UNIVERSITY OF HOHENHEIM

Project Report

Development of an agroforestry system for a part-time run farm in the South of Germany

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4908-450 Project in Organic Agriculture and Food Systems

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Introduction

Agroforestry is the practice, where trees are combined with agriculture and/or livestock (Augere-Granier 2020). „Agroforestry systems can provide an environmentally friendly approach to land management, combining agricultural and forestry practices.“ (Nerlich et al. 2013, p. 476). According to the FAO, „Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components. Agroforestry can also be defined as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. In particular, agroforestry is crucial to smallholder farmers and other rural people because it can enhance their food supply, income and health. Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural, and environmental benefits.“ (FAO 2015).

Agroforestry was a common agricultural practice in Europe, especially the combination of forestry and animal husbandry (silvopastoral agroforestry) and started in Germany 6000 years ago. These systems decreased with the industrialization and mechanization of agriculture (Mosquera-Losada et al. 2012). The loss of these traditional systems had many consequences: „loss of knowledge base amongst farmers, simplification and standardization of landscapes, increased environmental problems such as soil erosion and water pollution, significant carbon release, reduction of biodiversity, loss of habitat for natural enemies of crop pests and the loss of a source of alternative income for farmers” (Mosquera-Losada et al. 2012, p. 289; Dupraz et al. 2005).

Citing different references, Mosquera-Losada et al. (2012) claims that the most practiced agroforestry systems worldwide are silvoarable, forest farming, riparian buffer strips, improved fallow, multipurpose trees and silvopasture, while a study in 2018 comes to the conclusion that silvopasture, silvoarable, riparian buffer strips, forest farming and homegardens are the five most common agroforestry practices in Europe (Mosquera-Losada et al. 2018). In Germany, the most popular agroforestry systems are orchards, but also alley cropping with fast growing trees is common, especially for the production of biomass. These systems are as well called „modern agroforestry“ (Mosquera-Losada et al. 2012).

Agroforestry systems (AFS) are complex interactions between their agricultural and forestry elements and can be classified according to different aspects, which shows their multi-functionality.

Agroforestry practices are classified in the categories i) components, ii) predominant land-use, iii) spatial and temporal arrangement, iv) agro-ecological zone, v) socio-economic aspects and vi) functions. Components (i) can be the wood, the crop or the animal. This results in different forms of agroforestry, such as silvoarable or silvopastoral systems. The predominant land-use (ii) refers to either agriculture or forestry. The spatial arrangement (iii) means the arrangement of the trees on the area, while the temporal arrangement means the way of intercropping during the year. The classification of AFS according to their agro-ecological zone (iv) is done with the occurrence of different systems in different regions. Socio-economic aspects (v) can be used to differentiate between commercial or subsistence AFS, which can be as well linked to the agro-ecological zone. The ecosystem functions (vi) can be sub-classified in a) production, b) habitat, c) regulation and d) culture. Production includes the produce from the tree (fruits, timber, fuelwood or fodder), the crops (grains, fruits, vegetables or fodder) and the animals (mostly meat) (McAdam et al. 2009). Habitat and regulation can be summarized with environmental benefits of agroforestry, which arise in the fields of nutrient use, the carbon sequestration, increase of biodiversity and decrease of fire risk. The better nutrient management, due to a decrease of nutrient losses (on farm level), has impact on the water quality and the eutrophication risk. The trees develop deep roots and are able to take up nutrients not used by the crops (Rigueiro-Rodríguez et al. 2009). Another aspect is the improvement of nutrient cycling. For example, trees with deeper roots can take up nutrients, which crops are not able to reach. The cycle is closed when the leafs fall down and the nutrients are recycled by the crops. Therefore, nutrients can be used more efficiently and this is one reason for the higher soil fertility in agroforestry systems. In general, trees enhance the soil fertility (Garrity 2012). Reasons for the increase are N-fixation, fall of leaves, fine roots and exudates, mycorrhiza, subsoiling and formation of humus (out of Hoppe 2023). Moreover, it prevents that too high amounts of nitrate reach the groundwater (Mosquera-Losada et al. 2012). The carbon sequestration potential is higher, because the trees have a higher capacity to absorb carbon from the air and store it in themselves, but as well in the soil for a longer period. This helps to reduce the greenhouse gas emissions. Besides, as less use of fertilizer is required, emissions are reduced as well and the use of pesticides and herbicides is lower in AFS (Rigueiro-Rodríguez et al. 2009). The different components of an AFS use resources differently, which makes the production beneficial due to the ecological and economic interactions (McAdam et al. 2009). Within an AFS, we observe differences in radiation, humidity and temperature, creating microhabitats (Mosquera-Losada et al. 2012). AFS promote biodiversity, as they create different microclimates above and below the ground and with this, provide habitat for a great variety of organisms and species (Rigueiro-Rodríguez et al. 2009). AFS provide the possibility for soil conservation and protection against soil erosion (through wind and water) (Rigueiro-Rodríguez et al.

2009) and have the potential to reduce the wind speed and serve as windbreak (Böhm et al. 2014). Moreover, trees provide shade and protection for animals. Last, agroforestry comes along with cultural functions which are cultural heritage, recreation and landscape (McAdam et al. 2009).

Therefore, AFS provide environmental, social and economic value to the society. (McAdam et al. 2009) and we cannot only observe environmental benefits, but as well economic. Those arise due to diversification of the farm and the farming system with different, additional outputs, that can generate additional income (Mosquera-Losada et al. 2012). However, all these services differ among the different agroforestry systems (Nerlich et al. 2013). To conclude, agroforestry can help to address and improve current problems in the European agriculture, such as biodiversity, soil conservation, carbon sequestration and water quality (Rigueiro-Rodríguez et al. 2009). Additionally, trees play an important role in climate change mitigation (Maathai 2012; Pachauri 2012) and agroforestry systems can contribute to mitigate climate change (Mosquera-Losada et al. 2012).

A common traditional agroforestry practice in Germany are fruit orchards, nevertheless, due to mechanization and intensification of agriculture, those systems declined. Accompanying with that, the services combined with these systems disappeared. Today, in view of a biodiversity crisis, general environmental problems and climate change, agroforestry systems regain interest and importance. So called „modern agroforestry“ is based on the practice of traditional agroforestry, but is updated and fits todays agricultural practices (Nerlich et al. 2013).

The interest in agroforestry in Germany is increasing, as people are and become more aware of the (especially environmental) benefits linked to those systems and the ability to promote an alternative to intensive agriculture and negative effects related with it. However, the implementation of agroforestry systems is still low. In view of the benefits of agroforestry explained above and the increasing problems of today’s agriculture as well as the increasing interest in agroforestry, this project aims to develop an agroforestry system for a farm in the South of Germany.

The goal of the project is to design an agroforestry system for a farm with 17 ha and 20 sheep in the district of Rottweil in the South of Germany, which will be implemented afterwards. I will start to work out the aims and goals of the farm by designing a questionnaire for the farmer and doing a farm visit to get an idea of the farm, the sites and the possibilities. The farmer offers two possible sites for the agroforestry system, one field with 4 ha and one meadow with 6 ha. To start planning an agroforestry system, I first have to analyze the characteristics of the sites. Afterwards I can start my literature search for the planning of an agroforestry system and trees that could be used. The goal is to identify suitable sources of information on how to plan and design an agroforestry system and the

search for appropriate trees. One important step in this process as well is to contact the rural district office and to get aware of the legal guidelines.

To achieve this project, the following research questions are established:

1. What are the goals of the farm?
2. What has to be considered while designing the agroforestry system?
3. What are the characteristics of the project sites?
4. Which kind of overall system shall be designed?
5. Which agroforestry system can be designed?
6. Which trees can be used?

The expected outcome and result of this project is a plan of an agroforestry system with a map of the site including the trees (visual presentation) as well as a list with trees that could be used. The plan is suitable for the farm and the site and meets the expectations of the farmer. The goal is to design a system which can be implemented by the farmer afterwards. As well a management plan for the first years should be given to hand.

Material and Methods

1. Questionnaire for the farmer

My first step was a questionnaire for the farmer, to get an idea of his interests and goals for the farm and the agroforestry system, which I will use as guidelines for my further work. In this step as well a farm visit was included, to get an overview of the farm itself and to visit the project sites. I will summarize the information I got, the whole questionnaire with the answers can be found in the annex. Another action included in this step was the contact to the rural district office of Rottweil.

The farm for this project, which is owned by Marco Braasch and Gabriela Marmolejo, is a small part-time ran farm with 17 ha of area and 20 sheep of the breed Coburger Fuchsschaf. It is located in Bochingen, which belongs to Rottweil, in the South of Germany. The height is 540 m ASL, the mean annual temperature is 8,2°C, the average annual precipitation is 1089 mm (Climate Data 2022) and the main wind direction is west. With the beginning of 2023 the farm started the conversion to organic and will probably join the Bioland association. The region where the farm is located is the so called Neckarland, where you can see a lot of pinewoods in the landscape as well as typical deciduous trees such as maple, lime and cherry. Adjacent to the fields of the farm are small-scale farmers but with an intensive management.

The farmer offers two possible sites (shown in Fig. 1 and 2) for the implementation of the agroforestry system, whereat both sites shall be used someday as an agroforestry system. The first and more important site is a field with 4 ha around the farmstead and the second is a meadow with 6 ha which is around 1 km away from the farm. In the medium term the agroforestry system shall be used as pasture for the sheep, however, the possibility to manage the land with machinery as well as the arable status of the field shall be maintained in the long term. The long-term goal of the agroforestry system is to produce high grade woods and the space between these trees should be used efficiently, for example to produce wood for energy production, feed for the sheep, the production of fruits, serve as windbreak and potentially as a bee pasture. The system shall provide a high share of biodiversity and be as diverse as possible, nevertheless everything has to fit together.

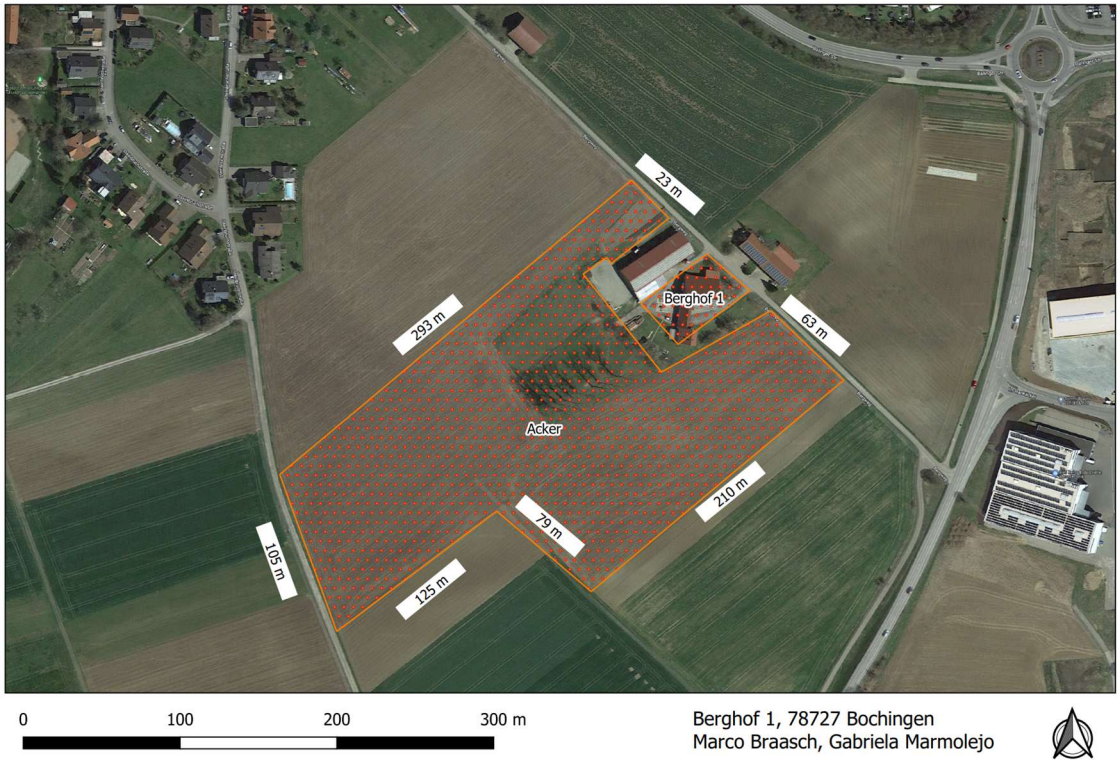

Figure 1: Site 1 - arable land with 4 ha around the farm (Marco Braasch 2023)

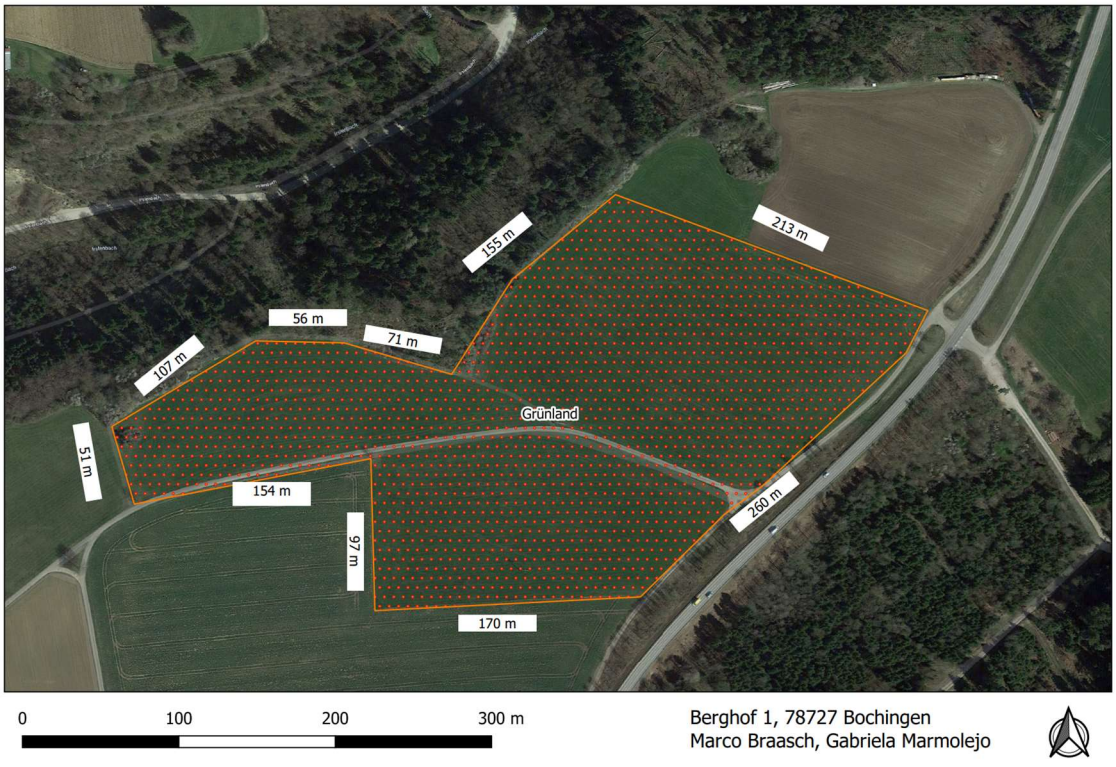

Figure 2: Site 2 - meadow with 6 ha (Marco Braasch 2023)

The main use of the arable land right now is as pasture for the sheep and the use of the meadow is the production of hay, while both sites can serve as pasture for the sheep in the future and the long-term goal of the agroforestry system is the production of high grade woods. Those trees are planted with a

greater distance and the space between them should be planted with smaller trees and be used efficiently to produce wood for energy, fodder, fruits, serve as windbreak and offer shadow for the sheep. As well fruit trees, hazelnut, berries, wildflower strips for bees and shrubs are possible. Important is to consider the nature protection and biodiversity while implementing this system. Therefore, the natural zones of a hedge can be used as inspiration (see Fig. 3). On the field, the focus should be on forest trees, windbreak and shadow for the sheep. On the meadow as well fruit trees could be possible, as well as bigger distances. A protection for the trees against sheep and wild animals is needed.

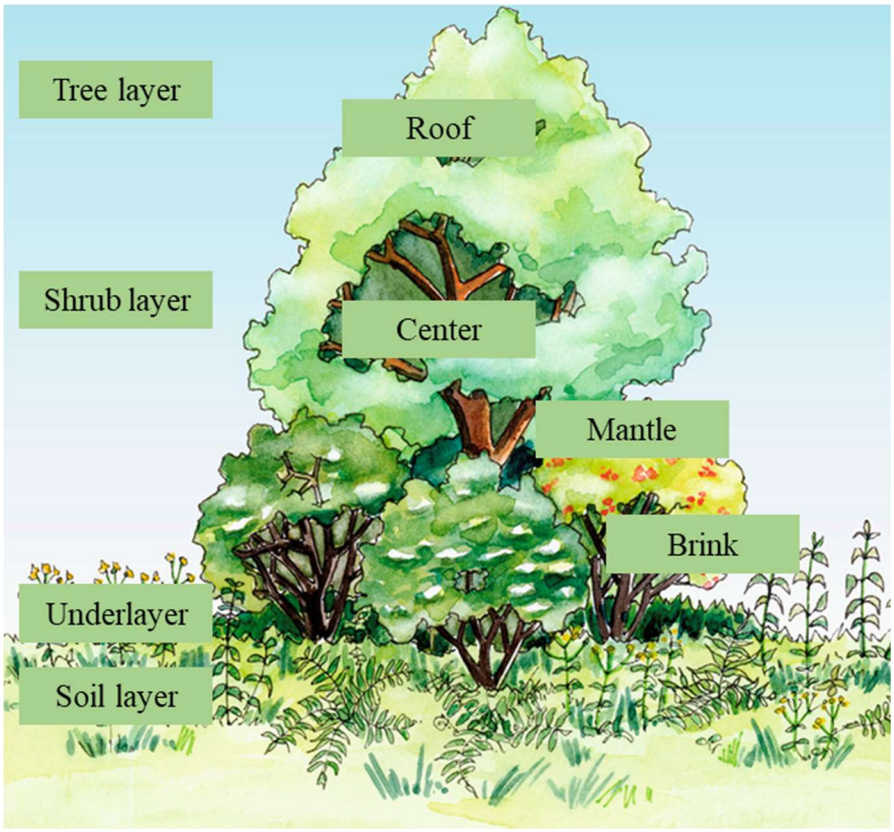

Figure 3: Cross section through a hedge (Cornelsen 2008)

Between two strips there should be at least 26 m to maintain the management with machinery, which is at the moment done by a contractor. Between two big trees as well a space without vegetation as "natural" passage for the sheep should be integrated. At the end of the field, at least 12-13 m of space should be considered for the machinery to turn. Moreover, the possible entry on the sites with the machinery has to be considered, which is limiting the orientation of the strips.

In the course of the eco-rule nr. 3, already existing agroforestry systems can get a subsidy of 60€ per hectare of wood. The guidelines can be looked up in the document "Agroforstsysteme in der GAP ab 2023 – ein Überblick" (Böhm 2022). As these guidelines are only relevant for agroforestry systems which were implemented before the 01.01.2023, they are not strictly used, nevertheless considered in

this planning. If there is a possibility to get the subsidy in the next period, the farmer will adapt the agroforestry system, if necessary.

Agroforestry systems can be implemented on arable land, permanent crops and permanent grassland and are considered as agricultural activity (Bundesministerium für Ernährung und Landwirtschaft 2021). Important information from the rural district office in Rottweil is:

- Consider the distances to the neighbour ("Gesetz über das Nachbarrecht", §§16, 19, 21) which are 2 m for pomaceous and stone fruit that are not higher than 4 m, 3 m for small to medium sized fruit trees, 4 m for e.g. birch, alder, willow or fruit trees, 8 m for e.g. chestnut, poplar or walnut. However, those distances do not have to be considered if the neighbour area is an outer space and to public roads (Justizministerium Baden-Württemberg 2014)
- Check if subsidies are possible (guidelines)
- Check if it is a forestation, if there is a duty of disclosure and if this would be a transformation of the meadow ("Landwirtschafts- und Landeskulturgesetz", §27) (Justizministerium Baden-Württemberg 1972)
- Agroforestry systems are not subject to approval
- Submit a concept to the rural district office before implementing the system.

Currently, there are no specific guidelines on agroforestry in the regulations of the Bioland association.

2. More detailed site analysis

The second step was a more detailed site analysis of the field with 4 ha and the meadow with 6 ha. The height of the farm is 540 m, the rock is keuper and the soil texture is heavy clay, therefore dammed-up water can occur (see Fig. 4). For this planning, no nutrient analysis is available. On both sites there are no old drainages. The two sites are more or less flat, however the field shows some issues with water erosion if there are heavy rainfalls. As well, the meadow can be moist.

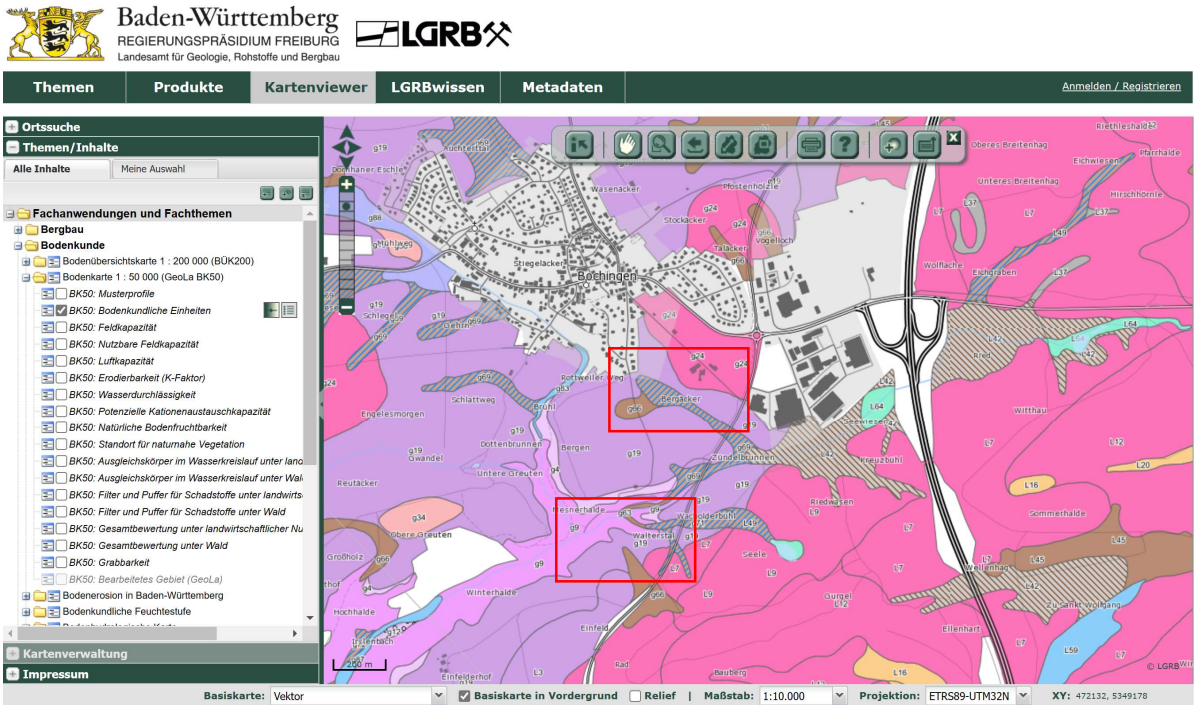

Figure 4: Soil science of the project sites (Landesamt für Geologie, Rohstoffe und Bergbau 2021)

The mean annual temperature is 8,2°C and the average annual precipitation 1089 mm (Climate Data 2022). The distribution over the year is shown in Fig. 5.

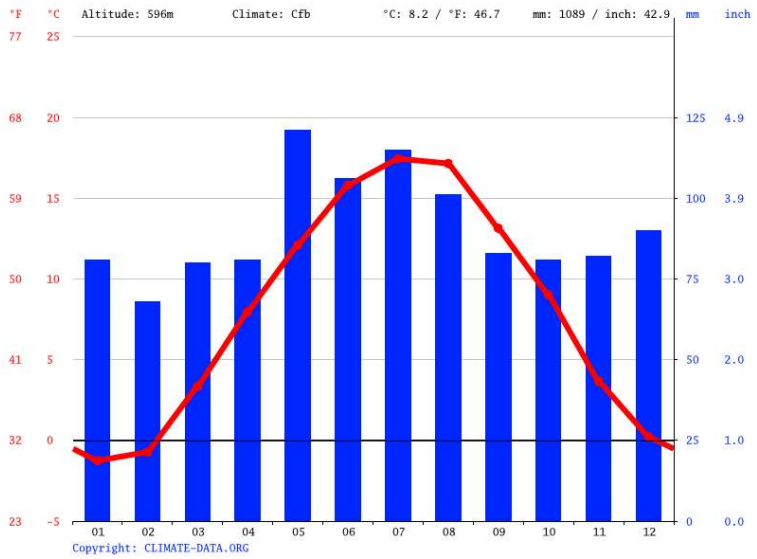

Figure 5: Climate graph for Rottweil (Climate Data 2022)

The field is also exposed to west wind, therefore windbreak (also with hedges) is important. Late frost can occur, as well as hot and dry periods during the summer, but an irrigation system is not necessary.

3. Literature search

The third step was a literature search on agroforestry concepts and designing of agroforestry systems. I identified the following sources of information which I used to plan this system:

1. Agroforst-Systeme zur Wertholzerzeugung (Schulz et al. 2020)
2. Moderne Agroforstsysteme mit Werthölzern. Leitfaden für die Praxis (Bender et al. 2009)
3. Agroforst. Von der Idee bis zur Umsetzung – Eine erste Orientierung (Markut et al. 2022)
4. Handbook for Agroforestry Planning and Design (Gold et al. 2013) with Training Manual for Applied Agroforestry Practices – 2018 Edition (Gold et al. 2018)
5. Wertholz-Produktion in Agroforst-Systemen. Ein Leitfaden für die Praxis (Morhart et al. 2015)

To plan and design an agroforestry system, different steps and criteria have to be considered, which are summarized in the following listing:

- Formulation of goals for the agroforestry system and farm capacity
- Selection of suitable sites and knowledge/analysis of site characteristics
- Get aware of different design concepts and chose different aspects/elements (arrangement of trees, distance between trees and strips, width of strip, number of trees, orientation, use of trees and strips)
- Guidelines (guidelines from the rural district office or nature conservation authority, distance to neighbours or streets, subsidies)
- Selection of trees (site characteristics, use/purpose, interaction with crop or animal, protection)
- Investment costs
- Maintenance and management of the system.

Included in this step was the search for suitable trees. Most important for the choice of appropriate trees is the goal of the agroforestry system and the purpose for the use of the trees. Interesting trees for the farmer are walnut, wild cherry, chestnut, hazelnut, apple, poplar and willow. He does not only want to use willow or poplar trees, yet faster growing trees should be selected. In Germany, there is a negative list of trees, that are not allowed to be used in agroforestry systems. These trees are manitoba maple, butterfly bush, red ash, black cherry, staghorn sumac, locust, rugosa rose, common snowberry, red oak and paulownia (Bundesministerium für Ernährung und Landwirtschaft 2021; Bundesrat 2021). As the farmer wants to have trees oriented towards forest trees on the arable land and for the orientation of the agroforestry system on the surrounding landscape, I checked the typical trees for the region of Oberndorf a.N. These are for example different types of maple, dogwood,

hazel, hawthorn, common beech, honeysuckle, aspen, different types of cherry and willow, elder, blackthorn or linden (Breunig et al. 2002). For the selection of appropriate trees, it is important to know about their requirements and characteristics. It is important to consider the climate, including temperature and precipitation. Site requirements of trees are climate, water demand and tolerance to dammed-up water, nutrients and soil characteristics. Important tree characteristics are shade tolerance, drought tolerance, acidity tolerance, resistance to late frost and tolerance to winter cold. Other characteristics to be considered are cold tolerance, tolerance to lack of nutrients, growth, stability or life span (Forster et al. 2019). To select appropriate trees, it is as well important to know the specific site characteristics in view of soil texture, temperature, precipitation (in total and distribution over the year), risk of early or late frost, water availability (groundwater, water holding capacity, dammed-up water), soil aeration and nutrient availability (Morhart et al. 2015). Moreover, the trees should not be poisonous for the sheep.

For the selection of the trees, the following sources were used:

1. Agroforst-Systeme zur Wertholzerzeugung (Schulz et al. 2020)
2. Moderne Agroforstsysteme mit Werthölzern. Leitfaden für die Praxis (Bender et al. 2009)
3. FiBL Merkblätter (FiBL 2023)
4. Anbauempfehlungen – Schnellwachsende Baumarten im Kurzumtrieb (Röhricht and Ruscher 2009)

4. Design of the agroforestry system

The fourth step was the design of the agroforestry system based on the answers of the farmer, the information of the literature search and the legal guidelines. The concept for the agroforestry system and the visual presentation as well as the list of trees will be presented in the following results.

Results

The results consist of three parts: the plan of the agroforestry system with visual presentation and the list of trees, a short overview of the costs and a management plan for the first years.

1. Plan of the agroforestry system with visual presentation and list of trees

Fig. 6 shows the concept for the first site (arable land), which will be planted with strips. The distance to the neighbour fields is 20 m until the first strip of trees is planted. The distances at the end of the field to the farm and the roads are 20 m, considering the space the machinery needs to turn. The field offers space for 5 strips, each with a width of 3 m. The orientation of the strips is east-west due to the entrance on the field with machinery. Between the strips there is a distance of 28 m. The high grade wood trees are planted in groups of three, to have a reserve if one tree is falling out. The trees within a group are planted with a distance of 2 m and the distance of group middle to group middle is 15 m. In between those 15 m, smaller trees and shrubs are planted. The rows at the outside are planted with willow and poplar and as well some bigger shrubs, to create a dense vegetation which can as well serve as a windbreak. The two rows in the middle will be planted with shrubs between the high grade wood trees and as well berry bushes are used.

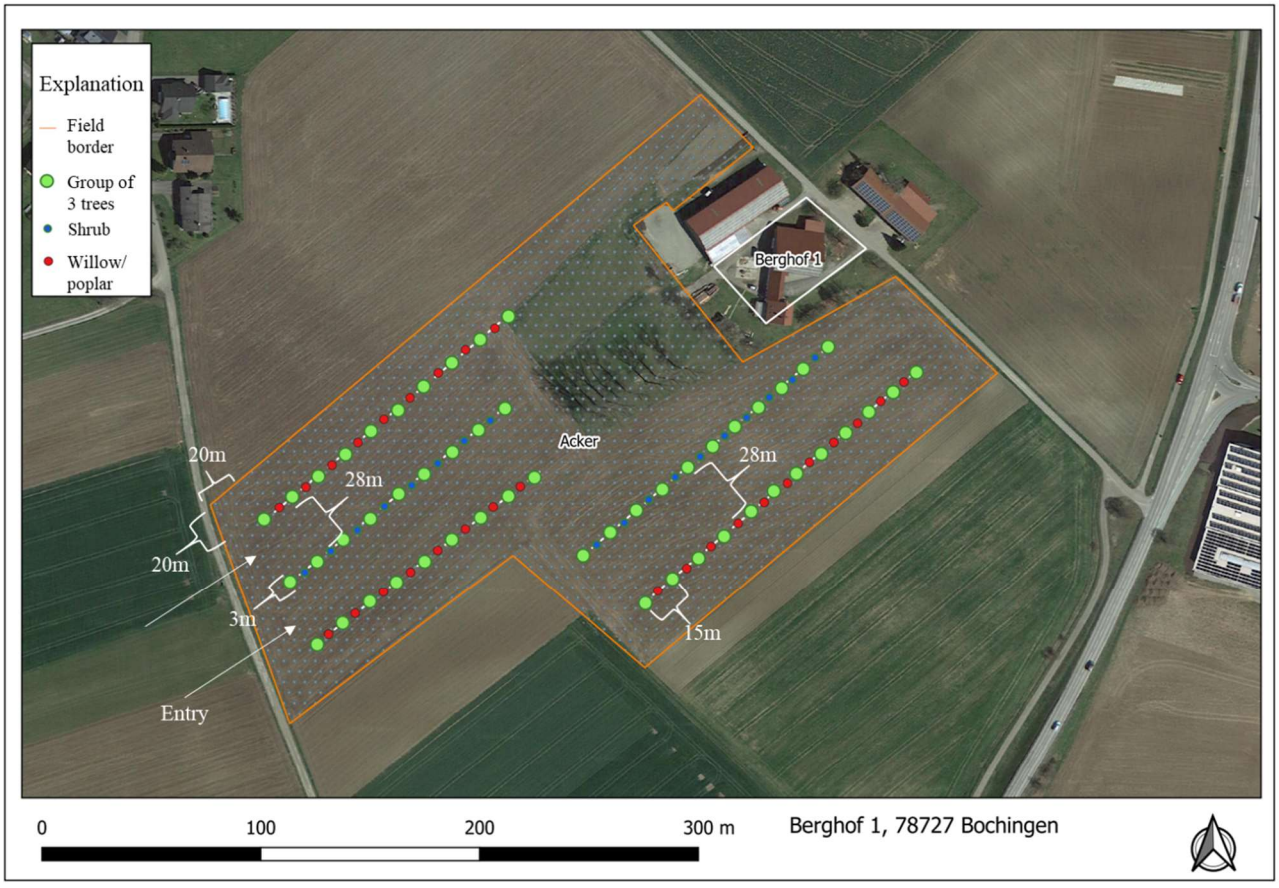

Figure 6: Visual presentation of agroforestry desgin site 1 - arable land

Trees and shrubs proposed for the arable land are: hybrid nut, wild cherry, walnut, service tree, whitebeam, willow, poplar, common alder, chestnut, hazelnut, elder, cornel cherry and berry bushes.

Fig. 7 shows the concept for the second site (meadow), which is created as a fruit orchard combined with high grade wood trees. Therefore, no strips are implemented, but the trees are planted in rows. The distance to the neighbour fields, the forest and the road are 20 m. As well the distance at the end of the row is 20 m, enabling the machinery to turn. Between the trees in the row there is a distance of 15 m and between the rows 57 m. The orientation of the rows is east-west, due to the possible entrance on the site with machinery and the driving direction.

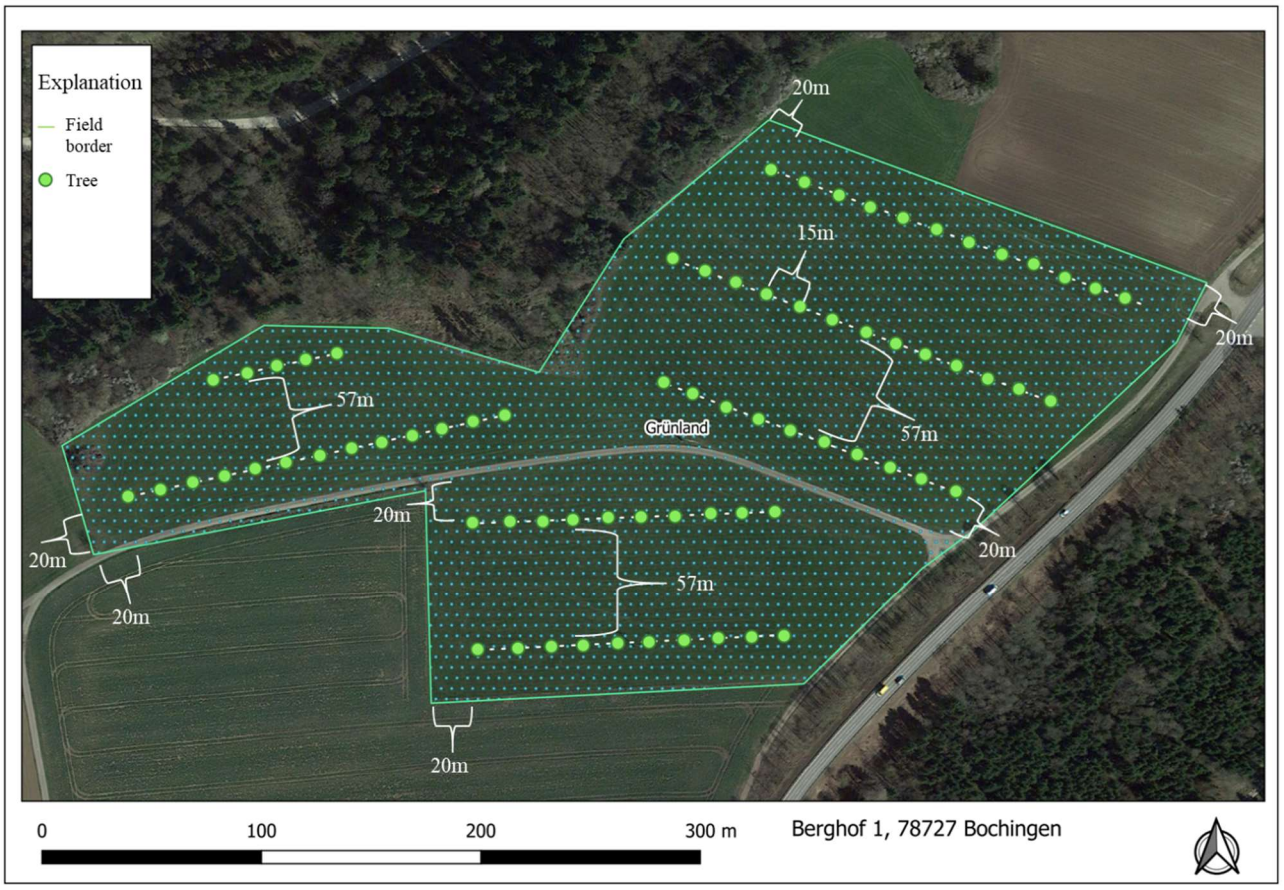

Figure 7: Visual presentation of agroforestry design site 2 - meadow

Trees proposed for the meadow are: apple, pear, wild cherry and hybrid nut.

2. Short overview of the costs

Tab. 1 shows the approximate costs per tree of planting and maintaining it in the first years. However, depending on the tree and the protection method, the planting costs per tree fluctuate between 15 and 57€ (Bender et al. 2009).

Table 1: Costs per tree in the first years (Schulz et al. 2020)

	Year	Activity/material	Required working hours (min)	Costs without interest (€)
Planting	0	Planting material		5
		Earth driller (manual)		2
		Protection and plant stick		3,5
		Working hours for planting	15	7,5
Management	1-3	Regulation of accompanying vegetation	5	2,5
	1-3	Delimbing (2x, each 5 min)	10	5
	4-7	Delimbing (2x, each 10 min)	20	10
Total				**35,50**

3. Management plan for the first years

For planting, the following materials are needed: i) spade, shovel, auger, sledgehammer or post driver as tools and ii) the seedling, planting stick, tree protection, fixing loop and if needed a wire to protect the roots against mouse. The best planting time is in autumn (October-November) or in spring (February-March) when the soil is saturated with water or if a rainy period is predicted. The first step is to remove accompanying vegetation and to prepare the soil. Then the planting whole is made, where it is helpful for the tree growth to make it angular. Afterwards, the tree seedling can be put into the whole and optionally the roots can be protected with wire against mouse. Then the whole is filled up, the soil is pressed on gently and the tree is cast on. After planting the tree, it is important to fix the planting stick, to support the growth of the tree. Here it is important to consider the main wind direction and the height of the fixation. It can be necessary to irrigate the seedlings if it is really dry. For the first years of growing, it is as well important to protect the trees against the sheep and wild animals. One option would be to fence the whole area. As the AFS should serve as pasture for the sheep, this is not the best option. Other possibilities are a tree protection cover made from self-degradable plastic or grid or a more robust one made with wooden piles and crossbars. As well an electric fence can be taken into account. What is important in addition, is to place a perch for birds of prey to control the mouse population and to avoid damages on the tree sprout. Beside the protection, the management in the first years is important for a good tree growth and the quality. One part is the weed control, as wild plants compete against the seedling. The area around the tree should be kept free by using mechanical weed control or mulch. The maintenance of the strips has to be done every

year. Another part is the tree-cut, which is important for the production of high grade wood. The timing and amount of cutting depends on the growth height and speed of the tree. The first cut can be done after two or three years and has to be done over several years until the desired tree height is achieved. In doing so, it is better to cut more frequently less branches, than cutting rarer but more branches. The best time for the tree-cut is in late winter or during the growth period. However, some trees are better cut during summer. It is important to consider that the tree-cut should not be done during a dry period. The way of cutting is important as well, the branch snag should be as short as possible and the cut surface smooth. The bark of the tree should not rip, therefore a so called relief cut can be done with bigger branches. The last management part is the so called root education, which has to be done in the first years. With the use of for example a cultivator, subsoiler or plough, the roots at the border of the strip are cut and as a consequence grow in deeper soil layers (Morhart et al. 2015; Schulz et al. 2020; Bender et al. 2009; FiBL 2023; Markut et al. 2022). Tab. 2 gives an overview on the different work steps during the year.

Table 2: Overview on work steps during the year (Morhart et al. 2015)

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Planting												
Irrigation (if necessary in the first year)												
Weed control (year 1-3)												
Tree-cut												

Discussion

Within the framework of this project, an agroforestry system was designed for a farm in the district of Rottweil in the South of Germany. Therefore, the goals and ideas of the farmer have been considered, appropriate literature was searched and the rural district office was contacted. With this components, a design concept for the two offered sites was worked out, as well as a list of suitable trees and recommendations for the first years of management.

The first and more important site is the arable land with 4 ha. The main goal is the production of high grade wood, while the land should serve as pasture for the sheep. However, the possibility to manage it with machinery and the arable status should be maintained in the long run. Moreover, the space between the high grade wood trees should be used efficiently, the system should be diverse and provide a high share of biodiversity.

The recommended concept includes planting the trees in 5 strips, which permits the management with machinery and therefore the maintenance of the arable status. During the time the arable land is used as pasture for the sheep, the trees provide shade and protection against wind or rain. For the selection of the trees, their climate requirements were considered as well as the specific site characteristics. On the other hand, trees were selected according to their use and the goals and ideas of the farmer. A high variety of trees and shrubs was selected, offering a high share of biodiversity and meeting the goals and ideas of the farmer. With the combination of trees and shrubs, as well the natural zones (shown in Fig. 3) can be imitated to a certain degree. For the high grade wood trees, the farmer would like to use nut trees, therefore hybrid nut is recommended, as it is less susceptible to frost. However, some walnut trees could be planted as well. The other high grade wood trees are wild cherry, common alder and some chestnut. As well service trees and some whitebeam are recommended, as they belong to the local, old and rare varieties and provide a good contribution to biodiversity. As shown in Fig. 4, in some parts of the site dammed-up water can occur, therefore in this part common alder will be planted. These high grade wood trees will be planted in groups of three trees each, because the probability is high, that one seedling is falling out. With this option, the farmer has a reserve and safety and can, after a few years, select the best tree without having an outage. The distance between the high grade wood trees is calculated with this formula: the desired diameter of the tree trunk (target diameter) measured at breast height (1.30 m) multiplied by 25, which leads to the 15 m of distance. The space between the high grade wood trees will be planted with willow and poplar in the outer strips, to have a faster closing and with that a wind protection. Additionally, some shrubs can be included, such as hazelnut or cornel cherry. The two inner strips will be complemented with shrubs, such as hazelnut, elder or berry bushes. Besides, some nature conservation elements could be added.

To this belongs nesting boxes, insect hotels, piled up wood, a branch heap or a benjes hedge (where cut branches could be used) or a heap of stones (Schulz et al. 2020). This concept considers the guidelines of the current subsidies, therefore it is possible for the farmer to apply for the subsidy in the next period. It can be assumed that, if anything, only small adjustments have to be done. The distance to the neighbours and the streets is with 20 m bigger than the minimum distance of the legal guidelines, considering a recommendation of the Bioland association. In this plan the "natural" passage for the sheep is not marked, this can be decided while implementing the system. However, some disadvantages can be found as well. To this belongs the orientation of the strips, which is east-west due to the possible entry with machinery. With that, more shade is falling in the area between the strips instead of in the strip, which can influence the growth of crops in this area. Moreover, as well due to the orientation, the windbreak of the system is not optimal, as the main wind direction is west. Therefore, poplars or hedges could be planted across the strips at the beginning and end of the site. The high variety of trees and shrubs is creating a diverse system, though causing more work for the farmer. During the time the system is used as pasture for the sheep, it can be assumed that the costs for tree protection are higher, especially in the first years of tree growth.

This agroforestry system fulfills several functions and interacts with its environment. To these belong the diversification of the farm due to the additional products (high grade wood, energy wood, fodder, fruits) and the upgrading of the landscape. This system is reducing water erosion, as the trees can hold the water and improve the hydrologic budget. Moreover, due to the trees a microclimate is created. To a certain degree, it also protects against wind and offers shade and protection for the sheep. With less wind, the evaporation is reduced, but the drying on wet days is deferred. Moreover, the shade reduces the drying of the soil on hot days. However, it influences as well the crop growth. The trees have an impact on the soil, as their leafs contribute to the building up of humus, their roots influence the soil structure and can reach nutrients in deeper soil layers and transport them to the top. Contributing to the mitigation of climate change, the trees are able to store carbon dioxide. The trees and shrubs create a habitat for a wide range of animals and plants and provide a high share of biodiversity (Bender et al. 2009; Schulz et al. 2020; Markut et al. 2022). Fig. 8 is showing these functions.

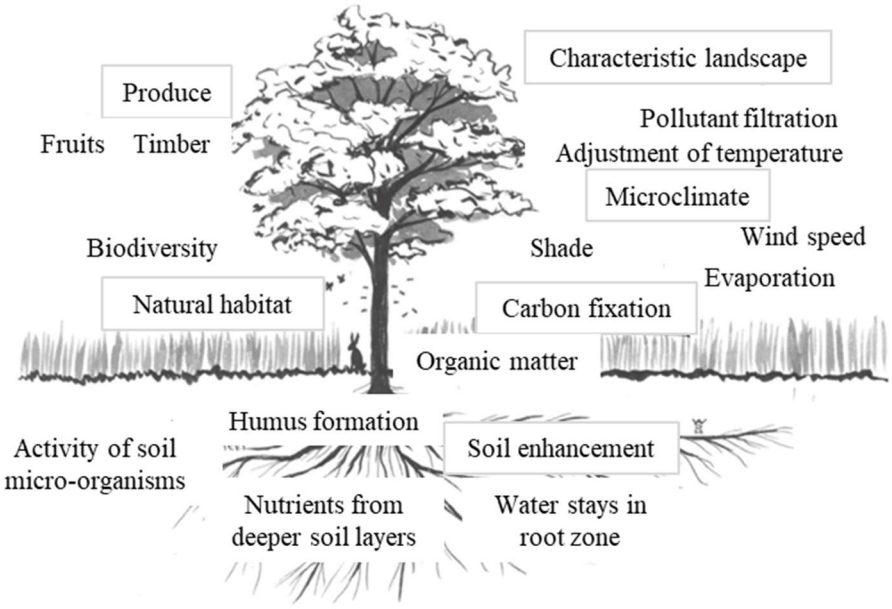

Figure 8: Functions of an agroforestry system (Markut et al. 2022)

The second site is a meadow with 6 ha, which is around 1 km away from the farm. Currently, this site is used for the production of hay and should serve as pasture for the sheep in the long run. The goal for this site is to implement a simpler agroforestry system and the integration of fruit trees.

The recommended concept gives this system the characteristic of a fruit orchard. The trees are planted in rows as well, with a distance of 15 m, however the distance between the rows is with 57 m considerably wider. With that, the management with machinery is possible. On this site, there will be planted only one tree each (not in groups). As well, the space between the trees in a row will not be planted. The distance to the neighbours, the street and the forest is as well 20 m, according to the recommendation of Bioland. With this simpler design, this system requires less work than the first one and is easier to manage. The trees were selected according to their climate requirements, the specific site characteristics and the ideas of the farmer. Proposed trees are a combination of fruit and high grade wood trees, including apple, pear and wild cherry and as well hybrid nut. If the meadow is used as pasture, the trees provide shade for the sheep and protection against wind and rain. The guidelines for the subsidies are considered in this concept as well, which enables the farmer to apply for the subsidy in the next period. Moreover, as this system is designed as a fruit orchard, there could be the possibility to apply for the subsidy for fruit orchards in Baden-Württemberg. Disadvantages of this system are as well the orientation, which is east-west due to the driving direction. As the main wind direction is west, the protection against wind is not optimal. It is possible, to turn the rows to

increase the wind protection. Due to the fact that this system is only planted with trees, the biodiversity share is lower. Nevertheless, a fruit orchard provides a great habitat as well.

This agroforestry system as well fulfills several functions. Diversification and upgrading of the landscape are part of it, just as the improvement of the hydrologic budget, the impact on the soil and the carbon dioxide storage. To a certain degree, the trees can serve as windbreak and offer shade and protection for the sheep.

For both systems, trees and shrubs are proposed which are not poisonous for the sheep, giving the farmer the possibility to use them as well as fodder. For this, an online database is available, collecting nutritional information on fodder trees in Europe (Luske et al. 2017).

My course of action was first to cross-read information on agroforestry systems and the designing of such a system. The next step was to get in contact with the farmer and to get aware of his goals and ideas for the agroforestry system. Afterwards I defined my research questions for this project and started to search for literature which I could use for planning this system. An important step was the contact to the rural district office. Unfortunately, they could not provide me a lot of information and support. This is due to the fact that themselves do not have a lot of information on agroforestry systems. They told me to consider the legal guidelines and checked if the system could be implemented on the offered sites. The legal guidelines and the legal frame in Germany are not extensive. With all the information I got from these actions, I was able to design an agroforestry system according to the legal guidelines and the goals of the farmer. However, all information provided are general and show the frame of what is possible, nevertheless every system is an individual case and has to be treated like that.

The literature I used focused on the planning of agroforestry systems with the production of high grade woods in Germany. Beyond that, it was difficult to find concrete literature on planning of agroforestry systems. In terms of content, all of them include information on similar subjects, which convinced me that these seem to be good sources to work with, covering the current information on planning of agroforestry systems. One source I identified was the “Handbook for Agroforestry Planning and Design”, which I rarely used because it was too general for me. Moreover, it was more difficult to find information on the selection of trees for agroforestry, because the literature I used mostly only covered high grade woods. The literature shows different opportunities for the design of an agroforestry system, however they strongly focus on the strip-design. The difference between theory and praxis is, that the wide range of possibilities is restricted very fast due to the specific site characteristics and the ideas of the farmer. For praxis it is important to consider the legal guidelines and the opportunities the specific site offers. The distance to the neighbour is according to the legal

guidelines only a few meters, here the Bioland association makes a different recommendation. The work with the materials I chose was useful to answer my research questions.

Agroforestry systems are part of the CAP from 2023 and with that for the first time the implementation of agroforestry systems in Germany is legally regulated. In the course of the eco-rule nr.3, already existing agroforestry systems can get a subsidy of 60€/ha. There would be the option, to subsidize agroforestry within the framework of agri-environment-climate measures (AECMs) in the federal states, but this is not done at the moment. According to the German CAP-strategic plan, the subsidy for the establishment of agroforestry systems should be done via the federal states. Currently, there are no subsidies for the establishment of agroforestry systems in Germany. A study by Tsonkova et al. (2018) aimed to identify opportunities and limits of agroforestry for farmers in Germany, by doing interviews with 32 farmers in Germany in 2015. The main question was to "state several positive and several negative aspects of agroforestry, with respect to its production, environment and social aspects" (Tsonkova et al. 2018, p. 1093). One of the main limits reported for the implementation but as well for maintenance of agroforestry systems (AFS) are the legal framework and the bureaucratic effort. Moreover, the profitability of those systems is often low as well as the payment and therefore there is almost no financial profit, as there are only low financial rewards of the environmental benefits and no higher prices (as well because there is no certification for products of an AFS). Sadly, the non-market benefits are often not considered because they are not rewarded and financial benefits are of great importance to the farmers. Another aspect is, that there are no subsidies for the implementation of an AFS. The study also conducted a lack of knowledge among farmers on agroforestry systems (Tsonkova et al. 2018). Another study came to similar results (Sollen-Norrlin et al. 2020).

Conclusion

Today, we are facing challenges in the fields of environment, ecosystems and health. These are pollution of groundwater, eutrophication and acidification of rivers, lakes and the sea, soil erosion, intensification of agriculture and with that changes in the landscape and the land use, overuse of natural resources, emissions of greenhouse gases, climate change and loss of biodiversity, to name only a few of them. However, agriculture is not just heavily influenced by them, but these problems also arise due to agricultural practices. Therefore, agriculture plays a significant role in mitigating these effects.

In view of these problems, agroforestry can play a key role in mitigating negative effects and improve current problems of agriculture, as it shows positive effects on the water quality, the nutrient use, biodiversity, protection of the soil against wind and water erosion, carbon sequestration, mitigation of climate change and as well the production of valuable goods. Benefits of agroforestry can be found in environmental, economic and social fields. As more and more people are becoming aware of these benefits, the interest in agroforestry systems is increasing and they gain importance as an alternative to the intensive agriculture.

With this project an agroforestry system was designed for a farm in the district of Rottweil in the South of Germany. The farm offered two sites, an arable land with 4 ha and a meadow with 6 ha. The long-term goal of the farm is to produce high grade wood, while the areas should serve as well as pasture for sheep or for the production of agricultural crops and grass. The agroforestry system should be used efficiently, be diverse and provide a high share of biodiversity. The concept for the arable land includes strips of trees and shrubs, offering the combination of high grade wood trees with faster growing trees and shrubs. This system is diverse, provides various services to the farmer and provides a high share of biodiversity. Meanwhile the meadow is designed as a fruit orchard combined with high grade woods, offering a simpler system, yet providing different functions to the farmer. Both systems were designed considering the goals and ideas of the farmer and the possibilities of the current literature as well as legal guidelines.

The results of this project can be used by the farmer to submit as a concept to the rural district office and to implement the agroforestry system on his sites. With that, he cannot only create a diversification of his farm, but also contribute to a more sustainable agriculture in the future.

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Annex

1. Questionnaire for farmer to implement a new agroforestry system

1. Ideas of the farmer / what he was thinking on so far / how should the system be used or what are the goals.

In medium term the land areas are used as pasture for sheeps, but the cultivation with machinery shall be sustained in the long term. The long term goal of the tree population is the production of high grade woods and eventually as well the use of fruits. The space between the trees shall be used efficiently. Possible land areas are 4,5 ha of grassland or 4 ha of arable land, which is currently used as pasture, but should remain its arable status. The implementation of a new agroforestry system is seen as a long-term investment.

Main goals are production of high quality woods, sell fruits, wind protection, fodder for sheep, shadow for sheep

2. Informations on the farm (history, area / size, crop rotation, animal husbandry, management, machinery, labour force).

Farm from grandmother, was under lease the last 20 years. Now back to the family, shall be managed organically. Areas are owned.

The farm is managed on a part-time basis. It's total land area are 17 ha. With beginning of 2023 the farm is converted to organic agriculture and will be following the regulations of the Bioland association.

Right now 20 sheeps of the breed Coburger Fuchsschaf, shall be increased to 30-40 mother sheeps.

Altitude 540 m

Average temperature 8,2°C

Average rainfall 1089 mm

Main wind direction west

Soil is heavy, loam, grassland is humid but not wet

3. Informations on the two possible land areas (site, position, height, rainfall, temperature, humidity, wind, topography, nature protection, soil, marginal site, characteristics of the site, owned or leased,

what kind of area and trees are around, landscape, use, slope, groundwater, risk of erosion). Which advantages or disadvantages to they have? Should both be used or only one?

Grassland with 6 ha: flat

Arable land with 4 ha around the farm: flat with a small bow, currently used as pasture for sheep but remain arable status, management with machinery should be possible, more interesting area

4. What is the long-term goal for the farm or where to you see your farm in 20 or 50 years?

5. Should costs be considered by me?

If I can include, yes.

6. Questions to the agroforestry system

6.1. Typical regional landscape should be considered while planing the AFS.

Region of Neckarland. Characteristic landscape: a lot of pinewood such as fir, spruce and pine as well as typical deciduous trees like maple, lime, cherry etc.

Areas around are managed by small scale farmers, but intensive

6.2. Should the trees be planted around the field or in strips on the field?

Grassland: planting around would be possible, but take care of required distance to neighbour

Arable land: strips

6.3. Due to the fact that the farm is only run part-time, could there occure time problems with the management? Should I especially focus on a system with lower amount of work?

The area on which the AFS is implemented is relatively slow, so there should be no time problems with management. Nevertheless, if there are systems with less work or easy to care, they can be considered.

6.4. What kind of trees should be used? Do you already thought about that? (E.g. high or less high, fast growing, mixture of fast and slow growing, high quality woods, fruits, fodder, shadow, wind protection, local trees, diverse, possible competition with crops)

System should be designed as diverse as possible, yet everything has to match (will not be possible to integrate all possible systems, as well consider amount of work)

High quality wood (higher trees) space between trees in strip is 12-15 m, this gap shall be used (here there can be lower trees)

Inbetween e.g. poplar and willow, can be used as energy plant, wind protection, fodder for sheep, as well as fruits e.g. from walnut or hazelnut, hedges/berries?

Trees: fast growing, but not only poplar and willow, as well cherry, walnut for high quality wood

Space between trees shall be used

Right now on arable land is grass, but shall be cultivated with grains (wheat, oats, barley)

Other possible use of space between trees is wildflower strip or so called „bee meadow“ (herbs are possible as well)

Consider: climate requirement, frost, soil humidity, tail water, nutrients, negative list of trees in Germany, eventually ask forestry office

Mostly used for high quality woods: wild cherry and other stonefruit kinds (Prunus spp.), walnut (Juglans spp.), maple (Acer spp.), alder (Alnus spp.), service tree (Sorbus spp.), pear (Pyrus spp.), ash (is getting less because of disease problems) -> best is a mixture of all, important are varieties with straight growth (especially apple and pear)

Select trees that are not poisonous for sheep and can as well be used as fodder

Is there a tree nursery in the area? Organic planting material

6.5. How to implement the system? (Only around or strips, orientation, landscape around, distance for machinery, plant everything at once or not, width of strips, distance between trees and strips, woods and fruits – rotate within strip or between them, protection, use as pasture for sheep).

Strips on the arable land, plant tress around would be possible on grassland

Distance for machinery: is done by contracting company (check), not too narrow, starting from the border and see how many strips have space

Consider access, this results the orientation (not much scope)

Plan that everything is planted at once

Protection of trees against sheep and wild animals

Between the strips pasture for sheeps, therefore inbetween the strip there should be a gap for the sheep

7. Specific rules from the Bioland association?

Not found, consultant for agroforestry?

8. Subsidies?

No subsidies in Germany for implementing an AFS

9. Legal questions, agricultural authority, nature conservation authority

Required distances to neighbours

Check required steps with agricultural authority in Rottweil

2. Second questionnaire for the farmer and farm visit

1. Which trees does the farmer want to use?

One the one hand, high value woods should be produced. Therefore, trees like wild cherry or walnut can be used. The space between these trees should be used efficiently, for example to produce energy wood and fodder with poplar and willow. Moreover, the trees should work as a windbreak. However, faster growing trees should be selected, oak for example is not suitable. As well fruit trees like apple, hazelnut, berries or a bee pasture could be used. On the arable land, the focus should be on forest trees, windbreak and shadow for the sheep. On the meadow as well fruit trees (with a higher trunk) could be possible as well as bigger distances and not planting in strips. Trees that are interesting for the farmer are walnut, wild cherry, chestnut, hazelnut, apple, poplar, willow. What is really important to the farmer, is to consider nature protection and biodiversity (e.g. a long period of flowering) while implementing the system. However, trees that are able to deal with climate change should be recommended as well. (Informations on fruit orchards before?)

2. Site analysis

The farm height is 540m. The soil is keuper, with a heavy clay. Therefore, dammed-up water can occur. The farmer has to check if there are old drainages in the field. Nutrients? Old maps with fruit orchards?

Between two strips (or the trees?), a distance from at least 26m should be given, that management with machinery is possible. 12-13m at the end of the field for the possibility to turn. The width of the strips is around 2m, and the distance between two big trees (high value wood trees – used as starting point) within in the strip is 15-20m. The space between them should be used, while the height, the roots and the treetop (light) have to be considered. Between two big trees, there can be as well a space without vegetation, as a "natural" passage for the sheep. The trees have to be protected against the sheep.

The two sites are more or less flat, there should be no problem with water erosion. The arable land is exposed to west wind, so windbreak is important here (hedges for the house), however there should be as well no problem with wind erosion. Late frost can occur as well as hot and dry summers.

I will receive a detailed map of the two sites. Moreover, I need to know the boarders from the rural district office. From the farmer I need to know the exact meters from one end to the other. This gives as well the amount of strips and the final distance. The possible entry on the sites with machinery limits the direction where the strips can be planted. Moreover, the distance to the neighbour has to be considered. The system shall be implemented according to the regulations to receive a subsidy.

Management plan with information on when to plant the trees and how to care for them.

3. Informations from the rural district office

The farmer needs to have a plan to check, whether he can receive subsidies. She needs to check if it would be forestation and if there is a duty of disclosure. For the meadow she has to check if it would be a transformation. The distance to the neighbours have to be considered. To get the subsidy of 60 Euro/ha you need to have between 2-35% of grove on the field or meadow, at least two continuous strips, the distance between the trees has to be 3-25m, the distance between the strips 20-100m and the harvesting of the wood is only possible in january, february and december. But: the implementation of new systems from the 1.1.2022 are not included in this anymore. (See as well DeFAF 2022).

Nevertheless, the farmer wants to work according to those guidelines, to have the possibility to get the subsidy later on, because there is a lot of change right now and the CAP offers the possibility for subidies.

Question: What do they consider as one area? Where are the boarders for them?

Declaration

I herewith declare under oath that I accomplished this work independently and without any outside help. All consulted sources in the document are acknowledged in the text and a list of references is given. I accept that my project report is checked for plagiarism using a software tool designed for this purpose.

This report has not been submitted for evaluation to any other institute, university or institution of higher education.

26. 4. 2023 ..... Date

..... Signature