THE FUTURE OF SUSTAINABLE FOOD PRODUCTION INTEGRATED WITH THE TERRITORY

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ABSTRACT

Food production and agriculture have a great impact on the physical environment and land use. Worldwide, biodiversity is disappearing at fast pace to make space for monoculture, this is affecting all humans. Nature and natural ecosystems are crucial for our existence and quality of life. A food production system determines how human use and treat the earth. In addition, transportation of goods takes up a large deal in the total CO2 emission, for that reason local production is key. Ideally, a food production system should combine nature and agriculture, to foster the biodiversity and let symbioses between species take place. Also, a circular production system of interrelated processes is able to increase the productivity and limit the waste generation. Traditional processes form the inspiration due the relation with the surroundings, technical innovations provide optimization for a higher efficiency. Besides, natural food production environments have the potential to be recreational and to enable visitors to reconnect with nature and their food. South Limburg is the ideal place to experiment with a new sustainable industry due to its exceptional natural qualities and the need for economic and social opportunities.

KEYWORDS: *Food production, systemic design, agroforestry, biodiversity, circular economy*

I. INTRODUCTION

This research will introduce a strategy for a sustainable food production system in Parkstad, located on the border of Heerlen. In the paper a narrative is constructed on how a production system is able to contribute towards a healthier planet. The theory is applied in a study for a sustainable food production system supporting the local community and visitors of Parkstad (provide provisions for at least 100 people). A systemic approach works towards a system of interrelated processes. It is designed with a specific location in mind: Imstenrade. Nevertheless, the solutions presented are answers to environmental, social and economic problems that are present all over South Limburg and beyond. In a sense this paper proposes a system that with minor adaptions can be applied anywhere else. Every village, city or community is able to profit from a similar system, hence the system is interpretable as a strategy.

1.1. The need for local production

The Dutch government published the national climate policy, their most important goal is to reduce the CO2 emission. The climate is changing due to the high level of CO2 emission. The temperature rise has great impact on flora and fauna, harvesting and water levels. The aim is to reduce the emission with 95% in 2050, and 49% in 2030 (Centraal planbureau, 2015). To accomplish these goals the next sectors are crucial: electricity production and consumption, industry, the built environment, transportation and agriculture. An architectural project concerning a sustainable food production system addresses all of these crucial sectors on a certain level. To reduce the amount of CO2 emission, local production is required to lower the transportation distance of products. In the Netherlands 21% of the CO2 emission is caused by the transportation sector, carrying trade takes up a large part of this number (CBS, 2019). Bringing the production closer to residential areas is a solution to reduce transportation. As a result methods in agriculture have to adapt. Developments in agriculture have a big impact on the physical living environment. At this moment agriculture takes up to 60% of the land use in the Netherlands. Agriculture has a direct influence on the landscape, nature and drinking water. These are all affected by manure, ammonia, CO_2 emission and pesticides that end up in the environment. Stricter rules are needed to protect the natural environment, however this results in a shrinking area available and less freedom for the agricultural sector. For the agricultural sector to become sustainable, choices of the consumer and the entrepreneurs are determinative. Intensification and scale do influence the process. The role of the consumer is also changing, the demands for food changed, not only price and quality but also the production methods (Centraal planbureau, 2015). The growing awareness of the consequences of the current system do speed up the demand for change.

1.2. Land use in agriculture to bring back biodiversity

The production of food is dominating the land use in South Limburg as everywhere else in the world. Agriculture has large impact on how we organize landscapes. Human activities are influencing terrestrial biodiversity. In the current system, more space for agriculture means less habitation space left for different species (all animals and plants). Biodiversity is the term used to describe the countless different forms of life on earth. It is the basis for all ecosystems. As humans we are part of ecosystems as well and we fully depend on them. At this moment human actions are at top of threatening species with extinction. An average of 25% of all plants and animals are threatened worldwide (IPBES, 2019). All forms of life interact with one another, food, water and fresh air are provided to us by the working of ecosystems. On all scales ecosystems support services that affect the wellbeing of life, like nutrient cycles and primary production. The last decades human activities led to a fast decline and extinction of species everywhere. Even in mild climate change affected scenario, 50% of the range of different species is decreased by 2050 (Jetz. 2007). The loss of species is affecting the functioning of ecosystems. It decreases the productivity of an ecosystem because all species are part of interconnecting relationships (Isbell, 2013). The following can be concluded, nature is able to exist without agriculture, like it did for millions of years. But agriculture does not endure without nature. Taking this into account, the design for a new production system including a configuration of agriculture clearly has to deal with these circumstances. Ideally food production should use a system where nature and agriculture are combined, to foster biodiversity and where symbioses takes place between the species.

1.3. Relationship of people with nature and their food production

Back in the days, before the industrialisation, people had a closer relationship with their food and the production. Most of the food consumed was produced in or just outside the city. The production provided not just food but also occupation, a sense of belonging and the feeling of being part of a community. When consumerism made its appearance, slowly new systems of ready-made and cheap industrialised food were implemented, replacing the networks of locally based food production. But changes are emerging, people start to understand the shortcomings of the current system and start to rethink this industrialized food system. Recently people develop more interest in ways of connecting with food that once seemed very much obsolete, such as community gardens and inner-city greenhouses (Bukowski, 2018). We are considering our relation with food, in terms of obtaining food and the environmental impact on the earth. A different system of food production is able to contribute in the sense of creating jobs, activity, community benefits and much more for Parkstad. To imply a new system it is crucial to understand the connection between the many related aspects. A sustainable food production system has to deal with the relationship between water, energy, environment, waste, climate change, social inequality and health, within a context of changing population, urbanisation and dietary change (Wiskerke, 2018 p.28). To ensure the needs of people it is important to keep testing to not overshoot the pressure on the natural life-supporting systems, such as a stable climate, the fertility of the soil and the ozone layer (Raworth, 2017).

1.4 New industry for South Limburg

South Limburg is known as a productive farming area, the region stands out for its beautiful landscape and local specialties. The inhabitants know their way around to get fresh products directly from the farmers. There is a peaceful rural atmosphere. Nevertheless, it is a problematic area in the Netherlands because the lack of social and economic opportunities. Young and ambitious people fly out in large numbers for a life in the city. As a solution new approaches are in need to bring more prospect to the area. Since the mining industry closed down in the 60's, the Parkstad region is searching for new sources of income and a corresponding identity. Tourism has the potential to fill the economical gap and create the jobs the mining industry left behind. South Limburg is a popular destination to escape the crowded cities and enjoy peaceful recreation in a natural environment. The tourism industry in South Limburg is growing and there is an increasing demand for day activities (ZKA, 2018). These activities have the potential to be productive, pleasant and educational at the same time. Furthermore, larger numbers of visitors result in a growing demand for provisions.

2. CHANGE IN AGRICULTURAL METHODS

The lack of an holistic approach in food production is causing environmental issues all over the world. The natural landscape had to make place for the monoculture used in agriculture. This resulted in a decrease of 60% in species in the last 50 years. Mainly to clear land for use by humans (our planet, 2019). Unfortunately, this system is and was adverted all over the world by experts holding up this is the only way to provide food for everyone. Saying it is efficient and also cost-effective. However, we start to face the disastrous ecological bill and it is time for change. It is time to apply systems inspired by permaculture and food forestry. These approaches consist of system thinking principles inspired by the observation of ecosystems. These holistic systems are based on the notion of understanding how nature works and our interplay with it.

Agriculture can be changed in different ways, one to make better use of available space. The level of production can be increased without adding external sources like water and energy, but by introducing circular systems. A forest has the potential to be a recreational space and produce food at the same time. This way the recreational function of a forest is maintained (Wiskerke, 2018). By using a forest as place of production means there is an opportunity to produce more food locally. But it also fosters the spatial and social relations between the food production and the consumer. This is often completely absent. During the process of industrialisation and globalisation the relation of production and the consumer has been lost. In a food forest consumers can not only consume the food but also participate in growing and processing. The potential of a food forest is high. Pigs can be introduced and feed themselves with the acorns, they enjoy rooting and also fertilize the ground. There are many different plants that are able to grow such as blueberries, blackberries, mushrooms, herbs and other fruits. Nature can remain but also provides a meaningful food experience. When leisure activities can become food productive, this is multifunctional use of space. The next paragraph will explain the working of a agroforestry in more detail.

Like a normal forest, a food forest does not need any supplies from the outside like extra water, pesticides, fertilizers or even weeding. A higher diversity of different plants and animals results in more stable and balanced ecosystems. By studying forests, we are able to learn from nature and can apply this in agroforestry. An average food forest contains around 200 to 500 plants that produce different seasonal goods all year long. A food forest is low maintenance and resilient. By selecting the right plants cooperation between the plants starts to happen. All plants fulfill various functions like: shelter for other plants, fixing nitrogen, production of nutrients, attracting insects to spread seeds and plague control. The food forest can be described as a virtually self-sustaining living ecosystem according to Angelo Eliades. There is symbioses between the different species (Aliades, 2011). By using these natural processes as a basis for inspiration, we are able to create the most sustainable food production systems.

The continuation of the forest as natural recreational area has even more benefits for its visitors. Being in a natural environment proved to recover people from stresses and strains of daily living. For people from the city of Heerlen or a visitor from a city elsewhere in the Netherlands a visit is good for the state of mind. A city generally has a more demanding and stressful social environment than rural areas (Lederbogen, 2011), a day in the forest will clear the mind. Next to that, inhabitants of cities might end up detached from their fundamental ground of being and they will lose sight of their dependence on nature, which is a mindset that this project is able to restore. City residents no longer see nature as mother but as a machine, it is hurtful for human health to lose touch with its biological origin (Louv, 2005).

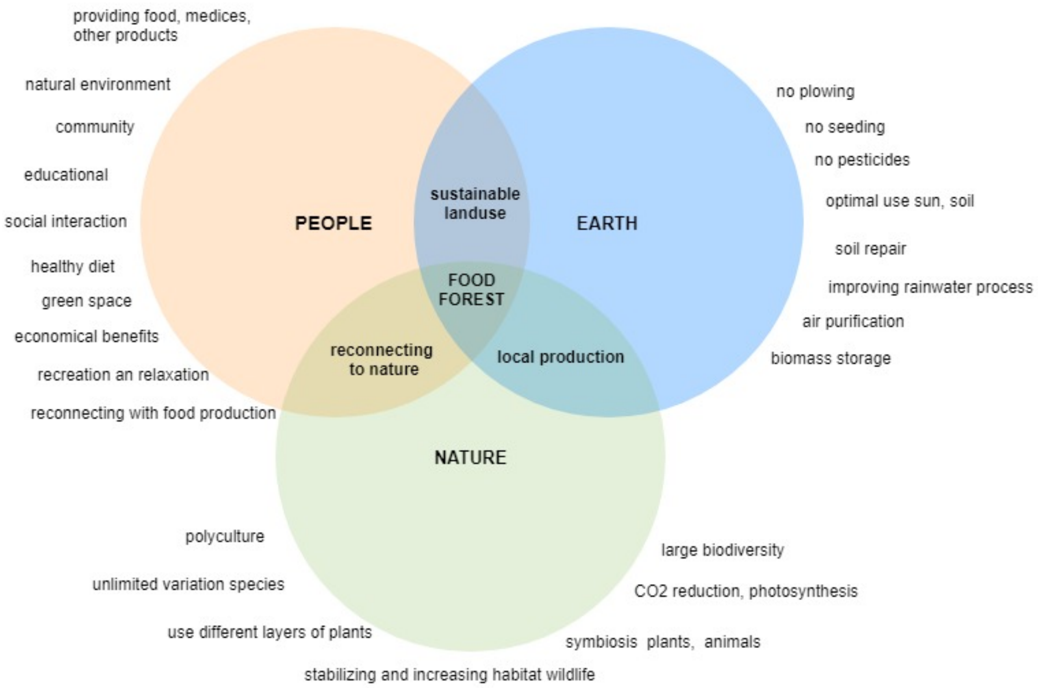

Figure 1. Scheme to summarize the beneficial aspects of the food forest (image by author)

2.1. Production system for a healthy diet

The food we consume has an effect on our health. The metabolic system uses food as energy. In addition, food influences our immune system that protects us from bacterial incursion. To prevent diseases we need certain bacteria and nutrients to strengthen our immune system. In the current common food production system most of our food derives from industrialized processes that focus on producing one product in a sterilized environment. In these systems there are no natural bacteria and pesticides to prevent insects or other bacteria to come in contact with plants. These kind of sterile environments are beneficial for the producers because of the guaranteed safety and minimized chance of losing crops. However, a diet of sterilized industrial food leads to weaker immune system, because natural bacteria are absent.
The research of Fern exposed that before modern civilisation and the rise of agriculture, hunters and gathers were eating around 600 different species by average yearly. In the current system most people consume only a fraction a the variation in diet compared to the hunters and gathers (Fern, 1997). Ketelbroek, a pioneering food forest learns us that many edible species can be grown in the Netherlands. There are plenty healthy and tasty plants, that are unknown to most people that are able to grow in the Netherlands. The Dutch climate is no obstacle.

In 2009 Eric Chivian published research about a healthy diet for humans, where he proves that variety is key for a healthy diet. One should receive enough micronutrients from a variety of berries, nuts, herbs, seeds or roots next to enough carbohydrates and proteins (Chivian, 2010). If a production system is able to provide a more varied diet, this is beneficial for the human body. Around the globe, over 3 billion people suffer from a lack of variation in their diet, which results in a shortage of vitamins and micronutrients leading to multiple issues such as: low productivity, morbidity, concentration problems and growing healthcare costs. This all affects the welfare and economic prospect of a country (Welch, 2004). To summarize, a healthy diet does not only affect the individual situation, but has an influence on the total welfare.

2.2. Systemic approach for circular systems

Design has become a valued tool to amplify innovations. Designers are able to identify the issue of growing needs in society and therefore produce solutions and explore new fields. In most cases new designs led to an increasing demand for raw materials, energy production and the generation of waste. When designers focus on sources early in the planning process, the designer is able to select legitimate sources based on local stocks and existing processes. It is a shift in thinking to see the use of resources not as an external factor that happens independently of the design process. A similar way of thinking can be applied in designing production processes. A production system always has a certain input and output, often raw material on one side and the products on the other side. However, the complete system usually consist of multiple processes. It is a challenge for designers to discover new connections between the existing processes, to spare material and make the whole system more efficient. Different production systems are able to provide input for another process. The processes are different, but together reduce raw material input. To work towards these interrelated processes to form systems, a multidisciplinary vision is required. Knowledge of different scientific fields is needed to bring all aspects together. In nature, production systems do not generate any waste. All waste is used by other species. This is inspiration for a new approach of interconnections in production systems (Bistagnino, 2011). The Cradle to Cradle certification for a production system guides designers to improve the processes with the help of the next five categories: material health, material reutilization, renewable energy, water stewardship and social fairness (MBDC, 2019).

All the interconnection flows within a production system generate a new economic model. In which waste is not of little value. This design strategy based on investigating positive transformation through the connection of flows, is improving the local resources and stimulates the uniqueness of the territory and culture.

2.3. Flow inputs and output

For the research a systemic approach is needed to look for efficient use of material and closing loops in a production system. Material flow analysis is a key method to link anthropogenic activities to the consumption of resources and the environmental load. For this research, the final output of the production system are determined at first. These are: food, energy and building material. The main focus is on the production of food, by examining all material sources, pathways, technologies, processes, optional links and intermediate stocks, a more efficient use of resources is achievable (Brunner, 2003). The next step is to create schemes that facilitates the inclusion of efficient processes and utilization of resources. The processes are linked by mass over a certain time, which we call flow. A flow that is entering a process is the input, the outcomes after a process are the output. The considerations in the scheme are the basis for the design process, since numbers of the stock and flow define the square meters required for a process.

2.4. Selection of processes

Unfortunately, everywhere in the world local production knowledge gets lost easily due to globalization, because processes are more efficient somewhere else. Within the proposed production system choices are made based on how and what we produce instead of maximizing amounts. Most of the selected processes are based on local traditional methods such as beer brewing and cheese making. There is a certain local pride in the production of these traditional goods which is beneficial for the social support of the project. The production system is not advocating that old and traditional production methods are better, the core is to develop a system that is integrated with the selected territory, to be capable of producing without depriving, leading to a sustainable welfare on all aspects. By putting so many processes in one complex, production chains and transportation distance are shortened, resulting in financial benefits. The new jobs and profits created might arouse some interest of younger people in agriculture.

3. The production system

South Limburg has a mild, temperate and generally warm climate. This temperate oceanic climate has an average rainfall of 750mm per year (Imeson, 2012), resulting in a fertile environment. For this reason South Limburg is a place of habitation from the Roman times until now. Imstenrade area has a hilly landscape with loess soils (see appendix figure 4). Under suited climate conditions loess soil is among the most productive terrain types for agriculture (Getis, 2000). The high fertility is due to the organic matter of the soil. The porosity allows plants to absorb nutrients more easily. The loess soil is between 2m and 20m thick on top of a natural stone layer. Loess soil has a potential danger of erosion, especially in a hilly landscape. Planting a food forest on a slope provides erosion control and also benefits the nutrient cycling (see appendix figure 11).

The food forest is the engine of the whole production system. The uniqueness about the forest is symbioses between all species, resulting in no external inputs (by humans) required, except from the seeds. The food forest forms a closed nutrient cycle, that will get stronger over the years. The input of the forest are rain, organic material from outside the system and nitrogen from the atmosphere (see appendix figure 12). The main outputs are denitrification (as in the reduction of nitrates in the soil), minerals draining away from the soil, volatilization of nitrogen, fires and crop harvesting (for nutrient and organic waste) (Ramachandran, 1993). Compared to other forms of agriculture, the big advantage of the food forest is the natural turnover of nutrients without a decrease in productivity. The different layers of vegetation such as high trees, lower trees, shrubs, herbaceous layer, ground cover and roots all have other outputs like nuts, fruits, edible leaves, berries, herbs and mushrooms (see appendix figure 10). The case study of Ketelbroek, a pioneer food forest in the Netherlands gives an example of the variation of plants and products that derive from it (see appendix case study Ketelbroek). The outputs change all year round producing high quality seasonal food. Due to the high variety of species the food forest is able to provide the complete healthy diet (see appendix food output for an healthy diet) and it will be part of an interrelated system of other processes and production methods.

Organizing the landscape into a food forest allows the integration of livestock. The forest is perfect for cattle the walk around freely, especially in a larger-scale situation. The design of the forest should include enough space for pasture to allow the animals to graze. The integration of cattle is able to reduce labor and fossil fuel needs. Animals can perform useful work in the forest such as: site preparation, grazing, insect control, weeding and picking up drops as a form of pest control (Toensmeier, 2013) (see appendix figure 13). Diseases are able to survive for a long time in decomposed fruits. Also poultry contribute by eating pest insects. Introducing honeybees will provide fresh honey but also improves the pollination. If designed well, the conditions are perfect for healthy livestock, which results in high quality animal products.

Water management is important in a food forest, preferably water is stored somewhere central in the forest for dry periods. Water is stored in the soil, but a pond is a great asset because of the additional purposes such as fish production, irrigation, wild life habitat and recreational purposes.

The food forest delivers input for some traditional production methods home to the region and the Netherlands, such as beer brewing, cheese making, bakery and a fish smokery. The case study of the Gulpener Brewery located only 10 kilometers away (appendix case study Gulpener brewery) shows the possibilities of requiring all the ingredients for beer brewing from the local environment. To a certain extend the food forest is able to grow these ingredients, with small input from neighboring farmers. An organic beer brewery will be part of the system. The heat of the installations in the brewery is collected for reuse (see appendix figure 19). Also, cheese making (cheese, yogurt, butter and milk) can be done with milk from the livestock within the system (see appendix figure 16). These small scale processes stand for high quality organic products and foster the local pride.

A combination of low- high technology methods is making the system more efficient and sustainable. A greenhouse is a large asset in the system. The greenhouse is a part of the food forest as a plant nursery for vulnerable species. The seeds will germinate and grow till a decent size in the greenhouse before they get planted in the forest. In addition, the greenhouse also takes part in the climate system as a heat collector (see appendix figure 18). Next to that, inside a hydroponic biofilter will be installed, this systems filters water in a natural way using plants. This system is used to clean waste water from other production methods. For example, the production of beer is very water consuming, for 1 liter beer 7 liter of water is used in the process, cleaning this water for reuse makes the system more sustainable (Trouw, 2018). The brewery takes input from the food forest, however in return its waste (beer broth) is used as animal feed and also to bake beer broth bread in the bakery. These are the loops the system is after, to create interrelated streams between the different processes to maximize efficiency and minimize waste generation.

All organic waste, such as plant waste from the forest and the greenhouse, but also fish waste, food waste and manure from animals is reusable. The organic waste is fuel for a biodigester, which turns it into biogas, a trigeneration process will turn biogas into electricity for all buildings in the complex (see appendix figure 17). Due to the high concentration of other local farmers, there is an opportunity for them to deliver their organic waste in return for fertilizers. The rest product of the biodigester is a rich fertilizer. A win-win situation is created, which lead to sustainable fertilizers and green energy.

The scheme presented next (also in another format in the appendix, figure 5) gives an overview of all the food production methods, inputs, outputs and interrelated streams.

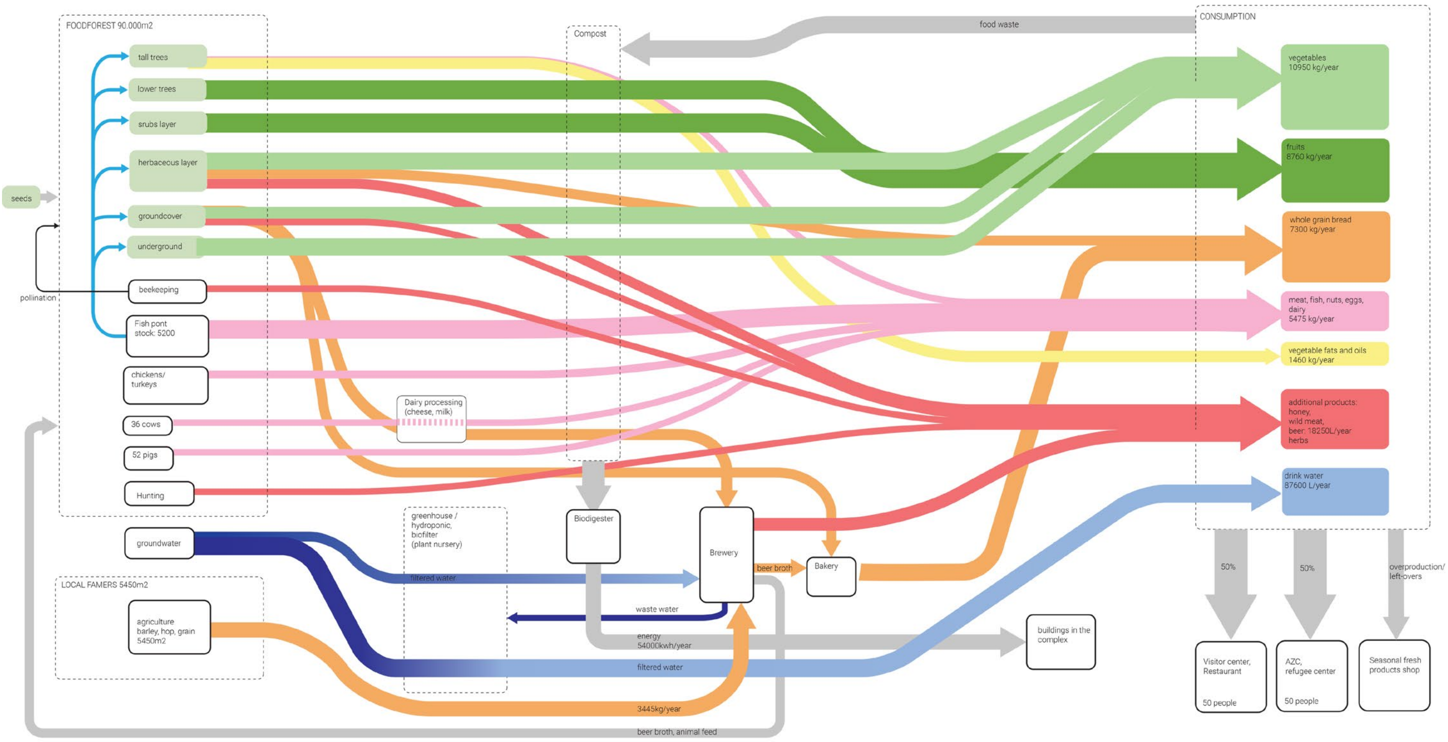

Figure 2. Scheme of the proposed production system including the processes, input- and output streams of the food production system (see appendix for other format and additional information) (image by author).

3.1. Translation to architectural program

The production system is based on the total food intake for 100 people and the existing site of Imstenrade. With the total output is calculated what the input and output numbers are for the production of every process. In one process the input and output are always in balance, the designer is able track down the missing numbers by calculations. This requires knowledge of exact processes.

When the type of process and estimated production quantity is specified, the next step is to determine the required square meters for a process. This is different for every process. For example, for a biodigester formulas help to work out the required volume and animals including fish all have distinct required living space. Furthermore, the scale of the process effects the size and numbers of the installations and storage spaces for production processes such as the brewery, dairy processing and bakery. The list below presents an overview of the square meters per process based on calculations and estimations. In the appendix provides additional information about the methods used.

Table 1. Production processes to program.

production process	minimal area (m2)	additional information	approximate area change (m2)
Food forest: ''romantic'' mixture of different species	40.000m2	Tall trees layer Lower trees layer Scrubs layer Herbaceous layer Ground plants layer Seasonal output all year round	+20% , prepare for potential crop failure
Food forest: Trees and a specific selection of crops on the ground	35.000m2	To be able to deliver the right input for the other production processes, certain crops (like grain) are planted in relative bigger numbers under a layer of larger trees.	+20% , prepare for potential crop failure
Food forest: trees with pasture in between	25.000m2	Pasture is needed for the larger animals to graze, the oak trees provide wood for a renovation of the buildings in the future.	+50%, prepare for slow growing oak trees and abundance of grass to feed the animals
Fish pond	260m2	Space for 5200 trout	+30%, to give fish more living space
Brewery	41m2	brewery capacity of 300L per brew brew area: 10m2 fermentation, storage cellar: 20m2 malt storage: 5m2 bottle: 6m2	-
Bakery	30m2	Based on installations and specific furniture	-
Cow shed	82m2	Only for winter, rest of the year cows are outside in the food forest	+30%, to give cows more living space
Pigs	60m2	Only for shelter against the elements, pigs mostly stay outside.	+20% to give the pigs more space
Dairy processing	25m2	Based on installations and specific furniture	-
Biodigester, trigeneration	224m3	input: green waste 200 ton/year energy output: 54000 kWh/year	-
Chicken coop	10m2	Based on shelter space at night	-
Compost	10m2	Additional compost	+100%, depends on use of biodigester
Greenhouse	300m2	space for upbringing plants (plants nursery) and hydroponic biofilters	+30%, extra space for more plants

The table only shows the food productive functions. The processes above need other supportive functions. These functions such as the restaurant, shop, storage, offices etc. to make the system work (see appendix). The architectural and landscape program derives partly from the processes presented above. The square meters determine the minimal size for every process in the program of demands.

The flow streams in the diagram are important for the logistics. Every stream is essentially transporting material from one process to the next. For maximum efficiency processes that are connected can be placed close to one another. The relation between certain processes should be taken into account when designing the whole. For example, the biodigester takes up many streams, so a central placement is ideal. However, it needs to be reachable for local farmers as well. The brewery needs to be close to the greenhouse to be able to filter water, but also the logistics to distribute the beer broth to the bakery and cattle are important. Putting all processes in place is a puzzle that works within the boundaries and possibilities of the selected site and existing buildings. In a later stage, the flow diagram can be projected on the new floorplan to test the efficiency of the logistics.

CONCLUSIONS

In agroforestry the biodiversity is stimulated, which is very much needed in a current system where production processes rob the world of its natural ecosystems. Next to that, the world is in need of more circular innovations to limit the generation of waste and save input from natural resources. The output of an agroforestry production method is input for other production processes.

A challenge lays in convincing policy makers and especially the public that as humans we are dependent on nature and we should act by it. Plants, animals and humans should work together since we rely on the goods and services nature produces. We should glimpse beyond our modernized civilization to advanced life-abundant growing systems of the natural world. Within this research it becomes clear that following nature is the way towards sustainable food production. Yet, humans do not fully understand nature and additional research is essential to broaden our understanding of natural systems, on how to exist and produce in harmony.

The goal of this research is to bring prosperity to a specific area, but also to contribute to solve wider issues in the Netherlands and the world. Local production and shortening transport chains contribute to CO_2 reduction. Also, using waste streams lead to a higher efficiency. This research presents an innovative form of agriculture (the food forest) in combination with traditional production processes and technical innovations. The new entity accomplishes in offering a complete varied food intake for 100 people, without affecting the landscape in a negative sense. The new production system is envisioned as part of a food center. This food production center offers the possibility for visitors to participate, this results in a pleasant environment with educational, recreational and economical benefits.

Since the industrial revolution the bond between people and their food production is lost. Involvement in the production of your food provides occupation, a sense of belonging and a community feeling arises. Leisure activities are becoming food productive in this food hub. Farming and producing high quality goods such as beer, meat and cheese is part of the local identity. This is the start to embed a new system in this specific context. The traditional techniques are merged with progressive methods like the food forest. The produced healthy food ameliorate living standards for all parties involved. The tourism industry and regional identity are promoted at the same time.

To conclude, this systemic system is designed for the Imstenrade area. The research outcomes are the input for the design task for a new function to make this abandoned site flourish like it once did. In a sense this paper proposes a system that with minor adaptions can be applied anywhere else. Every village, city or community is able to profit from a similar system, hence the system is interpretable as a strategy.

DISCUSSION

In 2019, an impactful report about loss of biodiversity was published by United Nations. It proved the loss of biodiversity is as dangerous for the world as the climate change has (IPBES, 2019). The production system in this paper, once implemented, brings prosperity and well-being on a micro-level for the individuals involved. To make an impact on macro-scale the concept needs to be multiplied. A system of agroforestry in combination with traditional production methods does not limit itself to the presented system in this research. There are endless variations possible, for every climate or site. The addition of modern technology fosters the outcomes, but this addition is not necessary. Traditional production methods are always based on the specific resources of the area, which makes the perfect match with local species (plants and animals) used in any agroforestry system. When this concept is applied in large numbers covering a significant percentage of the world, the people are able to give back agricultural land to nature, which causes a large recovery of biodiversity. Besides, the photosynthesis in all this new plants will lead to an immense conversion of CO_2, contributing to reverse climate change at the same time. Nonetheless, in an agroforestry system it is hard to meet all the demands of the current society. For example people are used to eat bread and in a food forest the outcomes are more varied. For this reason, it will be an illusion to presume that agroforestry will be capable of a complete takeover.

However, the largest obstacle for this production concept is knowledge. The more complicated the system and implementation, the harder is it to conduct or spread. Farmers do not know much about principles in nature, foresters do not know much about farming. There is a requirement of decent technological knowledge of methods to combine the different plants into a system of compatibility and to have the right effects on each other. Another problem is time, unlike crops, a food forest needs time grow to its full potential. This requires investment. The government is able to stimulate with subsidy for bridging time. Governments all over the world should recognize it is time to act, and not walk away for the potential dangers ahead of us. Nonetheless, local production is a key concept in solving global food needs and poverty reduction worldwide.

Generally people do not like to change their methods while the outcomes are not directly beneficial for them. In Parkstad many innovative programs have had a tough time to become successful. For example the local government failed in setting up a thriving market for local products. This project more or less failed because people already knew their way directly to the farmers, and also for the famers it is more convenient to stay on their property. Proposing a change in this area proved to be very difficult. The young and ambitious people are moving away from Parkstad to big cities because of the presumable opportunities. Leaving behind the older and less educated part of the population. It is in favor of this project, that in the long term, agroforestry has an economic advantage over conventional agricultural methods. This is proved in many case studies bundled on permaculture apprentice's website (permaculture apprentice, 2019). For many people economic benefits will be the most important reason to get involved, being eco-friendly is just a nice addition for them. To make a sustainable world the new reality a business model is key.

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Appendix

Case study 1, Food forest Ketelbroek

Location: Groesbeek
area: 23.000 m2
starting year: 2009-2012

Ketelbroek is a pioneer food forest located in the east part of the Netherlands. Groesbeek has a loess soil in the valleys, making it a fertile location (revolvy, 2018). The food forest contains the largest variation of edible plants (trees and shrubs) in the Netherlands. The forest delivers products for exquisite restaurants (De Nieuwe Winkel in Nijmegen). Ketelbroek proves the return of biodiversity in an agricultural system. In Ketelbroek, one will encounter singing birds, snakes, weasels and fireflies (Voedselbosbouw, 2016). University students did a comparison study about the natural values of Ketelbroek compared to a neighboring nature reserve. Ketelbroek scored similar on all indicators (bird species, ground beetles and night butterflies) (Wildschut, 2018). In the food forest there are about 350 different sorts of trees, shrubs, groundcovers. The plants all meet the requirement of delivering something edible. The land used to be a field for grain production. In 9 years, this piece of land has grown into an edible jungle, remarkable is the resilience that nature showed in this period. The system is based on lasting plants (perennials), instead of crops that live for one year. The plants grow every year making the forest richer and the harvest more abundant.

The summer of 2018 was extremely dry (a result of climate change) affecting crops negatively all over the Netherlands. It did not affect Ketelbroek that much as the other farms. In the food forest, the ground worked like a sponge sucking up the water. In contrast to the hard dry ground of conventional agriculture, where water just ran off. Because of the variation of plants in Ketelbroek the farmer is not that much dependent on specific conditions. One year the plums might disappoint, but the apples are great.

Ketelbroek demonstrates the concept of three-dimensional agriculture. By using plants on different heights, the yield per square meter is higher. The plants in Ketelbroek consist of a variation from plants native to the Netherlands to plants from all over the world. According to the owner, all plants that flourish in the Dutch climate are welcome (Dinther, 2018).

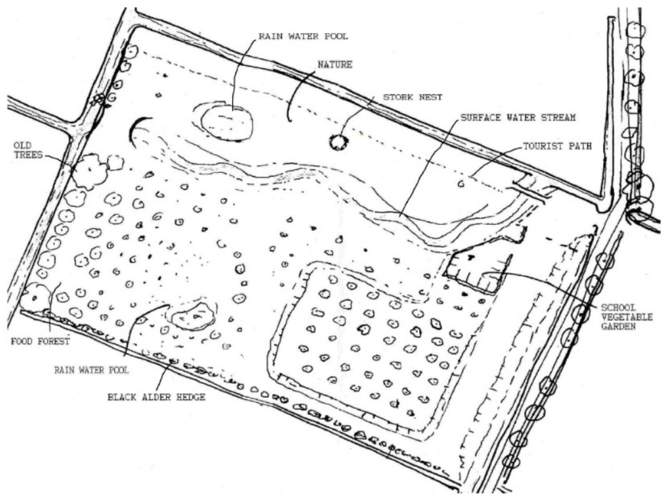


Figure 1. Map of Ketelbroek (Limavera, 2014).

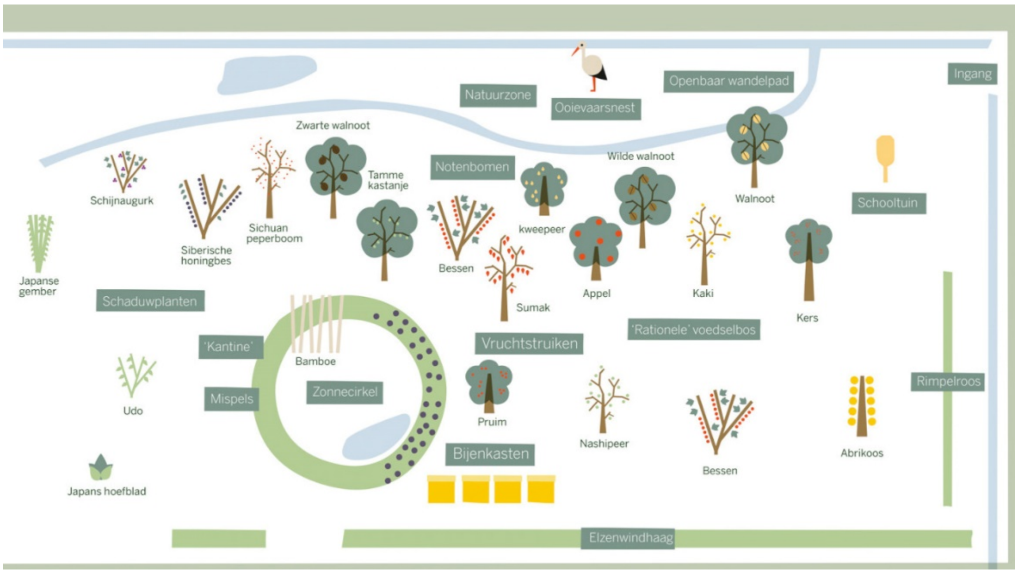


Figure 2. Scheme of plants in Ketelbroek (Wildschut, 2018).

Figure 1. Dish of restaurant De Nieuwe Winkel (located in the centre of Nijmegen) using ingredients from Ketelbroek (DNW, 2019).

Case study 2. Gulpener Brewery

Location: Gulpen, South Limburg.
Revenue in hectoliter: 108.000 (2017)

The Gulpener brewery is an independent brewery since 1825, located about 10 km from Imstenrade. It is an excellent example of a productive company with an ambitious sustainability policy. Their ambition statements focusses on the strength of the region and minimizing the burden on the environment. Gulpener works exclusively with suppliers from the region, they manage to acquire all their supplies within a range of 40 km (Gulpener, 2017). Most larger breweries need to turn to the world market for the more special ingredients, this makes Gulpener stand out in cutting down transport. This is not only beneficial for the environment, but also fosters the local economy.

Gulpener proved that South Limburg offers the right conditions to grow high quality raw materials for beer. The brewery tries to improve the food chain by using biological raw materials. Official labels for biological beer are hard to earn, farmers cannot use pesticides for 5 till 8 years before the label handed out. At this moment 10% of Gulpeners production is biological. In 2030, Gulpener wants to cut out the use of fossil fuel completely. The company wants to use exclusively green energy.

Figure 3. A local farmer is collecting beer broth (waste product) at the Gulpener brewery, the farmer uses it as animal feed (image by author, 2019).

Food output of the production system

The needs are based on a group of 100 people in total, consisting of 50 visitors and 50 refugees (based on current location). In the system some sources are not continual or have varying output (for example: hunting), which makes these sources extra. The system makes sure 100 people are always taken care of, all additional output ends up in the product shop available for anyone interested in fresh seasonal products.

Taking into account that the production system including a food forest is delivering varied fresh and healthy food, the next data is leading to calculate the output of the food production system.

Daily recommended needs for one person (Voedingscentrum, 2019):
- *250 gram of vegetables*
- *200 gram of fruits*
- *40 gram of fats like olive oil*
- *200 gram of bread, grain products or potatoes*
- *100-150 gram of fish, legumes, meat, eggs, nuts and dairy*

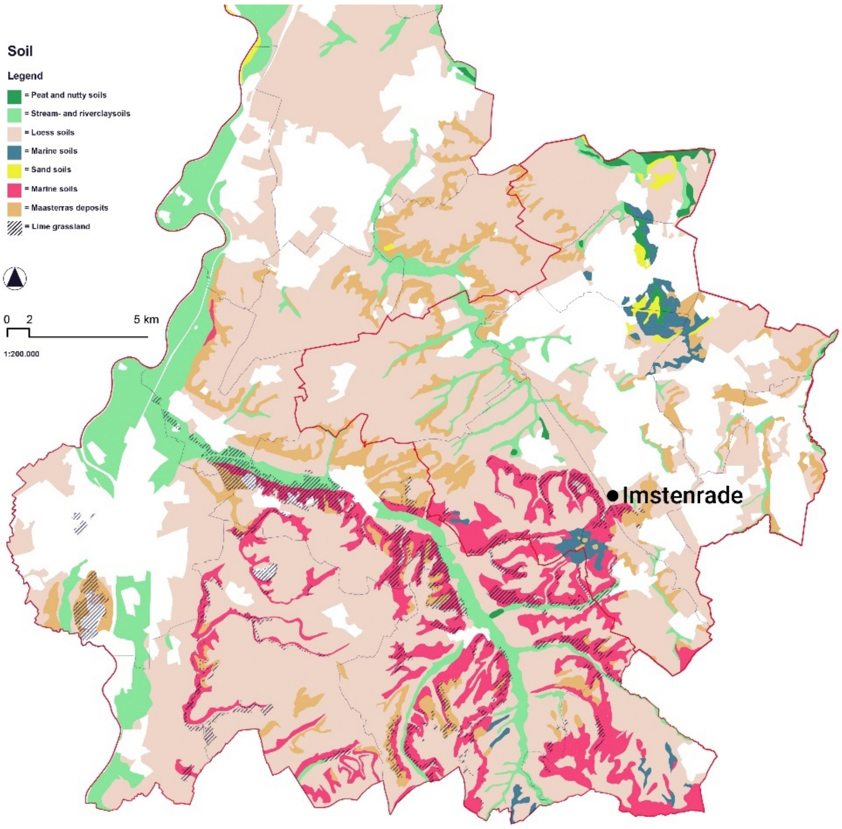
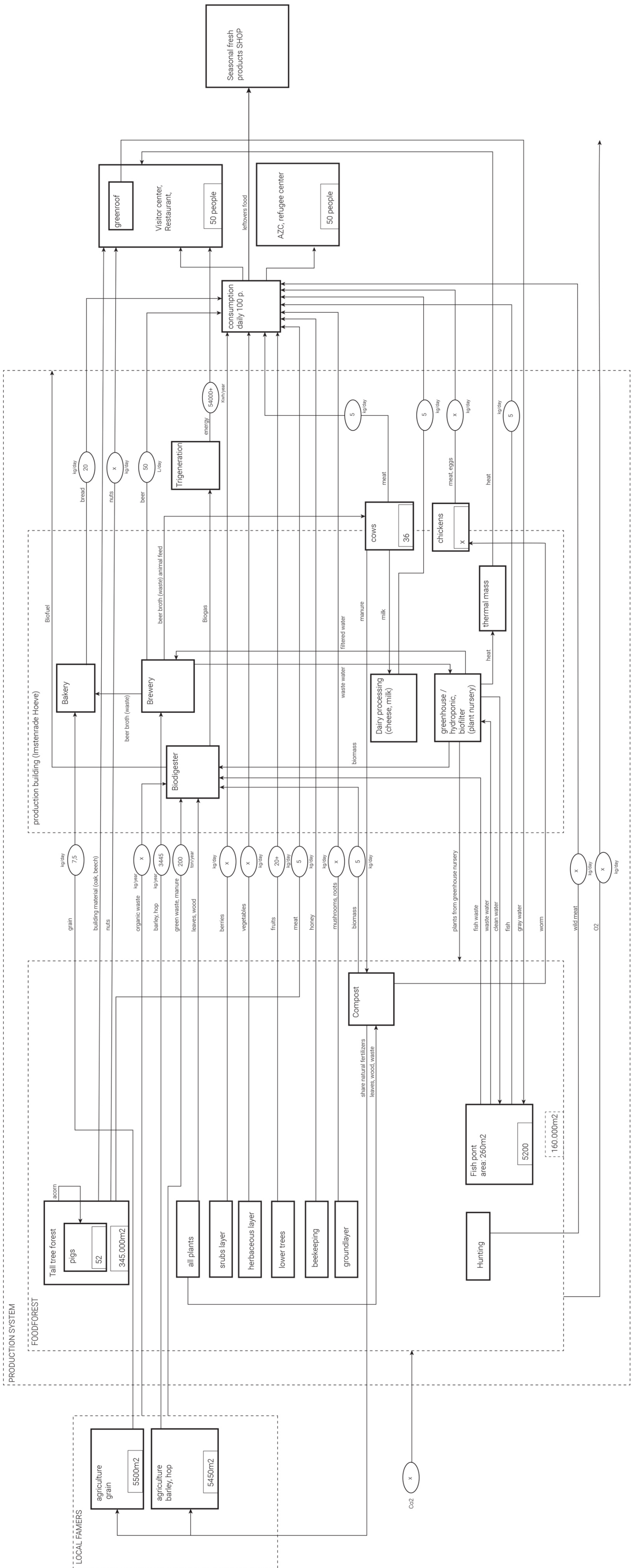


Figure 4. Soil map of South Limburg, Imstenrade has a loess soil (image by author).

Figure 5. Scheme of the proposed production system,
including all the processes,
input- and output streams (image by author).



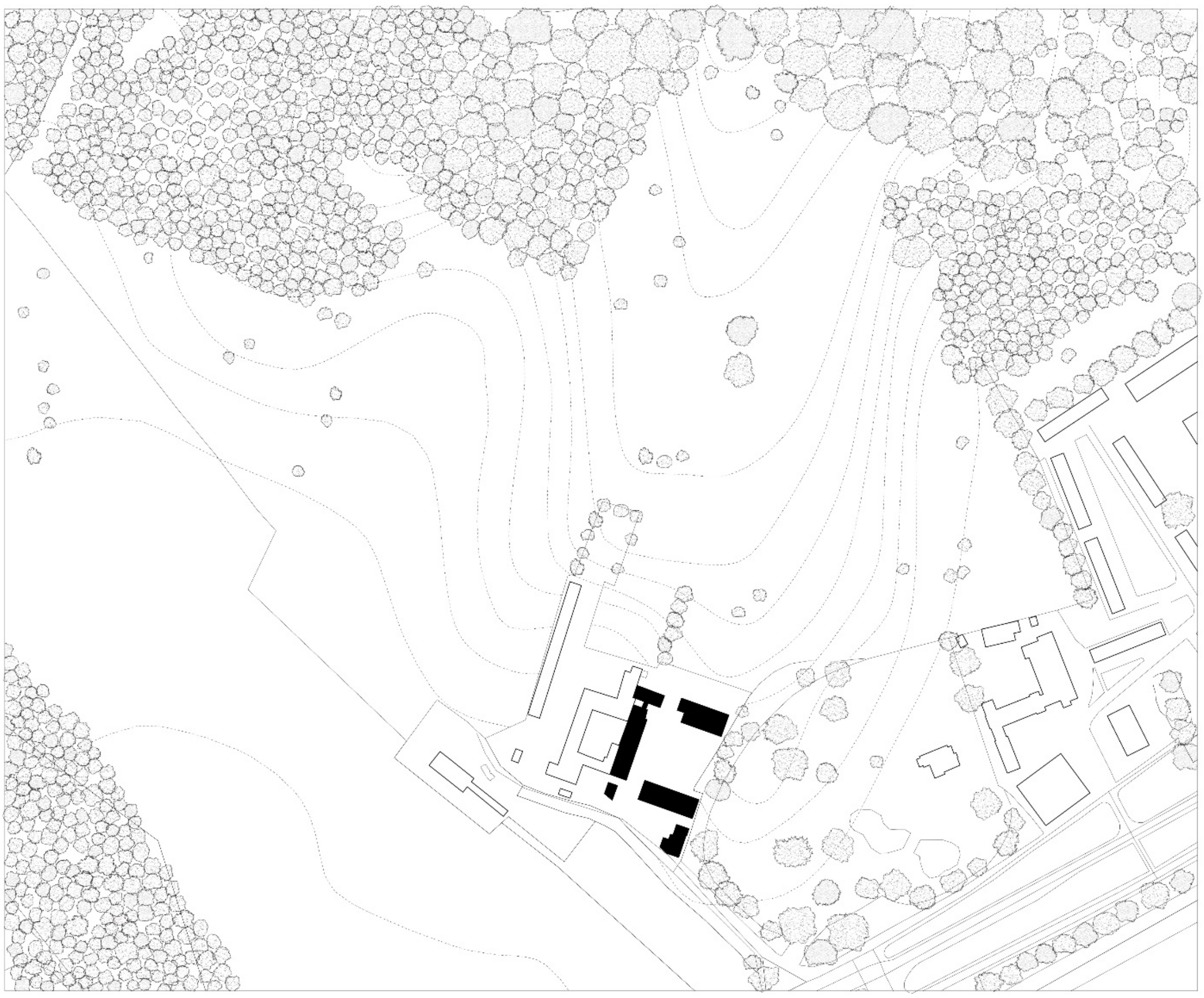


Figure 6. Existing situation Imstenrade area, the existing farm building in black (image by author).

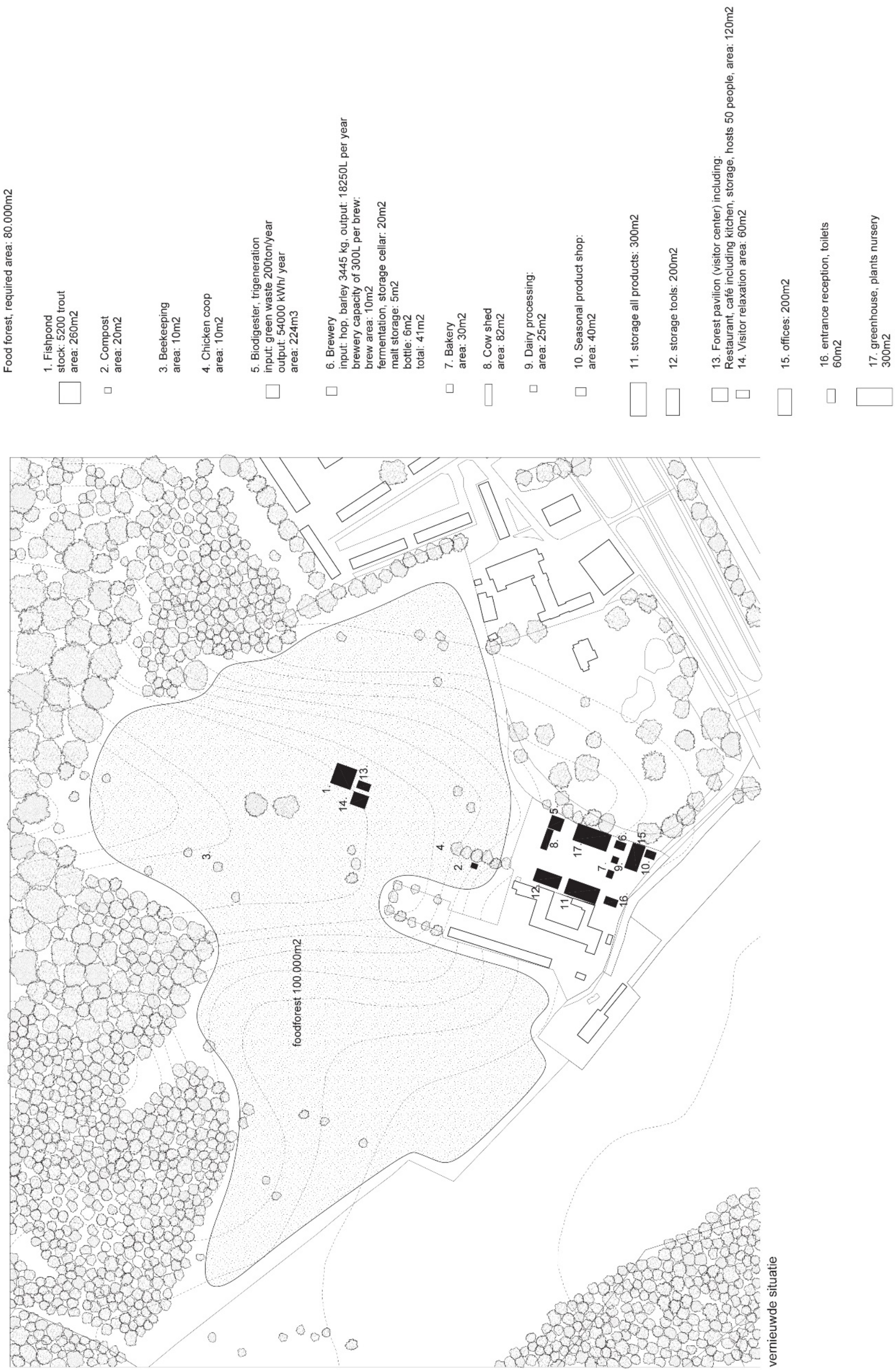


Figure 7. Projection of new program (only m2) in the existing situation (image by author).

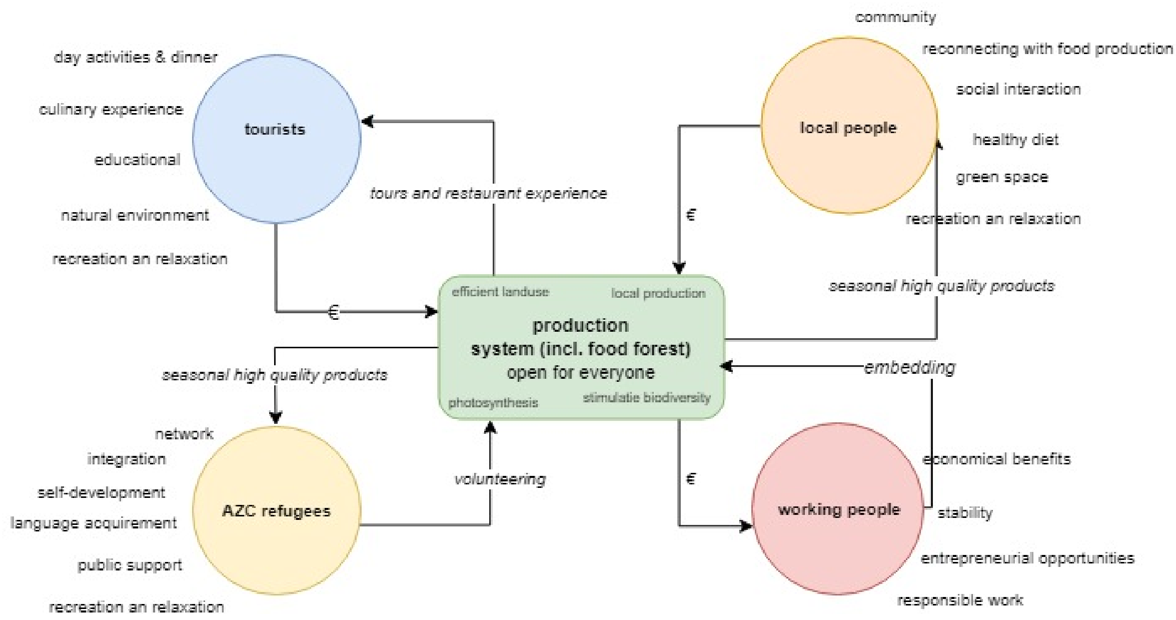


Figure 8. Involvement of different groups of people in the production system (image by author).

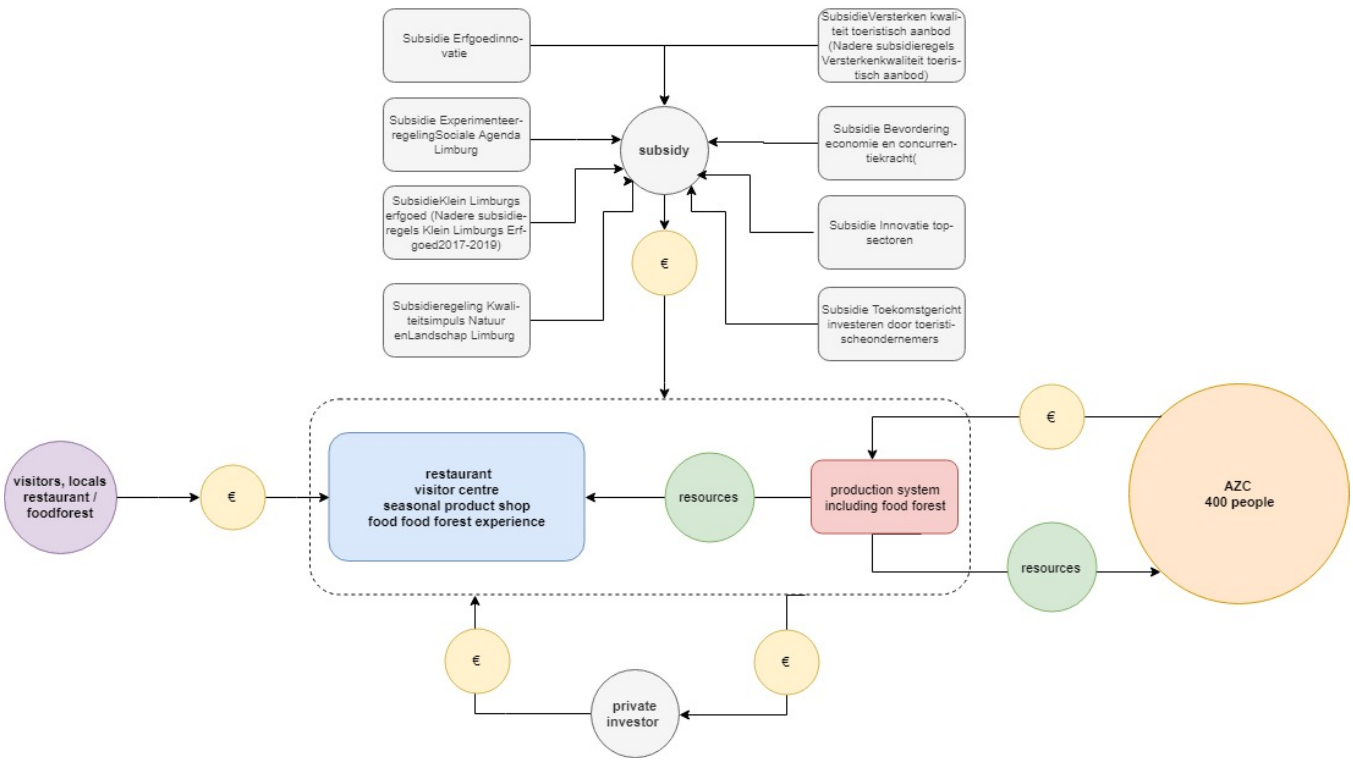


Figure 9. Business model for the production system (image by author).

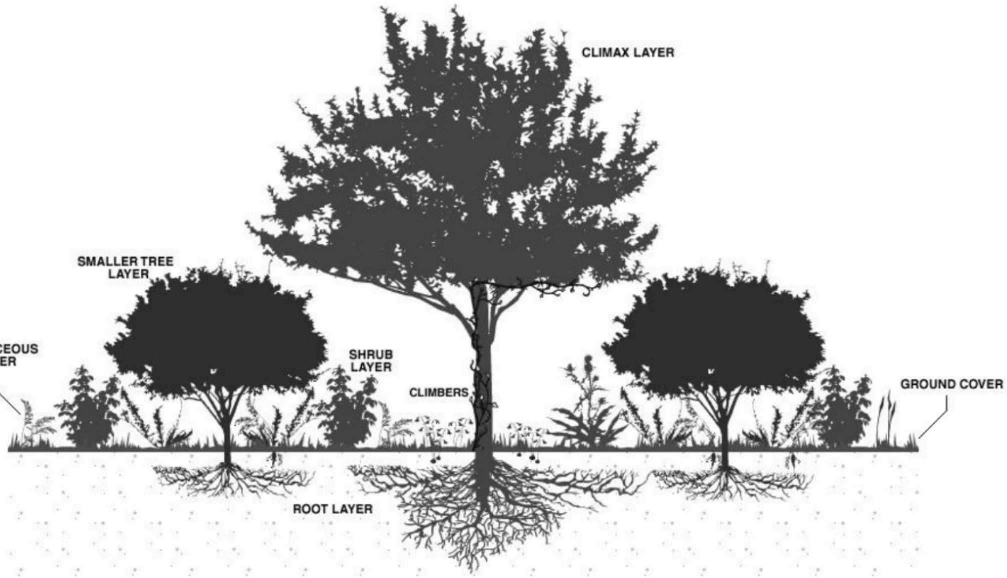


Figure 10. concept of different layers of plants in the food forest in a temperate climate (The Netherlands) (Limareva, 2014).

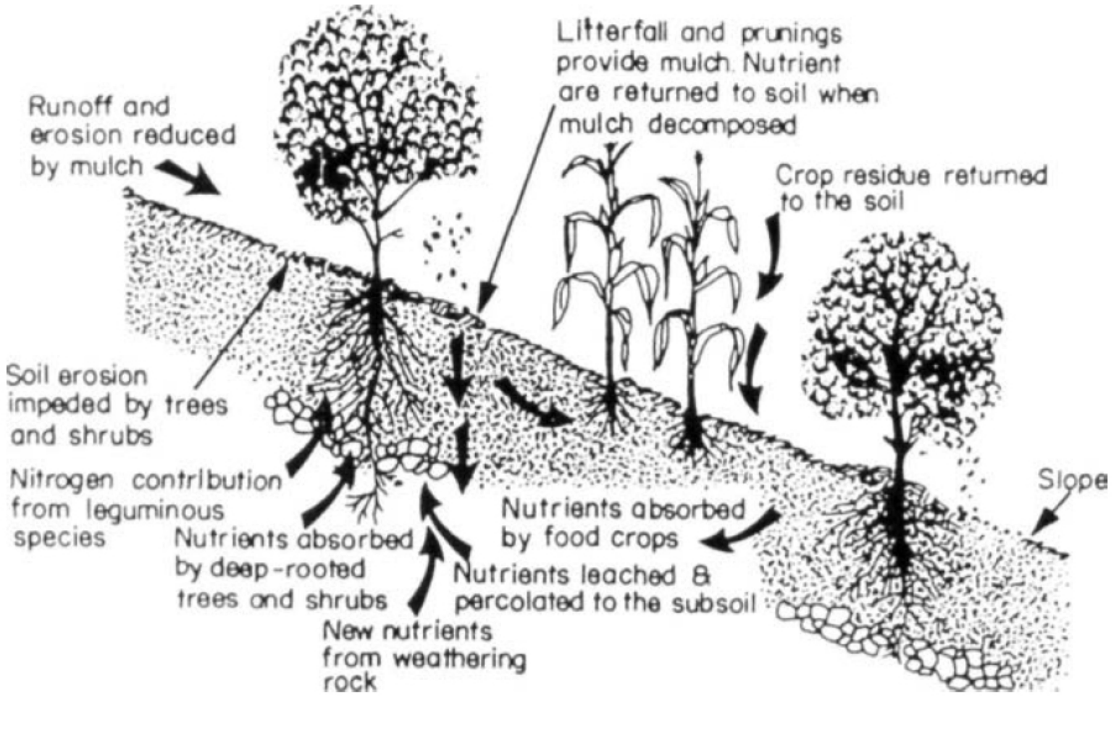


Figure 11. Imstenrade area has a hilly landscape, the image shows the benefits of nutrient cycling and erosion control for a diverse species farming system on a slope (Ramachandran, 1993).

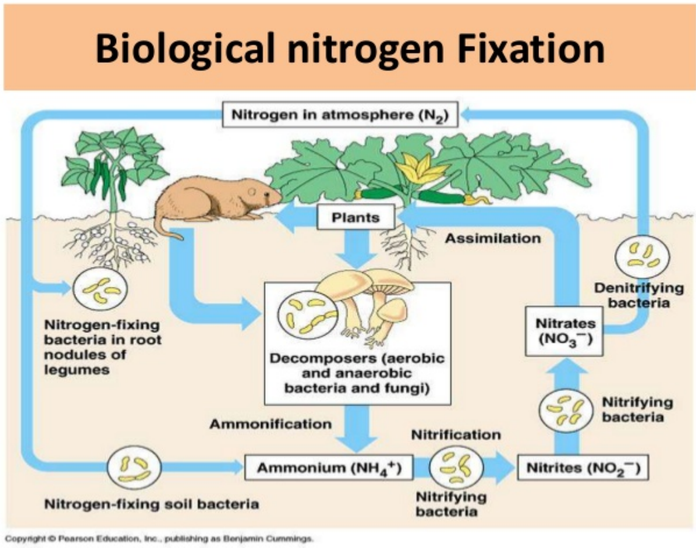


Figure 12. Biological nitrogen fixation scheme (Socratic, 2016).

Food forest functions of livestock						
Livestock species	**Mow & graze**	**Clear brush**	**Eat bugs**	**Till**	**Weed grass only**	**Clean drops**
Cattle	Yes					
Chickens	Yes		Yes	Yes		Yes
Ducks & muscovies	Yes		Yes			
Geese	Yes				Yes	
Goats	Yes	Yes				
Guinea fowl			Yes			
Hogs	Yes			Yes		Yes
Sheep	Yes	Some breeds				
Turkeys	Yes		Yes			Yes

Figure 13. functions of different livestock in a food forest. (Permaculturenews, 2015)

Tabel 3.9
Ontwikkeling vrachtvervoer

		Scenario Hoog		Scenario Laag	
	2011	2030	2050	2030	2050
	Mln ton	(2011=100)			
Vervoerd gewicht goederen	1075	121	152	105	114
over de weg	697	123	158	104	114
per spoor	37	143	222	128	161
binnenvaart	341	116	134	105	110
Ritten wegvervoer*	457	112	127	101	101

** in mln aantal ritten*

Figure 14. Numbers about the rising number of transportation of goods (CBS, 2015).

Tabel 3.5

Ontwikkeling van de bevolking naar landsdeel

		Scenario Hoog		Scenario Laag	
	2012	2030	2050	2030	2050
	mln	(2012=100)			
Randstad	7,9	113	123	105	102
Intermediaire zone	5,6	105	111	101	98
Overig Nederland	3,2	101	103	96	90
Totale bevolking	16,7	108	115	102	98

Figure 15. Numbers about the rising numbers of people living in cities and the decrease in other areas (CBS, 2015).

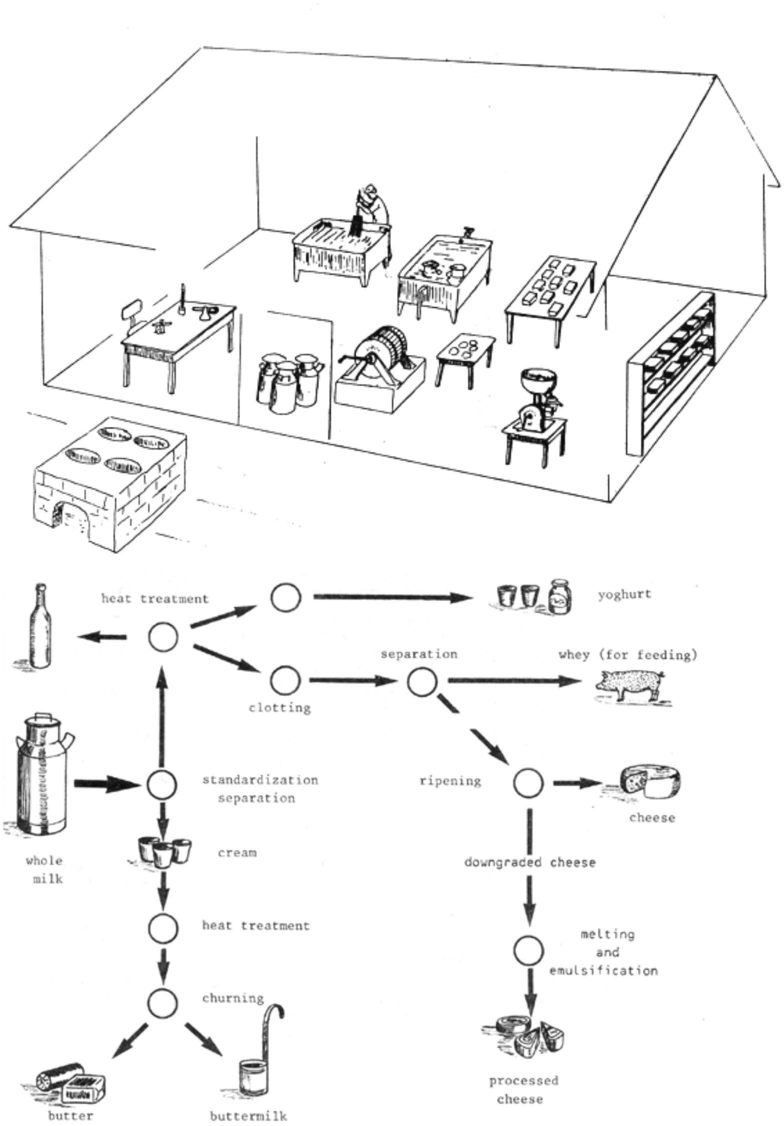


Figure 16. traditional dairy processing scheme (Lambert, 1988)

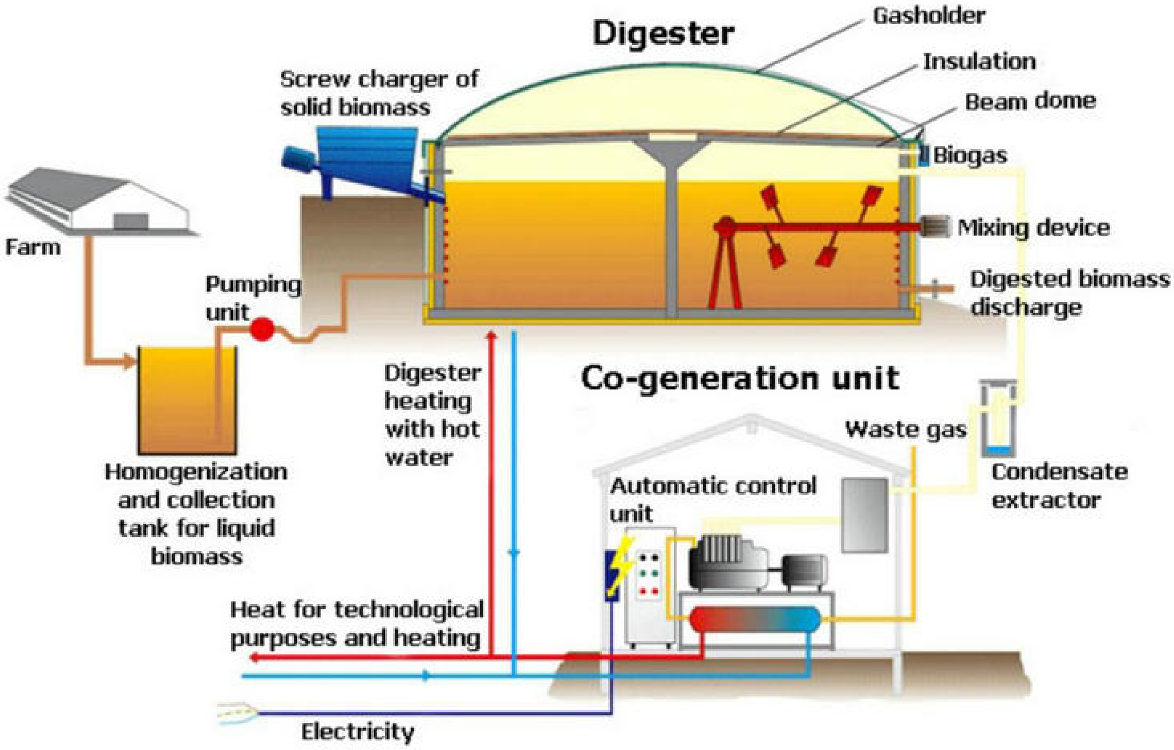


Figure 17. scheme of the biodigester to turn organic waste into electricity, heat and cooling. (Wortmann, 2005)

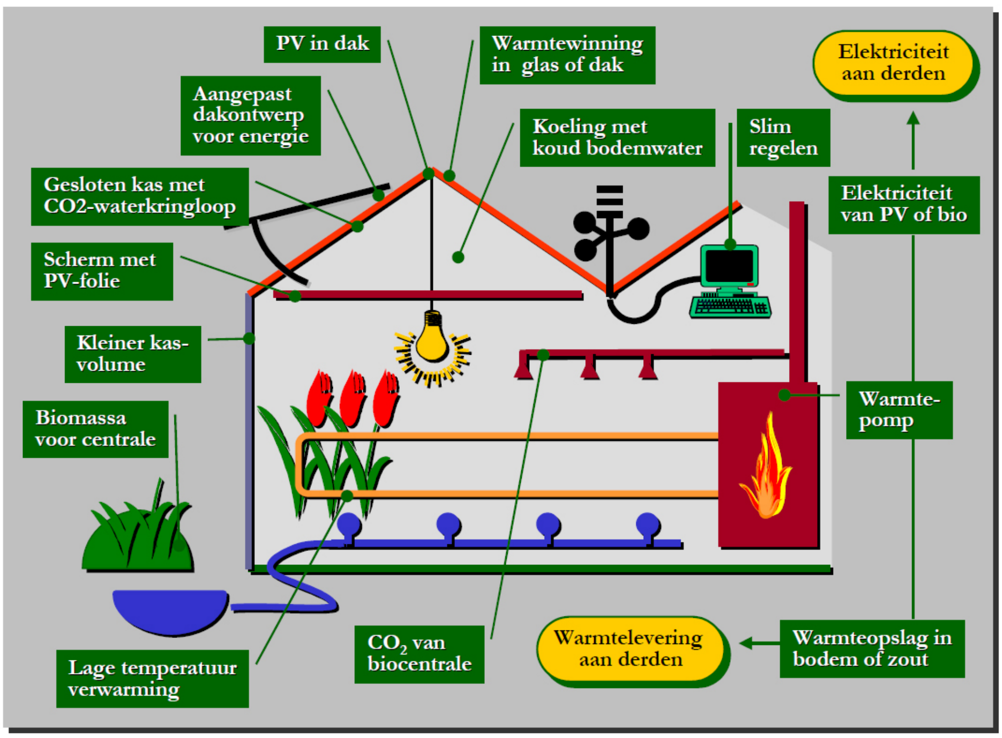


Figure 18. The potential of the greenhouse as supplier for other processes and energy production (Ruijgrok, 2002).

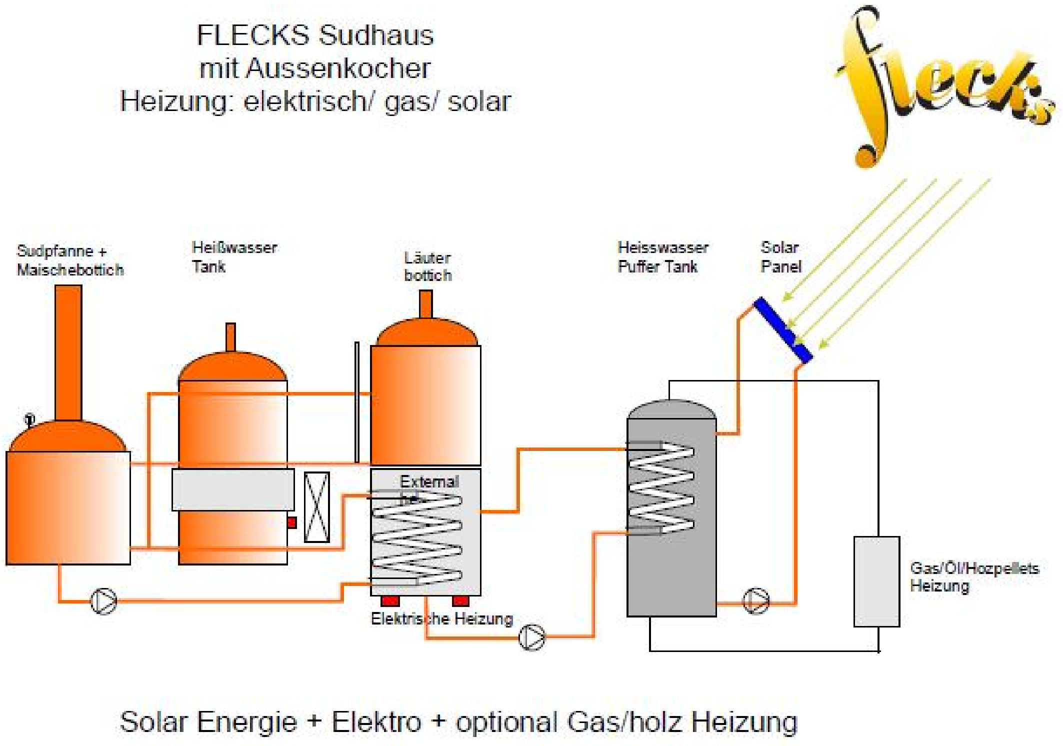


Figure 19. Scheme to present to system of the brewery on combination with solar energy. (Brauhaus, 2018)

Figure 20. Selected installations for the brewery based on the weekly production. (Brauhaus, 2018)

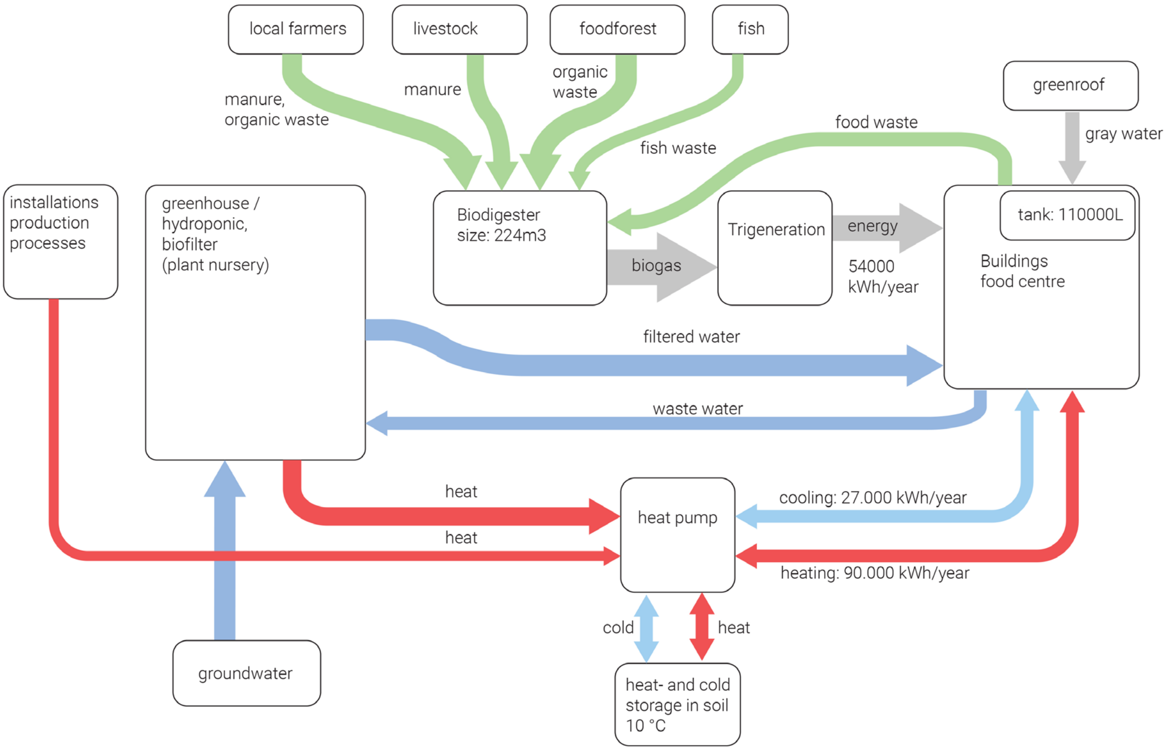


Figure 21. Scheme for energy and water management in connection to the production system (scheme by author)

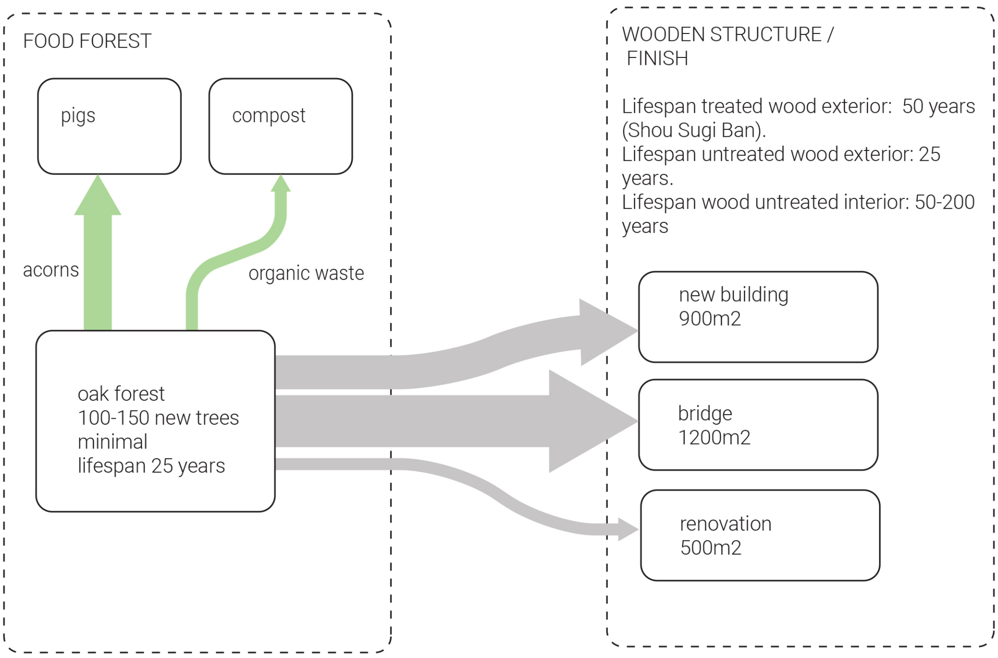


Figure 22. Scheme to produce wood as a building material within the production system (scheme by author).