GeoLiv

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Content

Forest garden design

Context of project

The forest garden project will be established at the homestead Kattekærhus, on the island Orø, as part of the garden design. The forest garden will contribute to the livelihood of the occupants, namely the diploma applicant, and visitors. The forest garden is one element in a design which includes the house, the old stables, the back garden, the front garden, the backyard and the driveway, as described in the "Homestead design for Kattekærhus". It is intended that Kattekærhus in the future will become a LAND centre. The garden will therefore be designed to be a demonstration garden as well as produce a significant contribution to the household food supply and have recreational and educational areas.

The aim with the forest garden is to supplement a lifestyle which is semi-self-sufficient. Its maintenance and harvest will be fitted in with other activities, and some work will be done in educational workshops, by volunteers or friends.

Photos: To the left, a corner of the forest garden in April before I moved in. To the right, the same corner in August after cutting down nettles and applying a mulch of cardboard and seaweed.

Survey

Different modes of observation and survey have been used.

Walk the boundaries

When I first got to the property in April 2014, I walked along the boundaries of the land to get a feel for what was there. It was an interesting walk on top of a big stone hedge with lots of bits of plastic, glass, old

buckets, polyprop rope bits, bottles, bricks etc. from the days when the recycling station did not exist and all the garbage was thrown in the hedge. A lot of cleaning needed to be done! There were also some amazing old trees, some of which were so rotten that they created their own small biotopes for insects and animals. I have left these trees to develop even more diversity.

Intuitive observation

I also used a more intuitive approach of being still and listening to the land. Something told me that it really needed a caretaker, being a garden for centuries it had grown together with humans and humans were a part of the ecological system here.

Another mode of observation, namely imagining what the land would look like if humans were not around, was also used. That was very easy, since the land had been left for three or more years to itself. Little ash trees and kreer (prunus) had started growing all over and the shrubs of lilac and jasmine had taken over a third of the garden area. It was not difficult to imagine what the garden would look like further on in the succession from grass to forest. Creating the forest garden as this edge between annuals and grass in the south and west and the mature ash trees behind to the north and east was very straight forward.

Systematic survey

I used a systematic approach of base mapping and noting down the different species on the map, see below. In June when I moved in, the forest garden area was mostly covered in 2 meter high stinging nettles, which had to be cut down before observation of the forest garden area could take place. The stinging nettles indicate that the soil is fertile. Below the stinging nettles I discovered numerous currants and gooseberry bushes, suffering from years of neglect. Below are the results of the survey.

Available Land:

- The forest garden area borders the property to the north and east. The northern area is about 22 m * 7 m = 154 m2. The eastern area is about 26 m * 3 m = 78 m2. A total of 232 m2, about a quarter of the total property.
- The forest garden borders the communal abandoned area with trees to the east, thus extending into a zone 5 type area.

Existing Trees:

- 3 apples trees (2 nice big apple trees that ripen in October, 1 paradise apple tree ripens in September)
- 1 Cherry. Fruits in July.
- Several Mirabelle (prunus). Fruits in June.
- Several elder. Flowers in May, fruits in August.
- Several kreer (prunus). Fruits in August
- Several full grown ash to the north and east

Existing shrubs:

- Lilac
- Jasmine
- Kreer

Existing fruit bushes:

- 1 Gooseberry
- 3 Red currants
- 3 Black currants

For details on climate, soil, slope, etc. please refer to the “Homestead design for Kattekærhus”.

Photos: To the left is the eastern boundary of the property with a paradise apple tree at the front. To the right is a look towards the north eastern corner with the big ash tree branching in from the left. April 2014.

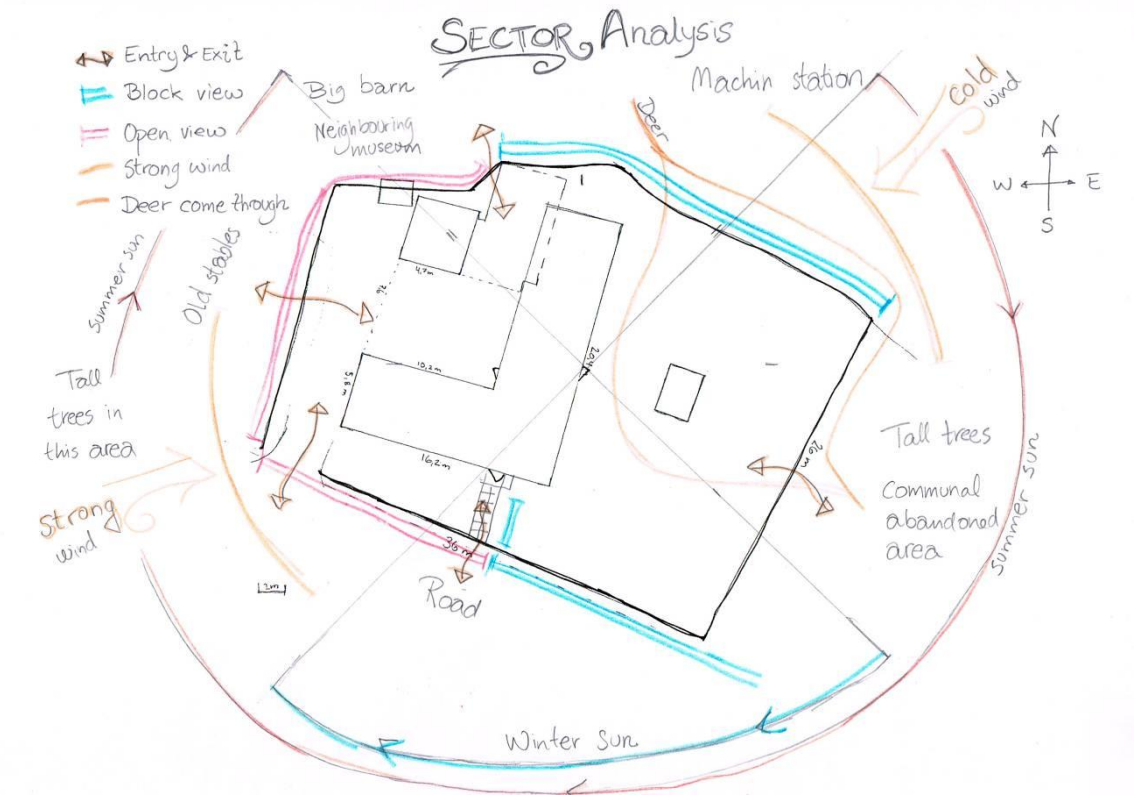
Sector analysis for the forest garden

The forest garden borders to north an open field and a machine station for agricultural equipment. This view is undesirable. To the east is an abandoned piece of communal land that has big trees and some shrubs. This view is desirable and cutting a bit off the hedge trees would be ok to let more light in from the east.

A cold north easterly can sometimes be very unpleasant at some protection from the wind is preferable.

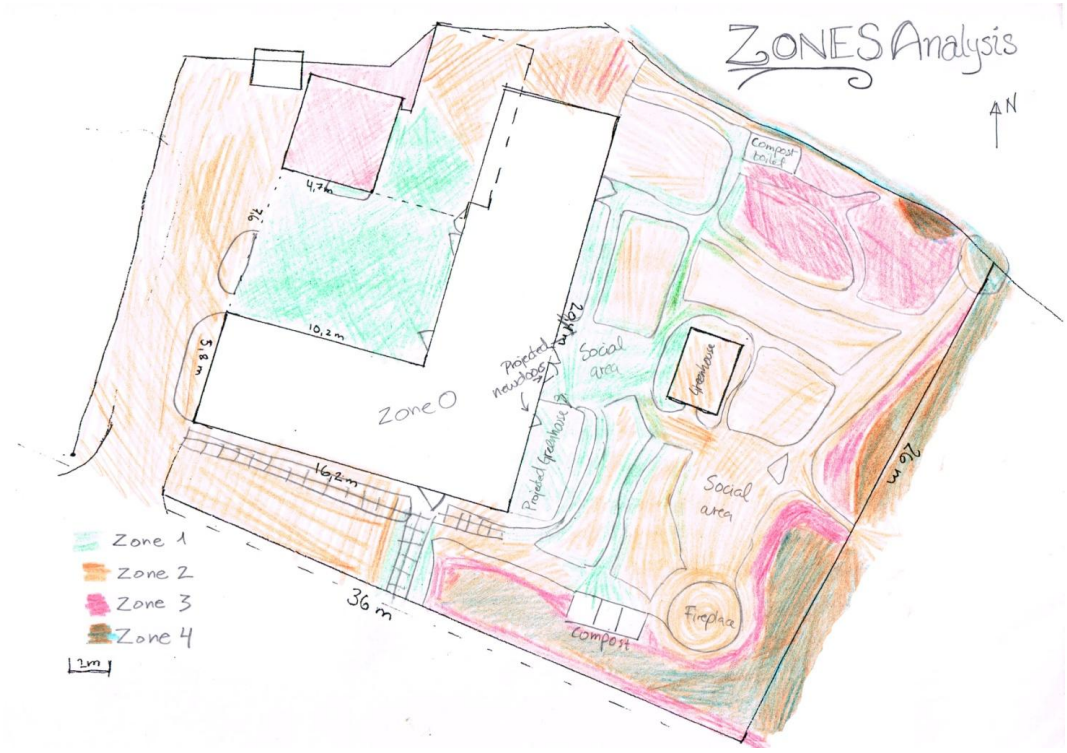
The sun in the summer is high on the sky an all part of the forest garden will have direct sunlight in smaller or larger amounts. The tall tree in the hedge and on the communal land, blocks out the sun in autumn. In winter when there are no leaves the sun lights up more of the forest garden, but it is very low on the horizon.

In conclusion, the northern part of the forest garden should be kept dense and act as both wind break and view break. The eastern part could be thinned and trimmed and some of the big trees in the hedge could be taken out to let more sun in. However, it should not be open as on the western side of the property, but still have healthy growth of vegetation, preferably with some fruiting trees.



Zoning of the forest garden

The survey of zones was done in the design of the Homestead, please refer to this document for more details on the zones. However, the zones in the garden are connected to the exits of the house and the entry point to the garden, see drawing below.



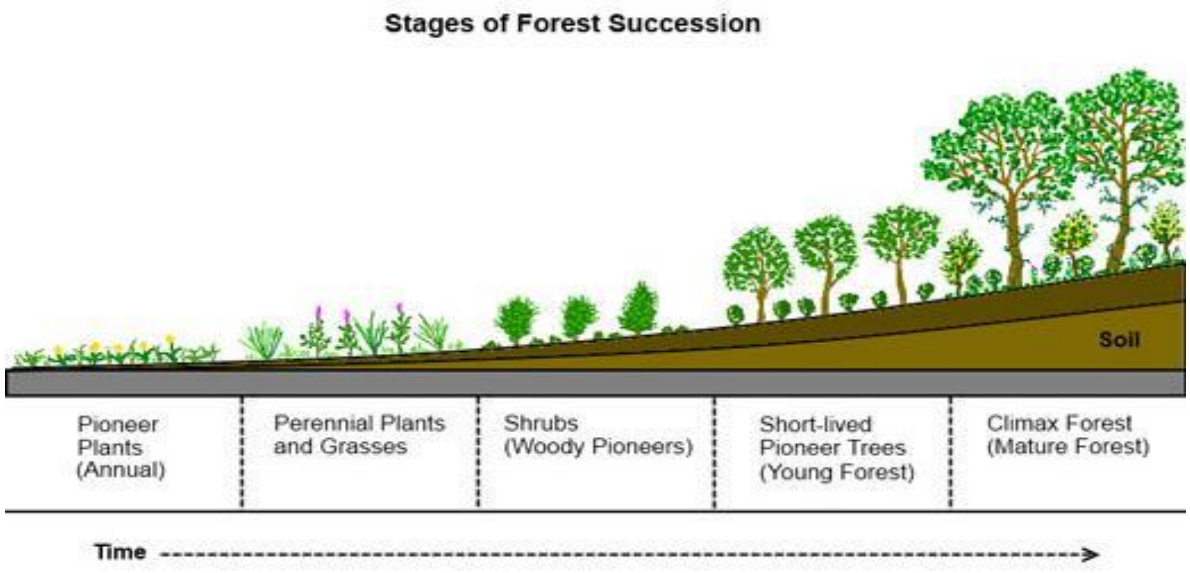
Analysis

Forest garden basics

"A forest garden is a garden modelled on the structure of young natural woodland, utilizing plants of direct and indirect benefit to people." Martin Crawford, "Creating a forest garden", 2010.

What characterizes the forest garden is mainly:

- Modelled on young woodland
- Edible plants
- Perennial plants
- Multipurpose plants
- Self-fertilising eco-system
- Ground cover
- Insect repelling and attracting plants
- High diversity to obtain resilience
- Close to the house and kitchen
- Companion planting



Stages of Forest Succession: Ecological succession, including forest succession, is the orderly and predictable process by which an ecological community progressively transforms itself to ultimately create a stable system. In temperate climates this is usually always the forest eco-system, which provides maximum protection of the soil and carbon storage in biomass and humus increasing resilience in dynamic equilibrium. We can accelerate the development of the forest eco-system by using existing plants to build soil, introduce hardy species that can tolerate the environment, artificially increase soil organic matter by mulching and substituting plants in the eco-system with plants that are useful to us. Source: http://deepgreenpermaculture.com/

Several principles of permaculture are pervading the forest gardening concept:

"Work with nature rather than against" by modelling a young woodland and creating a self-fertilising system with high diversity of species.

"The problem is the solution" is likely to refer to the current conventional farming system where the succession of plants is totally destroyed by repeated ploughing – whereas food, e.g. nuts, can be produced in a mature ecosystem without any soil management apart from appropriate ground cover.

"Each important function is supported by many elements" is evident in the forest garden. Eg. Food supply for humans is covered by many different species, nutrient cycling is done in several ways, e.g. Nitrogen-fixing plants, mulching, urine, ash and letting the microbes in the soil do their thing.

"Each important element performs many functions" is also evident. All plants have at least three different functions: as food supply for either humans or animals or insects, habitat for animals, nutrient cycling, beauty, etc etc.

"Understand and use niches" is what forest gardening is all about. Each plant has its preferred environment be it as an annual or perennial, tall or low, root crop or climber, early or late season, ways of spreading/fruiting, sun or shade tolerant etc etc.

"The yield of a system is theoretically unlimited" – if this applies anywhere it would be in the forest garden. The yields of a forest garden are endless if one's imagination is big enough. Yields could include fruit, food, bees, timber, mulch material, habitat, beauty, shelter, knowledge, recreation, just to name a few things off the top of my head.

"Make the least change for the greatest possible effect" and "Create small-scale intensive systems" are straightforward in the forest garden concept – by allowing nature to work and introducing minimum disturbance to the young forest edge ecosystem we harvest relatively more and if we can keep the system small scale and intensive, outside our kitchen door, to provide for our needs, we have come far in terms of both **earth care, people care and fair share**.

Ethics at work in the forest garden

If we look at some of the functions of the forest garden in terms of the ethics of permaculture, we might find that forest gardens enhance:

Earth care: biodiversity and habitat for a multitude of plants, insects, animals and fungi; carbon sequestration and storage counteracting climate change; nutrient recycling and uptake; soil protection through leaf layer, roots and enabling environment for soil structure and cohesion; retaining moisture; improving air quality and oxygen levels; creating microclimates.

People care: Providing food also in off-season times; providing healthy and diversified food items; providing a pleasing recreational space; creating connection with nature, healing and anti-stress environment.

Fair shares, sharing surplus: reducing the need for energy consumption and thereby sharing resources more fairly globally; creating surplus for community to enjoy; creating learning opportunities about nature and natural systems.

Key areas and Accessibility

One of the principles of permaculture is relative location, meaning that areas where people are most of the time will get the most attention. Key areas attract people and create more traffic along paths. Paths leading here will increase the use of the area, so putting in strategic paths while maintaining areas unmanaged for biodiversity is a balancing act.

Maintenance

Another principle is about maximum yield for minimum effort, meaning that the energy spent on maintenance of the forest garden should be kept to a minimum. Therefore, the need to dig is designed out of the forest garden plan. Neither is it necessary to mow lawns when the forest garden has reached its climax.

Placing elements in a beneficial relation to other elements also eases maintenance. Plants and beds that need regular harvesting or other kind of attention should be in areas where I often spend time. Often used herbs such as parsley, oregano, thyme, rosemary, etc should be placed close to the kitchen door for easy picking or along one of the paths.

Plants along paths and around often used structures can be plants that are beneficial to the activity going on.

Plants that only need attention few times of the year for harvesting can be placed in areas that are less accessed like most of the fruit trees and bushes.

Animals like chicken and ducks can help maintain the forest garden once it has been established.

Identifying beneficial functions and attributes

The trees and shrubs have been selected according to attributes like size, nitrogen-fixing ability, sun exposure requirement, soil type, moisture and temperature preferences, edibility and other beneficial features, see the text box on Species Niche Analysis. The hardiness zones listed in Martin Crawford's "Creating a forest garden" was used as a guideline, where zones 0-6 are readily suitable for the Danish climate. Hardiness zones 7 and higher requires more attention to keeping the plants free of frost over winter, so these plants were not prioritized. A list of plants is attached in the spreadsheet showing the different attributes. Another list has all the plants that were taken into consideration translated to latin, English and Danish.

The different functions in relation to plant and eco-system health that we have chosen are:

- Groundcover – to suppress grass and thereby increase fruiting in trees as well as protecting soil from leach of nutrients and soil erosion, good groundcover is essential. The plants can be chosen according to how much sunlight exposure they need and placed accordingly in the tree guilds.

- Nitrogen-fixers – are particularly important plants because they add nitrogen to the system, thus enabling higher production of e.g. fruiting trees and shrubs.

- Dynamic accumulators – are plants that often have deep (tap)roots. They have very developed roots that will uptake nutrients and minerals in depths where other plant roots do not extend. When the plant is cut for mulch or dies, the nutrient rich leaves decompose and make the nutrients available to other plants with roots closer to the soil surface.

- Stacking – plants can grow in the same area because some are growing in early spring and some are later developed. Or – plants can grow in different layers of the forest garden, root layer, ground cover, herbaceous layer, shrub layer, small canopy layer, canopy layer, climbers. Or – plants have different nutritional needs and can benefit each other rather than be in competition.

- Mulch material – is useful for protecting the soil against erosion, direct sunlight and evaporation of moisture. It suppresses undesired plants like grasses and nettles. It also provides habitat and food for decomposers like worms, insects, bacteria and fungi that help cycle nutrients and keep the soil fertile.

Species Niche Analysis

Developed by Sam Knowlton

Core Strategy of the plant
- Key mode of adaptive success (e.g., fast growing pioneer, mid-succession fruiting trees, late-succession emergent tree; etc.)
- Dispersal
- Ruderal, competitor, or stress tolerator

Context
- Eco-geography (climate, native region, habitat)
- Associates (co-evolutionary neighbors)
- Predators

Needs
- Tolerances and preferences (water, soil, light, pH, etc.)
- Allies (pollinators, dispersal agents, etc.)

Products
- Products directly useful to humans: fruit, leaves, fiber, timber, medicine, etc.
- Products useful to other species: nectar, shelter, etc.
- Other products (often considered "wastes")

Characteristics
- Evolutionary history/genetics (taxonomy)
- Form (morphology): size, shape, habit, root pattern, etc.

Function, Behaviors, and Influences
- Rate and means of spread and establishment, growth rate
- Nutrient dynamics: nitrogen fixation, dynamic accumulation
- Seasonal behaviors (time of flowering, leaf drop, etc
- Allelopathy, poisonousness

- Edibility – is essential to increase food security from the land.

- Insect attracting and repelling – plants that attract beneficial insects like bees and other pollinators and plants that give habitat to predators of aphides etc. It can also be plants that repel harmful insects because of their strong smell.

- Soil fumigants – are plants that release chemicals into the soil from their roots to control disease-causing nematodes (root worms), fungi or weeds.
- Habitat – for beneficial insects, animals and fungi is part of keeping the forest garden eco-system thriving and fertile.
- Space – for climbers like hops or wisteria to grow, for example up a tree. Space is a major constraint because the area already has full grown canopy trees.
- Taste enhancers – the flavor of fruits like apples can be enhanced by planting aromatic herbs like thyme, sage or lavender next to the tree.

Companion planting

The use of companion planting can be of benefit to the grower in a number of different ways, including:

Hedged investment – the growing of different crops in the same space increases the odds of some yield being given, even if one crop fails.

Increased level interaction – when crops are grown on different levels in the same space, such as providing ground cover or one crop working as a trellis for another, the overall yield of a plot may be increased.

Protective shelter is when one type of plant may serve as a wind break or provide shade for another.

Pest suppression – some companion plants may help prevent pest insects or pathogenic fungi from damaging the crop, through chemical means.

Predator recruitment and **positive hosting** – The use of companion plants that produce copious nectar or pollen in a vegetable garden (insectary plants) may help encourage higher populations of beneficial insects that control pests, as some beneficial predatory insects only consume pests in their larval form and are nectar or pollen feeders in their adult form.

Trap cropping – some companion plants are claimed to attract pests away from others.

Pattern disruption – in a monoculture pests spread easily from one crop plant to the next, whereas such easy progress may be disrupted by surrounding companion plants of a different type.

(source: Wikipedia)

Design

Infrastructure and placement of the forest garden area

The following interaction is based on careful analysis of wind, aspect, water and soil and is designed around existing beneficial structures, activities, the house and the mature growth of vegetation on the land.

The location of the forest garden has been explored in the “Homestead design for Kattekærhus”. To sum up the location was based on the concept that a **forest garden** mimics the ecosystem of a young forest edge. This fits well with the existing vegetation in the back garden. The first hand impression when entering the back garden is that of stepping into a clearing in a forest. Making the least change for the greatest possible effect was to design the forest garden area to include the area on the northern and eastern boundaries of the garden.

Most dominant is the enormous and beautiful ash tree on the northern boundary. The smaller fruit trees are situated to the south of the ash, creating a sun trap in the garden and wind breaks towards the northern and eastern boundaries. The flow between the vegetable patches, the fruit trees and the high canopy of the ash trees, creates a profile of maximum light absorption.

No major changes to the shape of the land are necessary for the creation of the forest garden.

Photo: September, the north west corner of the forest garden while laying out mulch.

The over all garden design for Kattekærhus with paths. The forest garden area is situated on the northern and eastern boundaries of the property.

Soil mulching and conditioning

Applying a mulch to the areas of the forest garden which was covered in 2 meter high stinging nettles was the first step to be able to observe what kind of plants and growth was going on (apart from nettles). Having looked into seaweed as the most appropriate mulching material for this task, I cut down the nettles

to observe the forest garden floor. After a month, when the nettles started coming back I covered a large part of the forest garden area with cardboard gathered while out shopping and seaweed collected from the beach. Seaweed is a very good material in terms of nutrition and is available in bulk and for free on the island. More on seaweed as mulch is found in the "Seaweed mulch design". I got help from friends and woofers to collect and pack the mulch.

Process of choice of plants

The big trees and shrubs were chosen first because they take up more space and will become part of the structure. Two main criteria were applied in the selection of trees and shrubs: Nitrogen-fixing ability and Number of beneficial functions, please see the tables in the appendix.

The survey showed that I would like to have fruits and nuts available. A range of different fruit and nut trees and bushes like apples, plums, cherries, walnut, chestnut and hazelnuts as well as gooseberries, currants, blackberries etc. are wanted as crops. Some of these are already available in the forest garden or nearby, so it is mostly about filling the gaps with useful trees and shrubs. The maturing of fruits is spread over the season so that there is some fresh fruit during the summer through to winter. A range of fruits also means that if one kind fails to give yields, other kinds are available.

Each tree was selected based on its attributes. I picked attributes from the list (see the tables in appendix and below) and tried to find trees that would cover multiple attributes. This complies with the permaculture principle of multiple elements to fulfil different functions. The function is also covered by multiple types of trees, shrubs and smaller plants. For example nitrogen fixing abilities is covered by Alders, Elaeagnuses, Wisteria, a range of smaller legumes.

The calculations of the nutrients budget for Nitrogen and Potassium is then calculated to make sure enough nutrients are available to the number of trees and shrubs, see at the end of this section.

The main sources of information around the selection of trees and other plants come from Martin Crawfords "Creating a forest garden", which has a nice range of different canopy species, shrub species and smaller plants. Also Ken Fern's "Plants for a future" inspired choices of plants. Recently I have got a copy of Martin Crawfords' "Perennial Vegetables" which also gives inspiration. But mostly choices are informed based on prior knowledge about the plants, their cultivation and their use. This can be own experience or recommendations from friends who have worked with forest gardens for a long time. Changing (eating) habits is a choice that comes with awareness of options and developing a forest garden opens up to a range of new uses of plants. Much new learning has to be acquired to make full use of these new options, which will take time. A combination of known plants with unknown plants is my preferred way to handle the challenge of securing food and experimenting with new varieties.

Edge materials

Looking at the resources in abundance for delineating the guild and keeping the grassy paths in check, stones, wood or car tires would be the most convenient choices.

- Stone has heat storing properties that improves microclimate and is an everlasting and beautiful material.

- Wood is used for firewood, logs for mushrooms and building material. Wood helps to spread mycelium and looks beautiful. Wood logs require work because they have to cut to the right size. Needs to be replaced in a few years.

- Car tires are an option, but right now I only have 12 of them. If cut in two they could just reach around the guild. However, I prefer a more natural material in the garden. The tires would be more suitable in the front garden next to the road, to match the materials of rubber and tarmac.

- No delineation is the default option. Requires no work on the short timescale, but will be more difficult to manage in the long run.

Example of a guild around an apple tree

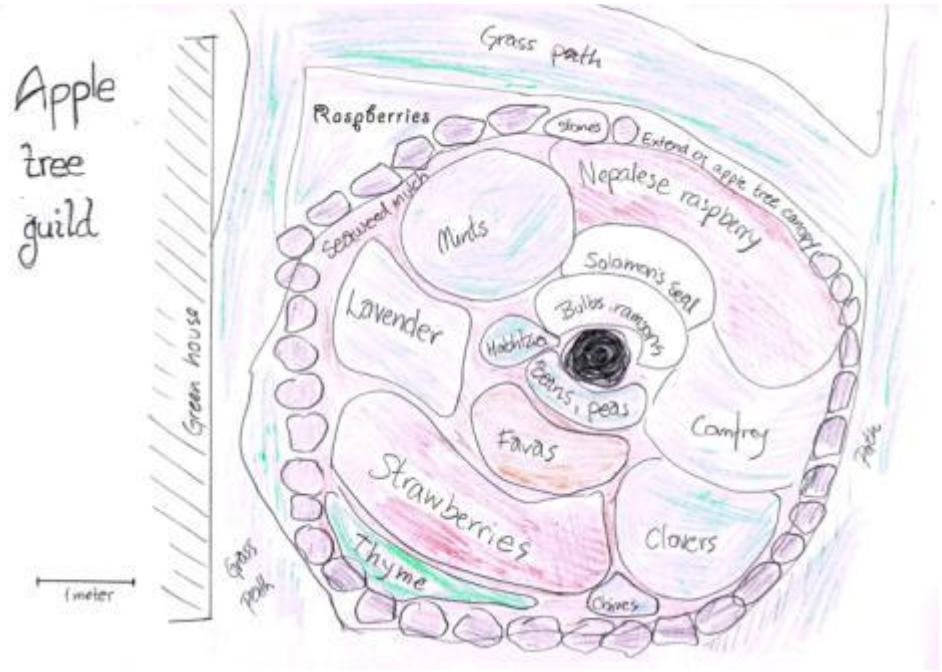
When creating a guild, all factors must come into consideration. An example of a guild is created here to show different possibilities and illustrate the principles.

The circumference of a dense canopy tree will have a drip line. The drip line can be the place where more water needing plants will thrive the most. It can also be the place of erosion if there is a slope or fragile soil. If soil erosion from water is a problem, a small trench can be dug at the drip line to enhance water infiltration in the soil.

The aspect and sunlight is important to plants and how they thrive. Nitrogen-fixing plants need full sunlight to produce N and yield to its maximum capacity. If nitrogen-fixing plants (e.g. alfalfa, vetch, beans, peas, lupins, clover) are used in the guild, they should preferably located to the south. Other plants (strawberries, artichoke, most herbs) also only produce well in a full sun position, while some prefer a partly shaded position (mints, Nepalese raspberry, comfrey, lovage, gooseberry).

Stacking in time is important in a guild and bulbs like Egyptian onion, ramsons, Solomon's seal, bluebells are early season growers and whither once the tree's canopy is in leaf.

Not all the plants mentioned are necessary to form a guild and can be interchanged. However, some of the functions, like nitrogen fixing and the dynamic accumulator function (comfrey mainly) and grass suppression/ground cover are essential to the fruitfulness of the forest garden. See the Guilds specification for more details on functions.



Apple tree guild: The apple tree trunk is black near the centre of the illustration. The guild is quite small because of the size of the apple tree and has only five layers. It has a low canopy layer (the apple tree), shrub layer (raspberries), herbaceous layer (comfrey, lavender, mints, chives, favas), rhizosphere layer (bulbs, onions), soil surface ground cover layer (ramsons, Nepalese raspberry, strawberry, thyme), vertical layer (hablitzia, beans, peas). Large canopy layer is missing. Seaweed and cardboard mulch will cover the ground until the plants are grown to their potential. Stones line the edge of the guild for a warmer micro-climate.

Nutrient calculations and budget

Nitrogen, potassium and phosphorous are the most critical plant nutrients. The idea of the forest garden is to create a closed loop system of nutrients where all the main nutrients are grown on-site. This complies with the principles of permaculture, especially Work with Nature, Maximum yield for minimum effort, Cycling energy, nutrient and resources. Especially Nitrogen and Potassium availability should be catered for. There is generally enough availability of phosphorous in the soil, so this nutrient is not especially planned for.

Nitrogen is demanded for the growth of most plants and for fruiting and must be planned for to be available in the required amounts in order not to create the work of bringing in an external source of nitrogen such as chemical fertilizers. This means that trees and other plants that fixate nitrogen are very valuable in the forest garden and are prioritized in the design. Trees, e.g. Alder, in full light yield more N/m2 than shrubs and herbs.

Nitrogen and other nutrients can be transported by mycelium up to about 100 meters. The forest garden is about 22 meters long and less wide, so if mycelium is given the right conditions, it will help distribute nutrients around the forest garden. The right conditions for mycelium can be created by pathways of

woodchips, straw or another material where the mycelium can thrive. The mature trees in the hedges have created a forest environment with falling leaves and branches over many years, so mycelium is probably already abundant. The nutrient budget is calculated for the whole system or forest garden area because of the ability of mycorrhizal to distribute nutrients.

Calculating the Nutrient budget - Demands

Nitrogen and potassium needs are based on the size of tree in meters of mature canopy and its demands for fruiting i.e. Moderate (2g/m^2 of canopy/year) and Heavy (8g/m^2/year) fruiting trees. For annual vegetables the N requirements are 28g/m^2. Calculations are based on Martin Crawford (2010): Creating a Forest Garden, pp. 53-66.

The trees and shrubs selected and already existing in the area are listed according to whether they are Moderate or Heavy croppers. For example apples, plums, cherries are heavy croppers. Juniper, sea buckthorn, medlar and most berry bushes are moderate croppers.

The formula for calculating the needed amount of Nitrogen equals Pi times the area of the canopy, which is the radius of the tree squared.

N (g) = π x r^2 x nutrient demand

Example: Apple is a heavy cropper (8g/m^2/year) with a mature canopy of 4 meters in diameter. Thus, its demand is calculated by:

Area = **π x r^2** = 3.14 x 2m^2 = 12.56 m^2

Nutrient demand = 12.56 m^2 x 8 g N / m^2 year = 100.48 g N / year

The need for **Potassium (K)** content is calculated in the same way, i.e. K (g/year) = π x r^2 x need of the tree, where the r is the radius of the mature canopy of a given tree. Moderate plant croppers need 3g/m2, Heavy croppers 10g/m2 and annual vegetables 38g/m2.

Total need of nutrients from existing and new trees and shrubs

All the tree and shrub Nitrogen and Potassium demands are calculated in this way and added up. This amount should be balanced by the production of Nitrogen by the N-fixing trees and shrubs and other inputs.

Calculating the Nutrient budget - Inputs

There are several sources of **Nitrogen**, the most important being from N-fixing trees and shrubs, legumes, urine, compost and seaweed, see table below.

N-fixer full light	10g/m2
N-fixer part light	5g/m2
Human urine	5.6g/pee

Manure	6g/kg
Compost	5g/kg
Comfrey (single cut)	0.5g/cut
Seaweed (fresh)	2g/kg

Source: Martin Crawford (2010): Creating a Forest Garden

The **inputs of Potassium (K)** is mainly supplied from the sources shown in the table below:

Human urine	7g/pee
Manure	4,2g/kg
Compost	6.7g/kg
Comfrey (single cut)	10g/cut
Seaweed meal	22g/kg
Wood ash	80g/kg

Source: Martin Crawford (2010): Creating a Forest Garden

Human urine is a very important source of both Nitrogen and Potassium. Urination in the forest garden should be encouraged and could have designated areas. The amount of urine per pee and thereby the amount of Nitrogen per pee is a practical measurement and therefore used in these calculations, but not a scientific one! To be more precise urine is an aqueous solution of greater than 95% water, with the remaining constituents, in order of decreasing concentration urea (Nitrogen) 9.3 g/L, chloride 1.87 g/L, sodium 1.17 g/L, potassium 0.750 g/L, creatinine 0.670 g/L and other dissolved ions, inorganic and organic compounds. (Source: Wikipedia).

Research is done by Martin Crawford and others on how much Nitrogen a legume can fix. Marc Peoples and Jill Griffiths (file:///C:/Users/Cat/Downloads/LegumesFixNitrogen_ento_pdf%20Standard.pdf, 2009) write that: The amount of nitrogen fixed by legumes is determined by rhizobia, soil nitrate levels and plant biomass production, and; Provided that there are adequate numbers of effective rhizobia in the soil and concentration of soil mineral nitrogen are not too high, nitrogen fixation is regulated by legume growth. Rhizobia are soil bacteria living in symbiosis in the plants Nitrogen-fixing nodules. Rhizobia is negatively affected by soil management and the absence of the host plant.

In conclusion, Nitrogen-fixing varies with rhizobia, soil nitrate level and biomass production, dependent upon sunlight and water uptake. The values used for calculation here are thus medium values, but in fact the actual amount of N fixed can vary substantially.

The overall Nutrient balance

The calculations of the requirements and the contributions to Nitrogen and Potassium are found in the spreadsheet attached. The calculations are based on the existing trees, shrubs and berry bushes in the forest garden area.

Each tree's canopy has been estimated and a rough estimate of its Nitrogen and Potassium requirements calculated. Only the fruiting trees such as apple are part of this calculation. The assumption is that the ash trees are neutral, because they shed their leaves and this creates mulch that will be recycled in the forest garden.

For the Nitrogen –fixing plants, the contribution of N has been calculated based on their canopy area.

Other contributions such as urine, seaweed, wood ash and compost have been taken into the calculation as well.

As seen from the calculations below, there is a large surplus of both Nitrogen and Potassium. Especially adding urine and seaweed increases the nutrient levels considerably. The surplus is presumably large enough to supply the kitchen garden's annual vegetable with some, if not all, of its nutrient requirements.

Nutrient calculations for the forest garden

	Nitrogen	**Potassium**	
Contributions	4044	7255	g/year
Requirements	677	839	g/year
Surplus/defeciency	**3367**	**6416**	g/year

Annual contributions						**Number-kilo/year**	
Yearly	**Source**	**Nitrogen**	**N content**	**Potassium**	**K content**	Nitrogen	Potassium
	N-fixer in full light	10 g/m2	10			228,2	
	N-fixer in partial light	5 g/m2	5				
600 pees	Human urine	5,6 g/pee	5,6	7 g/pee	7	3360	4200
	Manure	6 g/kg	6	4,2 g/kg	4,2		
50 kg	Compost	5 g/kg	5	6,7 g/kg	6,7	250	335
12	Comfrey (single cut)	0,5 g/cut	0,5	10 g/cut	10	6	120
100 kg	Seaweed (fresh)	2 g/kg	2	22 g/kg	22	200	2200
5 kg	Wood ash			80 g/kg	80		400
Total						**4044,2**	**7255,0**

N-fixers	number	diameter	m2	N fix g/year
Elaeagnus in sun	2	3	7,1	141,3
Siberean pea shrub	1	3	7,1	35,3
Seabuckthorn	1	3	7,1	39,6
Legumes (peas etc)	1		2,0	12,0
				228,2

Annual requirements			Nitrogen requirements			Potassium requirements				
		Full grown canopy area	Moderate croppers	Heavy croppers	Annual vegetable	Moderate croppers	Heavy croppers	Annual vegetable	Total	
			3 g/m2	8 g/m2	28 g/m2	3 g/m2	10 g/m2	37 g/m2		
			3	8	28	3	10	37	**N**	**P**
2	Grapes	3		24,0			30,0		48,0	60,0
3	Apple	7,1		56,5			70,7		169,6	212,0
1	Cherry	8,0		64,3			80,4		64,3	80,4
3	Mirabelle	7,1		56,5			70,7		169,6	212,0
3	Blackcurrant	0,8		6,3			7,9		18,8	23,6
3	Red currant	0,8		6,3			7,9		18,8	23,6
2	Gooseberry	0,8		6,3			7,9		12,6	15,7
3	Elder	7,1	21,2			21,2			63,6	63,6
	Potatoes	4,0			112,0			148,0	112,0	148,0
Total									**677,3**	**838,7**

Further plants can be added to the spreadsheet when necessary.

Decide

The analysis of the nutrient supply of Nitrogen and Potassium clearly showed that with the expected nutrient cycling there is room for more demanding plants. Some nitrogen-fixing plants have also been selected because of their benefits. Below is an account of the trees and shrubs selected. The canopy layer is however already very full, so my initial wish of having a chestnut tree did not match its spatial requirements. Hazel was chosen instead because it is smaller and still give delicious nuts.

Additional shrubs and trees

These are trees and shrubs, mostly unusual, that would serve my needs and can fit into the existing forest garden layout. Information is from Plants for a future (online), Martin Crawfords “Creating a forest garden” and “How to grow perennial vegetables”. The appendix has a list of plants that I explored the characteristics of and chose from.

Hazel (Corylus spp.)

- Appropriate size (other nut trees will grow too big)
- Good food (if no squirrels)
- Hedge plant
- Hardy
- Size: 5-6 meters high and wide

Autumn olive (Elaeagnus umbellate)

- Does well in windbreak hedge, shade tolerant, decidous but only between December and February.
- Fruits in late autumn
- Hardy
- Hedge plant
- Nitrogen fixing
- Size: Up to 5 m high and wide

Goumi (Elaeagnus multiflora)

- Fruits alright
- Bee tree
- Good in hedge
- Nitrogen fixing
- Size: 2-3 meters high and wide

Quince (Chaenomeles Cathayensis)

- Nice fruits
- Tolerates some shade
- Ripe in October or later
- Size: 3*3 meters

Siberian pea tree (Caragana arborescens)

- Hardy
- Edible pods
- Good bee plant
- Good for chicken fodder when the time comes
- Size: 2-3 meter high and 2 meter wide in temperate climate

Aronia (Aronia Melanocarpia)

- Superfood
- Nice berry
- Easy to grow in sun
- Bee plant
- Size: 2 meter high by 3 meter wide

Goji berry (Lycium barbarum)

- Superfood, dried fruits, shoots and leaves
- Bee plant
- Size: 2-3 meters high and wide

Jostaberry (Ribes x culverwellii)

- Nice fruits
- Bee plant
- Easy to maintain
- Size: 1,5 – 3 meters high and 1-2 meters wide

Japanese wineberry (Rubus phoenicolasius)

- Nice fruits
- Tolerates some shade
- Bee plant
- Size: 1,5 – 2 meters high and 2 meters wide

Saskatoon (Amelanchier alnifoila)

- Nice fruits
- Hedging
- Bee plant
- Size: 2-3 meters high by 2 meter wide

The best locations for the plants have been plotted on to the map of the forest garden below. Mostly considered were the sunlight available and the location relative to paths for access.

- Japanese wineberry is placed on the eastern facing wall. Here it can be trained and will get a lot of sun which is required to give good fruit.
- Autumn olive is placed in the hedge towards north. It keeps its leaves almost all year and is thus a good windbreak. It tolerates shade.
- Aronia is placed in the sun in the guild to the east for good fruiting.
- Hazel will replace some of the dying old trees along the eastern and northern boundaries. If they start to fruit, I will be happy to get the fruit. Or else the hazel will be good for coppicing.
- Siberian pea tree will be planted in the eastern forest garden area together with Quince, Goumi, Saskatoon and Goji berry.

Choice of smaller plants and herbs

Around each tree is a selection of plants that will support the tree to fruit and that are mutually beneficial as well as covering different desired functions. This constellation of plants supporting each other is called a guild. I designed guilds around the apple trees and in front of the big ash and Mirabella on the northern edge of the forest garden. The guilds can be delineated with paths for easy access and harvesting. The guilds are divided into smaller areas, zones, with different sun exposure.

Based on the survey a number of function related to non-edible uses were identified. Plants were chosen after analyzing their suitability to the function, climate and location. A list of plants and functions is in the appendix.

- Fiber (e.g. Hops, Nettles)

- Medicinal (e.g. Echinacea, Calendula, Camomile, Artemisia)

For edible uses the following functions were identified:

- Condiments (e.g. Calendula, Lovage, Horseradish, Lemon verbena, Ramsons, Sage, Thyme, Oregano, Parsley, Mustard)
- Fruit (Strawberries, Nepalese ground raspbeery)
- Nuts (e.g. Walnut, Chestnut, Hazel, Heartnut)
- Roots (e.g. Dandelion, Chicory, Jerusalem artichoke, Scorzonera)
- Tea substitutes (e.g. Lemon balm, Mints, Linden, Nettles, Lemon verbena)
- Leaves (e.g. Ground elder, Nettles, Scorzonera, Claytonia, Comfrey, Orpine)
- Stems and shoots (Rubarb, Hosta, Hops)
- Flowers (e.g. Chikory, Malva, Campanula, Dandelion, Hosta, Elder, Rose)

The plants were chosen for their suitability to be part of the forest garden environment and their appropriateness for fulfilling the identified functions. Most perennial plants are suited for a forest garden, whereas annuals need to be replanted each year and requires different attention and soil treatment than the conditions of the forest garden will offer.

The survey identified both annual and perennial plants. Perennials generally work well in forest gardens and have been taken into the forest garden design. Other plants, mainly annuals, will be located in a different part of the overall permaculture design for Kattekærhus more suitable to the conditions they require.

Implementation plan

Observation
2014: April – December

Mulching
2014: July, September, November – different parts of the forest garden mulched.

Planting
2014: October
Japanese wineberry, Autumn olives, blackberries, aronia
Orpine, ramsons, sweet cicily

Creating edges
2014: November - Using stones as delineator on edge of each guild.

Collecting plants
2015: Research on where to get the different plants, propagation. My financial resources are very limited, so I will only buy plants if necessary. This means that it will take time to establish the forest garden fully.

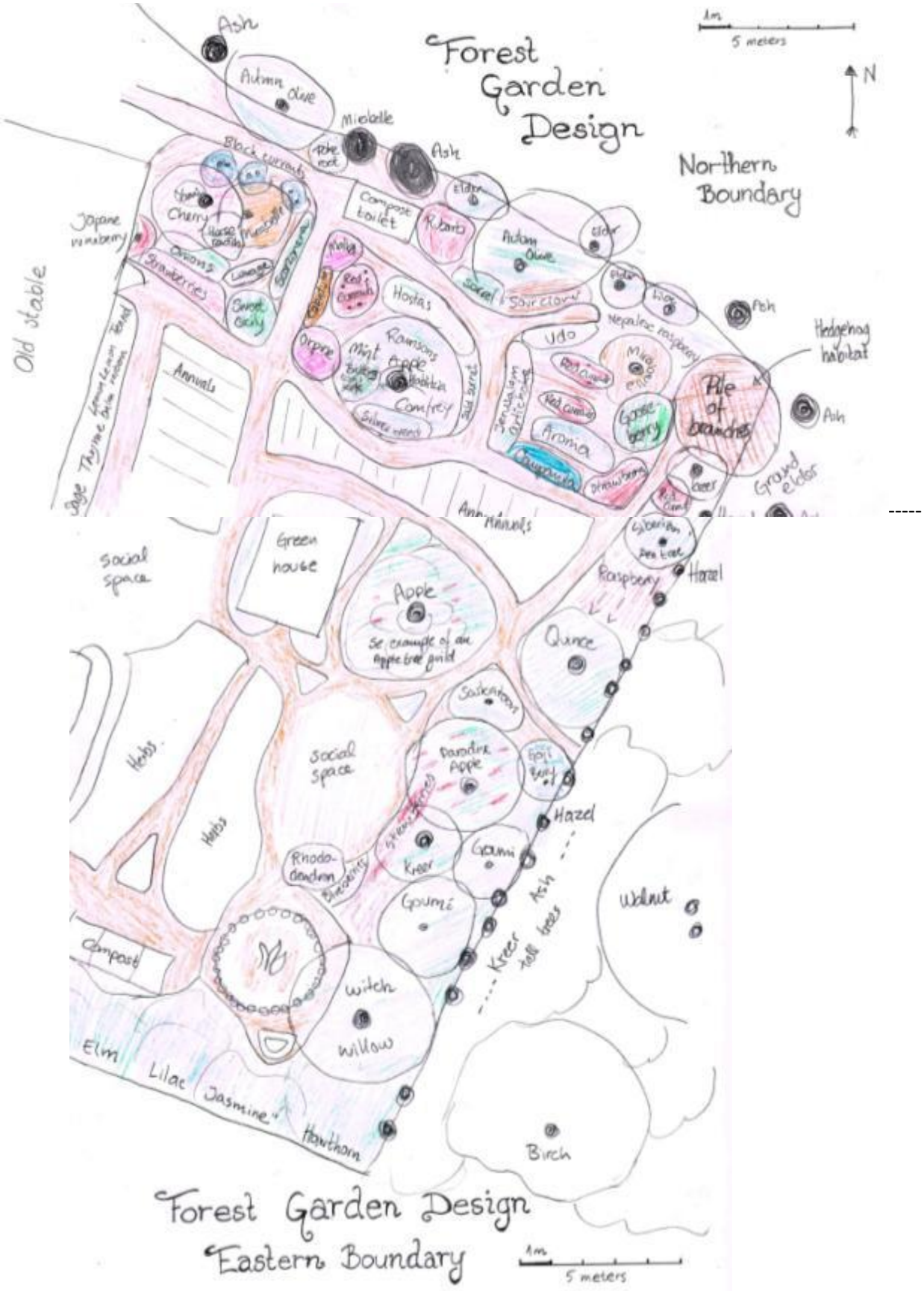
Planting
2015: Spring: Strawberries, bulbs, hops, hablitzia, herbs, sorrel, lavender, etc, etc. Normally, I can start planting in April or May, but with the current climate change every year seems to be getting more extreme and it is not to say whether the soil is frost free already in March or it will be early June before the frost has finally left. However, the forest garden's perennial plants are less sensitive than the kitchen garden because of its annual vegetables.

Grafting
2015: May – workshop on grafting apple trees. The paradise apple tree will be grafted with 2-3 different varieties of apple.

Photo: The forest garden northern area in August

The eastern part of the forest garden freshly mulched with cardboard and seaweed, November 2014.It is a Canadian volunteer to the left and me to the right. (Photo: Henri, another Canadian volunteer).

Map of forest garden



Diploma Criteria

Demonstrating Design Skills	**Applying permaculture in my own life**
- Observation - Forest garden design - Companion planting - Succession design - Nutrient calculation - Mapping	The forest garden broadens my experience with plants, growing and connection with nature.
Learning from and developing your permaculture practice	**Applying permaculture to my work and projects**
This is the second design I do for a forest garden. The first one was on a workshop and this time it was a good experience to have done the nutrient calculations and work more with the different options of plants and niches and design. Working with volunteers is quite new to me. I enjoyed the intuitive observations and feeling connected to the land.	Using Holmgren's domains this project is clearly within land stewardship. In the categories, mostly designing and site development.

Evaluation

The forest garden design is halfway in its implementation; so many lessons remain to be learned. Maps and plans are already effective and useful and I have had no reason to change the plans yet.

The calculations show a high level of nutrient availability, especially with all the seaweed added. It is already very fertile soil. Encouraging mycelium and carbon storage in the soil will make it even more so. I cannot do a comparison study of yields before and after applying mulch on my land, but I can keep monitoring yields from specific trees.

The mulch seems to work well so far. Weeds have broken through in some places, probably mostly because I've been walking on it and thereby ripping the cardboard.

I expect to be adapting the design for years to come, to try out new plants as I'm getting familiar with existing ones and to share my knowledge in the local community. It is the first forest garden on Orø and could attract people to know more about permaculture.

Working with volunteers has been beneficial. People who come are happy to work in the garden, because they often come from urban areas. The combination of a trip to the beach to get seaweed and to mulch and plant in the forest garden afterwards seems to be rewarding for people. Working with volunteers is quite new to me and I have to get used to the role of giving tasks. Having been a volunteer myself I understand that a balance between work, social activities and leisure time must be found. Some volunteers expect to be put to work straight away others not. Some expect tasks they can do by themselves and others want to

be social and do work together. Getting more experience with volunteers enables me to find the right balance quickly. I have a notice board with tasks described, so there is something to do for all volunteers.

The implementation plan has worked so far. I have not been too ambitious because of time constraints. I prefer developing small-scale intensive systems around each of the trees and in the delineated areas and the plan allows me to do just that.

I also expect to have workshops on forest gardening in the future either by myself or experts. The area is already a good example for education in permaculture because many principles can be seen in a natural context. The next workshop planned is a grafting workshop and I have made contact with a grafter who can teach a group in the spring.

I am very curious to see in the future I the forest garden will provide me with the amount of food and materials that I use, with not so much effort. I am aiming for semi self-sufficient which will mean that around 25% of my use of food and materials should be able to come from the forest garden. This will be the real evaluation point in the future to come.

Reflection on the process and tools

I feel more confident to work with forest garden designs and to demonstrate its functions, niches, succession and principles in practice.

Having been through the different stages of design before, it was quite easy to use the different methods and tools. Some tools like sector analysis and survey of resources, walking the boundaries and different modes of observation were also used in the Homestead design. I quite enjoyed looking at the land with these different modes of perception and each one of the modes had something to offer. This being my own land that I will take care of for maybe a long time, gives a different appreciation and attachment than any other piece of land. I already feel my roots intermingling with the big ash trees' roots.

Doing the mapping of the forest garden area was great and I used some triangulation with house corners as fixed points. As a geographer, I have learned all the tricks a long time ago on my first year of university, and bringing them back to live in a useful context was good.

The resulting maps are quite beautiful and they already look nice on my wall. It makes it easier for people to understand what's going on. And it makes good conversation too around forest gardening principles, permaculture, carbon sequestration and climate change. Neighbours and volunteers alike get something from seeing and understanding the design. I want to create a poster on forest garden design together with the LAND people.

I really look forward to spending more time with the plants and observing how they grow. Some plants are yet unknown to me and it always takes some time to get familiar with growing patterns, fruiting, water and nutrient need. At the moment, the amount of new plants seems overwhelming. I'd rather be sure to plant in the right place and take care of the new plants that I don't yet know than to plant lots of varieties and not be able to look after all of them.

The choice of plants was somewhere between random and carefully explored. Because I know some plants quite well, I was able to visualise how it would grow and where would be the optimal spot in the forest garden for it. Other plants are unknown and the description in the books does give an idea about the plant's growth and sun preferences. But still it is new and it might take a few changes of the design to allow for unexpected growth.

The process of writing up this design was not optimal – I'd rather be in the forest garden working with it hands-on at this point where I've just moved to the house. The planning and making maps was fine, because I needed to do this anyway, and they are maps that will be useful for a long time ahead.

Appendix

English, Dansk, Latin plant names

	Translations of some common forest garden plants' names						
	3 - number of plants growing		x - growing		o - will plant soon		
	Trees, bushes and climbers				**Herbs and shrubs**		
o	**English**	**Dansk**	**Latin**	**no**	**English**	**Dansk**	**Latin**
	Aerial yam				Alphalpha	Lucerne	
1	Aronia	Aronia			Angelica	Kvan	Angelica litoralis
3	Apple	Æble	Malus x domestica		Angelica, garden	Angelika	Angelica silvestris
	Barberry	Berberis	Berberis vulgaris		Aster/fern to step on	Trædebregne	Cotula minima
	Bay Tree	Laurbær			Asters	Asters	
x	Birch	Birk	Betula	o	Beans	Bønner	
2	Blackberry	Brombær	Rubus fructicosus		Black Medick	Humle-sneglebælg	
	Black Mulberry	Morbær, sort		x	Bluebells	Hyacinth	
3	Blackcurrent	Solbær			Bog myrtle	Mose-pors	
	Blue Brush			o	Borage	Hjulkrone	Borago officinalis
	Bog Myrtle	Pors		o	Chamomile	Kamille	Matricaria chamomilla
1	Cherry	Kirsebær		o	Campanula	Klokkeblomst	
	Chestnut Hybrids	Kastanje	Castanea sativa	x	Chikory	Cikorie	Cichorium intybus
	Chinese Yam	Kinesisk yams		x	Chives	Purløg	
4	Elder	Hyld	Sambucus nigra	o	Claytonia	Vinter portulak	
	Goji	Almindelig bukketorn	Lycium barbarum	x	Clover	Kløver	
	Golden Bamboo	Bambus, gylden		x	Comfrey	Kulsukker	Symphytum officinalis
2	Gooseberry	Stikkelsbær			Daffodils	Påskeliljer	
	Goumi		Elaeagnus multiflora	x	Dandelion	Mælkebøtter	
1	Hablitzia	Spinatranke	hablitzia tamnoides	x	Dock	Skræppe	
1	Hawthorn	Hvidtjørn	Crataegus oxycantha	x	Fat hen	Hønsetarm	

	Hazel	Hassel	Corylus		Fire lily		Lilium bulbiferum
3	Hop	Humle	Humulus lupulus	o	Garlic	Hvidløg	
	Italian alder	El			Globe artichoke	Artiskok	
1	Japanese wineberry	Japansk vinbær	Rubus phoenicolasius	x	Ground elder	Skvalderkål	
	Jostaberry	Jostabær		x	Hollyhock	Stokrose, læge	Althaea officinalis
	Judas Tree	Judastræ		o	Horseradish	Peberrod	
	Juneberries	Bærmispel		x	Hostas	Hosta	
	Juniper	Enebær		o	Jerusalem artichoke/sunchoke	Jordskokker	
	Lime/Linden	Lind		o	Lathyrus, peas	Ærteblomster	
	Medlar	Mispel		o	Lavender	Lavendel	
3	Mirabelle	Mirabelle	Prunus domestica subsp. syriaca	x	Lemon balm	Citronmelisse	Melissa officinalis
	Morello Cherry	Kirsebær, morel		o	Lemon verbena	Citron verbena	
3	Native Hops	Humle		o	Licorice	Lakridsrod	Glycyrrhiza glabra
	New Jersey Tea		Ceanothus americanus	x	Lovage	Løvstikke	
	Oleaster			o	Lupins	Lupiner	
	Pear	Pære		o	Malva	Katost	Malva spp
	Pepper trees	Peber		o	Marigolds	Morgenfrue	Calendula
o	Plum	Blomme (Kirkes, Opal, Oullins Reine Claude)			Meadow sweet	Almindelig mjødurt	
	Raspberry	Hindbær		o	Mints	Mynte	
3	Red currents	Ribs		x	Mugwort	Gråbynke	
x	Rowan	Røn		o	Mullein	Kongelys	Verbascum
	Sassafras	Sassafras	Sassafras albidum		Mustard	Sennep	
o	Sea Buckthorn	Havtorn	Hippophaë rhamnoides	x	Nasturtiums	Tallerkensmækker	
2	Silverberry	Smalbladet sølvblad	Elaeagnus angustifolia		Nepalese raspberry	Nepalesisk hindbær	
x	Sloe	Slåen		x	Nettles	Brændnælder	
	Small Leaved Lime	Småbladet lime		o	Onion	Løg	
1	Tara Vine (hardy kiwi)	Stikkelsbær-kiwi	Actinidia arguta	x	Oregano	Oregano	
	Tayberry	Taybær		o	Ostrich fern	Bregne	Matteuccia struthiopteris
x	Walnut	Valnød		o	Parsley	Persille	
	White Alder	El			Phacelia	Honningurt	
	White Mulberry	Morbær, hvid		x	pot majoram	Merian	
	Whortleberry	Wosterbær		o	Ramsons	Ramsløg	
x	Willow, witch	Troldpil		x	Rose	Rose	
				x	Rosemary	Rosmarin	
				x	Rubarb	Rabarber	
				x	Sage	Salvie	
				o	Scorzonera	Scorzonerrod	
					Snakeroot		Liatris punctata
					Solomon's seal	Stor konval/Salomons Segl	
				o	Sorrel, sheep	Havesyre	
					Stevia	Stevia	
				o	Strawberries	Jordbær	Fragraria vesca
					sunflower	Solsikke	
					Tagetes	Tagetes	
					Three-cornered leek	Porre, trekantet	

				x	Thyme	Timian	
					Tiger lily	Tigerlilje	
				o	Verbena	Verbena/Jernurt	Verbena officinalis
				o	Vetch	Vigge	
					Violets	Violer	
					Wax myrtle	Pors	
					Wisteria	Blåregn	
					Yam	Yams	
				x	Yarrow	Røllike	Achillea millefolium

Plants for different forest garden areas

Forest garden areas	Full sun	Partly sun/shade	Partly shade/sun	Mostly shaded (around trunks)	Shaded
General	Strawberries	Lemon balm	Black Medick	Wisteria	Ramsons (wild garlic)
	Oregano	Globe artichoke	Mustard	Daffodils	Lovage
	Sage	Tagetes	Fat hen	Bluebells	Fern/aster to step on
	Thyme	Marygolds	Meadow sweet	Chives	Ground elder
	Rosemary	Tiger lily	Lemon verbena	Sweet Flag	Nepalese raspberry
	Malva spp	Fire lily	Angelica	Solomons' seal	
	Violets	Chikory	White currants	Three-cornered leek	
	sunflower	Parsley	Mugwort	Hops	
	Vetch	Campanula	Comfrey		
	Jerusalem artichoke	Gooseberries	Mint		
	alphalpha	Blackcurrant	Snakeroot		
	Lupins	Wax myrtle	Stevia		
	Lathyrus, peas	Scorzonera	Rubarb		
	Phacelia	Red clover	Horseradish		
	Yarrow	Borage			
		Hollyhock			
	Licorice	Sour clover	Sheep sorrel		
Edibles	Strawberry	Lemon balm	Black Medick	Bluebells	Ramsons (wild garlic)
	Artichoke	Globe artichoke	Mustard	Chives	Lovage
	Malva spp	Parsley	Fat hen	Wisteria	
	Jerusalem artichoke	Scorzonera	Meadow sweet	Rubarb	Nepalese raspberry
	alphalpha	Tiger lily	Lemon verbena	Bog myrtle	Ground elder
	Sage	Fire lily	Angelica	Solomons' seal	
	Thyme	Chikory	White currants	Three-corned leek	
	Rosemary	Gooseberries	Stevia	Hops	
	Licorice	Sour clover	Sheep sorrel		
		Borage			
		Hollyhock			

	Oregano	Blackcurrant	Mint		
(Universal) tea plants	Strawberries	Lemon balm	Mint		
	Oregano	Blackcurrant	Lemon verbena		
	Yarrow	Borage			
	Licorice	Red clover	Mugwort		
Groundcovers	Strawberries	Clover	Black Medick	Daffodils	Ramsons (wild garlic)
	Oregano	Lemon balm	Mustard	Bluebells	Fern to step on
	Phacelia	Scorzonera	Fat hen	Solomons' seal	
	Violets	Parsley	Meadow sweet	Three-cornered leek	Ground elder
	Dandelion	Chamomile	Lemon verbena		Nepalese raspberry
	Horseradish	Sour clover	Comfrey		
	Thyme	Borage	Mint		
	Vetch		Sheep sorrel		
	Yarrow				
	alphalpha				
Insect attracting/bee plants	Strawberries	Chamomile	Lemon verbena	Chives	
	Dandelion	Clover	Mustard	Solomons' seal	
	Phacelia	Lemon balm	Angelica	Hops	
	Sunflower	Borage	Comfrey		
	Lupins	Hollyhock			
	Clover				
	Yarrow				
	Lathyrus		Black medick		
Nutrient accumulation		Sage	Comfrey		
Biomass for mulch	Jerusalem artichoke	Chikory	Black Medick		
	sunflower	Globe artichoke	Mustard		
	alphalpha	Clover	Comfrey		
	Lupins	Borage			
	Clover				
	Phacelia				
	Vetch				
	Lathyrus, peas				
Nitrogen fixing	alphalpha	Ground nut		Wisteria	
	Lupins	Clover			
	Clover				
	Vetch				
	Lathyrus, peas				
	Phacelia				
Pest repelling	Horseradish	Marygolds	Lemon verbena	Chives	Ramsons (wild garlic)
	Artemisia abrotanum	Scorzonera	Mugwort	Bog myrtle	
	Tagetes	Lemon balm	Mint		

	Oregano	Parsley			
	Rosemary	Wax myrtle			
Soil fumigants		Tagetes			
		Marygolds			
Climbers				Wisteria	
				Hops	
Taste improvers	Sage				
	Thyme				
	Rosemary				
Medicinal	Rosemary	Borage	Mugwort		Ramsons
	Oregano	Hollyhock	Angelica		
	Sage				
	Yarrow				
	Thyme				