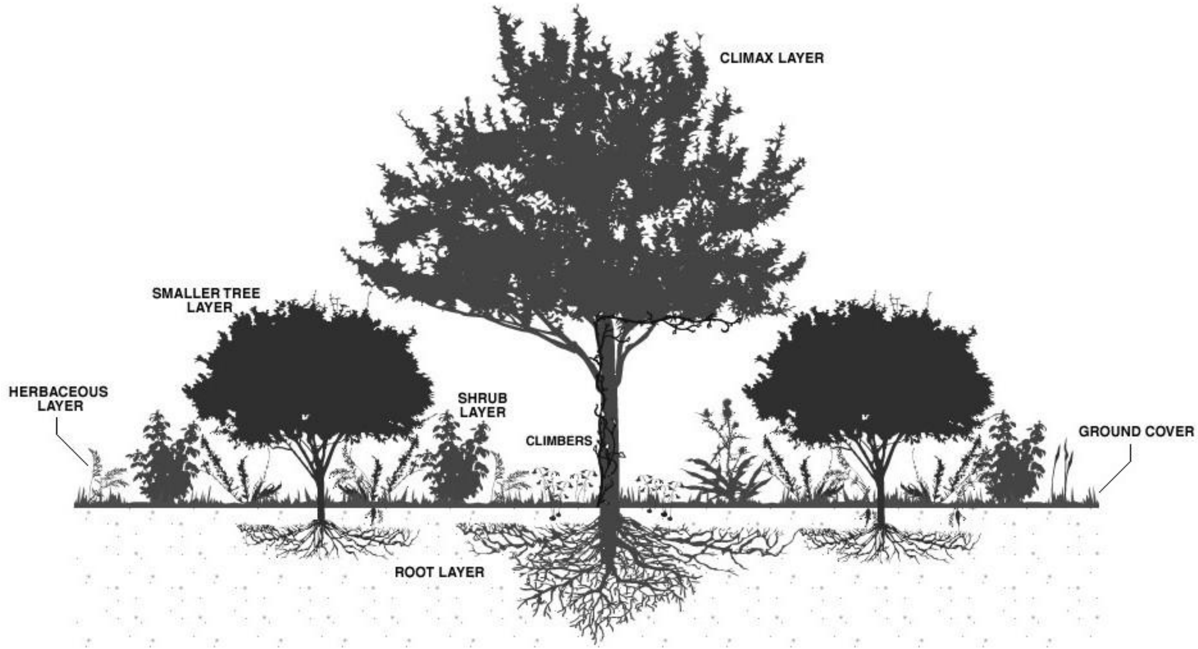


Figure 6 Concept of food forest in temperate climate with 7 layers (Clynewood, et al., 2014)

In the beginning of his gardening, Robert wanted a conventional garden with annual vegetables, fruit trees and various livestock such as chickens and cows. However, his views gradually changed when he found that perennial vegetables and herbs were much easier to grow and more productive than the annuals and the animals. Robert was very aware of the inequalities in society, especially between the western cultures and the less developed nations. With his food forest, Robert wanted to demonstrate a lifestyle that could help to provide more food and an improved standard of life for those areas of the world where starvation is growing. This was Robert´s wish for the world (Burnett, 1997).

Another aim of Robert´s was a creation of a garden that could heal - both the individual and the planet. The intention of Robert was also to provide a healthy and therapeutic environment for himself and his brother Lacon, born with severe learning disabilities. *"Robert's whole philosophy is based on love. He is convinced that this is the most powerful force in the world and that, when given unconditionally, it will transform. His life is a living example of his beliefs and so is his garden"* (Fern, et al., 1996).

Bill Mollison also visited Robert Hart at his forest garden in Wenlock Edge in October 1990. Hart's seven-layer system has since been adopted as a common permaculture design element. From that time, numerous permaculturists are propagating the idea of forest gardens, or food forests.

- In 1995 Graham Bell started building his forest garden in 1991 and wrote the book "The Permaculture Garden"

- In 1996 Ken and Addy Fern visited Robert Hart´s forest garden and liked it very much, and it had greatly inspired them to create a Plants for A Future project

- In 2002 Patrick Whitefield wrote the book "How to Make a Forest Garden"

- In 2005 Dave Jacke and Eric Toensmeier co-authored the two-volume book set "Edible Forest Gardens".

- In 2008 Geoff Lawton presented the movie" Establishing a Food Forest"

- Present: numerous food forest projects are starting all over the world

Practical experiments with food-forest ecosystems also created more understanding of ecological principles involved in design. So in addition, John Kitsteiner in 2013 described the 8th and 9th food forest layers as respectively aquatic and mushroom layers (Kitsteiner, 2013). Also permaculture garden on the south side of the food forest to have an annual and perennial vegetable harvest can be counted as a separate layer, creating in total a 10 layer foodforest.

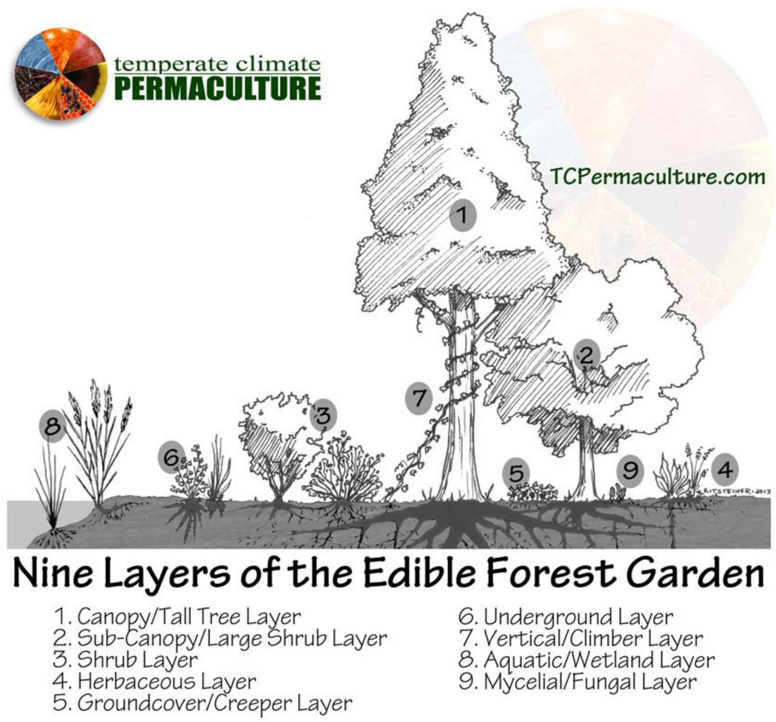


Figure 7 Nine layers concept of the food forest in temperate climate (Kitsteiner, 2013)

It does not mean that every food forest needs to have all layers included, but including them all can lead to the highest yields obtainable from a food forest. The choice of layers depends on design considerations and specified limiting factors such as available surface, soil type, financial means, etc.

5.4 Plants in a Food Forest

Jacke&Toensmeir (2005) in their book "Edible Forest Garden", Volume 2, provide an overview of 626 plant species considered useful and functional within the food forest ecosystem. If all the cultivars were considered too, the plant list would need to be multiplied by a factor of ten!

The majority of the plants within the food forest are multifunctional. An example is the nitrogen fixing tree of autumn olive *(Elaeagnus umbellata)* which is also an excellent plant for bees and produces a great yield of edible berries.

One practical example of productive food forest ecosystem in temperate climate is the food forest of Martin Crawford which was established about 20 years ago. Martin has up to 400 species incorporated in his food forest, and that makes it the most rich in biodiversity of the food forests of the temperate climate at present. This world- famous forest garden of Martin Crawford is located on around 800m^2 of the Darlington Estate in South Devon, England. An excellent photo tour of it is available online thanks to Peter Cow and Aranyagardens (Cow, et al., 2011) at **http://www.slideshare.net/PeterCowPermaculture/a-tour-of-martin-crawfords-forest-garden**

5.5 Goals of a Food Forest Ecosystem

"The ultimate goal of farming is not the growing of crops, but the cultivation and perfection of human beings"

Masanobu Fukuoka (1975)

Each person that starts to create a food forest has his/her own characteristic reason to start to plant trees. One of the first scientific research works on the subject of food forests came from D. Jacke and E. Toensmeier. Their work summarizes the goals that are considered as fundamental to food forest creators around the world (adapted from Jacke, et al., 2005):

- **Abundant diversity of delicious, highly nutritious food and other useful products**

The ultimate goal of food forests is to grow crops diverse in their time of growth, harvest, maintenance, niche, taste and character. No two food forests will be the same. The ecological and cultural factors will determine the selection and way of growing the plants in your unique food forest ecosystem. What is the general promise, is that you will be surprised and astonished at what can you grow anywhere on Earth. Discovery of your tastes will create your preference for particular species, leading you to answers as to what to plant more of in your food forest.

Stable, resilient ecosystem that is largely self-maintained

There is a wide range of definitions of stability in ecology (Kimmins, 1997). In the case of food forests it means constancy of function in terms of long standing functioning and resistance to loss of function. The goal of the food forest system is to be resilient and low-maintenance. This is achieved in well-designed food forest systems by using mostly perennial plants and by reducing the amount of human labour in weeding, soil preparation (digging), supplying the nutrients and water, weeding, mowing, insect and disease control.

Minimizing competition (of root system, nutrient & water requirements, shelter, food, etc.) and maximizing cooperation by selecting plants that fill the particular niches and perform multiple functions (fixing nitrogen, producing nutrient-rich mulch, attracting beneficial insects/animals for pollination and plague control, etc.).

Protection and restoration of ecosystem health

"The forests are dying, the rivers are dying, and we are called to act. To return Earth to harmony is to restore the harmonious principles within ourselves and to act as responsible caretakers - to save the forests and the waters for future generations."

Dhyani Ywahoo (2010)

The health of an ecosystem can be described as "the capacity of the land for self-renewal". There are different ways in which food forest ecosystems can contribute to the protection and restoration of ecosystem health. Some of the services of the food forest in regard of overall protection and restoration of ecosystem health can be summarized in the following list (Leopold, 1966):

- Stabilizing and increasing habitat for endangered wildlife, beneficial insects and plants in urban, suburban and rural landscapes
- Improving the ecosystem processes of rainwater infiltration, air and runoff purification, biomass storage, nutrient and soil conservation and development
- Providing locally grown foods, medicines and other products, reducing the impact of global industrial agriculture

Embody beauty, elegance and spirit of the landscape

The varied flowering, fruit and berry yielding landscape invites everyone to take a rest and to enjoy the abundance. For most people, the presence of trees, flowers and birds is a welcome part of their life. Nature has a therapeutic effect on humans and we feel it every time we see a flower. In addition to all the beauty, a food forest is also providing various fresh, delicious and healthy foods.

Improving of economic sustainability

"Growing your own food is like printing your own money"

Ron Finley (2013)

The quote says it all; even if the food forest usually requires a larger initial investment of money and time, once established it is low in maintenances and the economic value of it is literally growing with the years. Mark Shepard's New Forest Farm project in his recent book *"Restoration Agriculture: Real-world permaculture for farmers"* (2013) gives examples of profitable food forest ecosystems that provide in calories for human consumption per hectare 1,5 times as much as the average conventional corn field (Shepard, 2013).

New paradigm of human participation in the ecology of cultural and natural landscapes

In the last century of industrial revolution, humanity made a clear and sure step into the belief that most daily problems can be solved with the help of technological solutions. Now as we are in the beginning of the twenty first century, we still believe so. On the other hand, more and more people around the globe are finding ways to reconnect and participate with Nature through organic agriculture, permaculture, agroforestry, food forestry, and just going for walks in the countryside or birdwatching at the coast.

The challenge for modern humanity is to find a way of achieving completely sustainable interaction with our environment both in meeting our human needs and at same time having respect for the inherent value of other creatures, plants and Nature as whole. Food forestry is one of the paths to meet this challenge in a sustainable, environmentally friendly way.

6 Foodforest Ketelbroek

The first trees at Foodforest Ketelbroek were planted in 2009 on a former agrarian field used for growing corn near the village of Groesbeek in the province of Nijmegen, the Netherlands. The Foodforest Ketelbroek is much more than just a fruit garden where apple and/or pear trees are growing surrounded by grass fields. There are no cows or sheep walking here, but the land is widely colonized by, among others, a stork family, bees, bumblebees, insects, mice, wild rabbits and birds. Ketelbroek is located next to agricultural fields, as seen on its map in figure 8. The borders consist of drainage channels, a stream and open meadows. This food forest, still in its developing stage, represents a developing young forest. Fertilizers, pest-control and periodical pruning are not on the agenda at Foodforest Ketelbroek . Ecological factors adapted from natural forest ecosystems are playing a major role in creating the stability here, creating a low maintenance agricultural system.

The further establishment of the Foodforest Ketelbroek is often undertaken with the willing help of numerous volunteers. For many, the volunteer work might be a reason to see the Foodforest for the first time. The interest that people acquire during their first visit often leads them to follow the project and get to know more about food forests in general.

Without people around, days at Foodforest Ketelbroek are not unlike being at nature reserves where wildlife has sufficient space to be totally undisturbed.

Picture 3 A rare act of maintenance at Foodforest Ketelbroek
(Picture by Wouter van Eck,2013)

Picture 4 One of the excursions at Ketelbroek Foodforest. View of the Reichswald (Germany) in the background
(Picture by Pieter Jansen)

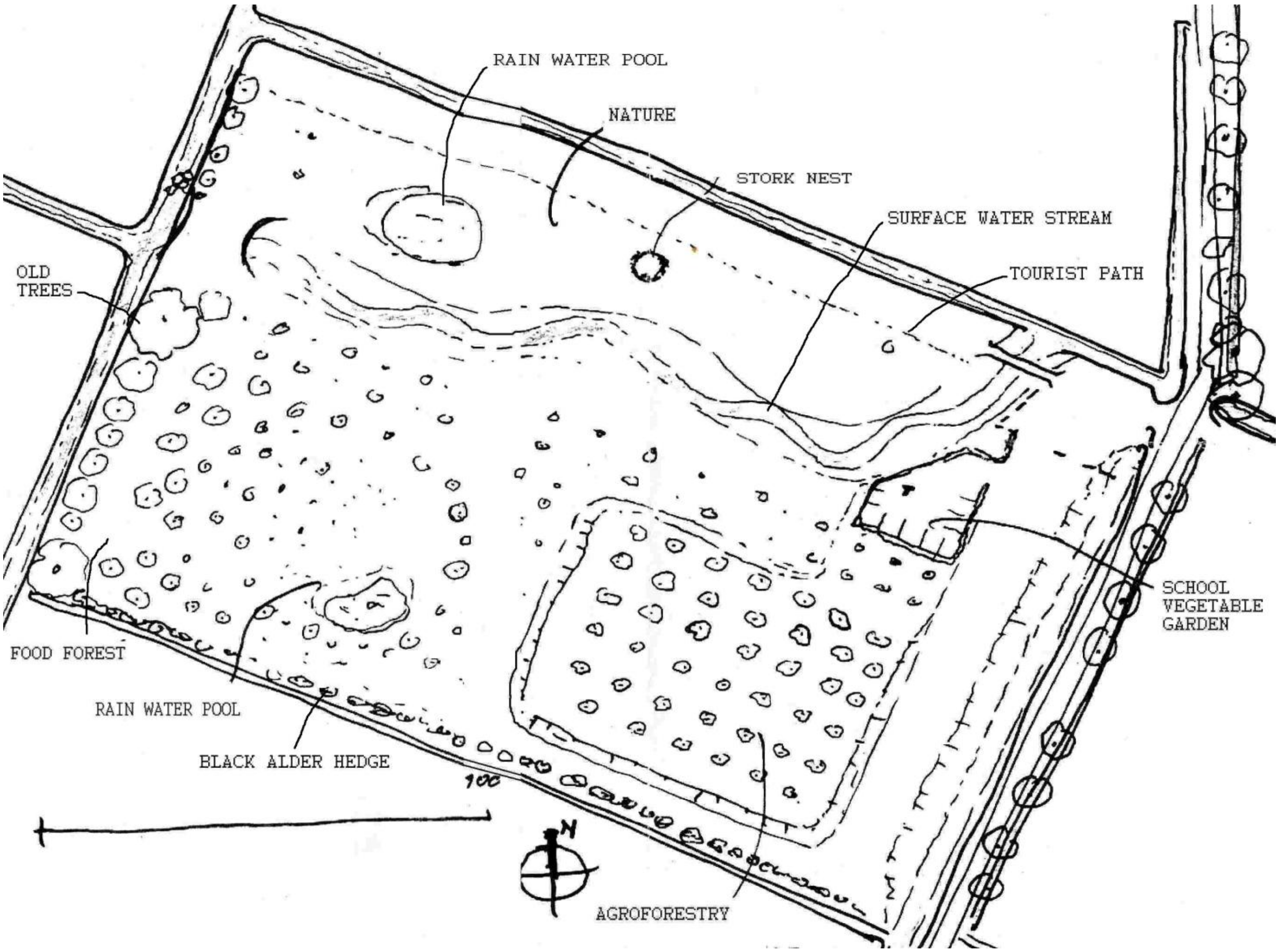


Figure 8 General design map of Foodforest Ketelbroek anno 2014 (by Xavier San Giorgi with adaptations by Anastasia Limareva)

The original design of Foodforest Ketelbroek, which dates to 2009, is presented in the map (figure 8), originally drawn by Xavier San Giorgi. On the western side of Foodforest Ketelbroek there were already old trees growing, such as mature oaks *(Quercus spp.)* and common aspens *(Populus tremula)* which are now already up to 15m high. They protect the food forest from the worst of the wind in this area that comes from the west. Another advantage is that this mature canopy is producing a great amount of organic matter.

The south-west side was originally completely open, so a hedge of fast growing black alder *(Alnus glutinosa)* has been planted there. After 3-4 years, these trees have already reached a height of 2,5 meters. This hedge has a double function: to break the wind and to fix nitrogen. The black alders bind nitrogen and release it to the soil in autumn through their leaves and roots: *"We even have nitrogen delivery here. The south west wind blows the leaves of black alders up to 20m into the food forest!"* smiles Wouter van Eck (Eck, 2014). Creating a clever design that incorporates the natural flows brings less work into the maintenance of the Foodforest Ketelbroek.

On the east side of Foodforest Ketelbroek a piece of land became available for children of De Horst Primary School where every year they can create their annual biological vegetable gardens. This is the only place at Foodforest Ketelbroek, where the ground is uncovered with vegetation, because plants are grown in "traditional" way that incorporates systematic weeding.

There are two food forest systems in the Foodforest Ketelbroek: one with rows that resembles a typical agroforestry plantation, and another, more dynamical, which Wouter van Eck calls "a romantic food forest". In both systems the nitrogen fixing plants are standing at a minimum distance of 20 m from each food-producing tree/plant/shrub etc. Therefore, in the long term the interaction is enhanced between fungi, soil biota and plants. Wouter van Eck points to some Sweetshoot bamboo (*Phyllostachys dulcis*) that is surrounded by two autumn olives (*Elaeagnus x ebbingei* and *E. umbellata*) – evergreen and deciduous shrubs: *"Bamboo is a nutrient demanding plant. When you keep on harvesting the shoots, bamboo needs sure supply of nitrogen and phosphorus. By this, the nitrogen fixing autumn olives are a perfect plant combination".*

In the south side, the Foodforest Ketelbroek has a nice neighbour – the 100 hectare nature reserve of "Het Bruuk". The plants in "Het Bruuk" are partly trees, surrounded by poor wet meadows on peat or sand. The typical blue colour of "Het Bruuk" in spring is caused by purple moor grass *(Molinia caerulea),* blue sedge *(Carex flacca)* and common heath grass *(Danthonia decumbens)* and many more protected Red List species (Nederland, 2014). Such plant biodiversity provides at the same time habitat for an enormous biodiversity of beneficial insects that can now also migrate into Foodforest Ketelbroek.

To provide a better access for the insects from side of the "Het Bruuk", an entrance was created in the black alder hedge of the Foodforest Ketelbroek filled with willow trees *(Salix spp.)* lower in height. Through this trick, the hedge can still break the wind, but the insects can now more freely find the way through the hedge and reach the "promised land" of Foodforest Ketelbroek. Wouter van Eck laughs *"Welcome, but follow the route!"*

The ground of Foodforest Ketelbroek is privately owned by Wouter van Eck and his partner Pieter Jansen. This food forest project in the Netherlands is gaining great popularity in the country. The creation of a walking path on the land of Foodforest Ketelbroek gives an opportunity for local tourism. The eye-catcher of the Foodforest Ketelbroek from afar is a stork's nest which is annually "rented" by a stork couple. The public can observe the storks from a distance or take a walk close to the nest on the specially made path. During the time when the stork couple has chicks, the visitors are kindly asked not to go with more than 3 people on this path at a time and not to disturb the birds while walking. With the rest of the property, it is kindly asked that people do not enter it without the supervision of the owners.

In cooperation with the local Water Authority, an existing surface water stream was reconstructed to make a wider and naturally overgrown one. The two main aims of this project were to provide a water retention space for the neighbouring areas during the peak rainfall, and at the same time, to serve as habitat for beneficial water animals and insects within the Foodforest Ketelbroek.

The other water place created (also in cooperation with local Water Authority) is not connected with other surface water in the area, and is fed by the rainwater and retention through the soil around it. This pool is 2 years old and has already been colonized by frogs. Moreover, the water pool is necessary for frost catchment. When the wind is absent in the spring time, the cold air goes down and it can damage some sensitive plants, like for example young walnuts *(Juglans spp.)*. Being naturally led to the water pool where more is laid down, the frost is "caught" there and the potential plant damage is reduced.

Wouter van der Eck has a nice habit of putting as many rare edible plant varieties and cultivars as possible in the Foodforest Ketelbroek. In some years his edible-plants hobby will need more land. Foodforest Ketelbroek is already almost fully planted.

Visit to Foodforest Ketelbroek in Spring 2014

The ground floor of the Foodforest Ketelbroek is mostly covered with grass and many yellow dandelions. Bumblebees are busy with collecting the nectar. There are also a lot of other insects flying around. Even Wouter, does not know the exact names of all of them!

Surrounded by the flat green pastures or cash-crop monocultures, the Foodforest Ketelbroek is a true oasis of life and biodiversity for humans and wildlife. If we see this on just 2,5 hectares of land, then you can imagine what the land could look like all round! Nature has so much more to offer to humans!

Wow, it´s beautiful here! The stork just brought a big piece of construction material to the nest to put it into the design of its "house". Constant "discussion" where to put the new branch for building the nest might be the only argument a stork couple can have.

From the western side, the old oak looks like a wise old man of the Foodforest Ketelbroek. The oak and other mature trees on this ribbon of Nature, are creating a base for a food forest system, providing shade, nutrients, wind protection to plants and developed symbiotic fungi.

Near the cosy place where I sit, called the Living Room of Ketelbroek, the kitchen herbs are growing like lavas and mints. On the other side, Siberian honeyberries are in *blossom. In the "living room" of Foodforest Ketelbroek, the excursion and course groups and visitors are welcomed with a with tea from a thermos flask brought by bicycle from Nijmegen personally by Wouter van Eck. The small paths through the grass, where only one person in row can walk, Wouter calls "highways". All visitors are politely asked to follow these official paths and not to make unnecessary steps closer to the trees. Walking between and close to the trees and shrubs can compact the ground in the long term - it is not only you that wants to have a look!*

I think that trees are Wouter's children. He has love and care for each plant, that he puts in the soil, like a father that cares for his children. Before an expected possible frost, Wouter goes to Ketelbroek to protect the young trees, vines and shrubs by putting a recycled old sock on each tender branch and treetop. It looks like no plant is unseen by this man. In our society, we think that plants and other non-human organisms have no feelings. I know that Wouter thinks differently about it. Me too.

The maintenance on Ketelbroek is not as in a usual garden. Weeding, digging and pruning are not necessary here. Nature is happy to help: the leaves of black alder are spread by the wind.

Sitting here on Ketelbroek, I am again surprised at how many special edible species can be grown in the Netherlands. Seeing the Foodforest Ketelbroek as an example, it becomes clear that so much is possible, that there is so much to learn and to discover from Nature - for each of us individually and as community.

It is beautiful to see the trees growing. It is like every plant and tree is sending you a smile and saying: "Thank you for giving me a chance! Wait, I will have fruits soon! You are welcome to come and to taste them!". Planted close to each other at the same time, trees have their own tempo of development. Each tree is unique, just as we think that each human is. Watching the plants teaches us humans the natural way of Life, acceptance and patience.

It is beautiful at Ketelbroek, really beautiful! To see such a place gives you great hope and inspiration. I want to plant lots of food forests. You too?!

Picture 5 View of the seven layers of Ketelbroek from the west side with Old Oak in leaf.

Picture 6 Stork couple discussing the interior of their nest

Picture 7 Preparation before the frost. Wouter van Eck with bag of old socks that get a new life as "frost protectors"

Picture 8 Autumn olive (*Elaeagnus umbellate)* blossom in spring

Story and pictures by the author.

15 of April, 2014

7 Ecological Principles of Forest Ecosystems

"Influencing badly only a segment of the interconnected life web of the forest will significantly reduce the productive potential of whole forest ecosystem "

Nicholas Malajczuk, Norman Jones and Constance Neely (1991)

"Food forest design is based on human creativity, natural biodiversity and ecological principles of natural forests. Promises of productive food forest systems are the high biodiversity in yields and very low maintenance"

Wouter van Eck (2014)

"Food forestry is extreme case of agroforestry"

Kees van Veluw (2014)

Natural forests are perfectly fine without human "help" in cutting dead branches, ploughing, weeding or using fertilizers. These principles can be taken also to food forests, as described by Wouter van Eck (Eck, 2014): *"A food forest is a man-made. We work together with Nature and not against. In food forests we want to use the positive effects of natural forests to create a food productive ecosystem"*.

For many of us, natural forests appear as abundant space covered with an uncountable number of trees, a wilderness teeming with life, inspiring our souls and giving power to our spirit. A natural forest receives no artificial fertilizers, fungicides or herbicides, yet it is thriving and feeds a wide range of mammals, birds and insects. No interaction through mowing, weeding, spraying, or digging is required in natural forest ecosystems. No artificial pesticides, fertilizers, herbicides or nasty chemicals need to be applied by us there. Nature does all the work herself without need of any human interaction.

There are fluctuations in the populations of different species, but no matter how hard the situation is, Nature will always seek for a balance. The biological diversity of the natural forests and food forests is dependent on complex interactions both above and below the ground surface. Because of poor land management practices, the survival of species within the forest is often being threatened. Higher diversity of species ensures the stability and balance in a natural forest ecosystem. Therefore natural forest cover is the true indicator of the health of the whole planet Earth. By understanding how forests grow and sustain themselves without human intervention, we can learn from Nature, copy the systems and patterns to model our own forests — ones filled with trees and plants that produce food we can eat. We can design and construct the most sustainable food production systems possible; perfected, refined and cared by Mother Nature herself (Aliades, 2011).

In this work you find the presentation of a selection of the main ecological principles of natural forests that are playing an essential role in food forest ecosystems, as it was conducted from theoretical research on food forestry (Hart,1996; Whitefield, 2002; Jacke & Toensmeier,2005; Crawford,2010) and as it was practically observed during the past 5 years of development at Foodforest Ketelbroek by Wouter van Eck, followed by Xavier San Giorgi.

7.1 Climate

Climate is the characteristic condition of the atmosphere near the earth's surface at a certain place on Earth. It can in essence be regarded as the long-term weather forecast for at least the next 30 years for a specific area. This includes the region's general pattern of weather conditions, seasons and weather extremes like hurricanes, droughts, or rainy periods. The climate of a region will determine which plants will grow there, and which animals will inhabit it. In the Netherlands the maritime temperate climate is dominant, strongly influenced by the oceans which maintain fairly steady temperatures across the seasons. Similar to the Netherlands are other coastlines in Western Europe, in particular the UK, and western North America at latitudes between 40° and 60° north (Köppen, 2014).

Table 2 Overview of hardiness zones, adapted from (Crawford, 2010)

Hardiness zone	Average min.temp (°C)
1	Below -46
2	-46 to -40
3	-40 to -34
4	-34 to -29
5	-29 to -23
6	-23 to -18
7	-18 to -12
8	-12 to -7
9	-7 to -1
10	-1 and above

All information in this work can be applied to design a robust food forest system within the temperate climate zone. The main characteristics of the temperate deciduous forests are the broadleaved trees, that lose their leaves in autumn and form the new leaves in spring. Such forests are best defined as ecosystems being exposed to hot summers and cold winters, with seasonal changes and a diverse range of flora and fauna (Bowes, 2010).

Average minimum temperatures are distinctive for specific hardiness zone, as shown in table 3. Taking into account the hardiness zone of species growing in the temperate climate regions is the first step to decide which plant species can possibly grow in your food forest.

The hardiness zone indicates the minimum average winter temperatures that plants can tolerate. This indicates that plants from zone 5, for example, can be grown also in zones 6,7,8,9 and 10, but do not tolerate and fruit in zones lower than 5. On the other hand, the specific microclimates locally created in a food forest ecosystem can move the potential hardiness zone one step higher in the rating- from 8 to 9 and so on (Crawford, 2010). Foodforest Ketelbroek is situated in hardiness zone 7. Most of the Netherlands is also classified as zone 7, with some areas of 8 or 6. Hardiness zone maps for Europe and North America can be found online free of charge, as **http://en.wikipedia.org/wiki/Hardiness_zone**

7.2 Forest Structure

A ditinction can be made between young developing and mature forest stages. The structure of both can be divided into the following layers according to Bowes (2010):

1. **Upper layer**- consists mainly of species from full grown trees such as for example beeche (*Fagaceae spp.)*, sweet chestnut *(Castanea spp.)*, maple *(Acer spp.),* hickory's *(Carya spp.)*, ash *(Fraxinus spp.)*, walnut *(Juglans spp.)*, lime, basswood *(Tilia spp.)* and elm *(Ulmus spp.)*
2. **Small tree layer**- is made both from saplings from large trees (as above) and species of less tall trees, such as serviceberrie *(Amelanchier spp.),* alder *(Alnus spp.)*, birch *(Betula spp.)*, dogwood *(Cornus spp.),* elder *(Sambacus spp.)* and sourwood *(Sassafras and Oxydendrum spp.)* Variation in specific species differs for different regions.
3. **Shrub layer**- is composed of various smaller woody species such as, for example, hazel *(Corylus spp.)*, witch hazel *(Hamamelis spp.)*, bramble *(Rubus spp.)* and rhododendrons *(Rhododendron spp.)*, heather *(Erica spp.)*, cranberry and blueberry *(Vacinium spp.)*
4. **Herbaceous layer**- consists primarily of perennial plants which often flower before the trees of upper and small tree layers unfold their leaves, and die down before or during the winter. Examples of such plants are wood anemone *(Anemone spp.)*, Dutchman´s breeches *(Dicentra cucullaria)*, buttercup *(Ranunculus spp.)*, bluebell *(Hyacinthoides non-scripta)*, dog´s mercury *(Mercurialis spp.)*, wood sorrel *(Oxalis spp.)*, ground ivy *(Glechoma hederacea)*, bloodroot *(Hepatica* and *Sanguinaria spp.)*, violet *(Trillium* and *Viola spp.)*.
5. **Ground layer**- covered with sometimes very dense leaf litter from the trees or small or middle branches of the trees, or otherwise made of various mosses, liverworts, lichens and fungi species.

As we see from the list above (Bowes, 2010), the underground, climber and aquatic layers are excluded from his description. In reality, all of these layers are commonly present in a natural forest with a wide range of plant species.

The practical advice from Wouter van Eck for a temperate climate food forest design is not immediately to try to get all layers in a food forest at once. Plan so that each plant can have enough light and space to develop and start first with establishing three layers, namely canopy, understorey, and herbaceous layer: *"This is quite easy. The example is a sweet chestnut (Castanea sativa) to form the canopy, with berry scrubs below, like* *redcurrant (Ribes rubrum) and a herbaceous undergrowth, such as woodland strawberry (Fragaria vesca), Salomon seal (Polygonatum spp.) or ostrich fern (Matteuccia struthiopteris). Also plan for the future; ask yourself how the sun or the shade will play a key role in a specific planting place"* advises Wouter (Eck, et al., 2014).

7.3 Sunlight and Shade

Most forest species are adapted to the growth at low light intensity. But in general, an increased light availability seems to have a positive effect on species diversity (Willems, 1999). The dense forest floor is at or beneath the limits of plant growth. Some forest plants have overcome this light deficiency with several physiological solutions, such as, according to Bowes (2010):

- Using shade leaves that are thinner and more efficient at low light levels than sun leaves
- Making use of sunny patches of sunlight passing through the gaps in the canopy. Such places in the forest can provide up to 70-80% of the total solar energy reaching the ground.

The plants of the ground layer in the forest cope with dark conditions by avoidance. Temperate deciduous forests are well-known for their colourful carpets of flowers early in the spring time, such as bluebell (*Hyacinthoides non-scripta*), lesser celandine (*Ranunculus ficaria)* and wood anemone (*Anemone nemerosa*). These plants make use of the light reaching the ground before the trees develop a dense canopy and they die back once the shade is too deep. Summer-greens such as dog's mercury (*Mercurialis perennis)* and sweet-scented bedstraw (*Galium odoratum)* keep their leaves through the summer using the light that comes in through the dense canopy of the forest. Wintergreens and evergreens keep their leaves even in the winter and start to grow as soon as spring conditions allow and continue to grow into a warm late autumn after the leaf fall. Such plants include wintergreen wood sorrel (*Oxalis acetosella*) and primrose (*Primula vulgaris)* and evergreens such as ivy (*Hedera helix)* and holly (*Ilex aquifolium*) (adapted from Poorter et.al 2005).

The problem of shade is also faced by young tree seedlings which want to make their way through in the natural forest. They have to grow up through dark layers of vegetation before reaching the canopy. The difference in how much shade can be tolerated by seedlings and saplings of different tree species is tremendous. Typical temperate climate tree species such as European beech *(Fagus sylvatica)* and sugar maple *(Acer saccharum)* are very tolerant of deep shade, while birches *(Betula spp.)* and poplars (*Populus spp.)* grow best under high light conditions. However the ability to tolerate shade can change through the lifespan of a tree, so some tree species are more shade tolerant as seedlings than as adults.

When tree seedlings grow upwards in a forest, there can be strong competition for light. Whichever seedling reaches the light first might dominate for decades. A common strategy is to have a seedling bank under the tree, such as European ash *(Fraxinus excelsiour).* Here, below the mother tree, the young plants survive in low light conditions, waiting for rapid growth when an opening in the canopy appears, which happens if the old tree suddenly collapses (Poorter et al., 2005). Keeping the canopy open is the main difference between natural and food forest ecosystems. More about adjustment is described in section 7.10 *Succession*.

The low average temperature in a temperate climate and relatively low sunlight per surface unit area forms one of the main differences with the tropical climate, where the temperature and sunlight availability are much higher. *"So even if a temperate food forest is a productive ecosystem with high biodiversity and high production, it will never become as abundant as the tropical food forest"* concludes Wouter (Eck, et al., 2014)

7.4 Wind

"The wind is of a greater importance than we might think. Thinking with Nature is also thinking in which direction the wind blows"

Wouter van Eck (2014)

The predominant wind direction in the Netherlands is southwest (Köppen, 2014). Within the food forest wind can have an influence on many aspects (Eck, et al., 2014):

- Blowing/spreading the nitrogen rich leaves from nitrogen-fixing trees/shrubs
- Increase of humidity evaporation with windy conditions and decrease with less wind
- Affecting the yield - too much wind makes it difficult for pollinating bees and other insects to attach to flowers
- Affecting the stability and straight growth of the plants- with more wind, trees and plants can become lees straight than expected, needed, or wanted
- Affecting the temperature of the air and soil- the temperature becomes lower (with more wind) or higher (with less wind)

On Foodforest Ketelbroek several natural windbreaks were established, which have successfully reduced the power of the predominant southwest wind.

7.5 Water

Water is of a great importance to overall forest ecosystem health and productivity. Unfortunately the availability and quality of water in many regions of the world are more and more threatened by overuse, misuse and pollution.

With regard to forest ecosystems, on the global scale, small changes in precipitation produce major variations in the type of forest able to grow in specific area. On a smaller scale the foresters are interested in catchment areas (or watershed) and water yield and quality. Catchment areas can be described as a hydrologically discrete area that feeds its water into a main river system (Thomas, et al., 2007) as depicted in figure 9.

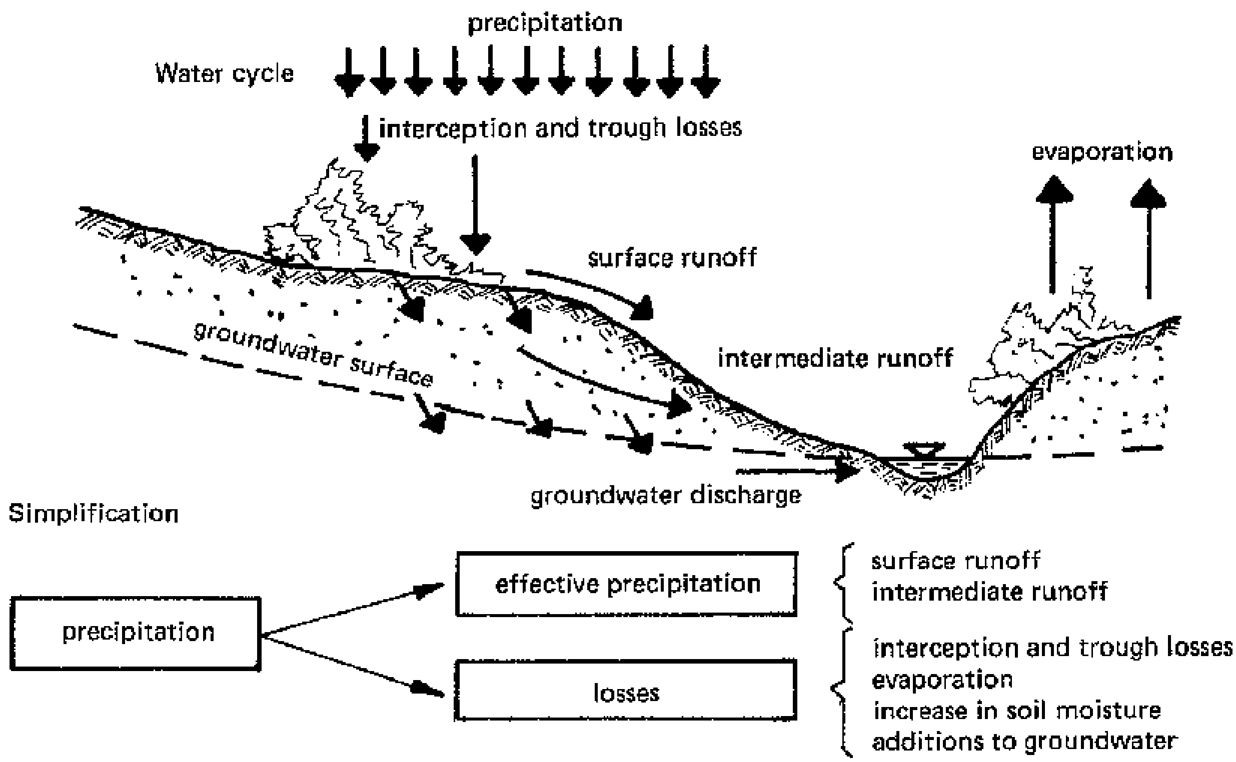


Figure 9 Hydrological processes of water cycle on forested hill slopes (Lauterjung, et al., 1989)

Maintaining high water quality is where the forests make their most significant contribution to the hydrological characteristics of watershed ecosystems. This is achieved through minimization of soil erosion on site, reduction of sediment in water bodies (wetlands, ponds, lakes, streams, rivers) and trapping or filtering of other water pollutants in the forest litter (Calder et al., 2007).

More than this, research conducted in the Melbourne water supply catchments demonstrates that the age of the forest determines the amount of water catchment runoff (Vertessy et al., 1998).

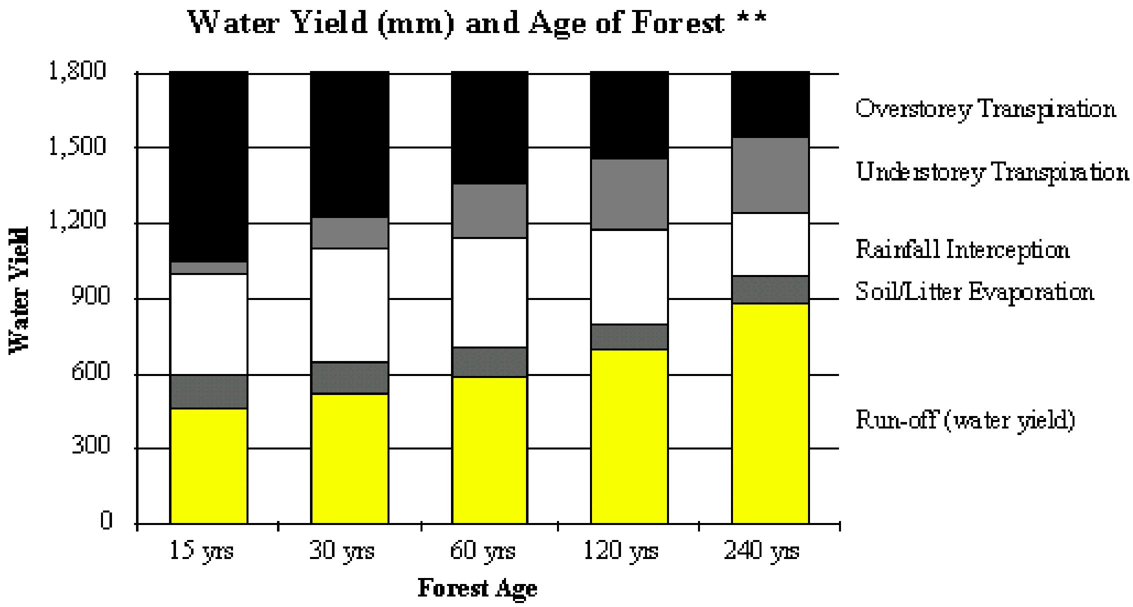


Figure 10 Water balance for Mountain Ash forest stands of various ages, assuming annual rainfall of 1,800mm (Vertessy et al., 1998)

As depicted in figure 10, older forests have greater yields of run-off water catchment and understorey transpiration. Conversely, rainfall interception and soil/litter evaporation is less than in young forests, creating overall positive conditions for development of vegetation and wildlife in the forest. Even though the research in Melbourne was conducted in temperate tropical climate, its conclusion likely applies to temperate deciduous forests too". Understanding Nature is very often beyond the abilities of humans. Therefore, by disturbing the natural balance in one way such as by clear-cutting of the forest on a large scale while promising great yields of cash crops and economic growth, simultaneously we disturb the natural balance in many more ways, unlocking problems like erosion, landslides, floods, etc.

7.6 Soil

Soils are the product of the integrated effects of five soil forming factors: climate, parent rock, vegetation and associated organisms and time (Thomas, et al., 2007). These factors determine the conditions under which all physical, chemical and biological processes within the soil are operating to produce the layers of new soil. Because not every aspect of natural soil formation can be enhanced directly by human intervention (such as climate, parent rock and time), the vegetation and its associated organism establishment is the only place where the food forester can make his contribution.

The enhancement of fertile soil formation processes is one of the key aims for creation of a productive food forest ecosystem. The task of a food forest designer is to do so by looking at how soil formation takes place in natural forest and to help it with additional planting of nitrogen fixing trees, spreading the nitrogen rich cuttings of shrubs or leaves and care for the mycorrhiza development by avoiding frequent soil disturbance.

Soil horizons

The knowledge of soil profiles and their texture will aid you in learning how to live with and how to improve the soil in your food forest ecosystem (Jacke, et al., 2005).

For better observation and eventually knowledge about the soil texture, the soil profile can be obtained with the help soil drill. By this means, the constructed soil horizons overview will allow you to determine a specific soil texture and possible particle size distribution (with the help of a professional laboratory) in each of the horizons.

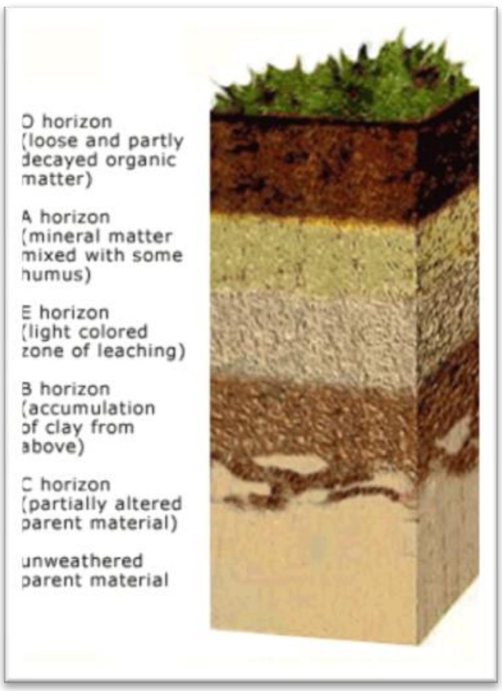


Figure 11 Hypothetical soil profile (UVM, 2014)

Soil scientists recognize four basic soil horizons, characteristic for mature temperate deciduous forests (Biology, 2014), as depicted in figure 10:

1. O- organic matter
2. A- topsoil
3. E- eluviation layer
4. B- subsoil
5. C- substratum
6. D- bedrock

Soil texture refers to the amount of sand, silt, or clay that a particular soil contains. Therefore it is one of the most important physical soil properties because it influences the ability of a soil to provide water, nutrients, and aeration necessary for plant growth. Soil type is the important factor affecting its structure, water holding capacity, vegetation and associated organisms composition and the available nutrients for the plant growth (Berg, et al., 2001).

Basic soil type characterization relevant to the food forests is as follows (adapted from van Eck & Giorgi, 2014): sandy and loam, loess or clay rich soils. At Foodforest Ketelbroek these basic soil types are present with considerable gradients between them. Recent soil works removed some upper layers of the rich soil from places such as constructed water pools and relocated them to other locations where trees with deep root systems had been planted, such as sweet chestnuts *(Castanea sativa)* and persimmons *(Diospyros spp.)*. A description of four main soil types is as follows:

Sandy soil

A sandy soil feels gritty and falls apart easily if formed into a ball when moist. Soils with high sand and/or gravel content let the water through very fast, potentially creating a humidity shortage for the plants. Such conditions make the establishment of trees and other plants more difficult and intensive in maintenance, although a mixture of sand and high humus content will provide fertile conditions for many plant species.

Loam rich soil

Loam soil is composed of sand, silt, and clay in relatively even concentrations, considered ideal for agricultural uses. Loam soils generally contain more nutrients and humus than sandy soils, have good infiltration and drainage, and are easier to till (during planting) than clay soils.

Loess rich soil

Loess is yellowish, brown silt-rich sediment which tends to develop into very rich soils because of rapid weathering. This soil type, formed by the accumulation of wind-blown dust, is present in the Netherlands, mainly in its southern part.

Clay rich soil

Rich clay is full of nutrients for plants, but is difficult to till (during planting). Very heavy clay also makes plant growth establishment problematic. A compaction of clay soil (due to agricultural uses of heavy machinery on the land etc.) creates an even more difficult combination. The way to improve this type of soil is to constantly increase the organic matter content and enhance the humus formation.

Acidity and alkalinity

Soil acidity and alkalinity are the most commonly measured soil chemical property detected by a pH test. Avoiding laboratory test, pH can be privately measured using one of the commercial pH grade soil kits, such as for example a "ECOstyle© pH-Bodemtest" for the Netherlands (ECOstyle, 2014). Acidity is important for plant nutrition due to its influence on biodiversity of soil organisms and availability of plant nutrients such as nitrogen, calcium, magnesium, phosphorus, potassium, sulphur, iron, zinc, manganese, copper, cobalt, molybdenum, and boron. The majority of agricultural crops and many hardwood forest species have optimal nutrition when soil pH = 6.0-7.0 (Seiler, 2014).

Some plants are naturally adapted to very acid soil conditions (pH < 5.0) (Seiler, 2014) and do tolerate and eventually require the acid soil. Such species include Ericaceae family (blueberries, cranberries, *Gaultheria spp.*), the strawberry tree *(Arbutus unedo)*, pines *(Pinus spp.)*, yews *(Taxus spp.)*, rowans, whitebeams and service trees *(Sorbus spp.)* and hawthorns *(Crataegus spp.)*. Blueberries and cranberries can also tolerate sandy soils, but will have no chance in clay ground (Crawford, 2010).

High alkalinity of the soil is also not preferable for most edible species. But there are species that do prefer slightly alkaline (pH = 6.5 - 8.0) conditions (Seiler, 2014). These species include beech *(Fagus sylvatica),* black locust *(Robinia pseudoacatia)*, Cornelian cherry *(Cornus mas)*, hazel *(Corylus avellana),* hawthorns (Crataegus spp.), holm oak *(Quercus ilex)*, elders *(Sambucus spp.)*, Siberian pea tree *(Caragana arborescens)*, service trees *(Sorbus spp.),* redbuds *(Cercis spp.)* and yews *(Taxus spp.)* (Crawford, 2010).

The ideal soil for most kinds of edible species is a deep, well-drained loam, slightly acid at about pH 6,5-6,7 (Whitefield, 2002). In reality, the plant growth will depend on the degree that the available soil differs from this ideal. As an example, an apple tree will grow less vigorously in a heavy clay or light sand than in medium loam. Working for a constant increase of organic matter content in the soil will improve any bad soil conditions in the long term. Therefore an establishment of sufficient canopy tree layer is an essential part of the food forest as it delivers annual free organic material.

Humus

"Humus is the product of living matter and the source of it"

A. Thaer (1808)

In naturally developing forests, the decomposition of the soil humus must keep in step with the addition of fresh residues from forest vegetation. When any process becomes slower, the one following (dependent on the first one), also gets slowed down, and the other way around, and so on and so on. In such circumstances, the rate of the tree growth in the forest will diminish (Waksman, 1938). Any disturbance to the process of humification will lead to potential disorder in the whole forest ecosystem (Rusanov, et al., 2009). Therefore humus formation plays an important role in the productive and healthy forest and food forest ecosystems.

The functions of humus in the soil are of physical, chemical and biological origin (Weber, 2014):

- **Physical**: : modifying the soil colour, texture, structure, moisture-holding capacity and aeration
- **Chemical**: influencing the solubility of certain soil minerals, forming compounds with certain elements which renders them more readily available for plant growth, thereby increasing the buffering properties of the soil
- **Biological**: serving as a source of energy for the development of microorganisms, as well by making the soil a better medium for the growth of

higher plants and by a supply of a slow but continuous stream of nutrients for them

The forest soils are annually fed with a considerable amount of organic matter, produced by the aboveground vegetation. The total aboveground biomass (dry weight of organic matter in an area) for temperate deciduous forests is typically 150 to 300 metric tons per hectare (Smith, 2014). Establishing the high productive canopy layer is a guarantee of sufficient organic matter and therefore high humus content, naturally produced on site in the food forest. Therefore the need of external delivery of organic matter in the form of compost is not necessary in a well-established food forest ecosystem.

There are even tree species that enhance the humus formation. Research in Belgium after 20 years of forest development on a formerly grassland sandy-loam soil showed a significant rise of the population of earthworms, the thickness and quality of the humus layer and even of a decrease in soil pH after planting of the species wild cherry (*Prunus avium*) and large-leaved-lime (*Tilia phtyphyllos)* (Muus, et al., 1992). These species have already found their way into food forests because of their edible produce: for wild cherry it is sweet cherries and aromatic leaves, while for large-leaved-lime it is the excellent big salad leaves.

When the students from the Dutch Ecological Research Institute NIOO were visiting Foodforest Ketelbroek they shared some of NIOO research results that showed that willows are able to raise the amount of organic matter in the soil by up to 1% annually, which is much more in contrast to other pioneer plants. Wouter van Eck (Eck, 2014): "*Such great rising up in humus is an ideal step towards creating a healthy and fertile soil. It is also wise to plant willow species with different flowering times, supporting by this the pollinator's populations*". An increase in organic matter not only makes the soil more fertile, but it also leads to better water management, keeping the water in the ecosystem and creating good humidity of the soil. "*This is the job that pioneer species do for you"* Wouter van Eck explains.

7.7 Nutrient cycles

Trees require up to 20 essential nutrients for survival, growth, maintenance, and reproduction. Carbon, hydrogen, and oxygen are obtained from carbon dioxide and water. Six nutrients are required in relatively large amounts (macronutrients): nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. These macronutrients are obtained from the soil. Micronutrients, or those required in small amounts, are boron, chlorine, cobalt, copper, iron, manganese, molybdenum, silicon, sodium, vanadium, and zinc. These are also generally obtained from the soil (Seiler, 2014). To maintain a self-fertilization of the soil, mineral-accumulating species can be selected and planted in a food forest. An example of such plants is given in table 5.

Table 3 Overview of minerals accumulating plant species, used in food forest ecosystems (San Giorgi, Xavier; Eck, Wouter van, 2014) (adapted table 5,4, page 187 Volume 1 and appendix 3, page 535-536,Volume 2, Jacke & Toensmeier, 2005)

English name	Botanical name	Nutrients
Dandelion	Taraxacum officinale	Ca,K,P,Cu,Fe,Mg,Si
Nettle	Urtica dioica	Ca,K,P,Cu,Fe,Na,N
Dock	Rumex spp.	Ca,K,P,Fe,Mg
Horsetails	Equisetum spp.	Ca,Co,Fe,Mg
Watercress	Nasturtium officinale	Ca,K,P,Fe,Na,S
Comfreys	Symphytum spp.	Ca,K,P,Fe,Mg,Si
Roman chamomile Black walnut Hickory tree Birches	Chamaemelus nobile Juglans nigra Carya ovate Betula spp.	Ca,K,P
Limes	Tilia spp.	Ca,K,Mg
Vetches	Vicia spp.	K,P,N

Picture 9 Flowers and leaves of Siberian comfrey *(Syphytum azuraum) at Foodforest Ketelbroek*

Reviewing of the table above shows the significance of plants that are considered as “weeds” and their importance for a fertile soil within the food forest ecosystem.

Therefore the weeds are not removed from the groundcover of Foodforest Ketelbroek. Weeding is excluded from the maintenance list of food forest ecosystems in general.

Soil organisms

Soil organisms are extremely diverse and contribute to a wide range of ecosystem services that are essential for the sustainable functioning of natural and managed forest ecosystems. The soil organism community can have direct and indirect impacts on land productivity. Direct impacts are those affecting crop yields immediately. Indirect effects include participating in carbon and nutrient cycles, soil structure modification and food web interactions that generate ecosystem services that ultimately affect soil productivity (Barrios, 2007). In figure 12, the generalized forest soil food web is depicted.

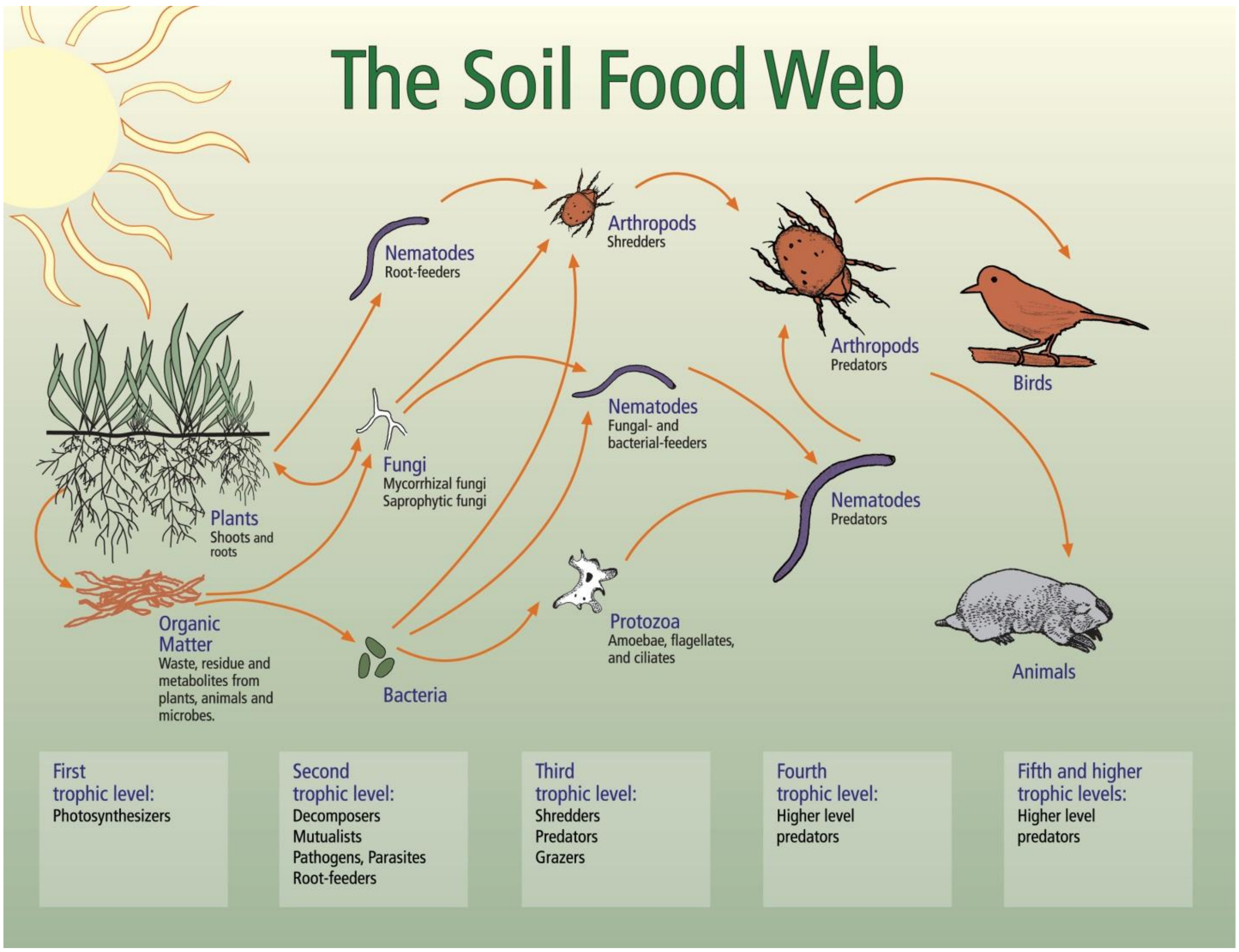


Figure 12 Generalisation of the soil food web (Ingham, 2014).

Although all groups shown in figure 10 have important roles in the forest soil web, up to 80 to 90% of the total metabolic activity in the food web is attributable to fungi and bacteria. This fact amplifies a need of special attention to fungi and bacteria development for the sake of a healthy and fertile soil and soil food web (Swift, 1999).

Five gifts of the forest soil food web

A vital and healthy soil food web delivers a great amount of ecosystem service to the food forest. Most of soil organisms are beneficial for fertile soil maintenance, but they cannot live long without plants above ground. More than that, soil organisms tend not to like soil disturbance, lack of oxygen, excessive wetness, or high nitrate or chemical levels. The negative effects on non-target soil organisms were determined for each artificial pesticide so far tested (Ingham, 2000). In general, it can be concluded that the use of chemical pesticides as part of conventional agriculture and non-organic forestry decreases the soil fertility tremendously. Left undisturbed (without ploughing), the interconnected soil food web can increase the soil fertility without great external inputs. Why should we choose the last option? Healthy soils have some great gifts to offer to us. Therefore the support of soil fertility is the main job of each food forester. How? Not to weed, plough, use any fertilizers, but instead to plant sufficient nitrogen-fixing and mineral-accumulating plants and avoid stepping beyond the paths in the food forest too often so as to keep the compaction of the soil to a minimum.

The following list of five gifts (adapted from Jacke & Toensmeier, 2005, previously adapted from Ingham (2000), gives the overview of advantages that are connected with fertile soil within the food forest ecosystem:

Increased nutrient retention, cycling and availability to plants

Soil biota is comparable with living, dynamic nutrient "containers" that retain the nutrients from organic and inorganic soil particles and deliver them to the right plant. Each specific plant variety releases its own unique mixture of sugars, carbohydrates and proteins which attract and support a unique mixture of soil biota.

Improved crop quality

The research on strawberries showed that plants grown in soils with a healthy soil food web contained three to seven times more protein than strawberries from the poor soil food webs. The improvement of sweetness and flavour in the first ones was an additional aspect too (Ingham, 2000).

Pest and disease suppression

As Martin Dickman noticed: *"In Nature, plant disease is the exception, rather than a rule"* (Dickman, 1993). In healthy soils there are sufficient soil biota that compete with disease and pest organisms for niche space or directly consume them. The situation becomes reversed when there is an insufficient amount of such "pest-controllers". In a study with cucumber diseases, it took 12 different beneficial bacteria species to control one pathogen over the duration of one growing season. During the other season, with slightly different weather and soil (humidity, humus and soil biota content, etc.) it might take even more than 12 different bacteria species for the same aim (Corwallis, 1999).

- **Enhancing soil biota and improving soil structure: drainage, aeration, water holding capacity**

Although it is commonly believed that high organic matter content is responsible for drainage, aeration and water holding, there is more scientific evidence that without soil organisms nothing of this would be possible as well (Fuhrmann, et al., 1998).

- **Decomposition of toxic chemicals and pollutants**

A well-functioning soil food web contains sufficient and diverse soil organisms (in particular microbes) to break down the toxins, chemicals and pollutants. More efficient decomposition means less contamination of groundwater and streams.

Concluding from information above, it becomes clear that supporting the soil organisms is one of the keys for sustaining a healthy fertile soil within the forest and food forest ecosystems.

7.8 Fungi

Fungi are species of a separate Kingdom which are dependent on living or dead organic matter for their growth. There are far more fungal species in the whole world than there are plants with developed lignified tissues (the xylem). They outnumber them by a ratio of at least 6 to 1 (fungi vs plants with xylem, respectively). Around 200,000 species have so far been described and it is thought that there are in total 1,5 million species out there on our planet (Hawksworth, 1991).

The fungi receive products of photosynthesis from the higher plants while supplying water and nutrients in return. The main role of the fungus appears to be in increasing the effective surface area of roots for nutrient absorption. Rousseau et al.(1994) found that fungus contributed up to 80% of the absorbing area of pine seedlings, showing a high dependence between fungi and plant. Different sorts of fungal communities and their place in the forest and eventually food forest ecosystems are saprothophs, parasites and mycchorizal fungi, described further below.

Saprothrophs

These fungi obtain their energy from dead organic matter which they digest. Many of them are completely harmless and even edible, like field mushroom (*Agaricus campestris*), but others cause plant damage, such as dry rot fungus (*Serpula lacrymans*). Nevertheless, most productive edible fungi that can be grown in the food forest on stumps or logs are the saprothrophs, such as shiitake *(Lentinula edodes)* or oyster mushroom (*Pleurotus ostereatus).*

Parasites

These fungi are dependent on living or dead organic matter for their life through heterotrophic nutrition, thus attacking living organisms such as fungal parasites that cause Dutch elm disease and chestnut blight. An edible example in the forest is honey fungus *(Armillaria spp.)* which spreads even on the healthy trees and shrubs (Crawford, 2010). Thus in the natural forest it can be widespread; you do not want to invite such a "guest" into the food forest ecosystem.

Mycorrhiza

These fungi form a beneficial association between plant roots and fungi, and they are very famous for this ability. They are found in over 80% of vascular plants. Only members of *Proteaceae*, rarely if ever, form mycorrhiza. Mycorrhiza benefit growth through uptake of 'immobile' nutrients such as phosphorus, zinc, copper and ammonium, usually present in soil in low concentrations in soluble form. Mycorrhizal fungi are usually extremely sensitive to excessive growth of other (saprophytic) fungi. The mycorrhizal fungi can be classified into two broad groups: ectomycorrhizas (ECM) and endomycorrhizas (EDM). EDM mycorrhizas are devided again into three subgroups, where vesicular-arbuscular mycorrhizal fungi (VAM) is the most common type in regard to the forest ecosystem. There are also trees that can form both ECM and EDM (in VAM form) associations, such as alders *(Alnus spp.)* and willows *(Salix spp.)*, as shown in table 6. In following chapters the species associated with ECM and EDM will be discussed in relation to the food forest (Evans, 1982).

Ectomycorrhizas (ECM)

Ectomycorrhizas develop an external fungal sheath around the fine root tissue and penetrate with its fungus between the cells of the tree root. Trees forming ECM include most of the commercially important species in the temperate and boreal forests and 70% of the species planted in tropics(Evans, 1982). Worldwide, there are more than 5000 species of fungi that form ECM with over 2000 species of woody plants (Janos, 1980). ECM have been shown greatly to enhance nutrient uptake, especially the uptake of phosphate, by plants possessing these mycorrhizas (Harley, 1959).ECM can form between 20 and 39% of the weight of tree roots (Abbott, et al., 1985). Moreover, tree species such as pines and oaks grow poorly on sites with total absence of ECM, because they are missing their indigenous (coevolved) fungi (Mikola, 1970).

Endomycorrhizas (EDM)

Endomycorrhizas are divided into 3 subgroups. From these subgroups of EDM, the vesicular-arbuscular mycorrhizal fungi (VAM) are the most common type in regard to the forest ecosystem, as mentioned previously. VAM enters the root cells causing no noticeable structural changes on the outside of the root. Therefore VAM is associated with legumes, cereals, temperate forest trees, tropical timber trees, as well as horticultural and ornamental crops (Barea, 1991). VAM hyphae found in the top 5 centimeters of the soil around subterranean clover roots were up to 30 meters in length for every centimeter of root length (Abbott, et al., 1985). VAM roots with a network of mycelia explore much larger soil volume than non-mycorrhizal roots and enhance the uptake of nutrients into the plant tissues (Powell, 1984).

Any change in the forest floor litter will affect populations of ECM and VAM fungi, since they predominate in the fine roots and organic layers of the soil (Trappe, et al., 1977). Greater variety of trees or weeds left on site will contribute substantially to maintenance of mycorrhizal fungi by providing essential nutrition and variety of habitats, by this means promoting the fungal diversity (Harvey, et al., 1982). In the long term the maintenance of mycorrhiza species may require continuation of natural patterns of succession, giving Nature time and space for its development. Forest practices that reduce the biological diversity through intense organic matter loss (cutting and taking away the biomass), compaction (by putting heavy machinery on the land) and erosion, have negative impact on mycorrhiza diversity (Parke, 1982).

Table 4 Important plant families and selected tree genera of temperate climate species known to form mycorrhizal associations, adapted from Malajczuk et.al.(1991)

Family	Genus	English	ECM	EDM (in VAM vorm)
Betulaceae	Alnus spp.	Alders	X	X
	Betula spp.	Birches	X	X
Ebenaceae	Diospyros spp.	Persimmons		X
Fagaceae	Fagus spp.	Beeches	X	
	Quercus spp.	Oaks	X	
Juglandaceae	Carya spp.	Pecans, hickories	X	
Rosaceae	Malus spp.	Appels		X
Salicaceae	Salix spp.	Willows	X	X

In general, within the food forest systems the beneficial mycorrhizal associations have the following ecosystem services (Crawford, 2010):

- reduction of drought and temperature stress
- improvement of nutrient uptake and transfer to plants
- protection from soil pathogens

Taking again into the account that mycorrhiza becomes damaged by soil disturbance activities (such as ploughing, digging etc.) and excess fertilization (Zahran, 1999) it is important to minimize or exclude such activities on a large scale in forests and food forests. The reason that many wild edible species of mycorrhizal fungi could not be cultivated for greater yields for many years, is that most agricultural soils have damaged mycorrhizal webs, and young planted timber tree plantations do not yet have a well-established mycorrhiza. Such examples are boletus (*Boletus spp*.), chanterelle (*Cantharellus cibarius),* russula (*Russula spp*.) and truffle (*Tuber spp*.). The old oak trees near Foodforest Ketelbroek and the nature ribbon area, which was not ploughed intensively and compressed with heavy machines, have potentially already established ECM and VAM. During the past five years of the existence of Foodforest Ketelbroek, these mycorrhrizal fungi may have spread further to colonize greater areas within the food forest ecosystem. By this, the "do-as-little-as-possible-maintenance" is in theory leading to a healthy and strong mycorrhiza web development.

Picture 10 Penny bun boletus *(Boletus edulsis)* (Assyov, 2014)

Picture 11 Chanterelle (*Cantharellus cibarius*) (2014)

Picture 12 Violet russula *(Russula Parazurea)* (Vianello, 2014)

Picture 13 Summer black truffle *(Tuber aestivum)* (Lexing , 2014)

An effort on tree selection and site preparation without care for mycorrhizal fungi cannot lead to a holistic and fully productive forest ecosystem. The challenge of re-establishing a productive food forest ecosystem is also a challenge of restoration of mycorrhizal populations and biodiversity.

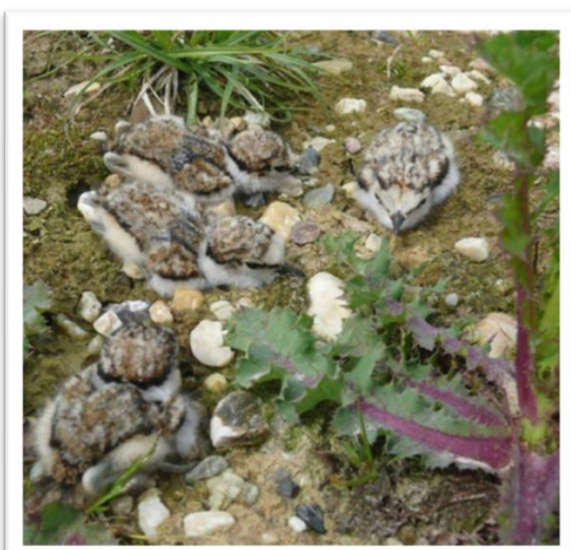
7.9 Beneficial Animal Interactions

"In Nature, diversity creates stability"

Wouter van Eck (2014)

A high biological diversity of animal species creates stability and plague resistance in an ecosystem. The task of a food forest designer is to create and attract a wide range of beneficial animal species within the food forest ecosystem. Complex interactions create a network between different plants in which they stimulate each other's growth and neutralize each other's diseases and other antagonistic factors. Coexistence is achieved by niche differentiation: such as separation of diets, activity periods and foraging locations between the species (Buckley, 2003).

Deforestation, unnatural monoculture landscapes of agricultural crops or grass pastures, is directly robbing wild animals of sources of their natural biodiverse food. The attacks of birds and animals on agricultural crops and rising plagues and pests are the consequences. The goal of a food forest is the creation of stable, resilient and self-maintaining communities of functional biodiversity with broad interrelationships and interdependencies of all organisms. Here follow stories of animal interactions, as they took place at Foodforest Ketelbroek, noted from personal communication with Wouter van Eck (Eck, 2014).



Picture 14 Little –ringed plover (Charadrius dubius), at June 2013 at Foodforest Ketelbroek

Caterpillars and Birds

Wouter van Eck: *"When we got Ketelbroek the soil was just a bare field. In the winter the biodiversity was zero and in the summer it was one, represented by corn monoculture. Not many animals can live in such circumstances rather than being a plague. On Ketelbroek we planted fruit trees, such as mostly apples and plums, quite soon in the first autumn. But there was no balance yet. And in the first spring we had an invasion of caterpillars on young trees - every single leaf was eaten. The only green that was visible was green caterpillars! Sometimes we took the caterpillars and "moved" them to* *caterpillar-poor natural zones. The start of the Foodforest Ketelbroek was not looking great. But as the spring continued many small birds started to come to Ketelbroek. Since there were some shrubs; they started to build nests in them. And the caterpillar plague was over. The majority of observed small birds were insect-eating birds. And whenever the baby birds were hungry, the mama and papa birds were going to our caterpillar trees. Since then there are still some caterpillars on Ketelbroek and it is lovely to see the resulting butterflies. But they are not becoming a plague any longer. They are incorporated in the system of the natural food chain. The numerous insect eating birds found the Foodforest Ketelbroek and colonized it. It is great to see it! And we do not need DDT!"*

An example of such caterpillar-hungry birds can be seen in picture 13, where the young birds of little-ringed plover (*Charadrius dubius)* are well camouflaged within the landscape of stones and thistles at Foodforest Ketelbroek.

Snails and slugs

Snails and slugs are not particularly popular animals, causing havoc in your vegetable garden, but in the food forest they are not much of a problem. Perennial plants, trees and shrubs, are much more resistant against some nibbling and just grow on afterwards. Wouter van Eck adds: *"By creating water pools, the number of amphibians, such as frogs and toads increased. Then the grass snake (Natrix natrix) came to eat from the abundant frogs and toads. Also mice came, and they eat snails and slugs too. When the mouse population became too high, predatory birds arrived. So you can see how the natural balance develops itself if you do not do too much"* says Wouter van Eck. Due to natural stabilization, many plague populations like snails and slugs on Ketelbroek become "incorporated" in the growing natural food webs.

Mice

The fertility rate of mice is very high: a family of 6 mice can multiply into a family of 60 mice in just 3 months (Critter Catchers, 2014). Wouter van Eck says*: "In the first summer, the population on Ketelbroek exploded. So, in August 2009 we had mouse holes everywhere and something was always moving under the ground. Once we put up a tent and stayed for an evening on Ketelbroek. During the sunset we heard the mice "knocking" on the walls of the tent, being unable to reach their holes as the place was covered with the tent flour. We were again a little bit worried: in the summer the mice might have enough small insects, seeds and roots to eat, but in the winter, the difficult season, there would be not so much to eat and they could start to nibble on tree bark from our freshly planted trees and shrubs. But in one weekend in November there fell lots of rain, so the holes were partly filled up and the mice needed to escape, whereupon they were noticed by hunting birds such as common buzzards, herons, falcons, owls and storks. They all had a feast on Ketelbroek. By this means, the balance was once* *again established. The mice are still on Ketelbroek- but they have never become a plague again since then".*

Observing "caterpillar trees", having a mouse "invasion" or any unexpected plague in the first years in your new food forest should not make you lose faith in your natural way of thinking. Such events are just indicating that the ecosystem is in a state if imbalance and it will need time to find a natural equilibrium. Be patient and keep on planting more trees in your food forest!

7.10 Succession

It can take up to many years to go through even one of step of natural succession. As can be seen in figure 13, the bare ground slowly but surely develops and becomes the deep forest with mature grown climax trees.

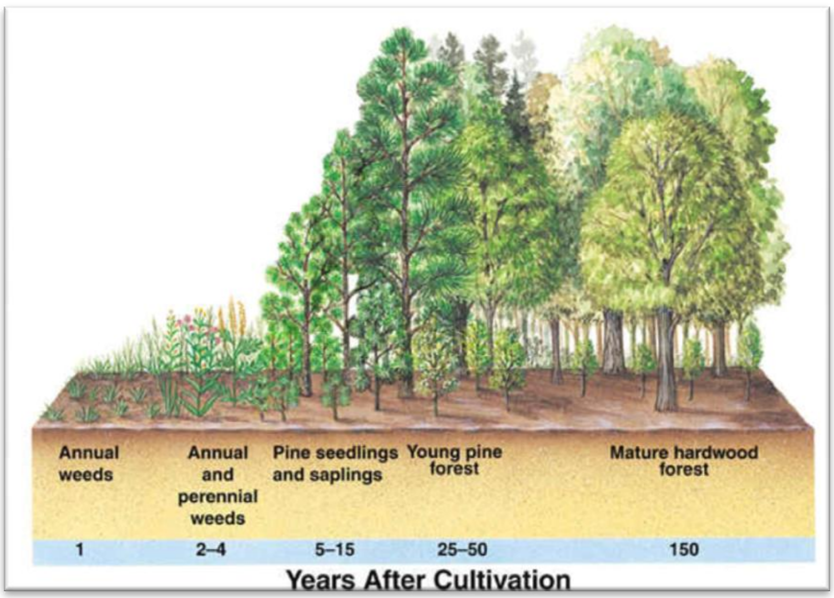


Figure 13 Natural succession development (Fischer, 2014).

In a food forest design, the natural process of succession is often adjusted, because deep forests or bare fields are not immediately ready for the most edible plant species. Therefore, the adjustment of natural succession is made for two main reasons: to increase the light availability and to restore the disturbed soil food web.

Increasing light availability

To increase the availability of the sun in the forest by making the canopy layer more open. The practical research of Martin Crawford´s Agroforestry Trust showed that for the productive food forest system, the young or mid-succession-stage of a natural forest has to be established and maintained (Crawford, 2010). Such succession adjustment is incorporated also in the design of Foodforest Ketelbroek and other projects of Foodforestry Netherlands.

Restoring the disturbed soil food web

To restore the disturbed soil food web (after agricultural uses of the land) by planting nitrogen-fixing trees. There is a ratio of one nitrogen-fixing tree per every 20 square meters of ground in Foodforest Ketelbroek. Lots of nitrogen-fixing trees have multifunctional aims. Willow trees *(Salix spp.)* for example, provide fast and extensive organic matter production and take up the excess humidity if needed, and autumn olive (*Elaeagnus umbellate*) is an excellent nitrogen fixing plant that also provides a great yield of edible berries.

Generally, Wouter van Eck distinguishes (Eck, et al., 2014) three types of plants, planted on Foodforest Ketelbroek:

Disappears

Plant species that will naturally disappear over time when conditions change, like from full sun to full shade for example.

Stayers

Species that will remain part of the food forest system for their lifetime. This sector can be divided in: *talls*, such as apples, pears, cherries grafted on different rootstocks with a lifetime up to 105 years and *halftalls*, often same species as talls, but on a different rootstock, that creates trees with a lifespan of up to 12 years. As Wouter describes the last ones: *"Live fast, die young"*.

Fillers

Species that will be cut and used as wood, nitrogen rich compost, etc.. For example sustainable timber of *Robinia spp.* and different nitrogen fixing trees.

Most disappears and fillers are pioneer species that in natural succession come into the bare field and establish the extensive herbaceous layer and later shrubs and trees. Therefore the pioneers increase the biomass amount, organic matter content (humus), and enhance soil organisms, resulting in creation of fertile soil, suitable for climax species. Pioneer species like goat willow (*Salix caprea*), white willow (*Salix alba*), white alder (*Alnus rhombifolia*), red alder (*Alnis rubra*) and black alder (*Alnus glutinosa*) grow fast and also create wind protected places for other species with increased shade and more moderate temperature.

7.11 Native or Exotic Plants

"Nature does not do mistakes. Humans do"

Sepp Holzer (2012)

Invasive exotic species are considered by the European Environmental Agency as one of the most important direct drivers of biodiversity loss and ecosystem service changes (EEA, 2012). The discussion about native and exotic plant species in the Netherlands took on another dimension due to geological discoveries that were revealed in the sediment of the Maas river, near Tegelen and Reuvers (Mijts, 2014) and Westerhoff et.al. (1998). It is remarkable that fossil remains of plant and animal species found near Tegelen and Reuvers previously native to this region of Netherlands but at present considered as exotic are still native in modern East-Asia and North America. An overview of found plant fossils can be seen in table 5.

Table 5 Fossil remains of plant species found near Tegelen and Reuvers, in the Netherlands (Mijts, 2014)

Latin name	English name	Native to
Actinidia arguta	Hardy kiwi	Japan, Korea, Northern China, and Russian Siberia
Carya ovata	Hickory	Eastern United States and southeast Canada
Castanea sativa	Sweet chestnut	Europe and Asia minor
Juglans cinerea	Butternut	Eastern United States and southeast Canada
Magnolia kobus	Kobushi magnolia	Japan
Vitis vinefera	Common grape vine	Mediterranean region, central Europe, and south western Asia

The main difference between exotic Dutch plants and native East-Asian and North American plants, is that in the case of the first ones, plant remigration after the end of the ice-age was hindered by the Alps in Europe as a barrier for the remigration of species from the South. Therefore, the European region cannot yet re-establish its original biodiversity. All our cherries, walnuts and even oak trees are actually human adjustments of natural succession because they were introduced by Europeans after the ice-age holocausts. Wouter van Eck (Eck, 2014): *"In our food forest projects we give such species a welcome-home treatment! It is very interesting that the insects are not hostile at all against these "exotic" species. For example, a visit to flowers of hardy kiwi (Actinidia arguta) is a real celebration for bumblebees during the spring. The bumblebees probably ask themselves: where have you been all this time, dear hardy kiwi?"*

Picture 15 Hardy kiwi (Actinidia arguta) (Marczyński, 2014)

Wouter van Eck adds:" *In Western agriculture, we find it completely normal to eat the "biodiversity" coming from different continents. A typical Dutch meal consists of potatoes (origin: Peru), applesauce (origin: Kazakhstan) and chicken (origin: Vietnam). So, we have little of really European species included in our daily food. People do often raise the question of native or exotic plant species in the food forest. Some nature-carers really have a meltdown, cutting all sweet chestnuts (Castanea sativa) that appear in the forest of the Netherlands, considering chestnuts "aggressive" exotic species. At the same time, if you look deeper in natural history, the sweet chestnuts were native species in the Netherlands, but disappeared due to the ice-age, and are now coming back naturally and with the help of humans. At the end we can conclude, because food forest is considered as an agricultural system, we as food forester designers have the full right to use useful edible species from somewhere else, as it is done in Western agriculture"*

On the other hand, Sholto Douglas & Hart (1985) report that trees and other plants that are native to a particular region over millennia tend to build a rich ecological association with birds, animals, insects and all small life forms. These bounds are far richer than those of exotic species, even if they were introduced centuries ago. Therefore the presence of old native plant species in the forest, whether natural or man-made, are of greatest value for the biological stability and prosperity of the food forest ecosystem. Using native species and biodiversity of species considered as exotic can both contribute to productive food forest ecosystems.

7.12 Nitrogen-Fixing Plant Species

Natural succession of bare grass field to well-developed forest ecosystem can take up to between 30 and 60 years, dependent upon the types of trees and plants in the area (PSU, 2002). To create productive food forest ecosystem in a reasonable period of time from the human perspective, the natural succession in a food forest is "speeded-up". This is done by planting nitrogen fixing shrubs and trees (mostly pioneer species) between the climax species.

Young developing forest needs high nitrogen concentrations as well as bonded carbon. Planting nitrogen-fixing trees and shrubs provides sufficient amounts of both nitrogen and bonded carbon, which in the case of carbon cannot be said of artificial fertilizers. Also because the artificial nitrogen gets washed off easily by rain and leaches away into the groundwater, the nitrogen-fixing plants that are there are needed to ensure that growth of a developing food forest is not held back. So, even if the ground is rich in artificial nitrogen, you should put nitrogen fixing trees in the design of your food forest. The problem with the presence of artificial nitrogen is that it suppresses the development of symbiotic relationships between the plants (Zahran, 1999)."We do not need your services!" the trees and plants will say to mycorrhiza fungi, thus disconnecting themselves from all beneficial services that fungi can provide. Using artificial fertilizers is like giving to your kids only sugar and never allowing them to try fresh ripe fruits. That's what you do to your plants if you use artificial fertilizers or big concentrations of animal origin manure, even if the second one might be better than the first.

To restore and enhance the interaction between plants and fungi, and at the same time to ensure the sufficient soil fertility, it is therefore important to have nitrogen-fixing trees in your food forest, even if it already has high levels of artificial nitrogen in the soil. That was also done all over the surface of Ketelbroek food forest at a density of one nitrogen-fixing tree or shrub per 20m². Animal manure or ecological fertilizers are absent in food forest ecosystems if you apply such clever design.

Biological nitrogen fixation in the forests occurs through different means (adapted from (Gutteridge , et al., 1998):

- Frankia or Rhyzobium bacterias growing on roots and in degrading litter;
- blue-green algae or cyanobacteria on soil and plant surfaces;
- associations of cyanobacteria with fungi and lichens
- associations of cyanobacteria with higher plants such as liverworts, mosses, cycads and the angiosperm *Gunnera*.

In this work the Rhyzobium and Frankia nitrogen fixation is described more detailed. Both Rhizobium and Frankia bacteria possess special enzymes, nitrogenases, that allow them to transform the nitrogen gas in the air into ammonium which is in turn converted into amino acids.

Many legumes build nodules with the bacterium Rhizobium (fast growing) or Bradyrhizobium (slow growing). Such nodulation fixes gaseous nitrogen thereby utilizing some of the 84,000 tons of nitrogen gas in the air above each hectare of land. Rhizobia move through the soil with a wetting front after rain, so soil moisture levels affect the ability of rhizobia to move along the root system and to colonise young roots. As a result, nodulation of rhyzobia is limited in dry soils (Gutteridge , et al., 1998). There are more than 18,000 species of legumes of which about 7,200 species are woody, so the choice of nitrogen fixers for every climate is huge.

Examples of non-legume plants that perform nitrogen fixation with the help of Frankia bacterium are alder *(Alnus spp.)*, bayberry *(Myrica pensylvanica, M. cerifera)*, sweet fern *(Comptonia peregrina),* sweet gale *(Myrica gale),* Russian olives *(Elaeagnus umbellata and E. angustifolia)*, various *Ceanothus spp.,Casuarina spp., Hippophae etc.* (Tredici, 1995). Because of these abilities, the named plants can be used parallel with woody species that fix nitrogen with the help of Rhyzobium, such as for example Siberian Pea-tree *(Caragana boisii)* and other plants listed in table 6.

In general, all nitrogen fixing plants are sun loving pioneers in early successional stages in the north and south temperate regions. All of these plants thrive best in nitrogen-poor, sandy, swampy soils where little else grows. Their ability to fix nitrogen is a significant factor in their survival under conditions that would be inhospitable to many ordinary plants.

Table 6 Nitrogen fixing plants selection (adapted from (Kitsteiner, 2011))

Food forest layer/height	English name	Botanical name
Canopy (more than 15 meters)	Gray Alder	Alnus incana
	Black Locust	Robnia pseudoacacia
	Japanese Pagoda Tree	Sophora japonica
Understory and big shrubs (between 1-15 meters)	Alder,Italian	Alnus cordata
	False Indigo	Amorpha fruticosa
	Siberian Pea Shrub	Caragana arborescens
	Russian Pea Shrub	Caragana frutex
	Autumn Olive	Elaeagnus umbellate
	Elaeagnus	Elaeagnus x ebbingei
	Sea Buckthorn	Hippophae rhamnoides
	Bristly Locust	Robina hispida
Small shrubs and herbaceous plants (less than 1 meter)	Groundplum Milkvetch	Astragalus crassicarpus
	Mountain Avens	Dryas octopetala
	Lupine	Lupinus species
	Alfalfa	Medicago sativa
	Breadroot (Prarie Turnip)	Psoralea esculenta
	Red Clover	Trifolium pratense
	White Clover	Trifolium repens

These systems of nitrogen fixation are very efficient in recycling nitrogen leached to lower depths in the soil through uptake by deep roots and recycling of leaf fall. By this means, nitrogen becomes concentrated in the litter and upper soil horizons. Disturbing this natural cycle, which conserves scarce nutrients so effectively, can lead to rapid loss of soil fertility. Therefore maintenance of the soil mulch is a very important aspect of maintaining soil fertility around trees and shrubs in natural and food forest ecosystems.

7.13 Time for Growth. Time for Harvest

Entering the forest in search of blueberries, mushrooms or just acorns or chestnuts, we usually find large fields of plants and many old trees yielding a great abundance of what we are searching for. Mostly it is difficult not to get too much from the forest (especially with children) than too little. But the situation is different if the trees are just planted and not yet established. Because many food forests are relatively young (oldest food forest of Martin Crawford of 20 years old) compared to natural ones, trees and plants are not able to produce great total yields of every planted species. Foodforest Ketelbroek is only five years old, so it too has not yet reached its highest productivity. Imagine a young forest of five years old with few mature trees; what would it look like? Such is the situation observed at the Foodforest Ketelbroek.

In general, at any stage of food forest ecosystem, the harvesting time after planting depends on the harvested part of the plant. From experience of Wouter van Eck, in the first three years the harvest was minimal. Wouter van Eck (Eck, 2014) explains: "*Flower and fruit are the produce of the plant, meant to be picked even in the first season. The fruits are meant to go into the world! Gooseberry and red currant are giving berries already after one year. But totally different is the case when you eat shoots or leaves from the plant. Plants are solar engines and roots and leaves are solar energy panels and storage of nutrients. Therefore plants like ostrich fern (Matteuccia struthiopteris) (picture 16), udo (Aralia cordata), Salomon seal (Polygonatum biflorum) (picture 17) and Japanese butterbur (Petasites japonicas) (picture 18) need first to be well established before the first harvest. In the case of ostrich fern, the harvest needs to be done wisely, keeping enough new leaves for the plant. In the case of Salomon seal, we can only harvest the shoots once or twice in spring, and leave enough of them to unfold into leaves, to keep the plant strong. If we eat young shoots and leaves in the first three years, we potentially weaken the plant and decrease drastically its chance for good establishment*".

Picture 16 Ostrich fern (Matteuccia struthiopteris) at Foodforest Ketelbroek

Picture 17 Salomon seal (Polygonatum biflorum) at Foodforest Ketelbroek

Picture 18 Japanese butterbur (Petasites japonicas) at Foodforest Ketelbroek

Wouter van Eck continues: *The first three years people came here and said: "You talk about food, but there is no food that you can harvest!". In food forests we need to exercise some patience. Think with the plant together. See how the plant is doing. On the other hand, later when some edible plants become a plague you can use the following advice: If you can´t beat it, eat it.*

8 Foodforestry Netherlands

Since Foodforestry Netherlands was created in 2013 by Xavier San Giorgi in cooperation with Wouter van Eck, more and more edible trees have been planted in the Netherlands. Together, these two Dutch food foresters are giving lectures and courses about food forests in temperate climates, as well as working on realisation of food forest projects throughout the Netherlands. The food forest concept is making more and more people enthusiastic all over the Netherlands, and the main source of that inspiration is Foodforest Ketelbroek.

In the courses and lectures of Foodforestry Netherlands, people get to know more about how to create a food forest and which plants can be used under climatic conditions in the Netherlands. Wouter reported that some rare varieties were sold out in tree nurseries in the Netherlands, Germany and Belgium after giving the first courses about food forests, so even Wouter and Xavier could not buy plants. Therefore recently Foodforestry Netherlands works together with plant nursery Arborealis to provide a reliable delivery of food forest plant species in the Netherlands. For more information visit their website at **www.voedselbos.arborealis.nl**

Another aim of Wouter and Xavier is to support local initiatives in design development, advice and establishment of food forests, primarily in the Netherlands. The services provided by Foodforestry Netherlands are:

- development of individual food forest design plans
- organizing plant material
- planting of food forest together with client(s)
- transfer maintenance details

Wouter van Eck comments (Eck, 2014): *"We went public just recently in the summer of 2013. And in the planting season of winter 2013/2014 we could already realize 5 food forests in the Netherlands, all different in character"*.

For more information about Foodforestry Netherlands see their webpage

www.foodforestry.nl and Facebook page
www.facebook.com/FoodforestryNetherlands

Already realized food forest projects are at the same time becoming educational and inspirational oases. The active core of caretakers of the realized food forest are creative and inspired people who are curious to learn more and more about food forests.

8.1 Beek-Ubbergen Foodpark

The inhabitants of Beek were asked by the local municipality about which type of park they want to have in their village in accordance with the Green Zone Project of the municipality Ubbergen. The aim of this project was the realization of attractive green spaces that will be fully maintained by the local inhabitants. One of these inhabitants had been on an excursion to Foodforest Ketelbroek before and shared this with the others. Very soon afterwards, a group of inhabitants from Beek and the project developers from the municipality came to visit Foodforest Ketelbroek and were very much inspired by it.

In December 2013, a food forest of 0,5 hectares was established under the name Beek-Ubbergen Foodpark. This food forest became the first public food forest in the Netherlands! The map in figure 13 gives a general overview of the Beek-Ubbergen Foodpark, as it was published in local newspaper (Houtappels, 2013).

The area of Beek-Ubbergen Foodpark already had many natural habitats present, such as hillside, water stream, ditch (different types of surface water) and old trees. The aim of the project was to incorporate all these natural elements and to create a food forest with common and uncommon edible plants.

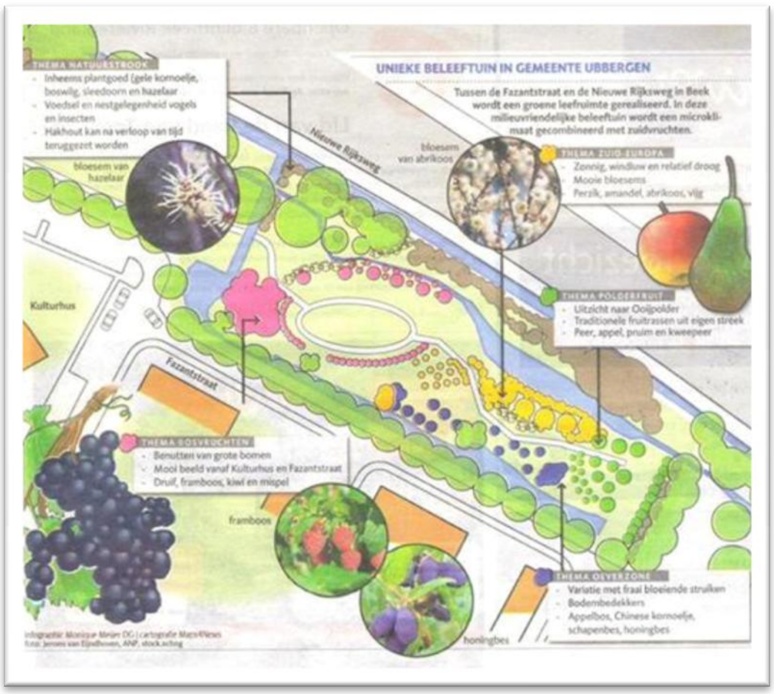


Figure 14 Design of the Foodforest Park Beek-Ubbergen (Houtappels, 2013)

The Beek-Ubbergen Foodpark was officially opened to public visitors on 18th of May 2014. The design of the Foodpark is divided in different zones (adapted from van Eck & Giorgi, 2014):

- ***Shoreline***- area across the water basin, creating a habitat for the edible water plants such as sheepberry *(Viburnum lentago)*, heartleaf *(Houttuynia cordata)* and water mint *(Mentha aquatica)*.

- ***South Europe*** –sunnier, warmer, dryer and wind-protected areas were created to establish a microclimate that is ideal for apricot *(Prunus armenica)*, almond *(Prunus dulcis)* peach*(Prunus persica)*, fig *(Ficus carica)* and rosemary *(Rosmarinus officinalis)*

- ***Polderfruit***– location for selection of old varieties traditionally grown in the Ooijpolder, such as pears *(Prunus communis)*, apple's *(Malus domestica)* and plums *(Prunus domestica)*

- ***Nature ribbon*** – parallel to the water stream, the edible hedges were planted to provide food and suitable nest sites for birds and insects that are beneficial in the pollination and pest control in the whole food forest
- **Wild forest fruits** – the half-shady place under the few big old trees created a perfect spot for growing red currant *(Ribes rubrum),* gooseberries *(Ribes uva-victa),* raspberries *(Rubus ideaus)*, hazel *(Corylus avellana)* and medlar *(Mespilus germanica)*

For more information about the food forest Beek-Ubbergen see the website (in Dutch) **http://eetbaarnijmegen.nl/voedselbossen/voedselbos-beek**

8.2 Architectural Park Makeblijde, near Houten, Utrecht

The development of the food forest Architectural Park Makeblijde was started on an area of 1 hectare (Groentje, 2013), (Reinders, 2014). There were already existing mature trees present which were planted around 1980. Wouter van Eck (Eck, 2014): *"The disadvantage is that in the 80s, the green management in the Netherlands tended towards the non-edible species. The functions of agriculture and Nature were separated: if agriculture got created, there was no place for Nature; if Nature areas were created, food aspects were excluded. So now, if you see urban green- it is like a green decoration which you are not allowed to eat from. In Houten there were even cherry and pear trees planted that were selected only for their big beautiful flowers, and not for delicious fruits. Architectural park Makeblijde is a beautiful park, and we will keep it beautiful. But we will change its character towards edible species".*

The food forest project Architectural Park Makeblijde is divided into seven zones, realized one by one. The only present layers of the tall trees (canopy) and grass (herbaceous cover) are now enlarged into seven layers of a food forest. Every zone has a different theme, giving a different range of food forest species. The strong educational value of the project is also supported by the different sign-boards, aimed to give information about specific elements of the food forest.

Before the realisation of the food forest project, the grass lawns in Architectural Park Makeblijde were uniformly mown. Now the conventional maintenance is replaced by an organic and natural one. Therefore, many more flowering herbs and beneficial insects and birds could find a new habitat.

The park is public and visitors are welcomed between 09:00-17.00 every day. The park is located at Oud Wulfseweg 3, 3992 LT Houten, The Netherlands

8.3 Food Forest Kralingen in Edible Park “Nieuwe Plantage”, Rotterdam

Due to the interest and request of a group of volunteers from Rotterdam, under the supervision of Max de Corte, the first urban food forest in Rotterdam was realized by Foodforestry Netherlands on just 800m² in the park “Nieuwe Plantage” in the suburb of Kralingen.

Wouter (Eck, 2014): *“I guess Max will soon need to change his name. During the realization of the food forest project, he truly transformed from the Gardenman into the real Foodforestman. Food forest Kralingen is only a small area, and it tastes like: I want more!!”*

Picture 19 Joyfull planting of Nashi-pear *(Pyrus pyrifolia)* at first planting day of Foodforest Kralingen (2014)

In Food forest Kralingen there was no developed canopy layer present; only shrubs and half-standard trees. The density and diversity of edible species increased enormously after establishing the system on 15th of December 2013 (picture 19). At present, the food forest Kralingen is a real educational plot where children and adults get the chance to find out more about different food forest species by observing, learning, sharing, tasting and just enjoying.

Food forest Kralingen is also a knowledge exchange project where the group of volunteers is going to visit the Foodforest Ketelbroek from time to time to observe the species development in both food forest ecosystems. For more information about the food forest Kralingen, see their www.voedselboskralingen.nl

8.4 Food Forest of the Institute of Ecology (NIOO) at Wageningen

On a summer day in 2013, a group of Institute of Ecology (NIOO) researchers came to visit Foodforest Ketelbroek. After being inspired by it, they successfully convinced the director of NIOO to create a food forest on their own terrain. Even if the available space was small, around 0,2 hectare, the trees in the food forest were planted by very famous people.

Picture 20 Planting day of the foodforest, 21 of February 2014 at NIOO, Wageningen (2014)

On the picture 19, you can see (from left to right) Xavier San Giorgi from Foodforestry Netherlands, Louise Vet- director of NIOO, Vandana Shiva- well-known Indian environmentalist, Pablo Tittonell professor from Wageningen University Research Centre, and Wouter van Eck (Foodforestry Netherlands).

Because NIOO advocates the establishment of exclusively native species in the Netherlands, an interesting discussion took place about native and non-native species before accomplishing the definitive design of the food forest.

As a result of this discussion, the design of the food forest was divided into three zones (Jansen, 2014) described as:

- **Indigenous flora**

Arrangement of edible plants that are indigenous to the Netherlands, such as common hazel *(Corylus avellana)*, ramson *(Allium ursinum),* woodland strawberry (*Fragaria vesca),* mallow *(Althaea officinalis),* limes (Tilia spp.), sea buckthorn (*Hippophae rhamnoides)* or Cornelian cherry (*Cornus mas*) and edible shoots of Solomon's seal *(Polygonatum spp.)*;

- **Archaeophytes (non-native before 1500)**

Before 1500, many edible plant species had already been brought to Europe by, among others, the Romans and Carolingians. These 'assimilated' species are called in biology archaeophytes. Some of these plants have established well in the current climate and are now part of the natural flora in the Netherlands. The examples of such species are wild horseradish (*Armoracia rusticana*), Alexanders (*Smyrnium olusatrum*), medlar (*Mespilus germanica*) and wild cherry (*Prunus avium).*

- **Pleicstocene**

In this zone you will find plant species that have been extinct in the Netherlands since the last ice age and that are mostly known from fossils found along the river Maas at Tegelen and Reuvers (Mijts, 2014), (Westerhoff, et al., 1998). Examples of such species are hardy kiwi (*Actinidia arguta*), butternut (*Juglans cinerea*), European bladdernut *(Staphylea pinnata),* grape *(Vitis vinifera)* and Japanese magnolia *(Magnolia kobus)*. They are considered to be exotic species in the Netherlands.

8.5 Private Commercial Food Forest in Request of Max de Corte

The surface of around 0.3 hectare, that is currently in management of Max de Corte for next five years, is being transformed to a food forest, targeting the commercial demand in Rotterdam area. Because the land for this project is only temporally available, the goal is to create a productive system that even after five years will have a potential value (plants that can be transplanted, seed harvest etc.).

This food forest was the first realized commercial food forest in the Netherlands. For more information contact personally Max de Corte via his website **www.moestuinman.nl**

8.6 Future Projects to be Realized in the Netherlands

Foodforest Lent

It the north of the city of Nijmegen, in Lent, the realisation of an ecological public housing area with collective facilities is planned for the near future. The plan is to create among others a helophyte water treatment unit, straw bale buildings and of course a food forest. Future inhabitants and the municipality of Lent asked Foodforestry Netherlands to create a food forest and to make the public area edible and ecologically sustainable (Giorgi, et al., 2014)

Estate in the Veluwe

In this project, around 4 hectares of monoculture forest in Veluwe, the largest area in the Netherlands covered with forest, are to be transformed into a food forest ecosystem. Therefore, the pine forest (*Pinus spp.*) will be replaced with a productive edible multi-storey food forest. After realization, it will become the largest food forest in the Netherlands.

Food forests in Flevoland

A great plan is to create a food forest of around 60 hectares near Almere in the province of Flevoland, the Netherlands. This project is to be carried out in cooperation with different stakeholders. More information is described in the report (in Dutch) "*Voedselbossen in Flevoland: iconen van verzoening tussen natuur, stad en landbouw*" (Foodforestry Netherlands et al., 2014).If the project is realised, it will become the biggest food forest in Europe.

9 General Design of a Food Forest in a Temperate Climate

There are some design tricks used in food forests that create labour extensive functionality and maintenance equivalent to that of natural forests. Here below follows a short summarized advice plan for the general design of a food forest in a temperate climate. For the main part these recommendations were observed by Wouter van Eck through practical experience at Foodforest Ketelbroek (Eck, 2014).

9.1 Inventarisation Phase

Before the design of a food forest system the data needs to be obtained about the present situation. Therefore, the "Species Niche Analysis Worksheets" are available for download from **www.edibleforestgardens.com** (Jacke, et al., 2005).

9.2 Design Phase

The following themes describe one by one the specific aspects of ecological principles used in the design of a food forest.

Precise positions of the sun for the whole year round

Depending on where the south side is of the area that shall become the food forest, the layers of the food forest can be built up. Personal observation plays here a key role, but

Picture 21 Blossoms of almonds *(Prunus dulcis)* at Foodforest Ketelbroek

Picture 22 Harvest of peaches (*Prunus persica)* from Foodforest Ketelbroek

you can also use available sun position data for your specific place on the internet or through local authorities.

Wouter van Eck explains (Eck, 2014): *"Choosing the right variety of apricots (Prunus armenica), peaches (Prunus persica) (picture 22) and almonds (Prunus dulcis) (picture*

21) you can grow these delicious south fruits in the Netherlands. But they need to get the sunniest south spot in your food forest!"

Good design of the canopy layer

With a proper design of the canopy layer, a continuous input of biomass in your food forest is secured. From experience in the projects of Foodforestry Netherlands, this can often be a problem on bare ground areas because of the lack of a constant biomass input. Such situations can lead to a deficit of organic matter that often needs to be solved by delivery of external compost etc. This takes manpower, money and time.

As substitutes for canopy layer, more nitrogen-fixing plants can be planted, such as alders and willows, as in the case of Foodforest Ketelbroek. Other species are described in section 7.11 *Nitrogen Fixing Plant Species*.

In the herb layer, species like comfrey *(Symphytum spp.)* can make a sustainable addition of nitrogen rich organic matter. Other dynamic accumulator or mulch producing plants are fireweed (*Epilobium angustifolium*), lemon balm (*Melissa officinalis*), mallow (*Malva alcea*), rhubarb (Rheum species), dandelion (*Taraxacum officinale*), stinging nettle (*Urtica dioca*) and horseradish (*Armoracia rusticana*). As you can see, the most hated "weeds" are at the same time amongst the greatest nutrient rich organic materials suppliers.

Total surface is important

A small plot available for a food forest might not be sufficient for some animals to create a stable population that can resist plagues. There is more research necessary on this subject to determine the optimum surface area for a productive and stable food forest ecosystem.

However, well-developed natural neighbouring ecosystems with great biodiversity can enhance and support positive interactions between animals, birds and insects. Wouter van Eck adds: *"Animals and insects do not know fences!"*

Secure biodiversity

The advice from Wouter van Eck is to aim for a high biodiversity if you have only a small food forest, and give more space to the same species if you have a greater area available. Wouter van Eck (Eck, 2014)*: "The higher the diversity is, the higher is the resistance against the plagues and higher the variation of "menu" for the soil life. On bigger area you just have more space to put more of the same species. On smaller area you need great variety to avoid the plagues"*.

Provide sufficient space for the plant roots

Thinking with the plant is not only very romantic but absolutely necessary. Wouter van Eck (Eck, 2014) advices: *"If you have a high groundwater level some trees, such as chestnuts (Castanea spp.), walnuts (Juglans spp.) kaki (Diospyros spp.) etc., will not like it, because they need space for their roots to be stable and not to fall down. If you still want to plant these trees, you can choose to dig out a pool and create an artificial hill. On this hill you can plant such "dry feet loving' trees, and in the pool you can introduce edible water plants"*.

Use nitrogen fixing plants

Covering every 20 square meters of food forest with a nitrogen fixing tree, as it is done at Foodforest Ketelbroek, restores the mycorrhizal connections and enhances the soil food web. The favourite nitrogen fixing species on Ketelbroek is the autumn olive (*Eleagnus umbellata),* which is also a very good bee plant and provides edible berries. More plants are described in section 7.12 *Nitrogen Fixing Plant Species*

9.3 Choice of Species

When considering which species to use in a food forest, the main considerations can be the following ones (adapted from Last 2001, Eck ,2014, Crawford ,2010):

Climatic matching (hardiness zone)

Some species are so adaptable, that they can tolerate huge changes in climate and still grow well. Therefore in the Netherlands with Hardiness zone 7, the species from North America, Japan or East Asia, can be grown and be productive.

Habitat preferences

It would be inadvisable to plant nutrient-demanding species in poor soils, sun loving plants in full shade, and plants that do not prefer wet conditions in the wet soils. Knowledge about specific habitat preferences of the plant species must therefore be obtained. Plant databases, such as Plants for A Future www.pfaf.org can give an excellent overview. When searching for a plant, you can type a Latin name with the addition "pfaf" to be redirected by your search engine directly to the PFAF database. An example would be: Symphytum officinale pfaf.

Pollination needs

If a plant is not self-pollinating, you need two or more of the same plant species. Also, knowledge about wind-pollination or the need for a specific pollinator is important. The different types of pollinators are usually bees, bumblebees, butterflies, flies, birds, ants and/or beetles, so providing a habitat for pollinators is also part of the food forest design.

- **Knowledge of performance and utilization**

It would be preferable, to know how much yield can be expected from specific plant species in different stages of their development. So arrangements for harvests and for utilization of the harvests can be made in advance. In addition, it could be interesting to gather information about the nutritional value of edible parts of any plant your want to plant in your food forest.

- **Safety in relation to stress factors, such as extreme weather events, pests, pathogens**

For example, a lot of species in a temperate climate can be damaged by late spring frosts which affect plants that make young shoots, leaves or flowers before the frost. The advice is to select species that alone or in combination with other species or incorporated design elements (frost catchment pools) can resist adverse climate factors such as extreme drought, deep winter frosts, late spring frosts, autumn frosts etc. Tree species damaged by frost might recover the next year, but some will not be able to produce in the year of damage, as in the case of walnuts (*Juglans spp.)*. On the other hand, the root system of frost-damaged species will develop more intensely, as has been experienced with plants at Foodforest Ketelbroek. As for pathogens, as already said by Wouter van Eck (Eck, 2014): "*The higher the diversity is, the higher is the resistance against the plagues"*

- **Extra factors such as nitrogen-fixing or allelopathic properties, and secondary uses**

Most of the plants in the food forest have not just a single function but multiple ones. There are lots of nitrogen-fixing trees and plants that produce an edible harvest. But you might want to grow some trees purely because you wish to harvest timber. Be aware that some plants can have allelopathic properties (they inhibit the growth of other plants), as for example the black walnuts (*Juglans nigra*). Therefore, good knowledge about the species in your food forest is very important.

9.4 Planting Phase

The advice of Wouter van Eck (Eck, 2014) is the following*: "Deciduous trees drop their leaves in autumn, so in wintertime the above system is more or less in rest. But the roots are not totally in rest even in the winter. Therefore, it is the best to (re)plant deciduous trees as soon as possible after they have dropped their leaves to give plants as long as possible to develop the root system. In the Netherlands it would be from November till December, before frosts. The sooner planted, the warmer the soil will be after the summer. When the leaves come out in March, April or May - the roots will have already established themselves."*

If you want to buy plants for less cost, they can be delivered by the tree nursery also with bare roots, without any soil. Wouter*: "For transporting the plant from the shop, you need to keep the roots humid. For this you can use a wet piece of cloth, paper or plastic. You can also use the paper of a newspaper - then the plants will have something to read during their travel".*

Picture 23 Wouter van Eck at Foodforest Ketelbroek during planting an apple tree *(Malus domestica)* companied with horseradish *(Armoracia rusticana)* for complementary root systems.

On the other hand, pot-grown plants (your own propagation or bought from the nursery) have their own "house" with already well-established roots inside the pot. Wouter van Eck adds*: "Therefore the pot-grown plants can be planted anytime, whenever there are no extreme temperatures or weather events, such as drought or frost".*

9.5 Design Example

Jacke & Toensmeir (2005) in their book "Edible Forest Garden", Volume 2, give an overview of 626 plant species, considered as useful and functional within the food forest ecosystem in a temperate climate. If you count all cultivars, this plant list would be easily have to be multiplied by a factor of ten! That amount of 6000 plants for your temperate food forest sounds tempting, does it not? As mentioned previously, the online database of Plants for a Future Project **www.pfaf.org** provides also a great overview of useful plants for different climates.

Within this work, the selection of 21 species is briefly presented in seven basic layers of the food forest. In other words, three species per layer will describe respectively canopy, understory, shrubs, climbers, herbaceous layer, groundcover and underground layer. The example of such basic food forest design of 21 plant species is created by the author and is presented in appendix I.

10 Maintenance of a Food Forest in a Temperate Climate

"For the proper maintenance of a food forest it is important to get out of the habits that are common for conventional gardens and agriculture. People are used to having bare ground in their vegetable gardens, to being able to give plants the full sun, growing the plants in rows, and eradicating all the upcoming weeds.

The paradox of the food forest is that it gains its strengths from the natural forest ecosystem. The activities common in conventional and even biological gardens can be destructive to a wide range of forest plants. What we need to realize, is that in natural forests there is nobody that weeds out "non-useful plants" and the soil is covered with a great amount of organic matter".

Wouter van Eck (2014)

Because it mimics natural forest ecosystem succession, the maintenance level of a food forest is potentially very low. The following sub-chapters describe the main aspects of food forest maintenance according to the advice of Wouter van Eck (Eck, 2014). Wouter van Eck summarizes his thoughts on food forest maintenance with the following words: *"You are welcome to do it, but you do not actually need to do it. The ecosystem of a food forest comes very close to the idea of "do-nothing farming" introduced by Masanobu Fukuoka in 1975. Masanobu described it as: learning from Nature, you can create a system that is self-supporting, self-maintaining, self-balancing and self-nurturing. For the food forest system, it means: do not hoe, weed, use pesticides and insecticides (even organic), do not irrigate and do not use manure. You do not need this in a natural forest, so you do not need this in a food forest either"*

Regular Observations and Understanding the System

"Our work is looking and doing small things, like planting the new trees in special places. That is why we need to recognize the ecological principles in the field and know the theoretical background information about them" explains Wouter van Eck (Eck, 2014).

10.1 Weeding

The negative image of weeds is deep rooted in the mind of conventional and even organic gardeners. Most weeds belong to the pioneer species. It is their natural urge to literally cover the soil and create biomass, creating conditions for climax species to appear. By digging the soil and keeping it bare, you create perfect conditions for the weeds, so the "eternal weed battle" goes on every season. Wouter van Eck (Eck, et al., 2014) describes his opinion which he applies successfully in all the projects of

Foodforestry Netherlands :"*In the beginning of the establishment of a food forest system, there will for sure be some weeds coming up, especially if the ground was disturbed. The art, is not to worry too much about it, and do not make energy-intense actions to "defeat" all of such weeds. You can make a lot of mistakes very quickly. The food forest ecosystem needs to develop and establish itself, and weeds are part of Nature's recovery plan. When canopy and shrub layer win out in volume, they will create more shadow and organic material by falling on the ground. When the levels of organic materials reach their optimum, most pioneer weeds will disappear by themselves. So it is with most unwanted weeds such as broad-leaved dock (Rumex obtusifolius), nettle (Urtica dioica), and creeping thistle (Cirsium arvense). In short: it's better to do nothing, and if you do do something, be sure that you don't do too much."*

Social aspects are at the same time also very important within the holistic ecosystem management. Wouter van Eck (Eck, 2014):*"So if your neighbours will be not happy with the appearance of weeds that can presumably seed themselves on their fields, be prepared to cut them locally using a hand-sickle, scythe or small kitchen knife. Also at Foodforest Ketelbroek the broad-leaved dock (Rumex obtusifolius) is manually cut away from the road side and on the edges close to neighbours agricultural monocultures".*

10.2 Dead Wood

"Dead wood" in the natural forest is actually full of life. Trees that are no longer alive provide essential habitats for many beneficial insects and forest fungi. Within the food forest, natural dead wood can be re-established using the "ringing" technique. The procedure is as follows: part of the bark of the tree close to the ground is cut off, gradually letting a living tree be converted into to the "dead wood" while at the same time keeping it in place. This sounds very cruel for the trees, but this action can be beneficial for many other forms of life that will profit from changing niche environments created in such a way. Wouter van Eck (Eck, 2014): *" At the moment at Ketelbroek we have artificial insect hotels for solitary bees and other insects and of course bird boxes, but it would be great for all these creatures to move from these "city apartments" back to Nature".*

10.3 Fertilization

When the climax species need more space, disruptive pioneers which are at that moment growing too close can be cut down using the so-called "chop-and drop" method. The essence of this method is that organic material created by cutting can be used as natural fertilizer for the species that yield and are harvested regularly. Wouter van Eck (Eck, 2014) warns though*: "When cutting anything, be precise. You planted plants, trees and* *shrubs, that might go unseen and accidentally be damaged or even cut off without you noticing it".*

Using the "chop-and-drop" method you can cut unwanted weeds (before they seed) and branches, or coppice nitrogen fixing trees or shrubs specially grown for coppicing. Wouter van Eck: *"In such a way, yielded organic material can be left in place or transported to the plants that potentially need extra nutrients, organic material or some mulch around the stem. For example, trees that have a surface root system and come from the Rosaceous family – apples (Malus spp.) plums (Prunus spp.) pears and cherries (Pyrus spp.). But in any case, do not fertilise too much, especially too close to the stem. Keep the mulch always at a distance of 5-10 cm from the stem to prevent rotting".*

It can also happen that pioneer species (such as birches etc.) unexpectedly appear. When such trees become too dominant, you are welcome to "chop-and-drop" them. Wouter van Eck adds: *"Consider it as a natural contribution of organic matter to your ecosystem delivered free of charge. To cut them, if they start to cause too much disturbance, will take you probably an couple of hours (for 2,5 hectares) once in three years"*. Such time investment is negligible if you consider all the benefits.

10.4 Watering

Wouter van Eck (Eck, 2014) advises to avoid systematic irrigation of planted plants. As an exception, it is okay to water (with 2-3 buckets of water) after planting and during periods of extreme drought, especially if the soil contains a lot of sand or loess. In all these situations your plants are more vulnerable. Wouter van Eck adds: *"Observe your plants regularly and carefully. They do not need to get yellow leaves because of a principle. When you have a loess soil type, you might need to water more. Because of having stronger water absorbance capacity, loess, in the dry periods can very easily take away the humidity from the "garden soil" used in the pot plants. Therefore, more care and more watering might be needed. In Foodforest Ketelbroek and other food forest projects of Foodforestry Netherlands, Xavier San Giorgi and I give the advice of not to "spoil" the plants with too much water, but making them grow their roots deeper and reach the humid areas close to the groundwater level. Otherwise the plants get lazy and develop their roots not as they naturally would. Under the plants, there is first dry soil, but their roots need to grow through this part and reach the humidity below. In the Netherlands we are lucky, because the groundwater level is never too far".*

Some more general watering advice from Wouter van Eck is:

- If you choose a planting time directly after a sufficient rain, extra watering is not necessary
- If you have a plant in a pot with soil, you can put it for 5 minutes before planting into a "water bath" at outside temperature. In this case, watering is also not necessary
- Some trees can require a ring of wood chips around them to decrease water evaporation and competition for root space and nutrients with shallow growing grasses. The wood chips prevent the intensive plant growth around the planted plant and keep the soil humid for longer time.

Wouter van Eck adds*:" Our experience at the Foodforest Ketelbroek is that plants planted in November or December never need any watering at all. Their roots are established well. Only in extreme droughts with no rain for 6 weeks did we give one bucket of water to help them through".*

10.5 Pruning

"If you ask five prune-experts for their best pruning technique, you might get five different answers and each of the experts will be completely convinced about his own truth. Me too. But if everyone says something different, where is the truth?"

Wouter van Eck (2014)

Pruning is for sure the point where a great discussion can take place considering the maintenance in the food forests. Why are the trees pruned? The answer is: because pruning increases the size of fruit. But what few know, with pruning the amount is decreased. As nowadays there is no commercial market for small-sized fruit in large amounts, many people prune the fruit trees with great pleasure.

Although, not so many know that trees grown from the seed never needs to be pruned. Nature is managing itself to be productive and humans do not need to make any effort for this. Practical experiments of Austrian agrarian rebel and world famous permaculturist Seep Holzer show real evidence of this statement (Holzer, 2011).

Wouter van Eck explains his view on pruning (Eck, 2014): *""You need to find your own opinion and way towards pruning. In Nature we do not observe pruning. But if the tree comes from a conventional tree nursery, the top was already clipped and the collateral branches are growing too dense to each other. In this case, you can intervene very selective and modestly by cutting some unwanted branches. Keep in mind not letting the tree grow one-sided, making it vulnerable for wind-damage. The* *observation of the further development of the tree will give you an idea for its further maintenance".*

Trees always grow towards the sun, naturally bending their own side-branches. Some people like to place a weight of stones and ropes to bend the side-branches artificially, explaining their action as preventive against accidental breaking during too heavy yield. Such maintenance is misplaced in a natural food forest ecosystem and was not applied in Foodforest Ketelbroek and other food forest projects of Foodforestry Netherlands.

10.6 Espaliering of Trees and Shrubs

The best description of espalier trees I heard from a friend, Lemke Statema, saying:" *The espalier trees remind me of Jesus Christ, put on a cross and needing to stay there till his death".*

Wouter van Eck (Eck, 2014) confirms: *"During summer/autumn of 2013 there was an abundant yield of the apple trees. The side-braches were covered with apples, at the same time naturally bending to carry their weight. In 2014 we could observe bent branches without any breaks. The trees are now well prepared to carry the harvest load of the next seasons".*

The trees on Ketelbroek are not pruned, artificially bent or espaliered. Wouter van Eck: *"You can get seriously addicted to weeding, pruning and bending the trees".* Give yourself time to unlearn such habits that are misplaced in a food forest ecosystems.

11Final Remarks

"People will become poor if they do not have a love of plants and animals. Protect trees and forests. Each tree will safe a human life"

Cosmas of Aetolia (1779)

Food producing species have inherently more value in the food forest than timber producing species (Swift, 1999). Forests and food forests are using the same ecological principles. The overall maintenance level of the food forest is low and the productivity of a mature developed system is high. Even in the temperate climate in the Netherlands the variety of edible plant species is great, and productive food forest ecosystems are possible. Knowing how to observe and use the ecological principles in this field will support you in making the right choices in design and maintenance, eventually creating an abundant food forest ecosystem of your own.

Incorporation of a food forest into our landscape is becoming essential all over the Netherlands and worldwide. Not only serving human needs in providing food, timber and secondary usage products, food forests are truly Nature reserves, creating habitats for a tremendous amounts of animal, insects and bird species among others. Moreover, food forests have a great potential in providing an extra source of income to local farmers in the Netherlands and worldwide.

Most existing parks in the Netherlands can be redesigned into public food forests, giving the park a multi-layered edibility and educational function. At the same time, community supported food forests could provide an opportunity for a harvest for people who do not own a food forest themselves.

In his book "Small is Beautiful" Dr. E.F. Schumacher (Sholto Douglas, et al., 1985) describes a simple, thus incredible solution to create food security and enhance the prosperity for the whole world: *"Imagine if the following ideology would be established: that every able-bodied person: man, women and child, needs to do a little thing- to plant a tree and look after it for the five-year period. It would give you two thousand million established trees. The economic value of tree planting is greater than anything that ever been promised by any politician. It could be done without a cent of foreign aid and there would be no problem of savings and investment. It would produce foodstuffs, fibres, building material, shade, water, almost anything that man really needs"*. For the Netherlands it would mean that 16.906.441 trees in 2014 could be planted.

What stops us following this example? Worldwide, people need to stand up for their rights to have access to land, water and seeds. By this means, a great deal of current local food problems can be solved in developed and so-called developing countries (both terms came from the Cold War period, and are in my opinion discriminative).

Close your eyes and imagine fruit and nut trees full of yield, integrated into parks, agricultural fields, pastures with grains, integrated into natural forests, lands full of abundance and prosperity, people sharing knowledge everywhere. It is vision of paradise that we all can create with our own two hands. Let’s start now!

Anastasia Limareva

Appendix I. Design Example of a Food Forest

Foodforest layer	English name	Botanical name
Canopy	Lime	Tilia cordata
	Black mulberry	Morus nigra
	Heartnut	Juglans ailantifolia var. Cordiformis
Understory	Rosseyanka kaki	Diospyros x Rossseyanka
	Pawpaw	Asimina triloba
	Blue bean	Decaisnea fargesii
Shrubs	Nanking cherry	Prunus tomentosa
	Snowbell	Halesia Carolina
	Japanese plum yews	Cephalotaxus harringtonii
Climbers	Hardy kiwi	Actinidia arguta)
	Chocolate vine	Akebia quinata
	Wu Wei Zi	Schisandra chinensis
Herbs	Sea kale	Crambe maritime
	Ostrich fern	Matteuccia struthiopteris
	Udo	Aralia cordata
Groundcovers	Siberian purslane	Claytonia siberica
	Nepalese rastberry	Rubus nepalensis
	Wild strawberry	Fragaria vesca
Underground	Oca	Oxalis tuberose
	Yacon	Smallianthus sonchifolia
	Groundnut	Apios americana

Descriptions of the plant species below, are based on the work of

Plants for a Future Team, Martin Crawford, Dave Jake and Eric Toensmeier.

The honour goes to them.

Note: abbreviation HZ means hardiness zone

Canopy

Botanical name	*Tilia cordata*	*Morus nigra*	*Juglans ailantifolia var. cordiformis*
English	Lime	Black mulberry	Heartnut
HZ	2-3	5	4
Size	20 m high& 12 m wide	5-10 m high & wide when mature	15 m high & wide when mature
Fertility	Self-fertile	Self-fertile	Cross-pollination
Sun/shade	Prefers full sun, but tolerates fairly deep shade , but grows than slower	Prefers full sun, tolerates light shade (4-5 hours full sun/day)	Prefers full sun, tolerates light shade (4-5 hours full sun/day)
Soil	Fine in any soil	Fine in any soil	Fine in any soil
Uses	The young leaves and the ends of the young shoots are excellent alternative to lettuce. From dried old leaves baking flower can be made for baking bread.	Delicious fruits fresh picked from the tree and eaten raw or dried. Tree produces a lot. Seedling might need 15 years to start fruiting, but grafted tree can start produce already after 2 years. Fruits are ripe between Aug. to Sept.	Heart-shaped nuts, smaller in size than walnuts, but with similar fine flavour and use. The trees are faster-growing and more frost-resistant than walnuts. Grafted varieties starts in 4-5 years, seedlings in 6-8 years.
Secondary	Excellent bee plant. Leaves are rich in minerals and rapidly improving the fertility of the soil	Edible leaves that can be steamed and used to wrap food or to lay in as lasagna leaves, etc.	The hulls are used in dyeing to create a range of brown ant tan colors. The sap is similar to maple sap
Propagation	By seed- needs long stratification	Grafting or semi-ripe cuttings	Grafting or seed (needs 3 months stratification)
Maintenance	None	Branches are brittle. Best to plant tree on a spot without extreme wind	Take into the account the allelopathy effect of *Juglans spp*.

Picture 24 Lime (Tilia cordata)
www.biopix.dk

Picture 25 Black mulberry *(Morus nigra)*
www.koanga.org.nz

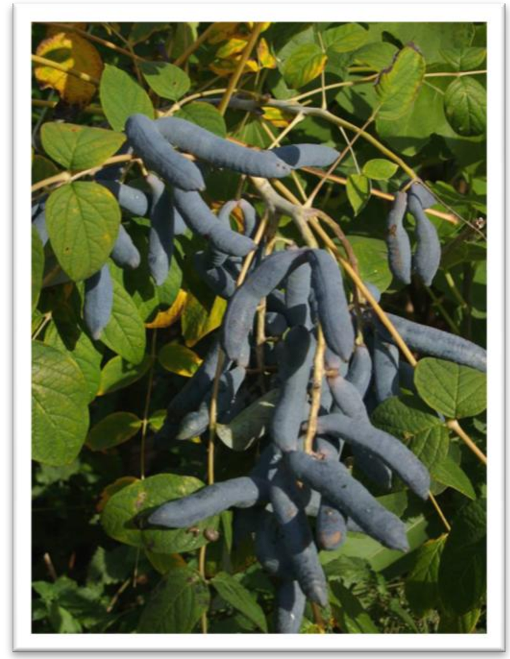
Picture 26 Heartnut
(Juglans ailantifolia var. cordiformis)
www. tcpermaculture.blogspot.com

Understory

Botanical name	***Diospyros x Rossseyanka***	***Asimina triloba***	***Decaisnea fargesii***
English	Rosseyanka kaki	American pawpaw	Blue bean
HZ	5-6	5	5
Size	8 m high & 3 wide	6 m high & wide. Slow growing	4-6 m high&2-4 m wide
Fertility	Self-fertile	Cross pollination	Self-fertile
Sun/shade	Prefers sun and tolerates no shade (for Dutch climate)	Needs full sun in Dutch climate	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)
Soil	Fine in any soil, not too moist	Acid-to-neutral, similar to grapes requirements	Fine in any soil
Uses	Delicious raw fruits, when fully ripe. The taste ranges from ripe date, apricot, peach and banana etc. Harvest as late as possible. The leaves can fall down and fruits remain on the tree, creating a fairly picture. When harvested, store in cool place and let ripen in warmth. Fruiting starts after 3-6 years	The aroma of the fruits remained on banana, mango, melon, ananas, vanilla etc. What a privilege that a similar fruit can be grown in colder climates! Fruiting starts after 4-5 years	The pulp inside the blue pods is edible and has a fine, delicate, melon flavour. Harvest the pods when they are blue and soft. They do not store long. Small black seeds are edible, the skin not. Fruiting starts in 3-4 years .
Secondary	Bee plant. Unripe fruits are high in tannins and can be used for dyeing	The seeds, leaves and bark contain insecticidal chemicals, so no edible	The blue skin contains natural latex
Propagation	By seed-needs 2-3 months stratification or grafting on to seedling rootstock	By seed-stratification of 3 month, or grafting on to seedling rootstock	By seed- requires 4 month stratification

Picture 27 Rosseyanka kaki
(Diospyros x Rossseyanka)
www.subtropy.webgarden.cz

Picture 28 Pawpaw *(Asimina triloba*)
www.benotforgot.com



Picture 29 Blue bean
(Decaisnea fargesii)
Foodforest Ketelbroek (Facebook page)

Shrubs

Botanical name	*Prunus tomentosa*	*Halesia carolina*	*Cephalotaxus harringtonii*
English	Nanking cherry	Snowbell	Japanese plum yews
HZ	2	5	6
Size	1,5-2,5 high &wide	3-4 m high &wide. Slowly growing and bushy	3-5 high & wide. Growing slowly. Takes 10-15 years to rich its full size
Fertility	Partly self-fertile. Richer yield with 2 trees	Self-fertile. Starts after 3-4 years	Dioecious
Sun/shade	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)	Prefers sun	Prefers light shade (4-5 hours of full sun/day), tolerates fairly deep shade (no direct sun). Fruiting well I both conditions
Soil	Fine in most soils	Fine in most soils	Fine in most soils
Uses	Best eaten raw, directly from the bush. Ripe in late summer. Can be cooked like cherries pie. Process quickly after harvest	Crunchy fruits with cucumber/pea-like flavour, great in salads or/and pickles. Use fast after harvesting. Flowers are edible as well.	Fresh raw fruits are best eaten from the bush, when are getting dark and soft in late October. Taste similar to butterscotch/pine nut
Secondary	Good bee plant	Good bee plant. Very ornamental flowers	Evergreen shrub
Propagatio n	By seed –requires 3 month stratification	By seed –requires 3 month stratification	By seed –requires 3 month stratification

Picture 30 Nanking cherry
(Prunus tomentosa)
www.acanadianfoodie.com

Picture 31 Snowbell
(Halesia carolina)
http://tcf.bh.cornell.edu

Picture 32 Japanese plum yews
(Cephalotaxus harringtonii)
www.dendrome.ucdavis.edu

Climbers

Botanical name	*Actinidia arguta*	*Akebia quinata*	*Schisandra chinensis*
English	Hardy kiwi	Chocolate vine	Wu Wei Zi
HZ	2	5	4
Size	Up to 30 m high in the trees	5-10 m high &40 cm wide	7 m high or more
Fertility	M&F	SS	Plants are male or female. Only "Eastern Prince" cultivar is self-fertile
Sun/shade	Prefers full sun, tolerates no direct sun, but indirect light. Fruiting well I both conditions	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)
Soil	Fine in any soil	Fine in most soils	Fine in most soils
Uses	Excellent fresh fruits that can be eaten with the skin. Get ripe in Sept. to Nov. Also possible to use in fruit leathers because seeds are very small)	Pulp in the pods is edible, having a sweet watermelon flavour. Seeds and flowers are edible as well. Flowers have spicy chocolate taste. Skin of the pods can be baked and tastes like aubergine	There are five tastes within a berry sweet, sour, salty, bitter and hot. Fruit ripens in Aug.-Oct.
Secondary	Good bee plant. Edible sap	Stems are good basketry material.	Good bee plant. Young leaves can be cooked as vegetables
Propagation	By layering the softwood cuttings. 1 male/8 female plants	By seed or layering	By seed, layering or division
Maintenance	Protect young plants from the cats, that get crazy because of attractive chemicals within the plant. Danger from snails/slugs. Plant do not tolerate frosts.	Can spread widely	Can spread widely

Picture 33 Hardy kiwi
(Acninidia arguta)
www.newplantsandflowers.com

Picture 34 Chocolate vine *(Akebia quinata)*
www.firstworldfacts.com

Picture 35 Wu Wei Zi
(Schisandra chinensis)
www.seedscollector.com

Herbaceaus layer

Botanical name	*Crambe maritima*	*Matteuccia struthiopteris*	*Aralia cordata*
English	Sea kale	Ostrich fern	Udo
HZ	4	2	8
Size	80 cm high& 50-60 cm wide	to 1,5 m high & 60 cm wide	5 m high & 2-3 m wide
Fertility	Self-fertile	Self-fertile	Cross pollination
Sun/shade	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)	Tolerates shade (4-5 hours full sun/day) or no direct sun, and only some indirect light	Prefers semi-shade and tolerates full shade
Soil	Anny well drained soil	Any moist soil	Any moist soils. Tolerates acidity
Uses	Edible young leaves (steamed, having a cabbage flavour), flower heads (remind and used as broccoli), roots(roasted or boiled). Roots can be taken from the soil in winter and stored for several months in damp/sand	One of few edible ferns. Harvest the young uncurled shoots in spring when they are up to 5-6cm high. Cook for 15 min (not less), otherwise you get stomach upsets. The flavour is a crossing between asparagus and broccoli	Young branched shoots - cooked or raw. can be sliced and added to salads, soups etc Harvested up to 1,5 m. Have a mild flavour. When blanched, become crisp and tender with a unique lemon-like flavour.
Secondary	Bee plant	Ornamental plant	Ornamental plant
Propagation	By seed, division in spring or root cuttings in the winter	Division in early spring, or sow spores	By seed, division in spring

Picture 36 Sea kale *(Crambe maritima)*
www.4seasonsseeds.com.au

Picture 37 Ostrich fern
(Matteuccia struthiopteris)
www.commons.wikimedia.org

Picture 38 Udo *(Aralia cordata)*
www.plantdelights.com

Groundcovers

Botanical name	*Claytonia siberica*	*Rubus nepalensis*	*Fregaria vesca*
English	Siberian purslane	Nepalese raspberry	Wild strawberry
HZ	3	7	3
Size	20-30 cm high & wide	30 cm high, spreading widely	15-25 cm high, spreading widely
Fertility	Self-fertile	Self-fertile	Self-fertile
Sun/shade	Prefers light shade (4-5 hours full sun light/day) or no direct sun, and only some indirect light	Prefers light shade (4-5 hours full sun light/day), tolerates deep shade beneath evergreen trees and shrubs	Prefers full sun, tolerates moderate shade (1-2 hours full sun light/day)
Soil	Fine in any soil, reasonably moist	Fine in any soil	Fine in most soils
Uses	Fresh & raw great in salads or like a snack. Stems and leaves are very tender, having a beetroot-like flovour. Can be harvested all year round. The tubers are eaten cooked, but are quite small in size	Excellent evergreen groundcover that tolerates foot traffic, deep shade, is attractive for bees and even fruits well with edible small raspberries! Harvest in late summer and autumn. Fruits needs to be directly processed in jam or used as fresh raspberries	Edible fruits with much stronger strawberry flavour, than cultivated strawberries, but smaller in size. Harvest in summer and autumn. Preserve fruits in jams or dried in slices. Leaves can be eaten in salads or used to make herbal teas any time
Propagation	By seed or division in spring	By detaching rooting system	By seed or runners
Maintenance	None	If you want to stop the plant, just mow it or detach runners	If you want to stop the plant, just detach runners.

Picture 39 Siberian purslane
(Claytonia siberica)
www.easttennesseewildflowers.com

Picture 40 Nepalese raspberry
(Rubus nepalensis)
www.flickr.com

Picture 41 Wild strawberry
(Fregaria vesca)
http://centerofthewebb.ecrater.com

Underground layer

Botanical name	*Oxalis tuberose*	*Smallianthus sonchifolia*	*Apios americana*
English	Oca	Yacon	Groundnut
HZ	9	9	3
Size	30 cm high &wide	1-2m high & 40 cm wide	2,5 m high& 30 cm wide
Fertility	Self-fertile	Self-fertile	Self-fertile
Sun/shade	Prefers full sun and do not tolerates shade	Prefers full sun, tolerates light shade (4-5 hours of full sun/day)	Prefers full sun, tolerates moderate shade (1-2 hours full sun light/day)
Soil	Likes well drained fertile soil	Likes well drained fertile soil	Any moist soil. Tolerates acid soils
Uses	Tubers are delicious raw or cooked. The flavor is sweet-acid and texture is crisp when raw. The oxalic acid within the tubers can be deleted by putting them into the sun for few days. Harvest the tubers carefully after the first frost in autumn. They store well in a cool dark place. Boiled or roasted for 10-15 min, the tubers taste like potatoes with little acid accent-very special	The tubers are great for eating raw being sweet and crisp like an apple. If eaten raw, can course flatulence at some people, as the Jerusalem artichokes do. Harvest the tubers carefully after the first frost in autumn. They store well in a cool dark place. Can reach the size of big potato. Cook like potato.	Tubers are eaten cooked and can be harvested all year round. Cooked as potatoes (boil for 10-15 min). The flavour is a mixture between peanut and potato . Might need 2-3 years for establishment
Secondary	Bee plant when flowers	Flowers attract beneficial insects	Bee plant and nitrogen-fixator
Propagation	By tubers in spring. Replant some harvested tubers from winter	By tubers in spring. Replant some harvested tubers from winter	From tubers

Maintenance	Hardy to only -5°C soil temp. Need to be annually replanted	Hardy to only -5°C soil temp. Need to be annually replanted	Plant towards the southern side of the shrubs it can climb in to

Picture 42 Tubers of Oca *(Oxalis tuberose)*
www.botanicalgarden.ubc.ca

Picture 43 Yacon
(Smallianthus sonchifolia)
www.slimfitteam.com

Picture 44 Groundnut
(Apios americana)
www.one-vibration.com

Bibliography

Abbott, L K. and Robson, A. D. 1985. Formation of external hyphae in soil by four species of vesicular-arbuscular mycorrhiza fungi. *New Phytologist*. 1985, Vols. Volume 99, Issue 2, pages 245–255, pp. 245-255.

Aliades, Angelo. 2011. Permaculture News. [Online] 21 10 2011. http://permaculturenews.org/2011/10/21/why-food-forests/.

2014. Amanitin. [Online] June 3 2014. http://amanitin.ru/.

An improved method for the rapid assesment of forest understory light environments. **Brown, N., et al. 2000.** 2000, Journal of Applied Ecology,37, pp. 1044-1053.

Assyov, Boris. 2014. Boletales. [Online] 18 June 2014. http://boletales.com/genera/boletus/b-edulis/.

Baarda, Ben, et al. 2012. *Basisboek Methoden en Technieken. Kwantitatief praktijkgericht onderzoek op wetenschappelijke basis.* Groningen/Houten : Noordhoff Uitgevers, 2012.

Barea, J. M. 1991. Vesicular-arbuscular mycorrhozae as modifiers of soil fertility. *Advances in Soil Science*. 1991, Vols. Volume 15, 1991, pp 1-40, pp. 2-33.

Barrios, Edmundo. 2007. *Soil biota, ecosystem services and land productivity.* 2007. pp. Volume 64, Issue 2, pp.269–285.

Berg, M. van der and Keizer, M. 2001. *Inleiding Bodem.Leertekst volume 1.* Wageningen : Wageningen University, 2001.

2001. Biology Online. [Online] 2001. [Cited: 10 April 2014.] http://www.biology-online.org/dictionary/Abiotic.

Biology, Forest. 2014. [Online] 2014. [Cited: 26 June 2014.] http://dendro.cnre.vt.edu/forestbiology/htmltext/chapter8new.htm.

Bowes, Bryan G. 2010. *Trees and forests. A colour guide. Biology,pathology,propagation,silviculture,surgery,biomes,ecology,conservation.* First editon. London : Manson Publishing Ltd., 2010.

Breeding for micronutrients in staple food crops from a human nutrition perspective. **Welch, Ross M. and Graham, Robin D. 2004.** 2004, Journal of Experimental Botany, Vol.55, No.365, pp. 353-354.

Buckley, Jr.,J.M. 2003. Oswego City School District Regents Exam Prep Center. [Online] 2003. [Cited: 11 03 2014.] http://regentsprep.org/Regents/biology/units/ecology/ecological.cfm.

Burnett, Graham. 1997. *SEVEN STOREYS OF ABUNDANCE; A VISIT TO ROBERT HART'S FOREST GARDEN.* [Online] 1997. http://web.archive.org/web/20120706165453/http://www.spiralseed.co.uk/forestgarden/page2.html.

Calder et al. 2007. Towards a new understanding of forests and water. *http://www.fao.org.* [Online] Food and Agriculture Organization of the United Nations, 2007. [Cited: 18 11 2014.] http://www.fao.org/docrep/010/a1598e/a1598e02.htm.

Chivian, Eric and Bernstein, Aaron. 2010. *How our health depends on biodiversity.* Boston : Center for Health and the Global Environment at Harvard Medical School, 2010.

—. 2010. *Sustaining Life: How Human Health Depends on Biodiversity.* Boston : Center for Health and the Global Environment at Harvard Medical School, 2010.

Clynewood, Jess and Wright, Rich. 2014. Coed Hills Forest Garden. [Online] 26 6 2014. http://coedforestgarden.co.uk/what-is-it/.

Corwallis. 1999. *A Plant Production Overview.CD lecture 1.* [interv.] Unisun Communications Soil Foodweb Inc. 1999.

Cotta, Heinrich. 1902. *Cotta's Preface: tr. from Anweisung zum Waldbau, 1817.* 1902. p. 5.

Cotta's Preface: tr. from Anweisung zum Waldbau, 1817. **Cotta, Heinrich. 1902.** 1902, Forestry Quarterly, Vol.1-1, p. 5.

Cow, Peter and Aranya. 2011. A Tour of Martin Crawford's Forest Garden. [Online] 17 June 2011. [Cited: 30 6 2014.] http://www.slideshare.net/PeterCowPermaculture/a-tour-of-martin-crawfords-forest-garden.

Crawford, Martin. 2010. *Creating a forest garden.Working with Nature to grow edible crops.* First edition. Foxhole,Dartington,Totnes,Devon : Green Books, 2010.

Critter Catchers, Inc. 2014. Michigan Critter Catchers Inc. [Online] 17 6 2014. http://www.crittercatchersinc.com/critters/Mice/Mousereproduction.html.

Curtis, B. C. 2014. Wheat in the world. [Online] 27 June 2014. http://www.fao.org/docrep/006/y4011e/y4011e04.htm.

2010. Danger Garden. [Online] 2 10 2010. [Cited: 30 6 2014.] http://dangergarden.blogspot.nl/2010/11/ubc-botanical-garden-part-1.html.

2013. Defenders of Wildlife. [Online] 2013. http://www.defenders.org/forest/basic-facts.

Dickman, Martin. 1993. Molecular biology of plant-parasite relations. [book auth.] Marcel Dekker. *Soil Microbial Ecology:Applications in Agricultural and Environmental Managment.* New York : Inc., 1993, pp. 177-202.

Eck, Wouter and Giorgi, Xavier San. 2014. *Basic course about Food Forests in temperate climate.* [interv.] Anastasia Limareva. Nijmegen,Groesbeek, 15,22,27 of April and 1,4 of May April-May 2014.

Eck, Wouter van. 2014. *Foodforest Basics course 2014.* Nijmegen, April 2014.

—. 2014. *Practical and theoretical backgrounds of the food forest in temperate climates and practical expirience at Foodforest Ketelbroek.* [interv.] Anastasia Limareva. 15 April 2014.

—. 2014. *Practical expiriences at Foodforest Ketelbroek.* 12 June 2014.

2014. ECOstyle. [Online] 26 6 2014. http://www.ecostyle.nl/tuin/gazon/producten/ph-bodemtest.

ECOstyle. 2014. ECOstyle. [Online] 26 6 2014. http://www.ecostyle.nl/tuin/gazon/producten/ph-bodemtest.

EEA. 2012. *The impacts of invasive alien species in Europe.* Copenhagen : European Environmental Agency, 2012. ISSN 1725-2237.

Eidt, Jack. 2014. http://www.wilderutopia.com. *http://www.wilderutopia.com.* [Online] 9 6 2014. [Cited: 9 6 2014.] http://www.wilderutopia.com/sustainability/permaculture-sustainable-antidote-agribusiness-consumer-culture/.

2014. Encyclopaedia Britannica. [Online] 10 April 2014. [Cited: 10 April 2014.] http://www.britannica.com/EBchecked/topic/276408/humus.

Evans, J. 1982. *Plantation forestry in the tropics.* Oxford : Clarendon Press, 1982.

2014. FAO. *Food and Agriculture Organisation of United Nations.* [Online] 5 March 2014. http://www.fao.org/forestry/en/.

FAO. 2011. FAO. *Global forest land-use change from 1900 to 2005: initial results from a global remote.* [Online] 2011. [Cited: 9 6 2014.] http://foris.fao.org/static/data/fra2010/RSS_Summary_Report_.

Feasibility of silviculture for complex. **Mizunaga et al. 2010.** 2010, J For Res, pp. 15:1–2.

Fern, K. 1997. *Plants for a future:edible&useful plants for a healthier world.* Hampshire : Permanent Publications, 1997.

Fern, Ken and Fern, Addy. 1996. *'The Garden of Love'.* 1996.

—. 1996. Robert Hart's Forest Garden. [Online] August 1996. [Cited: 8 June 2014.] http://www.pfaf.org/user/cmspage.aspx?pageid=93.

Finley, Ron. 2013. TED. [Online] 2 2013. http://www.ted.com/talks/ron_finley_a_guerilla_gardener_in_south_central_la.

Fischer, Ru. 2014. Environmental Life Science. *http://www.eiu.edu/*. [Online] 22 6 2014. http://www.ux1.eiu.edu/~cfruf/bio3002/secondary_succession.htm.

Floor-Anthoni, J. 2000. Seafriends Marine Conservation and Education Centre. [Online] 2000. [Cited: 11 03 2014.] www.seafriends.org.nz/enviro/soil/rocktbl2.htm.

2014. Foodforestry Netherlands. *Facebook*. [Online] 21 2 2014. https://www.facebook.com/FoodForestryNetherlands?hc_location=timeline.

Foodforestry Netherlands et al. 2014. *Voedselbossen in Flevoland:iconen van verzoening tussen natuur, stad en landbouw.* Netherlands : Natuur en Milieufederatie Flevoland, Embergy Consulting, De Waard Eetbaar Landschap, Food Forestry Netherlands, 2014. http://www.flevoland.nl/wat-doen-we/grote-projecten/nieuwe-natuur/projectvoorstellen/zuidelijk-flevoland/voedselbossen-in-flevolan/Voedselbossen-in-Flevoland.pdf.

2014. Forest Biology. [Online] 2014. [Cited: 26 June 2014.] http://dendro.cnre.vt.edu/forestbiology/htmltext/chapter8new.htm.

Formation of external hyphae in soil by four species of vesicular-arbuscular mycorrhiza fungi. **Abbott, L K. and Robson, A. D. 1985.** 1985, New Phytologist 99, pp. 245-255.

Fuhrmann, Sylvia, et al. 1998. *Principles and Applications of Soil Microbiology*. Upper Seddle River, New York : Prentice Hall, 1998.

Fukuoka, Masanobu. 1975. *One-straw revolution*. Tokyo : Hakujusha Co.Ltd., 1975.

Giorgi, Xavier San and Eck, Wouter van. 2014. *"Inrichtingplan groene ruimte Vossenpels Zuid-Oost"*. Utrecht : Foodforestry Netherlands, 2014.

Groentje, ´t Houtense weekblad´t. 2013. Aanleg van Voedselbos bij Makeblijde. [Online] 22 5 2013. http://media.wix.com/ugd/7869e4_390318c21d05375ba7a22f913c378f1d.pdf.

Gutteridge , Ross C. and Shelton, Max H. 1998. *Forage Tree Legumes in Tropical Agriculture*. Queensland 4072, Australia : Department of Agriculture The University of Queensland, 1998.

Harley, J.L. 1959. THE BIOLOGY OF MYCORRHIZA. London : Leonard Hill (Books) Ltd., 1959.

Hart, Robert A de J. 1996. *Forest Gardening.Rediscovering Nature&Community in a Post-industrial Age.* Foxhole, Dartington,Totnes,Devon : Green Earth Books, 1996.

2012. Harvard Public School of Health: Center for Health and the Global Environment. [Online] 2012. [Cited: 2014 5 22.] http://chge.med.harvard.edu/topic/biodiversity-and-food-production.

Harvey, A. E., Larsen, M. J. and Jurgensen, M. F. 1982. Clearcut harvesting and ectomycorrhizae:survival of activity on residual sites roots and influence on a bordering forest stand in western Montana. *Canadian Journal of Forest Research.* 1982, Vols. Volum 10(3), Pages: 300-303, pp. 300-303.

Havlis, Milan. 2014. [Online] Garden Center Zachradnichtvi, 2014. [Cited: 30 6 2014.] http://www.havlis.cz/karta_en.php?kytkaid=873.

Hawksworth, D. L. 1991. The fungal dimension of biodiversity:magnitude,significance and conservation. *International Mycological Institute.* 1991, pp. 641-655.

Hendrix, P. F., Crossley , D. A. and Blair, J. M. 1990. Soil biota as components of sustainable agroecosystems. [book auth.] R. Lal, P. Madden, R.H. Miller, G. House (Eds.) C.A. Edwards. Ankeny : Sustainable Agricultural Systems, Soil and Water Conservation Society, 1990, pp. pp.637–654.

Hieb, Monte. 2001. Geocraft. [Online] 1 1 2001. [Cited: 22 5 2014.] http://www.clearlight.com/~mhieb/WVFossils/GeolTimeScale.html..

Holzer, Sepp. 2011. *Sepp Holzer's Permaculture: A Practical Guide to Small-Scale, Integrative Farming and Gardening.* s.l. : Chelsea Green Publishing, USA, 2011.

Houtappels, Frank. 2013. De Gelderlander. [Online] 28 9 2013. http://media.wix.com/ugd/7869e4_b572127fd8fc23765878fbe1a0624ecc.pdf.

Howard, Wendy. 2014. Permaculturing in Portugal. [Online] 2014. http://www.permaculturinginportugal.net/content/growing.htm.

Ingham, Elaine R. 2014. United States Department of Agriculture. [Online] 2 April 2014. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868.

Ingham, Elaine. 2000. *Soil Food Web Workshop and intervieuw.* [interv.] Unity, Maine Maine Organic Farmer´s and Gardener´s Association. 18 3 2000.

2008. Interhort. [Online] 2008. [Cited: 30 6 2014.] http://www.interhort.com/pages/Horsetail_Equisetum_Arvense.php.

Jacke, Dave and Toensmeier, Eric. 2005. *Edible forest gardens Volume 1 Ecological vision and theory for temperate climate permaculture.* 1st. Vermont : Chelsea Green Publishing Company, 2005.

—. 2005. *Edible Forest Gardens. Ecological design and Practice for Temperate Climate Permaculture. Volume 2.* White River Junction,Vermount : Chealsea Green Publishing Company, 2005.

Janos, D. P. 1980. Mycorrhizae influence tropical succesion. *Biotropica.* The Association for Tropical Biology and Conservation, 1980, Vols. Vol. 12, No. 2, pp. 56-64.

Jansen, Carel. 2014. NIOO. [Online] 21 2 2014. http://www.nioo.knaw.nl/node/4694.

Kazlev, Alan. 2002. http://palaeos.com/. [Online] 2002. [Cited: 9 6 2014.] http://palaeos.com/paleozoic/devonian/devonian2.htm.

Kimmins, J. P. 1997. *Forest Ecology: A Foundation for Sustainable Managment.* Upper Saddle River, New Jersey : Prentice-Hall, 1997.

Kitsteiner. 2011. *Temperate Climate Permaculture.* [Online] 9 5 2011. [Cited: 13 11 2014.] http://www.tcpermaculture.blogspot.nl/2011/05/plants-nitrogen-fixers.html.

Kitsteiner, John. 2013. tcpermaculture.com. [Online] 27 5 2013. [Cited: 20 10 2014.] http://tcpermaculture.com/site/2013/05/27/nine-layers-of-the-edible-forest-garden/.

Köppen, Wladimir. 2014. Köppen Climate Classification System. *The sustainability council.* [Online] 2014. http://www.thesustainabilitycouncil.org/the-koppen-climate-classification-system/.

Kumar, Ranjit. 2014. *Research methodology. Step-by-step guide for beginners.* Los Angeles,London,new Dehli,Singapore, Washington DC : SAGE Publications Ltd, 2014.

Last, F.T. ed. 2001. *Ecosystems of the World 19.Tree crop ecosystems.* Amsterdam : Elsevier Science B.V., 2001.

Lauterjung, Helmut and Schmidt, Gangolf . 1989. *Planning of Water intake structures for irrigation or hydropower.* Eschborn : Deutsches Zentrum für Entwicklungstechnologien , 1989.

Lawton, Geoff. 2014. *A Masterclass in Designing Food Forests Across Dry, Cold and Tropical Climates.* The Channon, Australia, Australia : Geoff Lawton Pty. Ltd., http://permaculturedesigncourse.net/, 2014.

Leopold, Aldo. 1966. *A sand country almanac with essays from Round River.* 1st. New York : Oxford University Press/Sierra Club/Ballantine Books, 1966.

Lexing , Tian. 2014. Truffel types. [Online] 18 June 2014. http://www.delectations.org/types.html.

Malajczuk, N., Jones, N. and Neely, C. 1991. *The importance of mycorrhiza to the forest trees.* s.l. : The World Bank,Asia Technical Department, Agriculture Devision, 1991.

Marczyński, Clematis Sz. 2014. Early bearing and self-pollinating actinidia. [Online] 14 June 2014. http://www.newplantsandflowers.com/early-bearing-and-self-pollinating-actinidia/.

Maser, Chris. 2001. *Forest Primeval: The Natural History of an Ancient Forest.* Oregon : Oregon State University Press, 2001.

Mijts, Jody. 2014. Geologie van Nederland. [Online] 2014. [Cited: 21 4 2014.] http://www.geologievannederland.nl/fossielen/vindplaatsen/tegelen.

Mikola, P. 1970. Mycorrhizal inoculation in afforestation. *FAO.* [Online] 1970. [Cited: 1 9 2014.] http://www.fao.org/docrep/87903e/87903e08.htm.

Murphy, Dennis C. 2005. Devoniantimes. [Online] 9 July 2005. [Cited: 22 5 2014.] http://www.devoniantimes.org/who/pages/archaeopteris.html.

Muus, B., Lust, N. and Granval, Ph. 1992. Effects of grassland afforestation with different tree species on earthworm communities, litter decoposition and nutrient status. *Soil Biology and Biochemistry.* 1992, Vols. Volume 24, Issue 12,Pages 1459–1466, pp. 1459-1466.

Muys, B. 2003. *Haalt het wereldbompatrimonium de 22ste eeuw? Reflecties over de bos en globale verandering in Noord en Zuid.* Leeuven : Universitaire Press, 2003.

Naess, Arne. 2014. http://www.naturalforestpractice.com. *http://www.naturalforestpractice.com.* [Online] 9 6 2014. http://www.naturalforestpractice.com/deepecology.htm.

2013. Natural News. [Online] 19 8 2013. [Cited: 20 6 2014.] http://www.naturalnews.com/Quote-Growing-Food-Printing-Money.html#.

2014. Natuur in Nederland. *http://www.natuurlandschap.nl/.* [Online] 6 24 2014. http://www.natuurlandschap.nl/wouter2/gelderland/de-bruuk/.

Nederland, Natuur in. 2014. [Online] 6 24 2014. http://www.natuurlandschap.nl/wouter2/gelderland/de-bruuk/.

Nix, Steve. 2014. The History of Forestry in Europe. [Online] 2014. http://forestry.about.com/od/foresthistory/p/The-Histroy-Of-Forestry-In-Europe.htm.

Norton, Emily. 2012. Inspirational reforestation project nears significant milestone in Blueandgreentomorrow. [Online] 20 5 2012. [Cited: 22 5 2014.] http://blueandgreentomorrow.com/features/inspirational-reforestation-project-nears-significant-milestone/.

O'Toole, Garson. 2011. Quote Investigator . [Online] 20 10 2011. [Cited: 22 5 2014.] http://quoteinvestigator.com/2011/10/20/last-tree-cut/.

Ouden et.al. 2010. *Bosecologie en Bosbeheer.* Leuven : Acco, 2010.

Oxforddictionaries. 2014. www.oxforddictionaries.com. [Online] 2014. [Cited: 9 6 2014.] http://www.oxforddictionaries.com/definition/english/nature.

Parke, J. L. 1982. *Factors affecting the inoculum potencial of VA and ectomycorrhizal fungi in forest soils of south-west Oregon and northern California.* s.l. : Oregon State University, 1982. Ph.D. Thesis .

2013. Pinterest. [Online] 2013. [Cited: 20 10 2014.] https://www.pinterest.com/marjolijntje/greens-and-fruits-from-around-the-world/.

Poorter et al. 2005. A monocarpic tree species in polycarpic world:how can Tachigali vasqueszii maintain itself in a tropical rainforest. 2005, Vols. Vol. 93, No. 2, Journal of Ecology, pp. 268-278.

—. 2005. A monocarpic tree species in polycarpic world:how can Tachigali vasqueszii maintain itself in a tropical rainforest. *British Ecological Society.* Journal of Ecology, 2005, Vols. Vol. 93, No. 2, pp. 268-278.

Powell, C. L. 1984. Field inoculation with VA mycorrhizal fungi. [book auth.] C. L. Powell and D. J. Bagyaraj. *VA mycorrhiza.* Florida : CRC Press, 1984, pp. 205-222.

PSU. 2002. The Pennsylvania State University. [Online] 2002. [Cited: 2 6 2014.] http://www.psu.edu/dept/nkbiology/naturetrail/succession.htm.

Reinders, Chris. 2014. Algemeen Dagblad. Eten komt zo uit het bos. [Online] 10 5 2014. http://media.wix.com/ugd/7869e4_264462b1e09d42c7b89e6252a7e037c1.pdf.

Resources, World. 2000. *World Resources 2000-2001.People and ecosystems. The Fraying Web of Life.* Oxford : Elsevier Science, 2000.

Richter, J.P. 1970. *The Notebooks of Leonardo da Vinci. Dover. reprint from the original 1883.* 1970.

Rusanov, A. M. and Anilova, L. V. 2009. The Humus Formation and Humus in Forest-Steppe and Steppe Chernozems of the Southern Cisural Region. 2009, pp. 1101–1108.

2014. Saint Patrick High School. [Online] 2014. http://spworldstudiescp.wordpress.com/2011/02/23/europe-maps/.

San Giorgi, Xavier; Eck, Wouter van. 2014. *Mineralen-accumulatoren en hun specifieke bijdrage aan een vruchtbare bodem.* Utrecht : Foodforestry Netherlands, 2014.

Scheckler, S.E. 1999. Progymnosperms. [book auth.] R. Singer (ed.). *Encyclopedia of Paleontology Vol 2(M-Z).* Chicago & London : Fitzroy Dearborn Publ., 1999, pp. 992-995.

Seiler, John R. 2014. Forest Biology and Ecology for Educators. [Online] 6 March 2014. http://dendro.cnre.vt.edu/forbioeco/htmltext/index.html.

Shepard, Mark. 2013. *Restoration Agriculture:Real-world permaculture for farmers.* s.l. : Acres, USA, 2013.

Sholto Douglas, J. and Hart, R.A.de J. 1985. *Forest farming.* London : Intermediate technology publications, 1985.

Shut, Irwanto. 2014. http://www.irwantoshut.net. [Online] 2014. [Cited: 9 6 2014.] http://www.irwantoshut.net/forest_history.html.

Smith, Jeremy M.B. 2014. Encyclopaedia Britannica. [Online] 2014. [Cited: 18 6 2014.] http://www.britannica.com/EBchecked/topic/586555/temperate-forest/70782/Biological-productivity.

Stebbins, Leslie F. 2006. *Student Guide to Research in the Digital Age. How to locate and evaluate information sources.* Westport, Connecticut; London : Libraries Unlimited, 2006.

Stortelder, A.H. F., et al. 1999. *Beheer van bosranden. Van scherpe grens naar soortenrijke gradiënt.* Utrecht : Stichting Uitgeverij KNNV. Vereniging voor veldbiologie, 1999.

Suárez, S.M. and Emanuelli, M.S. 2009. *MONOCULTURES AND HUMAN RIGHTS. Guide for documenting violations of the right to adequate food and housing, to water, to land, and territory related to monocultures for industrial agriculture production.* Heidelberg : FIAN&HIC-AL, 2009.

SVC. Hydrological Cycle of a Watershed. *Skagit Valley College.* [Online] [Cited: 18 11 2014.] http://www.skagit.edu/news.asp_Q_pagenumber_E_1982.

Swift, M. J. 1999. *Towards the second paradigm integrated biological management of soil.* Lavras,Brazil : Universidade Federal de Lavras, 1999. pp. pp. 11–24.

Swift, M. J., Heal, O. W. and Anderson, J. M. 1979. *Decomposition in terrestrial ecosystems.* Berkeley : University of California Press, 1979.

2014. The University of Vermont. *http://www.uvm.edu.* [Online] 6 21 2014. http://www.uvm.edu/place/analyze/soil_horizons.html.

Thomas, P.A. 2000. *Trees:Their Natural History.* Cambridge : Cambridge University Press, 2000.

Thomas, Peter A. and Packham, John R. 2007. *Ecology of Woodlands and Forests. Description, Dynamics and Diversity.* Cmbridge : Cambridge University Press, 2007.

Trappe, J. M. and Fogal, R. D. 1977. Ecosystematic functions of mycorrhizae. *Below-ground ecosystems.* s.l. : Colorado University Scientific series, 1977, pp. 205-214.

Tredici, Peter Del. 1995. A Nitrogen Fixation:The Story of the Frankia Symbiosis. [Online] 1995. [Cited: 7 10 2014.] http://arnoldia.arboretum.harvard.edu/pdf/articles/1995-55-4-a-nitrogen-fixation-the-story-of-the-frankia-symbiosis.pdf.

Tree Morphology, (Part 2), Theory & Practice, Diagnostics & Management. **Neville-Fay et al. 2007.** Bristol : University of the West of England, 2007. Treework Environmental Practice 'Innovations in Arboriculture' seminar series.

2010. Trees for Life. [Online] 25 8 2010. http://www.treesforlife.org.uk/tfl.quotes.html.

UCMP. 2014. http://www.ucmp.berkeley.edu/. [Online] 2014. [Cited: 9 6 2014.] http://www.ucmp.berkeley.edu/seedplants/progymnosperms.html.

USDA. 2001. The United States Department of Agriculture (USDA). [Online] May 2001. [Cited: 11 03 2014.] http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051289.pdf.

Uses and modifications for the ´Moosehorn´crown closure estimator. **Garisson, G. A. 1949.** 1949, Jornal of Forestry,47, pp. 733-735.

UVM. 2014. The University of Vermont. [Online] 6 21 2014. http://www.uvm.edu/place/analyze/soil_horizons.html.

Verhoeven, Nel. 2004. *Doing Research. The Hows and Whys of Applied Research.* Amsterdam : Boom Academic, 2004.

Vertessy et al. 1998. *Predicting Water Yield From Mountain Ash Forest Catchments.* Melbourne, Australia : Cooperative Research Centre for Catchment Hydrology, 1998. Industry Report.

Vianello, Stefano. 2014. Flickr. [Online] 18 June 2014. https://www.flickr.com/photos/photostefano/4931284867/.

Vouté, A.D. 1964. Harmonious control of forest insects. [book auth.] J.A. Romberger and P. ed. Mikola. *International Review of Forest Research.* New York : Academic Press, 1964, pp. Vol.I, pp.325-383.

Waksman, Selman A. 1938. *Humus.Origin, chemical composition and importance in nature.* Baltimore : The Williams& Wilkins Company, 1938.

WBG. 2011. The World Bank Group. *Forest sourcebook. The World Bank, Washington, DC.* [Online] 2011. [Cited: 9 6 2014.] http://web.worldbank.org.

Weber, Jerzy. 2014. Department of Soil Science & Agricultural Environment Protection, of the Agricultural University of Wroclaw, Poland. [Online] 10 April 2014. http://karnet.up.wroc.pl/~weber/typy2.htm.

Welch, Ross M. and Graham, Robin D. 2004. *Breeding for micronutrients in staple food crops from a human nutrition perspective.* 2004. pp. 353-354.

Westerhoff, W. E., et al. 1998. The Lower Pleistocene fluvial (clay) deposits in the Maalbeek pit near. *Nederlands Instituut voor Toegepaste Geowetenschappen TNO, 60.* 1998, pp. 35-70.

Whitefield, Patrick. 2002. *How to make a forest garden.* 3rd. Hampshire : Permanent Publications , 2002.

2014. Wikipedia. [Online] 26 6 2014. http://en.wikipedia.org/wiki/Loam.

Willems, J. H. & Boessenkool, K. P. 1999. Coppiced woodlands and their significance for herbaceous plant species conservation. [book auth.] In Dong Ming & M. J. A. Werger (Eds.). *A spectrum of ecological studies. In honour of Professor Zhang Zhangcheng at his 70th birthday.* s.l. : Southwest China Normal University Press, 1999, pp. 188-196.

2014. Yavapai College.Organisms and Soil Ecology. *www.faculty.yc.edu/.* [Online] 22 6 2014. http://faculty.yc.edu/ycfaculty/ags105/week10/soil_organisms/soil_organisms_print.html.

Zahran, Hamdi Hussein. 1999. Rhizobium-Legume Symbiosis and Nitrogen Fixation under Severe Conditions and in an Arid Climate. *Microbiol. Mol. Biol. Rev.* . 1999, Vols. Vol. 63, No. 4 , Pages: 968-989 , pp. 968–989.

“The best time to plant a tree was 20 years ago. The second best time is Now.”

Chinese proverb

Let´s go and plant edible trees!

Anastasia Limareva