# Future proof farming practices

## A feasibility assessment of alternative business practices in Brummen

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LANDSCHAPSNETWERK BRUMMEN

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# Executive Summary

In this report, future proof business practices have been identified and checked on their feasibility. This was done in request from the Landschaps Netwerk Brummen with the aim to provide an overview of possible business practices that fit in future trends.

To perform the research we followed a stepwise methodology. An assessment of the area characteristics, climate, and future socio-economic and related policies trends was performed. The results from these assessments served as an inspiration to identify business practices. A list of fourteen business practices was obtained based within the scope of four landscape services: food production, water management, energy production, carbon sequestration. The selection was made based on the perspective of the consultancy team and in consideration with the opinions of the project commissioners. A feasibility check was performed on the business practices, against the parameters from the assessment. In the end two farm designs, one staying similar to the current dairy farm, and another one adopting a mixed farming system.

The results of the study showed that the future climate will become drier in the spring, but July and August will become wetter. The temperature will increase in all months and the groundwater table in the summer will be lower. From the socio-economic outlook and related policies, it became clear that the future market will become more local, and the consumption of meat and dairy products will persist. There will be a decline in demand for pork and beef, but this will be a small decline. Within policies biodiversity and renewable energy become more important. Regulations on pesticides and fertiliser probably become stricter. For water management, the changing climate will result in the fact that adaptation will become more important, meaning that water retention becomes increasingly important as well.

The assessments resulted in the selection of fourteen business practices based on the following four landscape services: food production, water management, carbon sequestration, and energy production. The following fourteen business practices were chosen: agroforestry, intercropping, permaculture, hydroponics, different cow breeds, cows in nature and meadows, producing on-farm feed, mulching, water storage, on-field water retention, legumes in pastures, increase tree cover, solar panels and wind energy.

The feasibility check of the above-mentioned business practices showed that almost all business practices would fit in the future climate and socio-economic trends. However, some of them need to be adapted to the local situation to fit in the area characteristics. Soil type and upwelling water can be limiting for the feasibility of some food production business practices like agroforestry. However, the conclusion is that there are quite some business practices that would fit in the future climate, socio-economic outlook and related policies trends.

Accounting for feasible business practices, a farm design was developed that mainly existed of dairy farming. In this design, different breeds of cows that graze in legume rich meadows were combined with wheat produced for the cows. Furthermore, on-field water retention was addressed through flowering field edges, hedges and trees on the edges of the meadows. On the courtyard, an orchard combined with chickens will be placed to make the farm more attractive and to attract customers to buy local products of the farm. As an addition, solar panels were placed on the roofs of the buildings to produce renewable energy for on-farm use and what is left can be sold to the energy company. Moreover, a completely new concept for a mixed farm was designed. The farm includes these elements among others: intercropping, permaculture, grass combined with hedges & trees, cows, orchards with chickens, solar panels, and a vegetable garden. In this design, a place for a bed and breakfast is

recommended and the use of an on-farm shop or start a collaboration between farmers and citizens in the 'Herenboeren' concept is advised.

The conclusion of this report was that there are business practices that can make farms in Brummen future proof. Finally, we give the following recommendations to the Science Shop of Wageningen UR and Landscape Network Brummen:

- To make an analysis of the economic feasibility for the business practices. This analysis should include costs of implementation, production, labour, and the possible profits from the products.
- To identify and select business practices for a farm design, together with farmers to ensure the practical feasibility of the presented business practices.
- Each farmer to look into specific characteristics of their farm for determining which crops are feasible within their requirements.
- To facilitate the collaboration between farmers to make the implementation of the business practices possible. Costs, knowledge, equipment and benefits can be shared.
- To examine what the impacts of the business practices are on the daily life of the farmers, and to what extent the farmers need education for the execution of the practices.
- To further develop a detailed socio-economic and related policies assessment on the trends.
- To examine together with local policymakers how policies could be adjusted to the situation of farmers in Brummen in the future.
- To further improve the climatic feasibility of the business practices by extending the climate projection with including more scenarios of the KNMI and the IPCC. To include windspeed projection, and to check for non-linear trends.
- To make an extensive analysis of the local markets that are available in Brummen. It is important that citizens in Brummen, Eerbeek, Apeldoorn and Zutphen are interested in creating collaboration with farmers.
- To attract young farmers, to involve them in the process of creating future proof business.

# Contents

# 1. Introduction

## 1.1 Agriculture in a changing world

Climate change could become a major threat in the next decades. The impacts of climate change, as well as its mitigation and adaptation, will have an effect on every part of society (IPCC, 2014). The agricultural sector is no exception and faces big challenges to become resilient and sustainable in this changing world (Wiebe et al., 2015). Worldwide, the agricultural sector is responsible for eleven percent of the total amount of historical greenhouse gas emissions (CAIT, 2019). Therefore, the sector is accountable for a substantial part of the problem and has the responsibility to reduce these emissions and mitigate climate change. Despite all the mitigation efforts, the climate will change in the next decades. Therefore is it important that the agricultural sector adapts to the changes and makes the sector climate resilient and future proof.

The Netherlands and its agricultural sector will also feel the effects of the changing climate (KNMI, 2014). A different and longer growing season, droughts, extreme precipitation, and an increasing risk of diseases could all be impacts that may become more visible in the next decades (Blom et al., 2008; Bresser et al., 2005). Besides the changing climate, there will be changes in future agricultural market and policies (Silvis et al., 2009). All these developments might threaten the current farming practices and other ways of farming can help farmers to assure their income, and be more sustainable.

## 1.2 Landscape Network Brummen

To adapt to future changes, an initiative of local residents in the municipality of Brummen (Figure 1.1) in the Netherlands called ‘Landscape Network Brummen’. This organisation is exploring the services that the landscape could provide, and the ways the landscape services can contribute in decreasing the impacts of future changes (LNB, n.d.). By doing so, Landscape Network Brummen wants to help and inspire farmers in the region to make their farms and businesses ready for the future (Opdam, 2019).

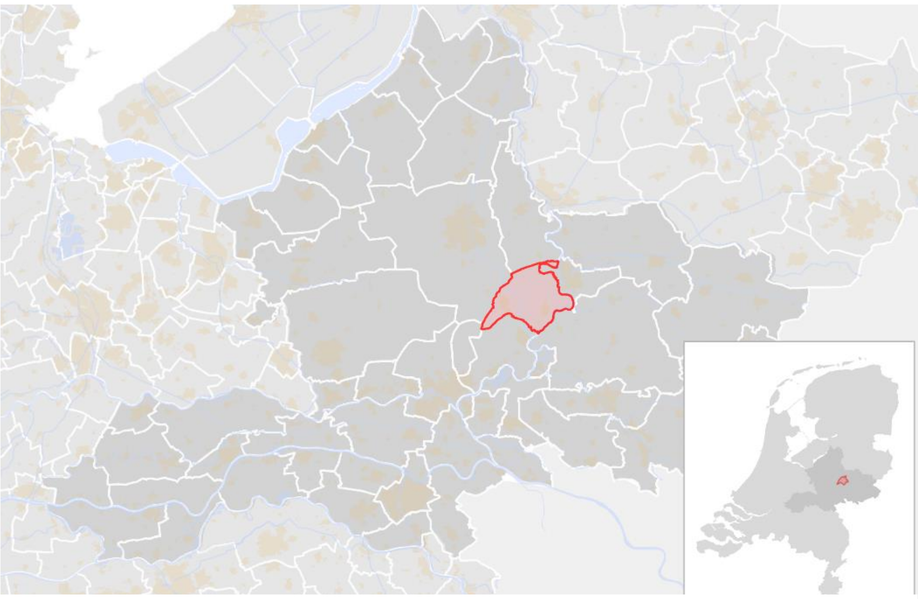

**Figure 1.1**: *Location of the municipality of Brummen in the province of Gelderland and in the Netherlands (Wikipedia, 2016)*

‘Landscape services’ describes the landscape in the way it affects and serves people and society, adding a social dimension to the landscape. Therefore, landscape services value both human and natural processes when it comes to providing human well-being (Vallés-Planells et al., 2014). A general distinction between three different landscapes services can be made: provisioning (e.g. nutrition and energy), regulation and maintenance (e.g. water flow regulation, regulation of physical/biotic environment), and cultural and social characteristics (e.g. health, enjoyment, social fulfilment).

## 1.3 Aims of the report

Commissioned by Landscape Network Brummen and the Science shop of Wageningen UR a study has been carried out to identify future proof business practices for farmers. This study will be an addition to the project of WaardeVOL Brummen. WaardeVOL Brummen is a project of Landscape Network Brummen and aims to reduce the impact of climate change and strengthen the nature in the area (WaardeVOL Brummen, 2019).

The report aims to advise the Landscape Network Brummen on possible business practices for farmers in the area of Brummen to adapt to the changing social, economic and physical environment. These business practices aim to be used as inspiration for sustainable, future market and climate-proof farming through landscape service development. Within this study there is a focus on business practices that provide a landscape service within four main landscape services: food production, water management, energy production, and carbon sequestration.

Therefore, the objectives of this project are:

1. The performance of a climate assessment for the year 2050 of how climate change will affect farming activities in the Brummen region.
2. To assess how market trends, policies, and regulations towards the year 2050 may affect the economic (farming) activities in the Brummen region.
3. To identify business practices that provide landscape services within the services of food production, water management, energy production, and carbon sequestration.
4. To assess the feasibility of the identified business practices according to the physical characteristics of Brummen, the projected climate trends, and the socio-economic and policy outlook.

# 2. Methodology

In this chapter, the methods used in this study are explained. The study was performed in five steps: 1. description of the Brummen region characteristics; 2. climate change projection; 3. socio-economic outlook and related policies; 4. identification of business practices; 5. feasibility check. Figure 2.1 is a graphical representation to clarify the methodological structure.

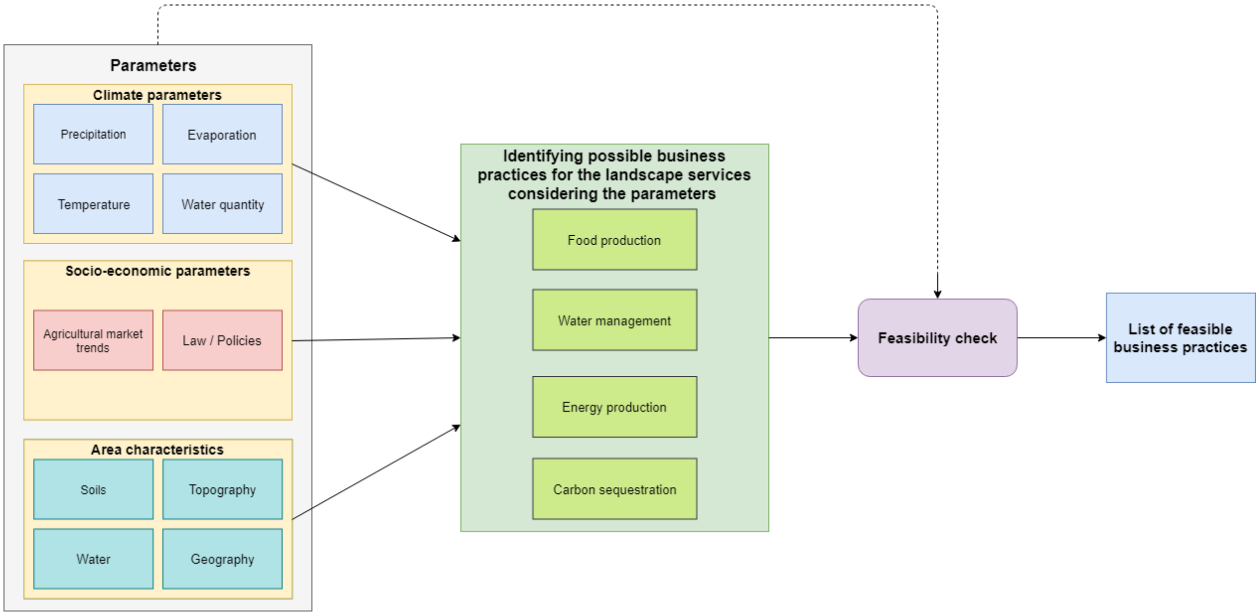


**Figure 2.1:** *Flowchart of the methodology.*

## 2.1 Area characteristics assessment

To get a clear overview of the current landscape of Brummen, a description was made including the different landscape characteristics. Firstly, the topography and the geography were examined, by using a topographic and a height map of the area. Furthermore, statistical information of Brummen was used. Additionally, a soil analysis was performed with the use of maps obtained from Klimaateffectatlas. Analysing the soil types was relevant for coming up with suitable business practices for different soils and checking the feasibility of the different practices for each soil. A map of upwelling water in the area was retrieved from Klimaateffectatlas. The maps was used to examine the potential effect of upwelling water on alternative business practices.

## 2.2 Climate assessment

Trends regarding climate change were examined between the present and 2050. To explore the trends regarding precipitation, temperature, evaporation, and groundwater tables various methods were used.

To obtain information about the trends regarding temperature and precipitation, the website of 'KNMI Transformatie tijdreeksen' was used. For precipitation, the weather station in Eerbeek was chosen. For temperature, the weather station of Deelen was selected. These two stations were used because they are closest situated to Brummen. The WH climate scenario of the KNMI was used to obtain the data for these parameters. The model produced information on the temperatures and precipitation amounts for each day in the years 2016-2055. For temperature, the average, number of days exceeding 25°C and 30°C and the number of freezing days were calculated for each month. Calculations were made regarding the average precipitation, the number of wet days and dry days, extremes (>20 mm) and the maximum length of the dry period per month. For all parameters, the 10-year average was taken for each month to account for periodical climate variation.

The trend for future evaporation was examined using the website of KNMI Climate Change Atlas. The General Circulation Model (GCM) CMIP5 was used to construct a graph calculating the average evaporation from multiple models. To construct this graph, coordinates for Brummen (52.05227N, 6.09264E) were used and the RCP 8.5 scenario was chosen.

For the examination of the groundwater tables, maps showing the average highest groundwater table for the municipality of Brummen were derived from the Klimaateffectatlas. A map of the current height of the groundwater table as well as a map of the changes expected in 2050 for the WH scenario of the KNMI were obtained. The WH scenario of the KNMI represents an increasing temperature and change in airflow pattern. For the region of WaardeVOL Brummen groundwater table maps were derived from the waterboard 'Vallei en Veluwe'. These maps show the current groundwater tables for the WH scenario in the spring, winter and summer and the changes that can be expected in 2050. We chose to show the map of the groundwater table in the summer since the largest change.

RCP 8.5 and the WH scenario were used as these scenarios presents the most drastic changes that can be expected in the future. Thus, it avoided the selection of business practices that will not be feasible in case of an extreme climate. The outcomes of the model runs were used for the feasibility check.

## 2.3 Socio-economic outlook and related policies

Firstly, the current age distribution was examined to understand what challenges the continuation of farming practices in the area may face. Then, an assessment is performed on the projected trends for the agricultural market, agricultural policies, energy and carbon sequestration policies, and water management policies. These trends were analysed for the year 2050, and in cases where no data was found for this year, the analysis was performed for the year 2030. In this case, it was assumed that the trend continued after 2030. The analysis was made at three different levels: European, national and regional-local. For water management, it was decided to only look at national and regional-local since it was most relevant for our outlook. To study what changes can be expected, scientific articles and reports regarding agricultural markets and future trends were reviewed. In the identification of the business practices, we have assumed that the socio-economic and policy trends examined will develop.

## 2.4 Business practices identification

The identification of possible business practices was done under the scope of four main landscape services: food production, energy production, water management, and carbon sequestration. By focusing on these landscape services, business practices were selected that have a clear link with mitigation and adaptation of future climate change. The identification and selection were done by exploring the relevant literature for business practices that fit the expected future climate, market trends, policies, and policies.

After selecting all relevant business practices, a long list was made with a description, which landscape service it belongs to and what co-benefits can be found. From this list, a shortlist consisting of fourteen business practices was made in consultation with the commission. Business practices were chosen in such a way that each landscape service was represented by a business practice. It was assured that some business practices stay close to the current farming system while others require some more change. These fourteen business practices were worked out in more detail.

In addition, several business practices were identified and explained that do not fit into the four main landscape services. These business practices focus on cultural services and livelihood diversification that can be used as an inspiration for the farmers to diversify their business and income.

## 2.5 Feasibility check

The identified business practices were assessed on their feasibility for the future situation in Brummen. The parameters on which the feasibility check was based, were grouped in three groups: area characteristics, climate parameters & socio-economic parameters. Based on the assessment of the area, the expected future climate, and socio-economic and related policies trends, a classification of each parameter was made. The business practice for a specific parameter was classified as feasible (✓), conditional or partly feasible depending on the designs and the situation of the farm (✓*), not feasible (X) or not applicable (-). This resulted in a table that shows for which parameters the business practices is suitable in the area and for which parameters it is not. In addition, a detailed description is provided in appendix 4. For most crops and trees characteristics the PFAF.org site was used to get information from. If other sources have been consulted, these are mentioned specifically.

## 2.6 Design of farms

Farm designs were created that showed a combination of different business practices. Two different designs were made: a farm design based on the short-term in which little changes are required and in which cattle is still the main source of income, and a farm design based on the long-term that requires bigger changes, more time and more investments. The designs were created by the project team, accounting for the outcomes of the assessments, landscape services and the possible future of Brummen.

# 3. Area characteristics

In this chapter, the area characteristics of Brummen will be described. The parameters analysed for the Brummen municipality are topography, geography, soils, water, and the farmers.

## 3.1 Topography and geography

The municipality of Brummen has a population of about 20662 people (CBS Statline, 2019a). As can be derived from Figure 3.1, Brummen is located between the river Ijssel in the East and the Veluwe in the West. This creates a unique landscape in which many different soils can be found. The municipality has two main cities: Brummen and the capital Eerbeek, which is the largest city within the area (Gemeente Brummen, 2019). It includes Leuvenheim, Oeken, Broek, Hall, Voorstonden and Empe. The total surface of the area is 8500 ha (Gemeente Brummen, 2019).

The highest point of Brummen municipality can be found in the west (Figure 3.1), which reaches a height of about 80-90 meters NAP. Towards the river in the east of the municipality, the height is decreasing to 6 meters NAP (Klimaateffectatlas, n.d.). The smaller streams run from the west to east, draining into the IJssel (Timan & Straatman, 2008).

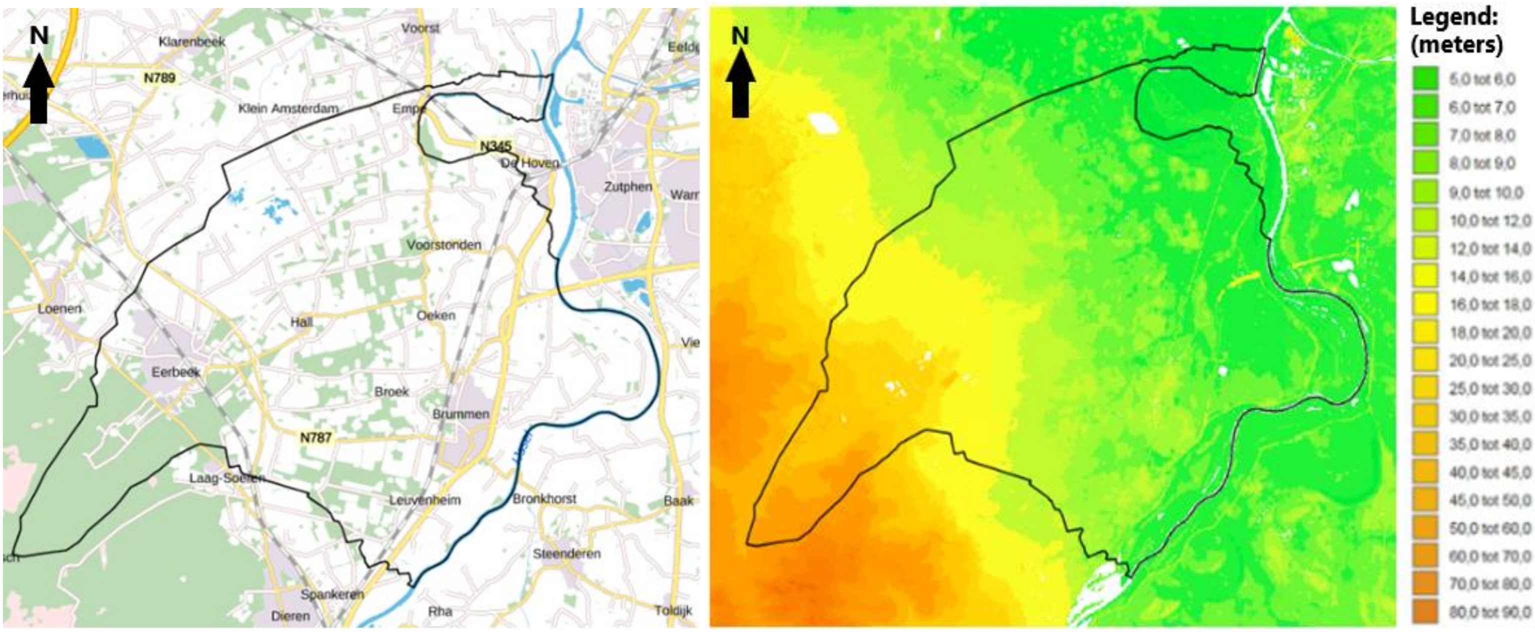


**Figure 3.1:** *Topographic map (left) and height map (right) of the municipality Brummen (Klimaateffectatlas, n.d.).*

## 3.2 Soils

The area near the rivers consists mostly of 'stroomruggen', on which some horticulture can be found, and 'komgronden'. The 'komgronden' are contain a high percentage of clay and can be soggy because of their low position (Haring et al., n.d.). On these grounds mainly meadows can be found, but due to drainage and some fertilisation, cultivation of crops has become possible (Haring et al., n.d.). From the soil map in Figure 3.2 the 'stroomruggen' can be recognised by the soils near the river that contain less clay and have more silt like structure. The 'komgronden' can be recognised by the heavy clay soils near the river. The middle part of the municipality mostly has a sand deck ('dekzand') (Figure 3.3). These soils were quite unproductive due to a lack of nutrients. However, artificial fertiliser helped to make these areas more productive. Nowadays this area became more productive and grassland, pastures, and feed production crops can be found. Furthermore, reforestation took place, so many forests can be found in a sandy landscape. Figure 3.2 shows that these areas consist of sandy to more loamy sandy soils. A small part of the municipality in the west can be classified as a lateral moraine ('stuwwal') and Figure 3.2 shows that these soils are mostly coarse sandy soils. The moraine is often not very suitable for agriculture. Agricultural activities mainly take place at the incline, the area in which erosion material is deposited. In this slightly sloping transition zone, suitable agricultural lands can be found (Gidsmodellen, n.d.).

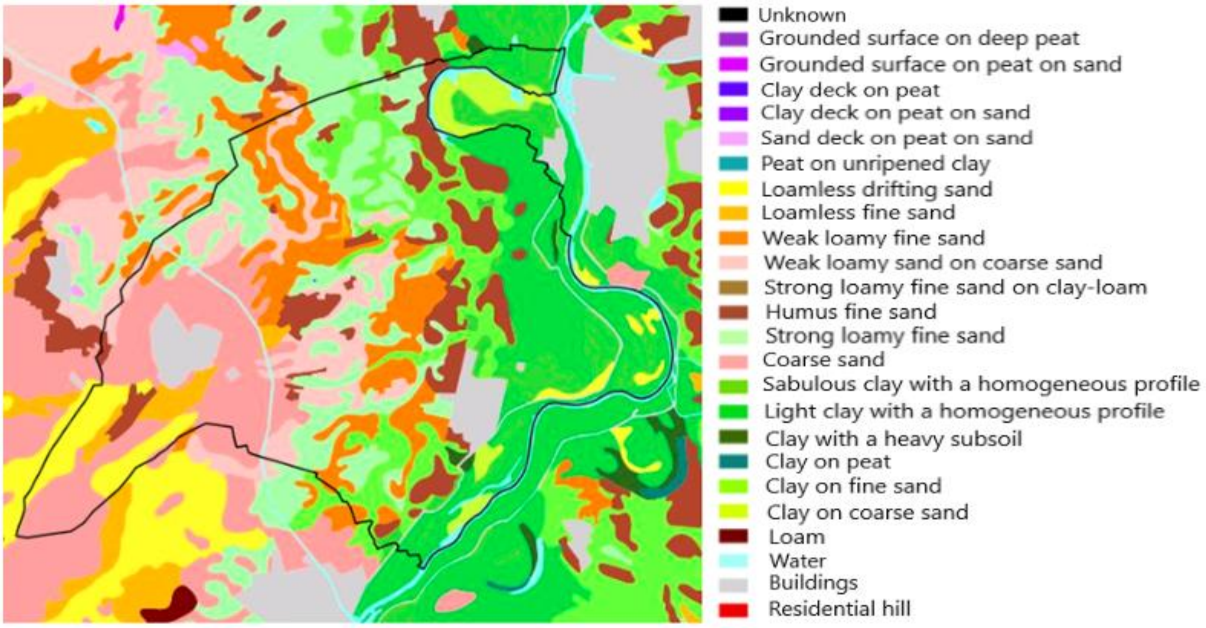


**Figure 3.2:** *Soil map of Brummen municipality (Klimaateffectatlas, n.d.).*

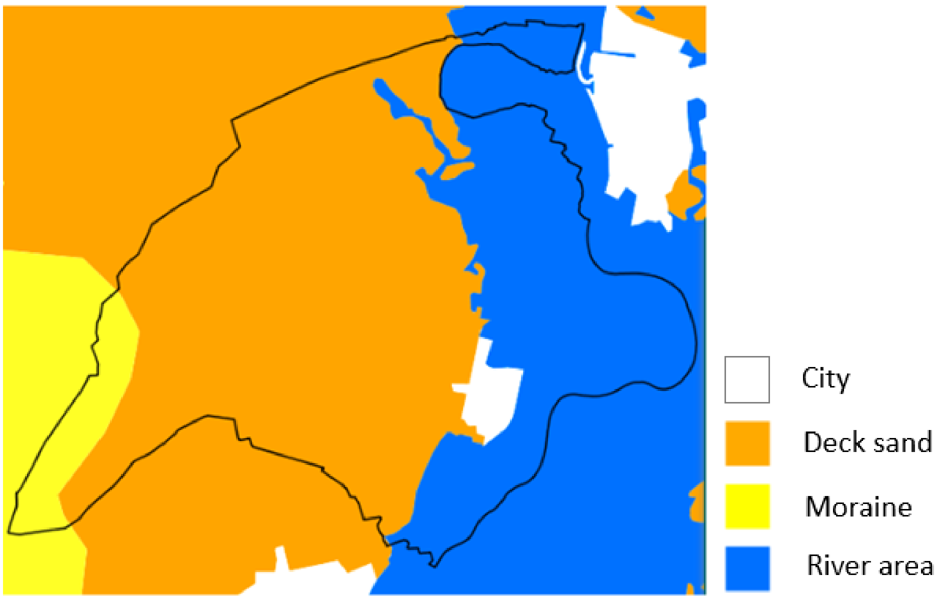


**Figure 3.3:** *Landscape types that can be found in the municipality of Brummen (Klimaateffectatlas, n.d.).*

## 3.3 Upwelling water

In the municipality of Brummen, areas can be found with a lot of upwelling water (more than 2 mm/day) as well as areas with strong infiltration (more than 2 mm/day). When combining the soil map (Figure 3.2) with the map of upwelling water and infiltration (Figure 3.4) and the height map (Figure 3.1), it can be concluded that most upwelling water can be found in the middle of the area. This area is quite low and the soils contain loamy fine sand or clay on fine sand. Infiltration is mostly found in areas that are built on and coarse sandy soils, and it is often found in the higher regions of the municipality.

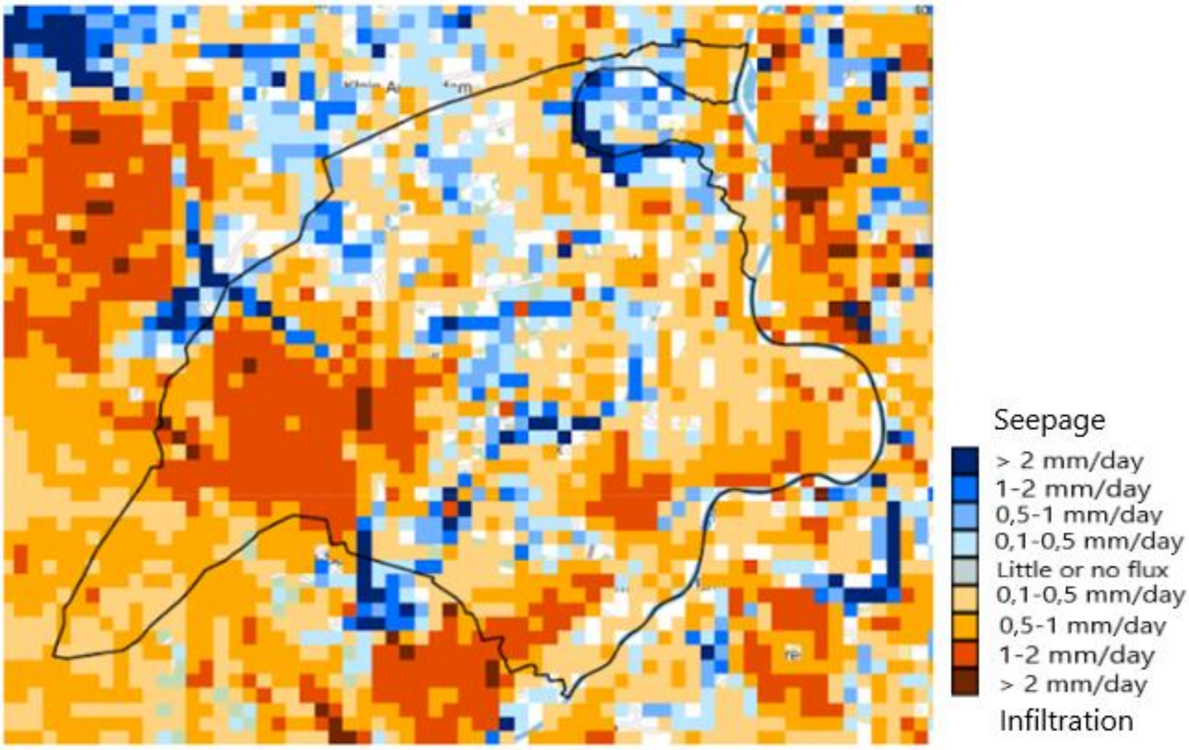


**Figure 3.4:** *Map of the upwelling water and infiltration in Brummen area (Klimaateffectatlas, n.d.).*

## 3.4 Farmers

Most farmers in the area are dairy farmers. In total, about 48 dairy farms can be found in the region (CBS Statline, 2019b). In general, the farms in Brummen have fewer cows than in the rest of the Netherlands. Another general point in the Brummen is that farmers have a decent allotment, however, the situation is not ideal and farmers have not enough land for an ideal grazing situation. In the Brummen area, two different farm types can be distinguished. The first type that can be distinguished is situated on sandy soils. These farms are relatively 'small', keeping about 100 to 120 cows. These farms are mostly located in a more forest-like area on different soil types but mostly sandy soils. Most of these farmers are also having other jobs besides farming to have an extra source of income. The second type of dairy farm is situated near the IJssel River on clayey soils. These farms often keep about 150 to 200 cows and have labour saving equipment. Farmers in Brummen are also having some difficulties finding succession for their farms and some farmers will stop farming in the coming years. (Fokkert, 2019).

# 4. Climate projections

In this chapter, the future climate of the area of Brummen is examined. This is done by looking at the precipitation, temperature, evaporation and groundwater projections of the area towards the year 2050.

## 4.1 Precipitation

An analyses of the precipitation trends in Brummen towards 2050 has been performed (Table 4.1). An increase in daily precipitation will be observed at the end of spring and in the summer, in the months July and August. Furthermore, the trend shows more wet days in February, July, and November. However, in January, April, June, and September, a decrease in number of wet days can be expected. From Table 4.1, it can be derived that the main increase in number of days exceeding 20 mm/day can be found in August. However, the coefficient of determination ($R^2$) has low values, which means that these trend does not fit the model data very well. The maximum length of a dry period is expected to increase in April.

Yearly precipitation is expected to increase. Currently, according to the models, the average annual amount of precipitation is about 827 mm. In the future, this will increase to about 892 mm per year.

**Table 4.1:** *Trends for Brummen in yearly change for the daily average precipitation, number of wet days, number of dry days, number of days >20 mm, maximum length of the dry period in days. The stars represent the $R^2$ and indicate how well the linear trend fits the model data.* (Data source: KNMI, 2014)

| | Average (mm per day) | | Wet days | | Dry days | | Number of days > 20mm | | Max length dry period (days) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2050 | 2021 | 2050 | 2021 | 2050 | 2021 | 2050 | 2021 | 2050 |
| January | 3,6 | 2,7** | 21,5 | 17,5** | 9,4 | 13,5** | 0,9 | 0,9* | 4,4 | 5,7* |
| February | 1,5 | 3,2**** | 10,6 | 17,5*** | 17,7 | 10,8*** | 0,4 | 0,6* | 10,8 | 10,3** |
| March | 2,8 | 2,3** | 21,2 | 20,9* | 9,8 | 10,0* | 0,6 | 0,4* | 5,2 | 5,5* |
| April | 1,4 | 1,4* | 16,2 | 12,4** | 13,8 | 17,6*** | 0,0 | 0,3** | 7,4 | 12,5*** |
| May | 2,8 | 2,9* | 21,2 | 18,1* | 9,8 | 12,9* | 0,6 | 0,9** | 5,2 | 7,0* |
| June | 2,3 | 1,6** | 16,7 | 12,4**** | 13,3 | 17,6**** | 0,4 | 0,2* | 6,1 | 6,4* |
| July | 1,1 | 2,4*** | 12,7 | 17,3*** | 18,3 | 13,7*** | 0,2 | 0,3* | 9,2 | 5,5** |
| August | 0,9 | 2,6**** | 12,9 | 14,0* | 18,1 | 17,0* | 0,0 | 0,8*** | 11,4 | 13,9* |
| September | 2,2 | 1,4* | 17,4 | 12,6**** | 12,6 | 17,4**** | 0,4 | 0,4* | 8,3 | 10,2** |
| October | 2,9 | 2,5* | 19,3 | 20,8* | 11,7 | 13,2* | 0,8 | 0,3*** | 5,4 | 6,9** |
| November | 2,8 | 3,5*** | 19,4 | 22,9*** | 10,6 | 7,1*** | 0,8 | 0,9* | 4,4 | 6,5*** |
| December | 2,8 | 2,6* | 20,4 | 18,5* | 10,6 | 12,5* | 0,5 | 0,6* | 5,7 | 4,8* |
| Year | 2,3 | 2,4** | 208,0 | 200,0* | 158,0 | 165,3* | 5,6 | 6,3* | 16,2 | 15,8* |

| Legend | | | $R^2$ |
|---|---|---|---|
| | Increase | * | 0-0.25 |
| | Decrease | ** | 0.26-0.50 |
| | No change | *** | 0.51-0.75 |
| | | **** | 0.76-1.00 |

## 4.2 Temperature

An analysis of the temperature trends in Brummen towards 2050 has been performed (table 4.2). The average daily temperature of all months is going to increase. The highest increase in temperatures are expected in February, April, and June, all with a high coefficient of determination. Additionally, in the months June and July, an increase in number of days exceeding a temperature of 25°C is expected. However, only the trend of the month June has a high trend coefficient and fits well with the model data. When modelling this factor over the whole year, a large increase in days exceeding 25°C is expected with a high extent to which it fits the model data. The same goes for the trend in the number of days in a year exceeding 30°C. The biggest increase is expected for July, followed by August and June. However, the coefficient of determination is not very high for both July and August. A decrease in number of freezing days is mainly found in February and November. In December, a slight increase in the amount of freezing days is expected. However, when looking at the whole year, a decrease in number of freezing days is found.

**Table 4.2:** *Trends in yearly change for the average daily temperature, number of days >25°C, number of days >30°C, number of freezing days. The stars represent the $R^2$ and indicate how well the linear trend fits the model data.* (Data source: KNMI, 2014)

| | Average daily temperature (°C) | | Number of days >25°C | | Number of days >30°C | | Number of freezing days | |
|---|---|---|---|---|---|---|---|---|
| | 2021 | 2050 | 2021 | 2050 | 2021 | 2050 | 2021 | 2050 |
| January | 3.4 | 5.2*** | | | | | 10.2 | 8.9* |
| February | 2.9 | 5.8*** | | | | | 13.5 | 6.4*** |
| March | 6.7 | 7.8** | | | | | 5.5 | 5.6* |
| April | 9.4 | 12**** | | | | | 2.6 | 2.9* |
| May | 13.4 | 15.1**** | 2.6 | 5.4** | | | | |
| June | 16.4 | 18.8**** | 6.1 | 12.7**** | 2.0 | 3.0*** | | |
| July | 19.3 | 20.8*** | 11.9 | 16.4*** | 5.1 | 8.0** | | |
| August | 18.8 | 19.5* | 11.1 | 11.8* | 3.4 | 5.0* | | |
| September | 16.0 | 17.3*** | 3.4 | 6.4** | | | | |
| October | 10.0 | 10.8** | | | | | | |
| November | 7.5 | 8.9*** | | | | | 4.9 | 1.9**** |
| December | 4.8 | 5.7** | | | | | 6.8 | 10.38*** |
| Year | 10.9 | 12.3**** | 34.9 | 54.3**** | 10.4 | 16.7*** | 45.3 | 37.6** |

| Legend | | | $R^2$ |
|---|---|---|---|
| (green) | Increase | * | 0-0.25 |
| (red) | Decrease | ** | 0.26-0.50 |
| (grey) | No change | *** | 0.51-0.75 |
| | | **** | 0.76-1.00 |

## 4.3 Evaporation

The projection of the evaporation in Brummen shows that there will not be any significant changes in the amount of evaporation towards to year 2050 (Figure 4.1).

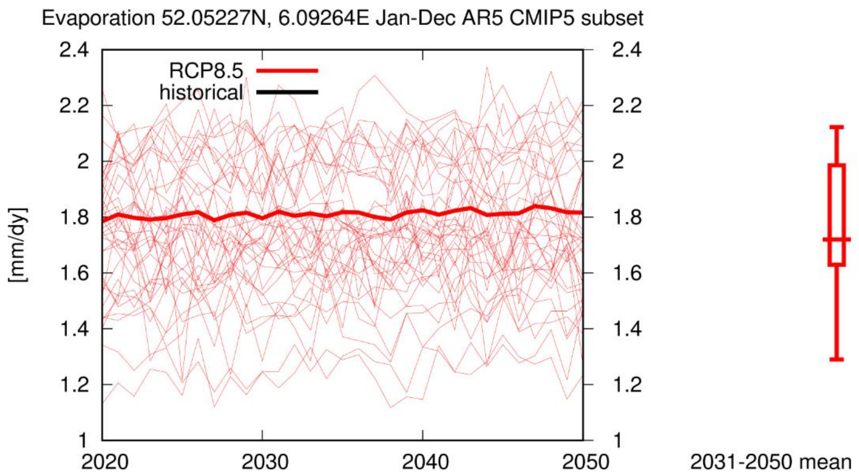


**Figure 4.1:** *Evaporation in Brummen from 2020-2050 for the RCP8.5 scenario (KNMI, n.d.).*

## 4.4 Groundwater tables

Currently, a lot of variation in the groundwater table of the municipality of Brummen can be found (Figure 4.2). When examining the situation in 2050, a strong increase in groundwater table will be observed in the western part of the municipality. However, in the rest of the municipality, hardly any change will be noticed (Figure 4.3).

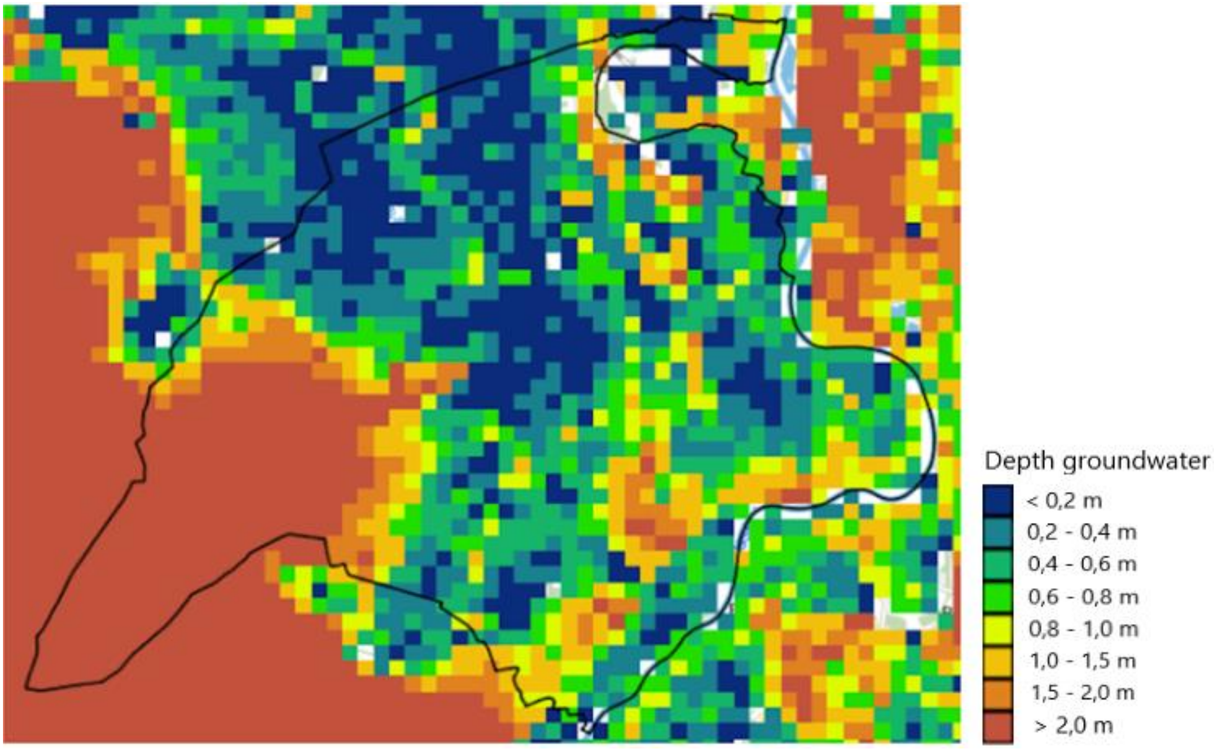


**Figure 4.2:** *Groundwater depths in Brummen (Klimaateffectatlas, n.d.).*

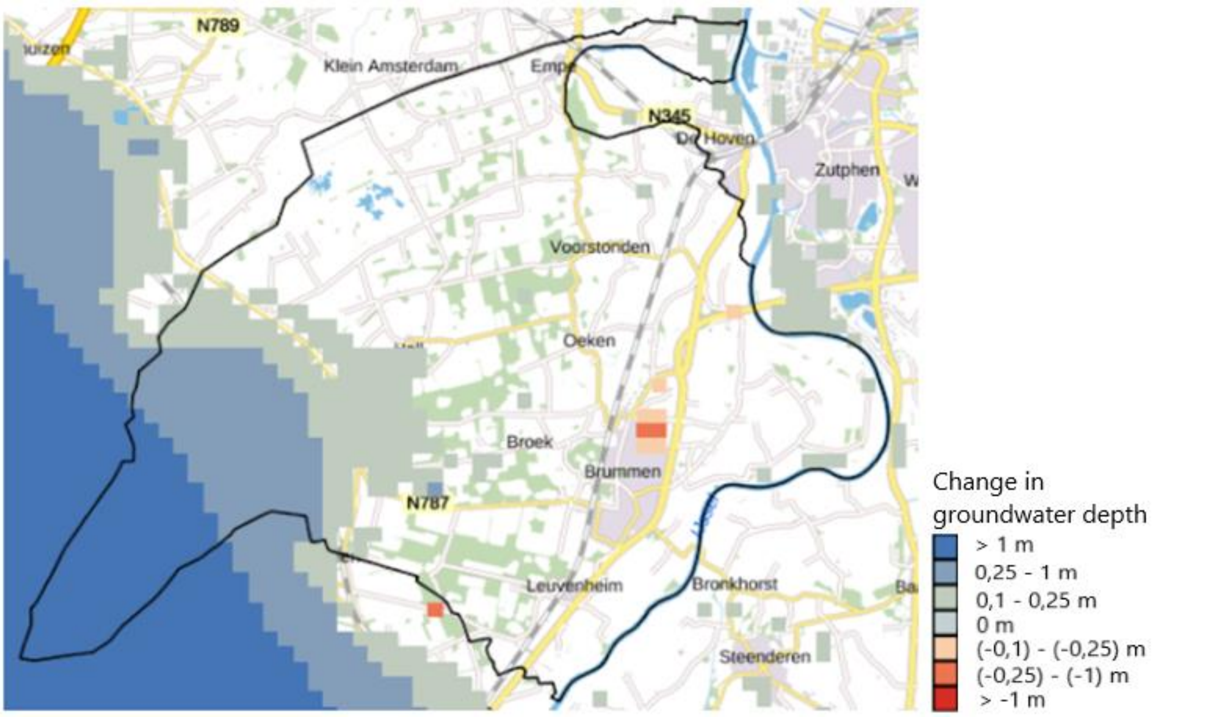


**Figure 4.3:** *Change in Groundwater depth in Brummen for the KNMI WH scenario (Klimaateffectatlas, n.d.).*

**Groundwater tables WaardeVOL brummen**

Currently, the groundwater tables in the area of WaardeVOL Brummen vary a lot during the spring. Near Brummen and Eerbeek, the groundwater table is currently deeper than 200 m, which means that it is quite low (Appendix 1, Figure A1.1). In the future, these areas will become wetter. In the rest of the municipality, little change is expected (Appendix 1, Figure A1.2). In the summer, the groundwater table in the area is much lower, especially in the area near the river IJssel and the area near the city Eerbeek (Figure 4.4). In the future, the groundwater table near Eerbeek is expected to increase slightly in the summer. However, the rest of the area will face a less reduction in the groundwater table compared to Eerbeek (Figure 4.5). In the winter, the groundwater table is low near Brummen and Eerbeek. In the other parts of WaardeVOL Brummen, the groundwater table is very high, only 0-40 cm below ground level (Appendix 1, Figure A1.3). In the future, the groundwater table is expected to increase strongly near Eerbeek. However, in the other parts of the area, little to no changes will be observed (Appendix 1, Figure A1.4).

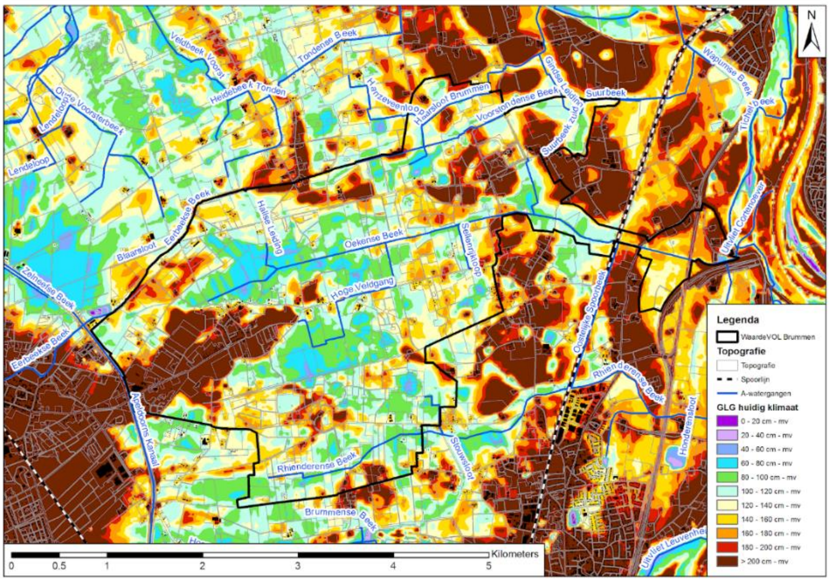


**Figure 4.4:** *Current depth of the groundwater table in the summer in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

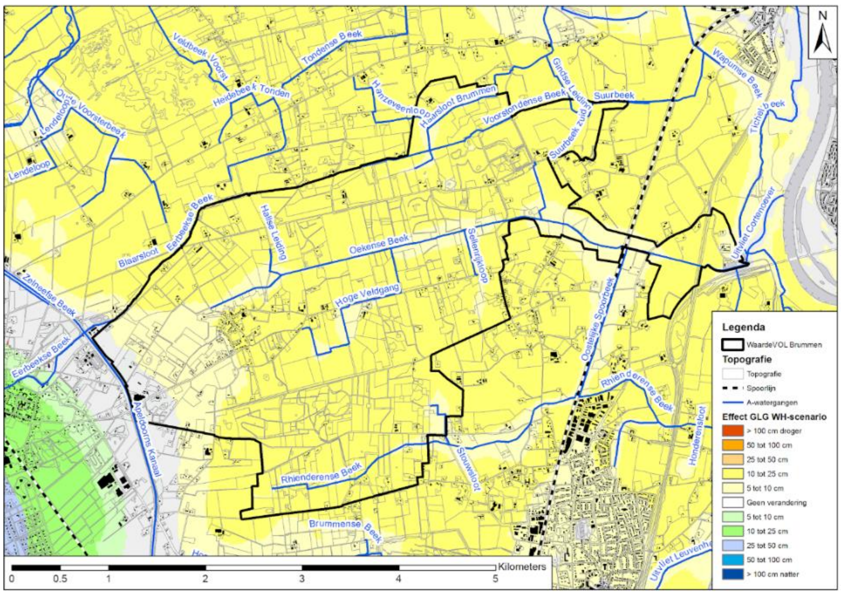


**Figure 4.5:** *Projected change in groundwater tables in the summer in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

## 4.5 Relation to agriculture

The decrease in precipitation in the spring, especially in combination with the higher temperatures, can affect the growing season. Seedlings require quite some water to mature and with the higher temperatures evaporation might increase in the spring, resulting in even higher water demand. This means that some crops might become unsuitable, however, it might also provide opportunities for the cultivation of other crops. The yearly rainfall will increase, and depending on when this falls it can have multiple effects on agriculture. When the extra rainfall falls in only a few days it can cause water damage like waterlogging. This scenario would call for extra water retention measures. When the precipitation would fall evenly over the year it could even have beneficial effects for the current crops in the drier periods. In the future, it is expected that the lowest groundwater level (summer) will be lower than it currently is. In some areas, this can result in a lack of capillary rise, which could cause problems for the crops. However, the increased amount of precipitation in July and August might relieve some of the water stress. In some regions of the Brummen municipality, the lower groundwater table in the summer can be beneficial for agriculture, since, in these regions, the groundwater table was quite high for certain crops. When the groundwater table drops, crops could be cultivated that currently cannot. However, this is not favourable for the nature areas that do depend on the high groundwater table for their existence.

# 5. Socio-economic outlook and related policies

## 5.1 Demographics

One-fifth of the inhabitants of the municipality is 19 or younger (Figure 5.1). Almost a quarter of the population is 65 years old or older. The demographic pressure is 81%. This means that there are 81 people that cannot work (younger than 20 or older than 65) for every 100 people that could potentially work (age 20-64). This number is relatively high compared to other municipalities in the area. In the coming years the population age will increase, while at the same time there will be less young people. This means the population in Brummen is aging in the future (KVNOG, 2018).

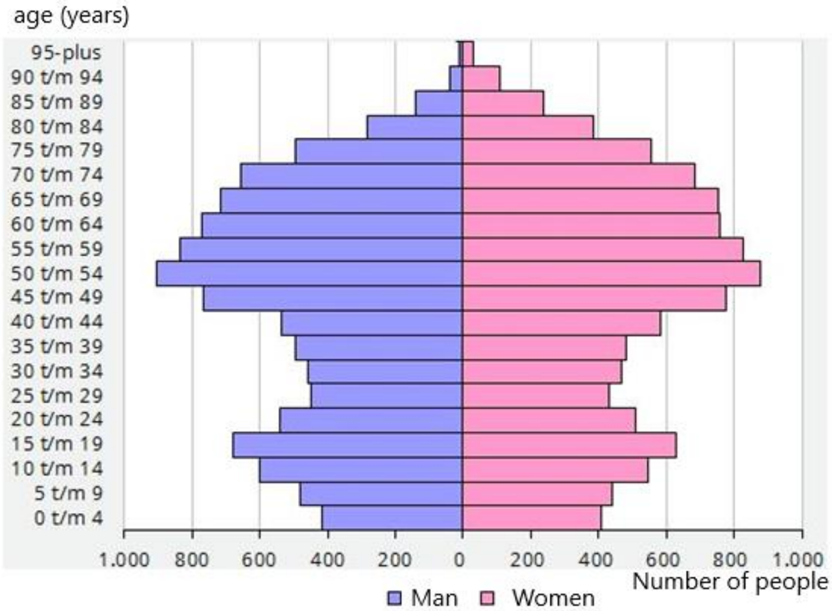


**Figure 5.1:** *Population pyramid of the municipality of Brummen (KVNOG, 2018).*

## 5.2 Overview table

Table 5.1 summarises the trends of agricultural markets, the trends in policies for agriculture, policies on energy and carbon sequestration, and policies on water management. The analysis was done at three levels: European, national and local. Detailed information on this can be found in Appendix 2.

At the European level, agricultural market trends analysis has shown that meat consumption will stabilise in the short-term, while it will experience a decrease in the long-term. Price volatility might pose difficulties for the dairy sector, the demand for plant-based proteins is expected to increase, and consumers will value the products they consume more which may increase the consumption of local and organic products. The latter trend occurs at the national and local level as well. Furthermore, the national trends are characterised by the decrease in dairy consumption, and an increase of vegetables and fruits consumption. At the local level, there is a general worry about the continuation of farming by young generations, which may be overcome by the innovation and technology introduction in farming.

Policies in agriculture are shaped at the three levels by the CAP post-2020 that focus on: subsidies for farms, prerequisites on food quality, young farmers, attention to biodiversity protection through initiatives such as nature inclusive agriculture, and attention to the role of agriculture in climate change adaptation and mitigation. Moreover, energy and carbon sequestration policies are moving towards targets for emission reductions at the European level and energy neutrality at the national and local level by the use of renewable energies. The role of agriculture emphasises on its potential for sequestration of carbon and production of energy from the use of natural resources. Water management was analysed at the national and local level, emphasising on water retention, pollution, quality and the relationship between water, nature and landscape.

**Table 5.1:** Summary of the socio-outlook and related policies.

| | Agricultural market trends | Agricultural policies | Energy and carbon sequestration policies | Water management policies |
|---|---|---|---|---|
| **European level** | • Meat consumption stabilize in the short-term and decrease in the long-term, except for poultry that is expected to increase<br>• EU dairy sector will benefit from the growing global and domestic demand, but it might face difficulties due to the high price volatility.<br>• The demand for plant-based proteins will increase<br>• Consumers will be more demanding on what they consume and will give value to the food which may increase consumption of local and organic products | • Post 2020 Common Agricultural Policy (CAP)<br>• Economic and social aspects:<br>→ Subsidies and fair shares to small and medium farms;<br>→ attention to young farmers;<br>→ stricter perquisites of food quality and health (e.g. reduced pesticides)<br>• Environmental aspects (budget; eco-schemes):<br>→ Climate change adaptation and mitigation<br>→ Efficient management of natural resources (water; soil; air)<br>→ Biodiversity protection; enhance ecosystem services; preserve habitats | • 'Competitive, secure and sustainable energy system'<br>• Renewable energy and low carbon technology<br>• Targets for emission reduction: 2030- 40% ; 2050- 80% to 95%<br>• Policy incentives: subsidies; taxes<br>• Agriculture sector role:<br>→ Livestock; Food and feed production<br>→ CAP<br>→ Potential for renewable energies from natural sources – 'on-farm renewables'<br>→ Easier permits and subsidies | → We considered that water management for European Level was not relevant for the farmers |
| **National level** | • Food value: local; organic; fair trade<br>• Big retailers will have more importance<br>• Attention will be given to food waste<br>• Technologies and social media will become influential on food consumption patterns<br>• Meat consumption varies<br>• Potatoes and dairy products consumption decreases<br>• Fruits and vegetables consumption increase | • Agro-food systems: regulations focus on climate; local markets; food waste; nature<br>• Aim or circular systems for raw material<br>• Nature inclusive agriculture<br>→ Increased attention for fair income for farmers (New business practices)<br>→ Increased attention to biodiversity (e.g. reduced pesticides) & landscape<br>• Subsidy system 'Rural Development Program': based on EU Eco-schemes<br>• System of phosphate rights: limit phosphate exceedance in dairy farming | • 'Energy agreement' – goals to produce most energy from renewable energy sources<br>• 'National Climate and Energy Plans'<br>• Focus on wind and solar energies<br>• Relevance of local participation and decentralization of energy production | • Efficiency use of fresh water:<br>→ Water retention in no fresh water supply areas<br>→ Focus on sectoral distribution of water<br>• Quality of water: removals of medicines and chemical substances<br>• Water and biodiversity: increased space for flora and fauna<br>• For 2050: climate resilient and water robust |
| **Local level** | • Large market for local food<br>• Risk of farm sustainability due to increased prices of local food unless consumers are willing to pay higher prices<br>• Potential partnerships between local food production health care<br>• Young migration which may be prevented with technological innovations in farms<br>• Increased attention to environment and landscape services in relation to food production through projects | • Local food support and shorten of food chain.<br>• Subsidies from province of Gelderland for sustainable project product development in agriculture (e.g. CO2 emission reductions) | • Gelderland aims for energy neutrality in 2050<br>• Brummen aims energy neutrality in 2030<br>• Energy sources:<br>→ Wind turbines<br>→ Solar panel fields in land or dikes<br>→ Water potential for energy is in doubt<br>→ Biomass needs further exploration | • DAW: proportionate subsidies for projects for farmers<br>→ Support for farmers water and improvement of water quality<br>• Vallei en Veluwe:<br>→ Retaining water in Brummen<br>→ Water as landscape service<br>→ Water treatment and protection<br>• 'Klimaatmantels':<br>→ Nature inclusive agriculture : recycling agriculture<br>→ Natural development<br>→ Water retention<br>→ Separation between rainwater & sewage water |

# 6. Business practices

## 6.1 Food production

### 6.1.1 Agroforestry

Agroforestry is an agricultural cultivation system in which trees and woody crops (perennials) are combined with arable farming, the growth of vegetables, or livestock farming on one field. By combining these crops, the resilience of the agricultural systems can be improved. In the Netherlands, agroforestry has been applied on small scales. Types of agroforestry systems that are found are combinations of growing poplar trees with husbandry for industrial purposes, combining the growth of alders (e.g. firewood or construction timber) with keeping cows or harvesting grass, the combination of walnuts with grass and occasionally cattle, walnuts with hazelnuts, robinia with potatoes, and walnuts with horticultural species (Oosterbaan & Kuiters, 2009). Other options could be: the combination of arable farming or growth of vegetables with fruit trees or berries; meadows with wood trees for biomass production in combination with chickens; or meadows with rows of fruit trees, hazelnuts, or walnuts (WUR, 2018).

The system can contribute to several landscape services, for example, food production, water management, and carbon storage for climate mitigation and adaptation (FAO, 2017). Agroforestry has the potential co-benefits to contribute to the production of fodder and biomass, the efficient use of ecological sources (light, nutrients), increase resilience, pest regulation, improve biodiversity, and increase sense of place identity (WUR, n.d.a). However, agroforestry may have several downsides depending on the design of the system. The trees and crops may compete with each other for light, water & nutrients. Furthermore, the system can be complex to harvest due to difficulties with machinery between the trees, and in case of trees with high stems, for example when combined with livestock. Additionally, the initial implementation of this system can be quite costly (Sanchez, 1995).

### 6.1.2 Intercropping

Intercropping can be defined as '*growing two or more crops simultaneously on the same field*' (Vandermeer, 1992, p. 6). Several types of intercropping can be distinguished (Vandermeer, 1992):

- Mixed intercropping: no distinct row arrangement.
- Row intercropping: one or more crops are planted in rows.
- Strip intercropping: growing the different crops in strips wide enough for independent cultivation, but narrow enough to interact.
- Relay intercropping: growing crops simultaneously during part of their life cycle.

At the moment, intercropping systems in the Netherlands are being researched. Current experiments include rows of 3 m with clover, cabbage, onion, potato, wheat and carrots (WUR, n.d.b). Other experiments in the Netherlands include the combination of maize and wheat in different designs or the combination of wheat-alfalfa (Beekman, 2017; Gou et al., 2016).

Intercropping mainly addresses three landscape services: food production, carbon sequestration & water management. Co-benefits of intercropping are: an increased production due to differences in resource consumption; reduced pests and diseases and a reduction of weeds; improved soil fertility when adding legumes; and a more stable yield due to risk spreading (Mousavi & Eskandari, 2011). As there is an increase of organic matter in the soil, carbon can be captured and increased biodiversity can be observed (WUR, 2017).

However, a careful look must be taken at the cultivar and the design of the system as the species, planting density and spatial geometry are determining factors in the success of the system (Yildirim & Ekicinci, 2017). Furthermore, planting date is of big influence since species planted earlier may limit the growth of the other species (Bedoussac et al., 2015). Additionally, difficulties may occur during management and harvesting since most of the current machines are not adapted to intercropping systems (Apeldoorn, 2017).

### 6.1.3 Permaculture

Permaculture is '*a consciously designed landscapes, which mimic the patterns and relationships found in nature while yielding an abundance of food, fibre, and energy for provision of local needs*' (Holmgren, 2002). By mimicking natural ecosystems and making your farm almost self-regulating, food should be produced while taking nature and diversity into account. There is no regulated set of practices specific to permaculture. Still, the way a permaculture agroecosystem is designed can be summarised with the following three points: site characteristics, the interactions between elements at several levels, and the way elements are spatially arranged should be drivers for multiple functions (Ferguson & Lovell, 2014; Holmgren, 2002; Morel et al., 2018).

Permaculture farms always consist of different landscape elements. This means that hedges, ponds and forests will be alternated with pastures and, for example, poultry areas. A system will be most productive around the edges of different landscape elements so it is recommended to plan many edges in the farm designed. Other than landscape elements, there are some principles that should be taken into account: the farm should be producing no waste, the system should be as self-regulating as possible, renewable energy is very important, and diversity of the system is key (Krebs & Bach, 2018).

Common to all permaculture farms is that trees, shrubs, aquatic plants, herbs and mostly perennial vegetables are combined with animals. A way to combine all these different species together is by creating a guild in which plants that have a beneficial effect for each other are combined in one location (Neverendingfood, 2019). There are a lot of ways to combine the options (TCPermaculture, n.d.).

Permaculture is focused on making a system self-regulating, thus, permaculture is a diversifying farming system that reduces labour intensity and diversifies farming income (Ferguson & Lovell, 2017). The yield of permaculture systems for single products is not as large as in monocultures. Instead more products are harvested which result in a sometimes even higher will yield (Whitefield, 1993). However, for all those products, a local market should be available to sell all the products. The farmers should consider this when choosing the crops and animals products they want to have.

Permaculture addresses landscape services such as: food production, energy production with a large focus on renewable energy, and water management. Co-benefits of permaculture are: the provision of natural habitats for pest and weed regulators that can help pollination; increased diversity of flora and fauna; reduced soil disturbances by the use of perennials; increased carbon sequestration and improved water retention. Permaculture requires good planning and knowledge to become profitable. In the beginning, the trees do not give harvest yet, making the first years hard to gain an income from the farm. Another downside is the fact that labour should mostly be done manually. However, in quite some permaculture farms it works to let people come and harvest (pick) their own products. In the end, most permaculture farms depend to some extend on incomes from education or giving tours, this means that when completely switching to permaculture, farmers should be willing to do so. On the other hand, a farmer can choose to convert only part of the farm to permaculture (Papprentice, 2015).

### 6.1.4 Feed production

A large variety of different crops that act as raw material for this feed are needed to produce on-farm feed for the cows. In feed for lactating cows, cereals, beet pulp, seeds from oily plants, seeds from legumes and some other forage crops (e.g. fodder beet or silage) are essential. For taste it is possible to add, for example, molasses ('melasse') and carob bean ('johannesbroodpitmeel') (Victor Pellet Mill, 2017). To process these ingredients into the feed it is recommended to use a feed mill. The summer wheat can be combined with clover to reduce the amount of weeds and to fix nitrogen for the wheat. The clover can be harvested as well to be incorporated in the feed of the cows (Edupot, 2005). For the oily crops rapeseed can be used to replace soybeans to maintain milk quality. It should only be considered that there is not so much energy in rapeseed so this should be compensated (Boerenbusiness, 2013).

This business practice focuses on the following landscape services: food production as the cows fed will produce milk and meat. Co-benefits of producing on-farm cow feed are: increased diversity from the introduction of multiple crops, and increased pollination as new crops may also attract insects.

### 6.1.5 Different cow breeds

Changing the cow breeds on dairy farms is another possible business practice for farming. In a population of dual-purpose cows, cows are held for both their milk and meat. In most dairy farms, the Holstein Friesian cow is bred, since it is a high-yielding dairy cow (Kaptijn, 2016). However, this cow breed has some disadvantages in terms of production, such as short productive life, high rates of stillbirths and difficulties with calving (Brade, 2012). Crossbreeding, keeping multiple breeds, or using different cow breeds altogether increase meat production while keeping milk production. Furthermore, crossbreeding may improve the health of the Holstein Friesian cow population. Several suitable breeds are (CRV, n.d.; Jansen et al., 2013; Koopman, 2018; LTO Noord, 2018; SZH, n.d.):

- Fleckvieh: The breed is able to cope with large temperature fluctuations and produces milk and meat efficiently. Fleckvieh cows have a high classification of the meat index, meaning that the breed performs best economically when looking at the revenue.
- Maas-Rijn-IJssel: MRIJ cows are easy to keep. Both milk production and the quality of their meat are good. The cows have a high degree of beef conformation.
- Blaarkop: These cows can be deployed as nature manager. Their meat is tender and of high quality. The status of this breed is 'threatened', it's a rare species in the Netherlands. Keeping this species also improves biodiversity and genetic variability.
- Montbéliarde: The breed can be used for both the production of milk and meat. The cows have a lower chance on mastitis. Their meat is dark and fat.
- Fries Hollands: These cows are mainly bred with an emphasis on milk production, but also produce meat. The breed perform well on roughage. The status of this breed is 'threatened'. Therefore, keeping this species also improves biodiversity.
- Fries Roodbont: These cows can also be kept for both their milk and meat. The breed is classified as 'threatened'.
- Lakenvelder: This breed can be kept for their milk, but often their meat is more important. Their status is also 'threatened'. A US variant of the breed is more productive when it comes to dairy.

Some farmers in Brummen already use some of these breeds. This practice can be expanded to other farmers. Furthermore, threatened species such as Blaarkop, Fries Roodbont, and Lakenvelder can be added as well. Furthermore, farmers can choose to sell their milk separately, for example, special milk for cheese or A2A2 milk. This type of milk is similar to other milk, but it excludes the protein casein (Battell & Maitland, 2003). Studies showed that digestive enzymes interact with the A1 (in the milk of 'normal cows') and A2 proteins in a different way, which influences the digestibility of milk for some people (Bayern Genetik, n.d.). However, this effect is still arguable.

Dual-purpose breeds are also interesting regarding climate change. Increasing the milk production per cow is not that effective to reduce greenhouse gasses in dairy farming when also looking at the production of milk and meat combined (Stokkermans, 2018). Furthermore, if more meat is produced in the Netherlands, less has to be imported from meat producing countries in South-America or Ireland. Meat produced in these areas have much higher greenhouse gas emissions than the production of beef as a product of the Dutch dairy farms (Stevens, 2018; Vellinga & de Vries, 2018).

This business practice mainly addresses food production as landscape services, since the different cow breeds produce both milk and meat. A co-benefit are the introduction of characteristic plants and animals, an increase of biodiversity, and the enhancement of place identity.

### 6.1.6 Cows in nature and meadows

There are already some farms where cows graze in nature areas of Natuurmonumenten. With this collaboration, farmers have livestock roaming on hired land that is in extensive management (Natuurmonumenten, 2019). This means that farmers do not use fertiliser, and are not allowed to use chemical pesticides. Cows roaming in these areas cannot easily be fed with concentrates. This especially affects Holstein Friesian cows, which are more productive when they are fed with a controlled amount of concentrates and roughage (Bargo et al., 2002). To produce cows that have a high lactating period it is important that the young stock has a good and high-quality feed. This means that, for instance, they need high amounts of concentrates (Lely, n.d.). To overcome the problems with concentrates, a different breed of cow like Blaarkoppen might be a good option to graze on those areas (Bb4food, 2019).

The main landscape service addressed in this business practice is food production. Co-benefits of keeping cows in nature/meadows are: increased biodiversity as the reduction in chemical fertiliser and pesticides can increase meadow birds and more herbs in the meadows; increased amount of natural pollinators and pest regulators since there are alternative food sources for insects; and the creation a feeling of place identity and mental health as citizens may be able to walk around and see animals and nature outside.

### 6.1.7 Hydroponics

Hydroponics is a way of agriculture where the crops grow in water instead of in soil. This method uses the water as the transporter of nutrients to the roots of the plants (Jensen, 1997). The nutrients needed by the plants are added to the water to create a nutrient solution, or they can produced with the use of fish waste by adding fish in the water reservoir. Aquaponics does not change the concept of hydroponics and can be applied on all form of hydroponics (HHS, n.d.).

There are six general methods for applying hydroponics, each different in how it delivers the water, oxygen and nutrients to the plants roots (NoSoilSolutions, n.d.):

1. ‘Nutrient Film Technique’, where a nutrient solution is pumped through a sloped tube and the plants are stationed in this tube and extract the nutrients out of the pumped water.
2. ‘Deep Water Culture’: this system the roots of the plants are hanging in the nutrient solution water, which is also supplied with oxygen
3. ‘Wicked Hydroponics System’ that is a passive system and requires no electricity. The plants grow in a special medium that absorbs the nutrient solution from a reservoir.
4. ‘Ebb and Flow method’ in which the plants are placed in a growth medium. The nutrient solution is pumped through the medium at fixed times, creating flooding and drainage into the grow medium
5. ‘Drip System’ which drip irrigation system to deliver the nutrient solution to the roots of the plants.
6. ‘Aeroponics’ that sprays the nutrient solution onto the roots of the plants (HHS, n.d.; NoSoilSolutions, n.d.).

Since hydroponics has the goal of producing crops, the main landscape services it addresses is food production, and water management. Co-benefits of hydroponics are: pest regulation, and the ability for farmers to grow crops inside and outside, and the whole year around. Crops also need less space and uses less water. This increases the yields and results in better quality products. A down side of hydroponics is that you need a lot of know-how knowledge and high investments to start (Sardare &

Admane, 2013). Harvesting in hydroponics is similar to the harvest in a greenhouse and is labour intensive. Therefore, the size of the practice must be set by the farmer to be feasible.

## 6.2 Water management

### 6.2.1 Rainwater ponds/storage

Rainwater storage is the collection and storage of rainwater that would otherwise be lost due to the transport by water streams, evaporation or soaked in the ground and aquifers (FAO, 2014; UK E.A., 2009). Rainwater collection systems can be set up in three different ways (UK E.A., 2009):

1. Indirectly pumped systems that collect water on a surface and pump in to a higher storage tank, from which it can be extracted with the use of gravity.
2. Directly pumped systems which pump the collected water in a storage tank, from which it can also be pumped out again.
3. Gravity fed systems that do not use any pumps and the movement of water is completely with the use of gravity.

Rainwater storage changes the amount of water that is available for agriculture use and reduces direct runoff. The water can be stored in underground or in on-ground water tanks, or in ponds or water reservoirs. It can be used for irrigation if the tank is of sufficient size for the amount of hectares to be irrigated. Therefore, rainwater storage measures addresses water management as a landscape service. The advantage of water storage is a more stable water supply over the year.

### 6.2.2 On-field water retention

Vegetation buffers are strips of vegetation like grasses, bushes or trees at the borders of agricultural fields. These buffer strips will influence the runoff of water surface flows. The vegetation will slow down water flows and increase the infiltration of the water in the soils. The vegetation buffers will retain water for a longer time on and in the agricultural fields, spreading the drainage of water and lowering the discharge peak. This reduces flood risk and increases the water availability for agricultural usage. Therefore vegetation buffer strips can provide an effective water management (EC, 2015).

Vegetation buffer strips are also beneficial for other landscape elements than water management: increase carbon sequestration; hold the sediment on place and reduce the amount of soil erosion; filter the water from pollutants; increase the biodiversity of plants and animals and consequent improvement in pollination (Bos & Musters, 2014; EC, 2015).

In the Hoekse Waard in the Netherlands there has been leading experiments with vegetation flower strips at the borders of agricultural fields. One of the successfully tested examples included a one yearly flower strip containing a combination of buckwheat, gypsophila, cornflower, goose flower and sunflower (van Rijn, 2018).

### 6.2.3 Mulching

Mulch is a layer of organic matter applied on the soil surface. This layer may have several materials, such as plant residues, straw, compost and chips (DAFF, n.d.; Michigan, n.d). Mulch is a layer of organic matter applied on the soil surface. Special attention needs to be given to lower lying soils since these soils are more likely to harbor fungus diseases (Vickery et al., 1981). Additionally, low nitrogen mulches such as straw can reduce the nitrogen available in the soil, since the microorganism pull nitrogen out of the soil and away from the crop while decomposing. Therefore, additional nitrogen should be added before mulching (KSU, 2004).

Mulching mainly addresses water management as landscape services, and food production indirectly by improving the soil structure and texture. Applying this layer has several co-benefits for the soil: the water holding capacity of the soil improves due to protection against sun and wind (Vickery et al., 1981); moderates soil temperature (KSU, 2004); increases soil fertility as mulch contains minerals and nutrients which are released during decomposition and become available for plants; the growth of weeds decreases since the layer prevents their growth; prevents the contact of fruits with the soil, reducing fruit rot and fungus diseases.

## 6.3 Carbon sequestration

### 6.3.1 Increasing tree cover in pastures

The presence of trees often lacks in pastures, which are mostly dedicated to the feed of cattle. Thus, an increase of land covered by trees in pastures will help to improve carbon sequestration in farms. The amount of trees and the location of trees is up to the farmers. An applicable option may be to locate the trees on the pasture edges or the surroundings of the household.

The carbon sequestration capacity of trees depends largely on its leaves. Leaves falling to the ground are a huge contribution to storage of $CO_2$, thus annual or deciduous trees are favorable for carbon sequestration. Large tree leaves with more surface sequestrate more carbon. The levels of carbon sequestration can also vary depending on the rotation lengths. For instance, a species like the Scots pine (*Pinus sylvestris*) can store more amount of carbon when applying the longest rotation length. On the other hand, other species like the Norway spruce (*Picea abies*) show higher levels of carbon storage in the shortest rotation length (Nowak & Crane, 2002).

Depending on the land use and the type of management, the potential of some tree species varies and it has to be taken in account for future management plans. For example, when carbon sequestration is the main purpose, poplars (*Populus spp)* can sequester the highest amount of $CO_2$ in the least but their lifetime is short (25-30 yrs), and white cedar *(Thuja occidentalis)* has the more potential for long-time carbon sequestration and they can be planted close together, which provides a greater tree density. It is also possible to choose for trees that provide other types of production such as the red oak (*Quercus rubra*) from which you can obtain wood, or the horse chestnut (*Aesculus hippocastanum*) and walnut tree (*Juglans regia* & *Juglans nigra*), which adds up to the production from cattle.

Co-benefits by adding trees to pastures may be: food production depending on the tree introduced; wood production; increased diversity of flora and fauna; and improved pollination.

### 6.3.2 Legumes in pastures

The inclusion of legumes in pastures is another option for climate resilient business practices. Legumes are resistant crops that can survive during wet and dry periods due to its tap roots that allow them to get moisture from deep in the soil. On the other hand, legumes provide large amount of digestible protein, minerals and calcium suitable for animal grazing. In combination with grass, legumes promote an increase of quality of the pasture (Naturesseed, 2019). The legumes identified as suitable for the combination with pasture areas for livestock are alfalfa, birdsfoot trefoil and white clover. The type of legume should be chosen according the characteristics of the soil, temperature and humidity.

The introduction of legumes in pastures contributes to the landscape service carbon sequestration in soils (EP, 2017; Gonzálvez et al., 2018; Hernández-Esteban et al., 2017). This seems to be an important challenge for pastoral systems management in a climate change scenario (Hernández-Esteban et al., 2017). Co-benefits promoted by this practice are various: increased soil productivity, contribution to pest control, and own-produced fertilisation as they are nitrogen fixing crops (Naturesseed, 2019; Gonzálvez et al., 2018). Attention must be given to the extent of legume inclusion, a pure legume pasture may cause bloating in cattle. Therefore it is important to combine it with another type of pasture, such as grass (Naturesseed, 2019; Gonzálvez et al., 2018).

## 6.4 Energy production

The agricultural sector has been identified to have a large potential for the promotion and use of renewable energies. Renewable energy in farms can be derived from the large extent of natural resources which are naturally restored. Two promising options for energy production are the solar energy and wind energy (EP, 2016).

The involvement of farmers in energy production from renewable sources can be an opportunity for them to diversify, increase and stabilise their income. Furthermore, farmers become less dependent on external suppliers and can contribute to sustainable energy production. It may also trigger rural development through improvement of infrastructure and generating employment, which may attract young generations (EP, 2016). Thus, the choice of the extent to which on-farm renewables energies will be implemented is left to the decision of farmers.

### 6.4.1 Solar Panels

Solar energy will be obtained through the installation of solar panels, which can either contribute to the production of electricity or thermal energy (EP, 2016). The use of the energy produced can be directed to household's uses, for the farm installations or it can be sold for the common use for the province. Several options can be arranged for the installation of solar panels: solar panels installed on the household's rooftop for its use; solar panels installed on the farms buildings (e.g. cowsheds); solar panels installed on land; dual-use solar panels installed on land. The latter option is named as 'Agrivoltaics' (Civileats, 2019), a system where solar panels are arranged away from the ground and distanced from each other so agriculture activities, such as cattle, can still take place.

### 6.4.2 Wind energy

Wind energy is a great resource for on-farm production of electricity and it can be collected through wind turbines. Similar to energy produced from the solar panels, energy from the wind can be used either within the household, for on-farm activities or sold to the province as energy production (EP, 2016). In this case, there are several sizes for wind turbines, ranging for small turbines that can be easily installed on the rooftops, medium on-land wind turbines, or big on-land turbines (Extension, 2019). The size of the installation may differ according to the desires of the farmer.

## 6.5 Diversification practices

### 6.5.1 Tourism and leisure

Farmers in Brummen may have the choice to diversify their income through expanding their agricultural activity towards tourism and leisure practices in their farms. Options for activities that can be developed are the provision of housing for tourists, such as AirBnB or hostels; the arrangement of cycling or walking routes, or routes through the different farms; opening of the farms for groups, such as families or the engagement of farmers in school activities as a destination for excursions, where children can learn about farming activities and may trigger them to become farmers; workshops on the management of local products, for example, milking cows and cooking workshops with local crops.

These are only some options for farmers to engage in activities related to tourism, in addition to their agricultural practices, that can promote and open the market for the consumption of local products. Tourism and leisure is expected to increase in the Netherlands due to climate change: as temperature increases in Europe, especially in southern countries, tourist may shift their preferences towards northern countries to spend their holidays (Scott & Lemieux, 2010). Therefore, the engagement in tourism and leisure practices can be a secure and an appropriate strategy for ensuring income for farmers in the region in a climate change context.

### 6.5.2 Local products' restaurant and shop

Setting up an on-farm restaurant is a possibility for farmers to diversify their income with other practices rather than farming or combined with farming. The restaurant can use products from their own farm such as meat, milk, vegetables, fruits etc. Another option is to set up partnerships with restaurants in the area to sell their local products directly. This business practice may have limitations as other external products may be required.

An on-farm local shop can also be managed by the farmers as a diversification activity. The products grown or produced in the farms can then be directly sold to the public. This activity may be resilient to any changes in the climate or context, as the products sold may differ according to the possibilities of production. Other business practices proposed may promote diverse product development, such as agroforestry, since cattle, vegetables, fruits, and nuts can be obtained. There is a possibility for farmers to coordinate themselves and cooperate to open up a larger local food, combining the products they produce.

# 7. Feasibility check

Table 7.1 gives an overview of the feasibility of all the assessed business practices within the parameters. The figure shows that most of business practices will fit in the applicable parameters. The results indicate that especially for business practices cultivating different types of crops, the crop choice is important in the feasibility of the business practices. For example, in agroforestry, the types of trees and vegetables combined should fit the soil type of the farm. Furthermore, a farmer should not choose crops that cannot deal with wetter periods in the months July and August or droughts in June. Feed production might not fit the water quantity of the future. This means that this business practice might not be feasible in the way it is described. However, there is also an option to cultivate wheat to produce feed for your cows and this option might help to overcome the problems with alfalfa and beets (Fokkert, 2019). Storing water might not be feasible for farmers. If farmers want to use the stored water for irrigation, large quantities of water are needed. This means that large tanks need to be installed. This might be costly and can take up a lot of space. It might not be suitable for farmers to install tanks if they live close to nature areas or villages or if they have small farms. Therefore, installing these tanks might not be suitable.

For farmers, it is possible to combine different business practices to have a variety of strategies. For instance, It is an option to have a small area with permaculture, but still keep cows and let them feed in pastures with legumes. The idea of the table is to get an overview of the different possibilities and in combination with the different landscape services the business practices provide, farmers can choose different business practices that fit in their farms.

**Table 7.1:** *Overview of the feasibility of the business practices within the parameters.*

**[** **✓** = feasible **✓*** = conditionally or partly feasible **X** = not feasible ‘ **–** ’ = not applicable **]**

| Business Practices | Area characteristics | | | | Climate parameters | | | | Socio economic parameters | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Soil | Water | Topography | Geography | Precipitation | Temperature | Evaporation | Water quantity | Agricultural market trends | Policies |
| Agroforestry | ✓ | ✓* | ✓* | ✓* | ✓* | ✓* | ✓ | ✓* | ✓ | ✓ |
| Intercropping | ✓* | ✓* | - | ✓* | ✓* | ✓* | ✓ | ✓* | ✓ | ✓ |
| Permaculture | ✓ | ✓* | ✓ | - | ✓ | ✓ | - | ✓* | ✓ | ✓ |
| Feed production | ✓ | ✓* | - | - | ✓* | ✓* | - | X | ✓ | ✓ |
| Different cow breeds | ✓* | ✓* | - | - | - | ✓* | - | - | ✓* | ✓* |
| Cows in nature and meadows | ✓* | ✓* | - | - | - | ✓* | - | - | ✓* | ✓* |
| Hydroponics | - | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Rainwater storage | - | - | X | ✓ | ✓ | - | ✓* | ✓ | - | ✓ |
| On field water retention | ✓ | ✓* | ✓ | - | ✓ | ✓ | ✓ | ✓ | - | ✓ |
| Mulching | ✓ | ✓* | - | - | ✓* | ✓* | ✓ | ✓* | - | ✓ |
| Increasing tree cover | ✓* | ✓* | ✓* | ✓* | ✓* | ✓* | - | ✓* | ✓ | ✓ |
| Legumes in pastures | ✓* | ✓* | ✓* | ✓* | ✓* | ✓* | - | ✓* | ✓ | ✓ |
| Solar panels | - | - | ✓* | ✓* | - | - | - | - | ✓ | ✓ |
| Wind turbines | - | - | ✓* | ✓* | - | - | - | - | ✓ | ✓ |

# 8. Farm designs

## 8.1 Future dairy farm

A design was made including dairy farming as main source of income, but combined this with other business practices (Figure 8.1). An option for farmers is to include different breeds in their livestock population. Farmers can decide to change their livestock population altogether by keeping one or several cow breeds and possibly to crossbreed them. Dual-purpose cows can be used since they offer both beef and milk. This can be a way of diversifying the income. Furthermore, the farmers may be able to sell the beef, milk and perhaps cheese in their on-farm shop, to nearby supermarkets or to restaurants. Another possibility is to market the milk of specific cow breeds separately from the milk of Holstein-Friesian or see whether it is possible to market it with a special quality label (e.g. ‘A2A2’).

The cows can graze in meadows in which legumes (e.g. clover) are grown. Legumes provide a lot of digestible protein, minerals and calcium, which makes it suitable for animal grazing. In combination with grass, legumes promote an increase of quality of the pasture. A part of the cows (e.g. yearlings) can go to nature areas. This increases biodiversity, the amount of natural pollinators and it can create a feeling of place identity and improves mental health if citizens are able to walk around and see the animals in nature. In addition, farmers can produce a part of the cow feed themselves. They can decide to grow for example wheat since it has high energy values, crush it and feed it to their cows (Klop & Plomp, 2006). On the edge of the pasture, hedges are combined with trees. This increases biodiversity, but also provides shade for the cows during the summer days.

Additionally, hedges and/or flowering field edges can be planted on a part of the fields. This practice improves food production through increased biodiversity and pollination. Furthermore, it improves water retention, which will be useful in drier areas. Farmers can plant trees on their farm to increase carbon sequestration, and possibly sell the harvest of the trees. An option would be to grow fruit trees or nuts, and sell them locally. Furthermore, chickens can roam around in the area in which these trees are planted. The eggs they produce can also be sold, either in an on-farm shop, or to a restaurant or a supermarket.

Lastly, it is possible to install solar panels on the farm buildings to produce energy (e.g. cowshed). The energy produced can be used by the household, for farm installations or it can be re-delivered to the energy grid.

Farmers can also decide to diversify their income by expanding their agricultural activity towards tourism and leisure practices, such as organising workshops, provide housing for tourists (e.g. AirBnB, bed-and-breakfast), the arrangement by farms of cycling or walking routes, or routes through the different farms. Furthermore, as described previously, farmers can set up an on- farm shop or an on-farm restaurant. Another option is to set up partnerships with shops, restaurants or supermarkets in the area.

This adapted farm design relates to the trends in several ways. Firstly, the trend shows that it is expected that people want to buy their products locally. Eggs, milk, beef and other products can be sold on the farm, to nearby restaurants, and to supermarkets. This also fits the socio-economic trends. However, beef consumption in the future is unsure, which means that local consumers may be less interested in buying this. However, the trend still shows that people prefer to buy local products, which means that people who still want to purchase beef can do this in their own region instead of getting it from other continents. Furthermore, energy is produced in a renewable way, which reduces the emission of greenhouse gasses from fossil fuels. Additionally, the trees on the farm sequester carbon, which contributes to climate mitigation.

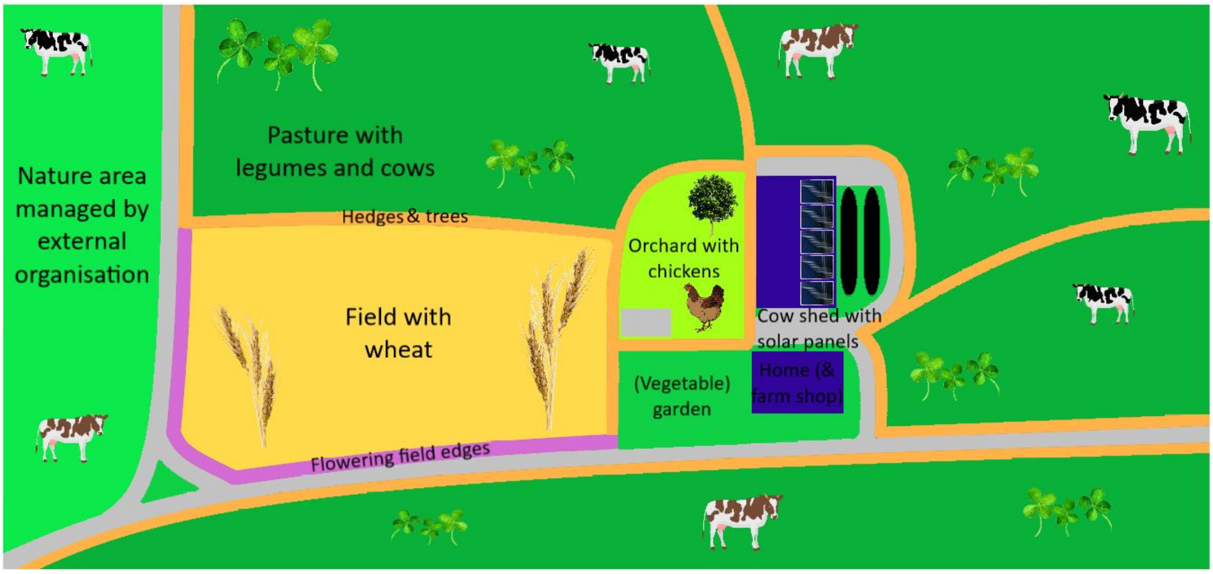


**Figure 8.1:** *An alternative farm design for a farmer that still wants to keep dairy farming, which includes different cow breeds, producing feed for cows, orchards with chickens, grasslands rich in clover and producing (a part of) the farms' own energy.*

## 8.2 Future mixed farm

In this farm design, it was decided to replace some of the cows and meadows by arable land. This means that less cows will be present resulting in less dairy production. An alternative income source is found in the production of vegetables, nuts, fruits and eggs. In this farm, a combination of permaculture, agroforestry, renewable energy and hydroponics can be found. Figure 8.2 shows a possible design for a farm with these business practices and is explained below.

To make the farm sustainable, solar panels will be placed on all the farm buildings and pole mounted solar panels (agrivoltaics) will be placed on meadows. When the farm is located near a forest it is not recommended to include windmills, but if there is an opportunity, windmills can be placed as well. The renewable energy sources will not only replace part of the on-farm fossil fuel use, but will also become an extra source of income for the farmers. In the housing area, a vegetable garden for home use will be created. In the courtyard, an orchard with different fruit trees and hedges will be created. In this orchard, chickens can roam and to attract people for picking fruits and gathering eggs, fruit pick days will be organised. Furthermore, the products of the farm will be sold in an on-farm shop and in a collaboration between farmers and citizens like the 'Herenboeren' concept. In this concept around 200 households invest 2000 euros and together with the farmer, a cultivation plan for the different vegetables will be created. The households come every week to the farm to collect a package with food which they buy for a market confirm price (Herenboeren, n.d.). This way the farmer is ensured of a decent income and the households have healthy and organically produced food. To supplement the income from farming businesses, it is also possible to renovate one of the old cow stables into a bed and breakfast with a room where conferences or other meetings can be organised.

On the farm, a part of the fields will be meadows with rows of hedges and trees. In the meadows a mixture of grass and legumes will be sown. The trees can be walnuts, linden trees, sweet chestnuts or different species of fruit trees. For the hedges, hazelnut or for example hawthorn can be used. The meadows can be used for cows to graze. There will also be chickens in a moveable chicken shed to regulate pests and diseases in a natural way. The other parts of the fields will be used for intercropping or permaculture fields. For the permaculture guilds, high trees can be the walnut, linden or sweet chestnut tree. The lower trees can be the elderberry, apple or apricot tree (this last tree might be a tree that is better planted somewhere in the middle of the field to protect it against frost in the early spring). The layer with perennials or climbing crops could consist of the following crops: blackberries, pies, goji berry, and rosehip. The vegetable layer could consist of the following crops: Strawberry, endive, rhubarb, broccoli, buckwheat and sunflowers.

There can also be some root vegetables in the guilds, for example, unions, garlic and celeriac. In the ponds, bulrush and reeds can be cultivated. In the fields used for intercropping the crops cultivated will be in consultation with the households but examples can be combining maize and fava bean, combining wheat and lupine or combining carrots and unions. To increase the variety of crops that can be cultivated, a hydroponic system will be made in a greenhouse. In this system, different herbs and water demanding or sensitive crops like lettuce can be cultivated to supplement the harvest from the fields and orchards. Near the greenhouse, a composting area will be made to create compost for fertilisation and to grow vegetables like pumpkins and zucchinis. On the leftover wood from cutting hedges and tree branches, mushrooms can be cultivated.

In this farm design, flowering field edges and hedges are used as buffering water strips and creating different landscape elements in the design. The flowers that can be used are: buckwheat, gypsophila, cornflower, goose flower and sunflower. The hedges can consist of hawthorn, blackberries or beech.

The cows in this farm design will graze in the meadows between the hedges. It is advised to have some multipurpose cows to provide some meat to the households in the 'Herenboeren' concept. The young stock or non-lactating cows can be brought to nature areas in the neighbourhood to graze and roam free. As a supplement to the cows and the chickens, pigs will be kept as well (some national breeds are recommended to apply to the local market). These pigs will rotate with the guilds to improve soil structure. When the pigs are moving around, first grass will be sown. In the pig area, the trees will be oak, beech and hazelnut tree. The barn of the pigs will be a moveable one so they can be located where they are needed to prepare the soil (also in the intercropping areas). To apply this design it is recommended to start with planting trees while keeping your farm productive in the previous way since it will take some time before the trees start to produce fruits. After this, the rest of the design could be implemented in steps while at the same time the 'Herenboeren' association will develop.

This farm design will fit in the future climate and socio-economic trends since the design helps to increase the diversity of products from the farm. This will help to meet the demands for local food consumption and at the same time provides more natural pest regulation (by the chickens and the variety of trees and hedges as natural shelters for natural predators). The farm will also be able to deal with the changing rainfall patterns since water is retained more on the fields and organic matter will increase in the soils. Due to the application of trees, the increasing temperature in the summer will not cause heat stress for the crops in the permaculture design and the renewable energy technologies in the farm will fit in the trend that renewables will become more important.

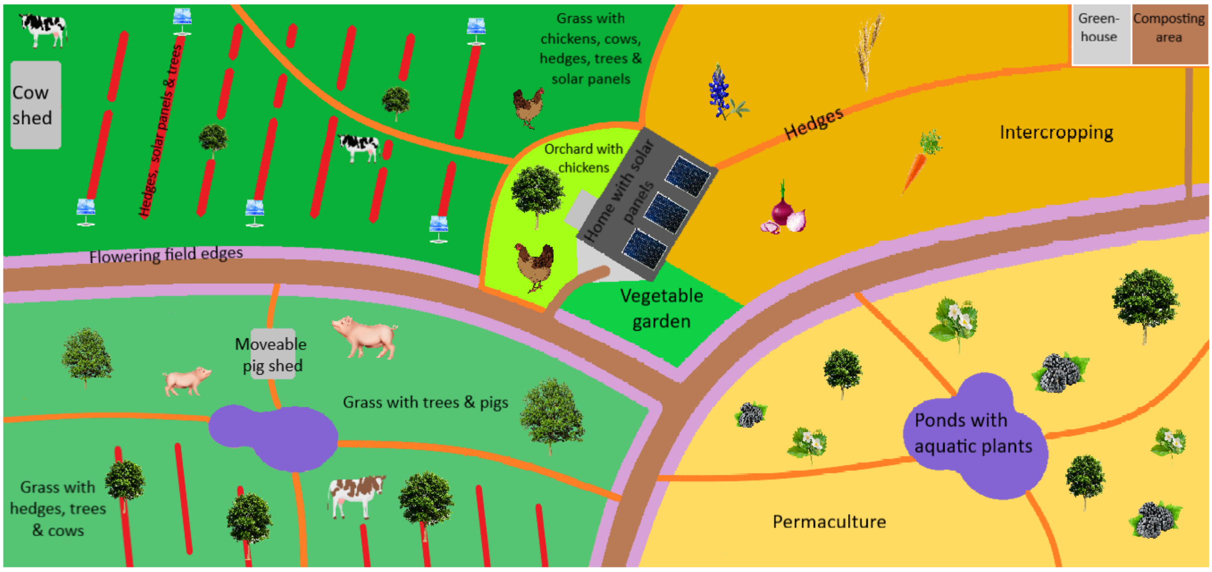


**Figure 8.2:** *A farm design of a future mixed farm, which includes among others: intercropping, permaculture, grass combined with hedges, trees & cows, orchards with chickens, solar panels, and a vegetable garden.*

# 9. Conclusions

The assessments made in this study indicate the future climate and socio-economic trends in Brummen. However, there are different business practices that do fit in these trends. From the climate projections, the temperature shows an increase of 2°C in the future and the number of freezing days will reduce especially in January and February. The precipitation will decrease in the spring and more dry days are expected. However, in July and August there will be more wet days. Due to the drier spring and warmer temperatures, the groundwater table is expected to become lower in the future. The outlook on the future socio-economic trends showed that there is an increasing demand for local and more sustainable food.

There is a trend that the demand for beef and pork will slightly decline. Therefore, plant based proteins could become an important substitute for these products. The European and Dutch national policies and trends regarding agricultural law clearly show that sustainable and nature-friendly farming will become important in the post-2020 CAP. Nature-friendly farming means that pesticides and fertilisers regulations will likely become stricter, and other methods to cultivate food will be promoted. Energy policies focus on renewable sources and becoming energy neutral. For the municipality of Brummen this is already the goal in 2030. Policies specific for water management also deal with climate change on adapting the local water management regimes. Adaptation will not only be done in the major streams in the region but especially in nature areas and the surrounding agricultural areas. Water retention will become important in those areas as well.

The assessments of the climate and socio-economic trends resulted in the identification of the several business practices, from which the following fourteen were selected: hydroponics, intercropping, agroforestry, permaculture, different cow breeds, cows in nature and meadows, production of feed, water storage ponds, on-field water retention, mulching, legumes in pastures, increasing tree cover, solar panels, and windmills. From the feasibility check, it became clear that most of the business practices would feasible in the future according to the assessed trends. However, for some of the business practices like agroforestry and permaculture, it is important that the designs are adapted to the local situation of the farm. This means that the type of crops chosen should fit the local soil type and groundwater table. As examples and inspiration, two farm designs were made. These designs were based on a possible future farm, and show a possible combination of different business practices in one farm. Furthermore, several other ways of diversifying farm practices were identified which diversifies the income of farmers, and increases the resilience of farms to other possible futures.

In conclusion, most business practices that were identified and described fit in the future climate, socio-economic, and related policy trends towards 2050. The implementation of a combination of business practices, like in the designed farm types, can ensure future proof farming in Brummen.

## 9.1 Recommendations

Based on this study, we give the following recommendations to the Science Shop of Wageningen UR and Landscape Network Brummen:

- To make an analysis of the economic feasibility for the business practices. This analysis should include costs of implementation, production, labour, and the possible profits from the products.

- To identify and select business practices for a farm design, together with farmers to ensure the practical feasibility of the presented business practices.

- Each farmer to look into specific characteristics of their farm for determining which crops are feasible within their requirements.
- To facilitate the collaboration between farmers to make the implementation of the business practices possible. Costs, knowledge, equipment and benefits can be shared.
- To examine what the impacts of the business practices are on the daily life of the farmers, and to what extent the farmers need education for the execution of the practices.
- To further develop a detailed socio-economic and related policies assessment on the trends.
- To examine together with local policymakers how policies could be adjusted to the situation of farmers in Brummen in the future.
- To further improve the climatic feasibility of the business practices with extending the climate projection by including more scenarios of the KNMI and the IPCC. To include windspeed projection, and to check for non-linear trends.
- To make an extensive analysis of the local markets that are available in Brummen. It is important that citizens in Brummen, Eerbeek, Apeldoorn and Zutphen are interested in creating collaboration with farmers.
- To attract young farmers, to involve them in the process of creating future proof business.

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## RAppendix 4: Feasibility check

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# Appendix 1: Groundwater tables

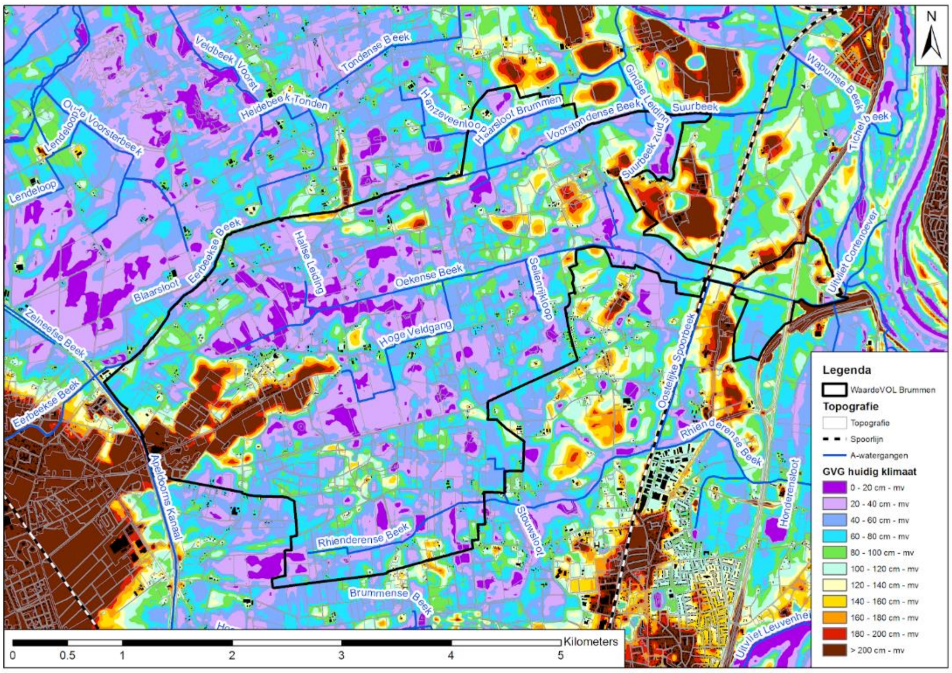


**Figure A1.1:** *Current depth of the groundwater table in the spring in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

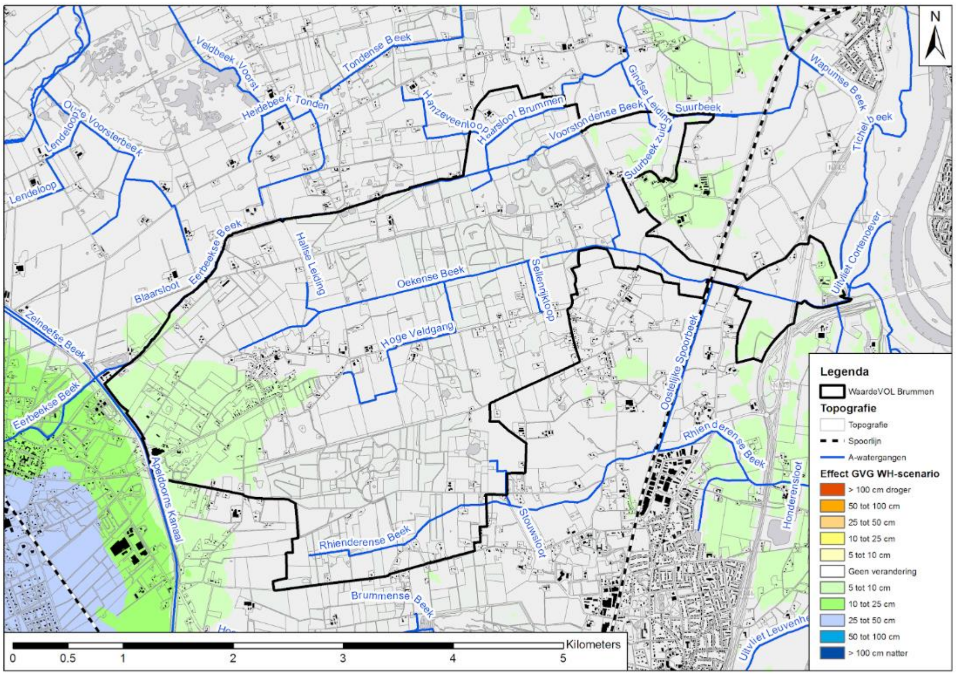


**Figure A1.2:** *Projected change in groundwater tables in the spring in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

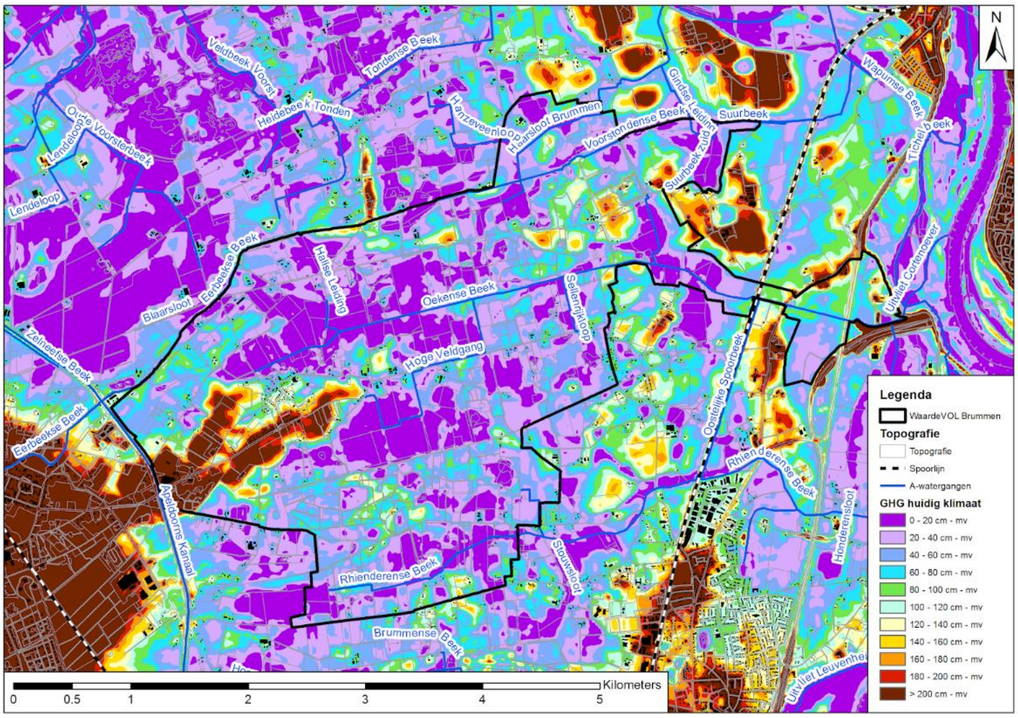


**Figure A1.3:** *Current depth of the groundwater table in the winter in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

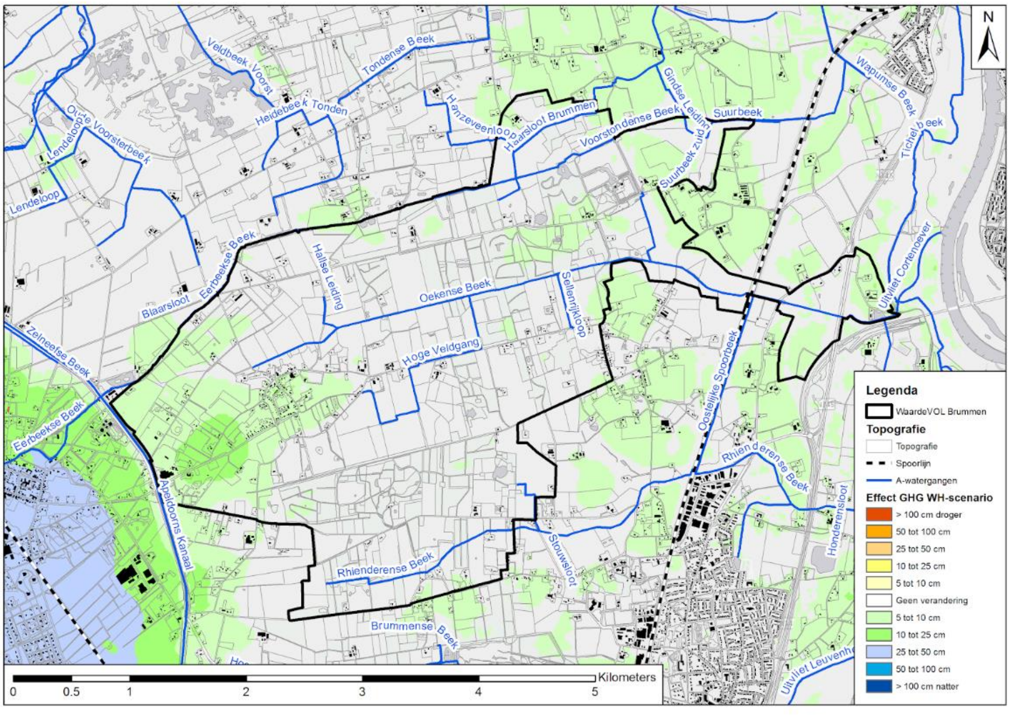


**Figure A1.4:** *Projected change in groundwater tables in the winter in the area of WaardeVOL Brummen (Waterschap Vallei en Veluwe, 2019).*

# Appendix 2: Socio-economic outlook and related policies

## A2.1 Market trends

**European level**
At EU level it is projected that consumers will demand more from their food. It should be clear where it came from and the impacts on the environment and climate will become more important for consumers. This increased demand might lead to increased costs for producers, while it also gives them opportunities to differentiate their products, by adding value and reducing environmental and climatic negative impacts (EC, 2018).

In relation to the livestock sector, it is expected that the EU dairy sector benefits from the growing global and domestic demand. On the other hand, the dairy sector might face difficulties due to the high price volatility. Figure 5.2 shows that the price of milk is indeed not stable and will stay around the same level in 2030. From the projections, the EU would be able to supply 35% of the global demand, including milk, cheese, butter, milk powder, and whey powder, with more focus on processed milk products (EC, 2018).

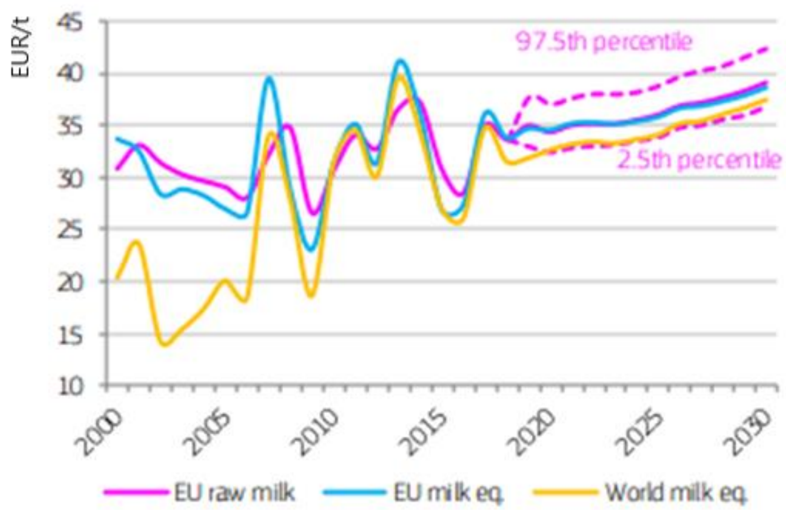


**Figure A2.1:** *Milk price development and possible price paths (EC, 2018).*

In general, meat consumption is expected to be stable on the short-term, while it will show a slight decrease in the future. It is expected that poultry will be produced and consumed more, while pork and beef consumption and production are expected to decrease in the future (EC, 2018). These projections are shown in Figure 5.3.

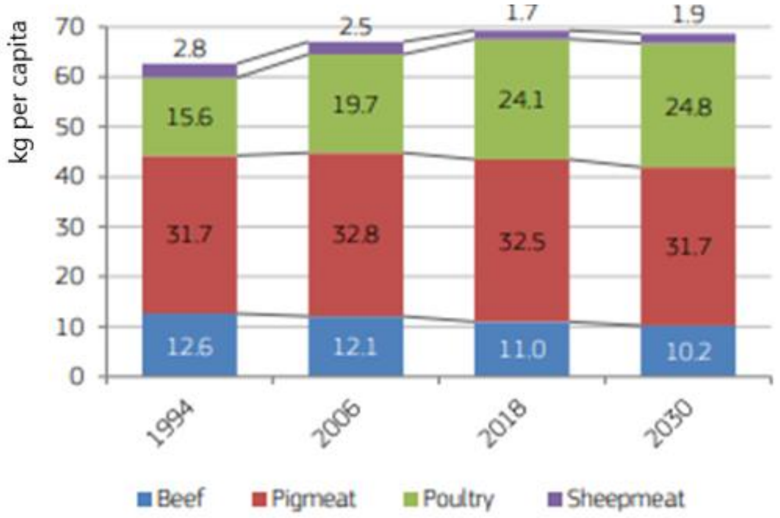


**Figure A2.2:** *EU consumption for beef, pigmeat, poultry, and sheepmeat (EC, 2018).*

Cereal production is expected to increase moderately due to a growth in demand. More interesting is the rise and growth in production of domestic soybean and other alternative protein sources. Part of this production is needed for the increase in plant-based drinks (Figure 5.4). The increase in plant-based products is also supported by policies. The horticulture sector (i.e. vegetables and fruits) is expected to decrease in terms of consumption of traditional products but an increase in new products from other countries and exports is expected (EC, 2018).

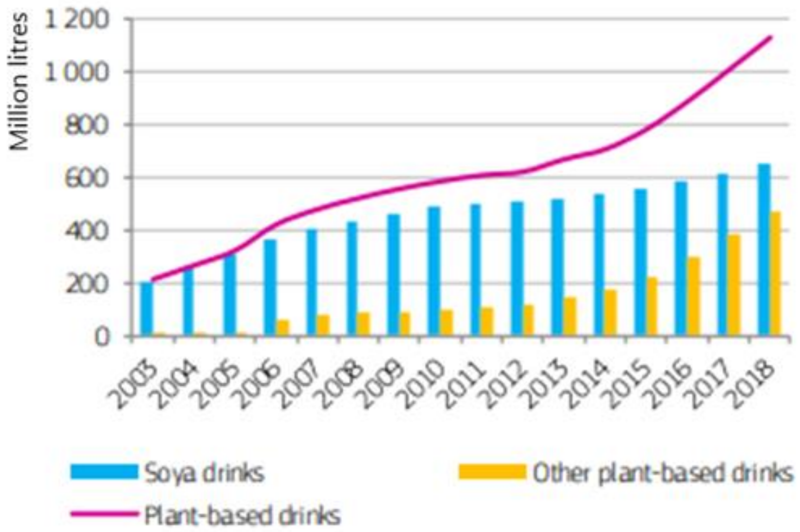


**Figure A2.3:** *Retail and foodservice volume of plant-based drinks (EC, 2018).*

According to the analysis, agricultural labour will stabilise due to an increase in the value of agricultural production. This is compensated by an increase in production costs due to energy prices and depreciation of agricultural products. According to the projections, the production in the EU will mostly be consumed within domestic boundaries. However, the export of especially dairy products will stay important as well (EC, 2018).

In sum:

- Meat consumption will stabilise in the short-term and decrease in the long-term, except for poultry that is expected to increase.

- EU dairy sector will benefit from the growing global and domestic demand, but it might face difficulties due to the high price volatility.
- The demand for plant-based proteins will increase which may increase its imports.
- Consumers will be more demanding on what they consume and will try to give value to the food which may increase consumption of local and organic products.

### National level

In the Netherlands, there are quite some changes that affect the agricultural market. The Dutch population is aging and single households are getting more common. There are challenges, but also opportunities in these developments. One of the challenges is that food needs to be affordable for everyone and price fluctuations are a challenge for farmers as well (ING EBZ, 2012).

There was a trend that food needed to be fast and simple to fit in the fast Dutch society. However, at the moment there is counter movement. The number of local food initiatives is increasing and consumers start to become more aware of their food again. Not only local but also animal-friendly and fair trade are important terms in the coming years, partly due to the focus of NGO's on these themes. To answer this new trend in demand more collaboration between farmers and local NGO's becomes more relevant. Big retailers are also important in the transition towards more local and sustainable food since their market share has grown considerably. However, there is also a trend towards more locally produced food and initiatives to help reduce the emissions related to the logistics of food. To reduce emissions not only attention is given to local food. Flexibility and a higher efficiency will have to reduce the amount of food waste. The development of different technologies for this will become more important. Technologies will also become more important in the kitchens. More and more apps about healthy food and food waste are being developed. This can be an interesting development for the agricultural markets to respond to. Politics might also become increasingly important in the development of more healthy food and the promotion of this (ING EBZ, 2012).

Competition in economic and environmental terms with other agricultural activities such as dairy production is likely to reduce suckler cow herds further in certain intensive meat-producing regions of the EU (such as the Netherlands) (EC, 2018).

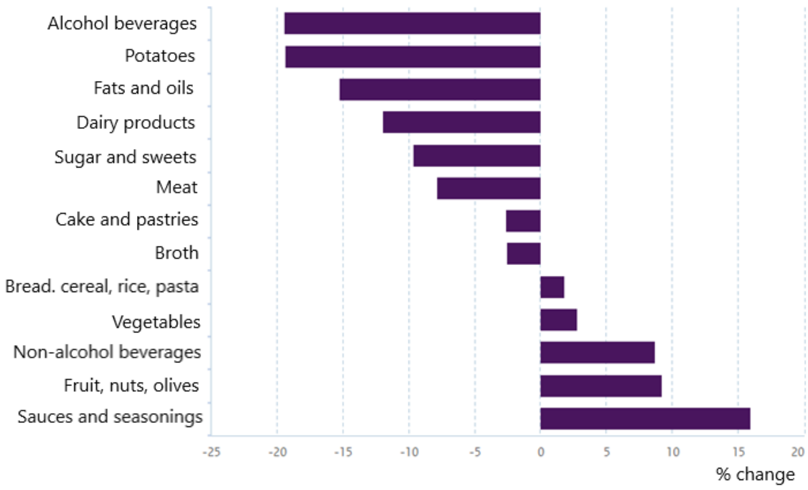


**Figure A2.4:** *Change in food consumption in the years 2012-2016 compared with 2007-2010 (RIVM, n.d.).*

In figure 5.5 the changes in the consumption of different products are shown. From this figure, it becomes clear that in comparison to 2007-2010 the consumption of potatoes and dairy products has reduced in 2012-2016. In this same timeframe an increase in the consumption of fruits and nuts and some sauces and seasonings (RIVM, n.d.).

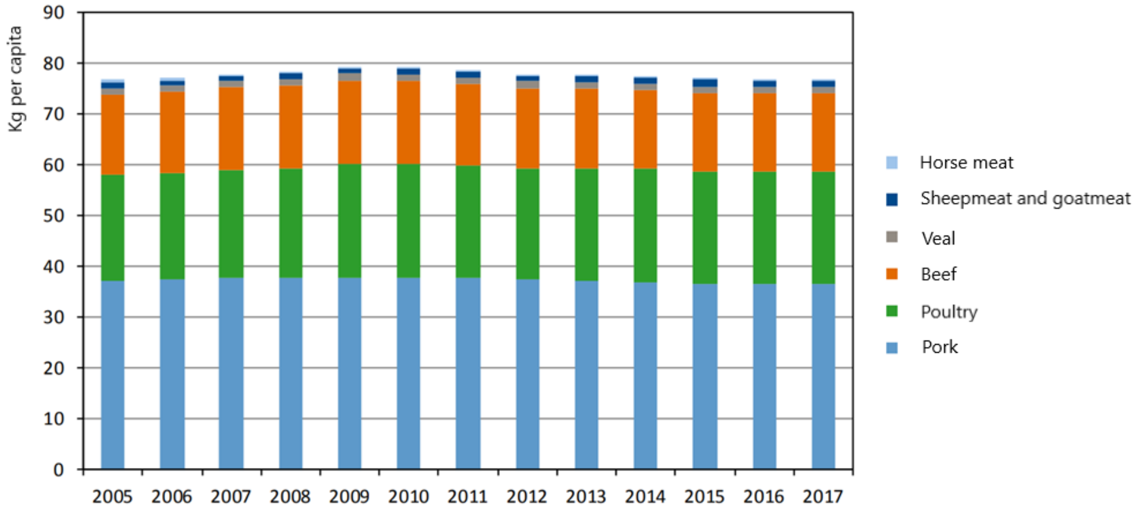


**Figure A2.5:** *Consumption of horse meat, sheepmeat and goatmeat, veal, beef, poultry, and pork in the Netherlands from 2005-2017 (Dooren, 2018).*

Figure 5.6 shows that the slight decline in meat consumption of the last years did not continue in 2017. Despite more attention to vegetarian food and flexitarianism (Dooren, 2018; Natuur & milieu 2016), there is a stop in the decline of meat consumption.

### Regional and local level

The trend in aging is also visible in Brummen. For the local market, this can be beneficial since elderly people have the tendency to buy more local food than the younger generation. However, since the younger people are migrating, there is a risk for the continuation of the farming businesses. This might be countered by the implementation of new technologies on farms (Velp, 2016).

In the Brummen region, some farmers sell local products and the trend is indicating that consumers in the future are willing to pay more for these products as well (Velp, 2016). There are already collaborations between local health care institutes and farmers to purchase local food and a food coordinator is assigned to inform people about the benefits of local food (Gemeente Brummen, n.d.). The increased interest in local food is also related to the larger care for the landscape and the larger interest in organic food. This trend is hard to relate to the future, but at the moment local organic food is valued more (Velp, 2016).

## A2.2 Agriculture

### European level

The European policy context is characterised by the Common Agricultural Policy (CAP) from the European Commission. On the 1st of June 2018, the European Commission has presented proposals on the CAP legislation and functions after 2020. With these proposals, the intention is that the CAP responds better to the present and future challenges, such as climate change. The CAP post-2020 has developed nine new objectives that include social, economic and environmental aspects (EC, 2019).

In relation to the economic and social aspects, the CAP post-2020 emphasises on providing subsidies and fair shares to small and medium farms. A part of the direct payment that is assigned to each country will be saved for young farmers. Moreover, help for new generations to participate in farming activities will be promoted to ensure that farming activities will be continued by the new generations. Furthermore, stricter prerequisites on food quality and health, such as the reduction of pesticides or antibiotics, will be required from farmers (EC, 2019; EP, 2016).

In relation to environmental aspects, farmers play an important role in mitigating climate change, environmental protection, and landscape and biodiversity conservation. Three objectives of the CAP post-2020 relate to environment and climate:

- *'Contribution to climate change mitigation and adaptation, as well as sustainable energy;*
- *Foster sustainable development and efficient management of natural resources such as water, soil, and air;*
- *Contribution to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes'* (EC, 2019, p.4).

The CAP is based on the conditionality system, which links area and animal-based CAP payments and obligations that have to be met by farmers. Mandatory requirements to achieve environmental objectives include the conservation of carbon-rich soils through protecting wetlands and peatlands. A mandatory instrument for managing the nutrients to improve water quality and reducing ammonia and nitrous oxide in water will be developed. Shifting from diversified crops to a crop rotation systems will be mandatory as well. Member states have to make clear how they will achieve the CAP's environmental objectives (EC, 2019; Europa 2019). Moreover, the CAP will make a 'Farm Sustainability Tool for Nutrients' available for farmers to help farmers on the application of nutrients, reduce nutrient leakage, GHG emissions and avoid over- or under- fertilisation (EC, 2019).

Other tools are offered for farmers to achieve the CAP objectives, such as eco-schemes in which payments for care for environment and climate to farmers will be mandatory for the Member States to implement, while farmers voluntarily participate. The future development of the CAP will aim to support rural development and also promote climate-relevant management practices, investment, and innovation. Thus, 30% of the rural development budget will be directed on environmental and climate focused activities (EC, 2019; Europa 2019) within the 'Rural Development Program'.

### National level

The Dutch Ministry of Agriculture will emphasize on climate, local markets, food waste and nature through the promotion of circular agro-food systems ('kringlooplandbouw'). In the system, economic profit will no longer be the most important factor, but a shift will be made towards production using little raw materials and reusing. Thus, the goal for 2030 is that the circular systems for raw materials will be closed at the smallest scale possible, international or national. Moreover, attention will be given to a fair and decent income for farmers, more appreciation for food through shorter chains, and innovative agricultural with a leading position on the world market. To reduce food waste, the government wants to adjust and facilitate the regulations regarding local foods sales, but the quality of food must continue to meet certain standards. Collaboration between different stakeholders like local and national government and farmers will become more important (Ministerie van LNV, 2018).

To deal with nature, the Netherlands promotes 'nature inclusive agriculture' as a 'form of sustainable agriculture based on a resilient food and ecosystem' (WUR, n.d.). The province of Gelderland aims to make the implementation of nature inclusive measures on farms more attractive by constructing new business practices. The goal is that all farmers are at least 'basic nature inclusive' by 2027, which means that measures increasing biodiversity need to be applied on at least a part of their farm. Another goal is that half of the farms with land reach the level of 'aware nature inclusive', which includes an improved functional diversity by improving soil, crop and animal cycles in addition to giving room for the natural behaviour of animals and the management of landscape elements. Additionally, a minimum of 10% of the farmers should reach the level of 'best nature inclusive' in 2027, implying that cycles are optimised and nature and landscape are part of the business operations (GNMF, 2019).

One of the causes for biodiversity decline is the use of pesticides and herbicides in agriculture (Berendse & Geiger, 2013). Yet, the trend in use of pesticides shows a decrease, as 2012 till 2016 the use of pesticides has declined with 3.5%. However, still, 96% of all arable area is treated with pesticides

(CLO, 2019). By 2027, the Netherlands wants to achieve the objectives of the Water Framework Directive in phases which regards the quality of surface water (Rijksoverheid, 2012).

To continue, a new system of phosphate rights has been introduced on the 1st January 2018. The goal of these system for dairy cattle is that the production of phosphate remains below the limit. After the milk quota was lifted, dairy farming has grown strongly. As a result, the production ceiling for phosphate was exceeded (RVO, n.d.a). It is expected that this law will still be in force by 2030.

The 'Rural Development Program' from the EU aims to restore, preserve and enhance ecosystems related to agriculture (EC, n.d.). This will be done by developing the Dutch countryside, while at the same time improving sustainability and making room for innovation (RVO, n.d.b). The program provides a subsidy for organisations that provide training to farmers, organise workshops and coach a group of farmers focused on sustainable and nature inclusive farming. Applications for the next round of subsidies is from June 3rd 2019 to July 15th 2019 (Provincie Gelderland, n.d.a). Currently, the third Rural Development Program (POP3) is executed. This subsidy is for organisations that provide training to farmers, organise workshops and coach a group of farmers focused on sustainable and nature inclusive farming. Applications for the next round of subsidies is from June 3rd 2019 to July 15th 2019 (Provincie Gelderland, n.d.a). In the beginning of 2020, the POP4 program will follow (Provincie Fryslan, n.d.).

### Regional and local level

The province of Gelderland has the initiative to support the idea of producing local food and making the food chain shorter (Provincie Gelderland, n.d.b). Additionally, when an agricultural building is no longer needed for agricultural activities, a farmer can contact the municipality and the province of Gelderland to apply for a project to give it a different function (Forum Gelderland, n.d.).

Another possibility is to apply for a subsidy from the province of Gelderland to get money from the European funds for regional development (EFRO). Farmers can apply for this when they have a new idea for the development of a (sustainable) product. Working together with other stakeholders and focusing on innovation and $CO_2$ neutral will be appreciated (Provincie Gelderland, 2019).

## A2.3 Energy and carbon sequestration

### European level

The future energy policies are set out by the European Commission (EC) for the short term in 2030 and longer term in 2050. The policies will be set in order to achieve the targets for a more competitive, secure, and sustainable energy system, and the reduction of greenhouse gas (GHG) emissions (EC, 2011; EC, 2014). Achieving those targets through renewable energies will not be more costly than paying to replace a new energy system, thus emphasis is made on shifting towards low-carbon technologies. The agricultural sector seems to have a great role in this strategy (EC, 2014).

The targets for 2030 include a 40% GHG emission reduction compared to 1990 levels, a 32% use of renewable energies at least, and 32.5% improvement on energy efficiency at least (EC, 2014). To achieve the targets the European Commission proposed measures such as the improvement of the EU Emission Trading Systems, and the submission of National Climate and Energy Plans (NECPs). The Netherlands submitted their drafts at the end of 2018.

The EC sharpens Europe's targets towards 2050, which focuses on the reduction of GHG emissions by 80%-95% compared to 1990s levels. Thus, the EC's Energy Roadmap (2011) sets out more ambitious routes on energy efficiency, renewable energy, and carbon capture storage. Therefore, more policy incentives (e.g. subsidies, taxes) for energy systems will be supplied, and more emphasis is given on the responsibility for local organisations. Furthermore, it appears that renewables will contribute to the biggest share of energy supply technologies, and renewables will become an important energy source in Europe. The EC calls for the need for low carbon and locally produced energy sources and renewable energies (EC, 2011).

The agriculture sector contributes to almost 10% of GHG emissions especially for food production and transport, but it also contributes to the removal of GHG. Livestock production or fertiliser cause a lot of emissions for example, while activities such as agroforestry contribute to emission reductions through carbon sequestration. Therefore, the sector may help to achieve several objectives, for instance, food and feed production, energy production, rising environmental quality and climate change mitigation and adaptation (EC, 2014). At the moment, the emissions and removals of GHG are treated in different parts of EU's climate policy and the aim is to include those in the GHG reduction targets for 2030 and 2050 building on the CAP and ensuring coherence with other European Union policies (EP, 2016).

The agriculture sector is an important player in the implementation of new energy systems and renewable energy sources (EC, 2011). There is a great potential from the availability of natural sources: wind, sunlight, biomass and agricultural waste. The development of on-farm renewables can contribute to rural development. Farmers in the EU get involved in renewable energy production for economic reasons, as a way of income diversification and stabilisation. Furthermore, farmers become less dependent on other energy suppliers and contribute to sustainability objectives. Additionally, this expansion may lead to infrastructure development and increase of employment, as more labour and expertise is required on farms for renewable energy production. High investment costs and profitability uncertainty are main challenges for including those activities, which explains why small scale farmers are excluded from such investment. To address this problem, policies aim to provide easier permits and subsidies to encourage all farmers to engage in these activities (EP, 2016).

### National level

The Netherlands has made an 'energy agreement' with more than 40 organisations on the future of Dutch energy production (GEA, 2015). In this agreement, it is stated that the Netherlands is aiming to produce more renewable energy in the future. They have set the goal to produce 14% of the energy by renewable energy sources in 2020 and 16% in 2023. The agreement mentions the agricultural sector as an energy-intensive sector and therefore as a potential sector where contributions for energy efficiency can be made. One of the pillars of the agreement states that an importance of creating more renewable energy is through the upscaling of renewable energy production projects. On land, the focus is put on wind and solar energy. A main part of the agreement is the importance of the participation of local citizens in these projects. Furthermore, the decentral production of energy by people is stimulated (SER, 2013).

The policy for the future demands that a new tree needs to be planted once a tree is cut down. Furthermore, it is stated that changes in soil management need to take place. Practices like plowing cause the soil to store less carbon. If these kind of practices are changed, for example, by is for example changed to conservation tillage. This policy increases the carbon storage in the soil. (Klimaatakkoord, n.d.)

### Regional and local level

The province of Gelderland aims to follow the goals set by the social-economic council (SER), and has the ambition to be climate neutral in 2050. Within the Gelders energy agreement the province of Gelderland stated the vision for renewable energy production with wind, solar, water, and biomass (GEA, 2015):

- Wind: the province of Gelderland states that there are possibilities to build wind turbines. Furthermore, there is a corporation of different actors in the IJsselwind project. The IJsselwind project is a collaboration between four energy corporations in which citizens make efforts to produce sustainable energy. Cooperating in this project is also a possibility for farmers.

- Solar: the province of Gelderland stimulates to use unused agricultural land for the placement of solar panel fields. Additionally, other unused lands like dikes are recommended for the placement of solar panels.
  The province of Gelderland currently_finances several projects that stimulate the installation of solar panels on farmyards. These solar panels are placed on the location of empty barns. This could be a possibility for farmers that consider different ways of farming or stop farming altogether (Omroep Gelderland, 2018)
- Water: RoyalHaskoningDHV (2016) did exploring research on the potential of energy production out of the water in the province and identified specific potential places. The conclusions do not indicate any potential for energy production by water in the area of Brummen. Cribs on the IJssel seem currently less suitable because of the shorter length of the cribs compared to the size of the turbines. Furthermore, compared to other rivers in the Netherlands the impact on the waterway is expected to be greater in this river as well.
- Biomass: the Gelders energy agreement states biomass as a potential for an important energy source. However, this source needs to be upscaled and more research is needed to be profitable in the market.

The municipality of Brummen has the ambition to produce all the energy used in the municipality self-sufficient and sustainable. They also aim to be energy neutral in 2030. By doing this, the municipality wants to contribute and be part of the energy agreement of the province of Gelderland (Gemeente Brummen, 2016).

## A2.4 Water management

### National level

In the Netherlands there are some regions where fresh water supply is available, the waterboard will ensure that these regions will be secured in their freshwater supply in the future. There are also some regions that do not have their own fresh water supply. In these regions, retention will become highly important instead of the current removal of this water. In case of shortages in freshwater, the government will decide which sectors will receive freshwater. Economically important areas will be protected against a decrease in freshwater availability. To improve the efficient use of freshwater, pilot projects will be developed (MIW, 2015).

Many rivers and streams in the Netherlands are not meeting the requirements for water quality. This means that extra effort is needed to reach the water framework directive. For this more collaboration with among others ’Planbureau Leefomgeving’ is desired. To improve water quality, it is planned to study the manure and pesticides applications. In the end, extra effort is needed to improve the water quality by reducing the input of chemical substances and increasing the space for plants and fish, especially in regional waters (MIW, 2015).

The Dutch government wants to be climate resilient and water robust in 2050. This means that for example areas and water systems should be protected against floods. To test measures taken on their effectiveness against floodings a tool (‘de watertoets’) has been developed (MIW, 2015).

### Regional and local level

On the local level, the waterboard Vallei en Veluwe will put more focus on retaining water in the area and efficiency in water use. They will focus on using water as a landscape service and water in soils and small streams will become more important. The water treatment will be done more at the point of the contamination. When water is cleaned in the larger treatment plants, it will be returned to the area to improve the water retention. Not only water treatment is important, but the efficient use of water will also become more important (Waterschap Vallei en Veluwe, 2019).

When water protection measures are taken, sustainable agriculture and nature areas will be considered. On the hilly parts of the Veluwe, wet nature areas are going to be developed, called the ‘klimaatmantel’. Especially in the areas where dry and wet periods are alternating each other, this will be an important focus point. Areas surrounding the ‘klimaatmantel’ will become more important for nature inclusive agriculture, water retention, and natural development will be major focus points. To give nature more space in agriculture in these areas, a lot of small streams are intended. This is needed since nature areas in Brummen will become too dry in the future. When farmers are disadvantaged by this water retention, they will be compensated. In the agricultural sector, more focus will be put on recycling agriculture (‘kringlooplandbouw’) in which healthy soil and less dependence on pesticides and fertilizer are important goals. For that, organic matter retention is important, which will influence water retention in agricultural soils as well. The water systems will also be adapted to the local soils and in close collaboration with its users. Due to less water in the summer, the IJssel will not be available for water for farmers, the water board will make sewage water available as an optional source of water. When farmers themselves want to take measures considering water retention, the waterboard is willing to think along and might provide some subsidies (van der Werfhorst, 2019; Waterschap Vallei en Veluwe, 2019).

In the municipality of Brummen, water is also important. The goal is to separate rainwater from sewage water in cities which will increase the water availability for streams. However, research is still ongoing to make sewage water suitable for agricultural areas. Furthermore, the municipality of Brummen wants to develop water retention areas along the ‘Apeldoornse Kanaal’ and streams will be widened to reduce water problems for the agricultural sector (Tauw, 2008).

From DAW (Deltaplan Agrarisch Waterbeheer), subsidies are available when a farmer wants to contribute to different projects (DAW, n.d.). Currently, DAW has a project which focuses on working together with organisations and farmers on agricultural water management in Zuid-Oost Veluwe. In this project, dry and wet periods of the area will be dealt with and farmers can play an important role to retain water on their land and improve the water quality by reducing the impact of nutrients and pesticides.

# Appendix 3: List of business practices

| Business practice | Description | Landscape services | Sources |
|---|---|---|---|
| **Flowering field edges** | Flower strips around the fields. | • Food production<br>• Water purification<br>• Biodiversity<br>• Characteristic plants<br>• Pollination | Erisman et al., 2017<br>Marshall, 2004<br>Robert et al., 2015<br>Winkler, 2005 |
| **Cover crops** | Prevent bare soils by planting winter crops | • Food production<br>• Water retention<br>• Biodiversity<br>• Pollination<br>• Carbon storage<br>• Decomposition | Fageria et al., 2005<br>Teasdale, 1996<br>Yao et al., 2019 |
| **Conservation tillage** | Reduce tillage, leaving some crop residues behind | • Carbon storage<br>• Decomposition<br>• Water retention<br>• Food production | Balota et al., 2003<br>Erisman et al., 2017<br>Gebhardt et al., 1985<br>Peigné et al., 2007 |
| **Hydroponics** | Cultivate crops in mineral rich water | • Food production | AlShrouf, 2017<br>Banks, 1993 |
| **Aquaponics** | Water, plants and fish combined in a cycle | • Food production<br>• Water purification | AlShrouf, 2017<br>Diver & Rinehart, 2000 |
| **Agroforestry** | Combine crops, trees and animals | • Food production<br>• Pest regulation<br>• Biodiversity<br>• Water retention<br>• Pollination<br>• Characteristics plants & animals | Boosten, 2018<br>WUR, 2019 |

| | | | |
|---|---|---|---|
| **Intercropping** | Combine different crops in one field | • Pollination<br>• Biodiversity<br>• Food production<br>• Carbon sequestration<br>• Pest control | Liebman & Dyck, 1993<br>Vandermeer, 1992<br>Ofori & Stern, 1987 |
| **Cows in meadows** | Keep the cows in meadows | • Food production<br>• Place identity<br>• Biodiversity | Erisman et al., 2017<br>Reijs et al., 2013<br>Rook & Tallowin, 2003<br>Williamson, 2015 |
| **Grass-fed cows** | Feed the cows grass only | • Food production<br>• Biodiversity<br>• Place identity | Erisman et al., 2017<br>Orr et al., 2001 |
| **Herb rich grass** | Increase variety in grass that is fed to cows | • Biodiversity<br>• Food production<br>• Natural pollination | Erisman et al,. 2017<br>Laldi, n.d.<br>Karydi, 2015 |
| **Food production dairy cows** | Grow a variety of crops to make feed | • Biodiversity<br>• Inspiration<br>• Food production<br>• Raw material | Victor Pellet Mill, 2017<br>Edupot, 2005 |
| **Guilds** | Combination of different plant and animals | • Biodiversity<br>• Food production<br>• Pollination<br>• Water retention<br>• Pest regulation | Neverendingfood, 2019 |
| **Cow specific milk** | A milking robot that tracks from which cow it came | • Food production<br>• Place identity | Lely, 2018 |
| **Diversification cow breeds** | Different breeds of cows are added in the herd | • Food production<br>• Biodiversity<br>• Characteristic plants & animals<br>• Place identity | Hofman, 2018<br>Stokkermans, 2018<br>Vellinga, 2018 |

| | | | |
|---|---|---|---|
| **Crop rotation** | Grow a variety of crops alternating each other | • Food production<br>• Carbon sequestration<br>• Pest regulation<br>• Biodiversity | Natuurinclusief-landbouwinitiatief, 2019<br>Rangarajan, n.d.<br>Wolf et al., 2017 |
| **Integrated pest management** | Efficient and effective use of less and natural pesticides | • Pest regulation<br>• Water purification<br>• Biodiversity<br>• Food production | Barzman et al., 2015<br>Kogan, 1998<br>Stenberg, 2017 |
| **Permaculture** | Agriculture using natural ecosystems | • Food production<br>• Pollination<br>• Biodiversity<br>• Water retention<br>• Pest regulation<br>• Carbon sequestration | Doherty 2018<br>Ferguson & Lovell, 2017<br>Krebs & Bach, 2018<br>Mollison et al., 1991 |
| **Mulching** | Leaving crop residues behind | • Water retention<br>• Decomposition<br>• Carbon sequestration<br>• Biodiversity | Mulumba & Lal, 2008<br>Sabata, n.d.<br>Qin et al., 2015 |
| **Adding compost** | Add compost as a fertilisation method | • Carbon sequestration<br>• Water retention | Wong et al., 1999 |
| **Rainwater harvesting ponds** | Having ponds on the farm to catch water | • Water storage<br>• Recreation | Pandey et al., 2003 |
| **Increasing forest cover** | Planting more trees on farm | • Carbon sequestration<br>• Biodiversity<br>• Pest regulation<br>• Natural pollination | EC, 2014 |

| | | | |
|---|---|---|---|
| **Incorporate legumes in meadows** | Have crops like clover more in the meadows | • Carbon sequestration<br>• Water purification<br>• Biodiversity<br>• Pest control | EP, 2017<br>Gonzálvez et al., 2018<br>Naturesseed, 2019 |
| **Cows in nature** | Fattening of cows by letting them roam in nature areas | • Place identity<br>• Food production<br>• Biodiversity | Natuurmonumenten, 2019 |
| **Sewage water as manure** | Using sewage as manure | • Food production | Toekomstboeren, 2019<br>Sciencedaily, 2019<br>Hargreaves et al., 2008 |
| **Solar panels** | Partly or full installation of solar panels | • Energy production<br>• Air purification | EP, 2016 |
| **(Mini) wind turbines** | Big or small wind turbines that can be installed in farms | • Energy production<br>• Air purification | EP, 2016<br>Extension, 2019 |
| **Biomass** | Growing crops for energy production | • Carbon sequestration<br>• Bio-energy<br>• Raw materials | EP, 2016<br>Zegada-Lizarazu & Monti, 2011 |
| **Manure biogas** | The CO2 and Methane in manure can be transformed into natural gas | • Bio-energy<br>• Carbon sequestration<br>• Air purification | Plochl & Heiermann, 2006 |
| **Rainwater harvesting energy** | To generate electricity and freshwater | • Water retention<br>• Energy production | Vierira et al., 2014 |

# Appendix 4: Feasibility check

## A4.1 Food production

### Hydroponics

**Area characteristics**

- Soil: This parameter does not affect hydroponic production.
- Upwelling water: This parameter does not affect hydroponic production.
- Topography: This parameter does not affect hydroponic production.
- Geography: This parameter does not affect hydroponic production.

**Climate parameters**

- Precipitation: Hydroponic systems are less dependent on the amount of precipitation and are therefore more robust and reliable in a changing amount of precipitation. Overall, hydroponics is feasible in the precipitation of Brummen.
- Temperature: Hydroponic systems are less dependent on the outside temperature and are therefore more robust and reliable in changing temperatures. Overall, hydroponics is feasible in the temperatures of Brummen.
- Evaporation: Hydroponic systems are less dependent on the amount of evaporation and are therefore more robust and reliable in a changing amount of evaporation. Overall, hydroponics is feasible in the amount of evaporation of Brummen.
- Water quantity: Hydroponic systems are less dependent on the amount of available water in the ground and are therefore more robust and reliable in a changing groundwater availability and depth. Overall, hydroponics is feasible in the available water quantity of Brummen.

**Socio-economic parameters**

- Agricultural market trends: There is a trend towards higher demand for local products. Hydroponics can create more variation in the products that are produced in Brummen. Overall, hydroponics fits in the trends in agricultural markets.
- Policies: Policies are aiming for more climate-resilient agriculture. Hydroponics is less dependent on climate variables and is, therefore, more resilient in a changing climate. Overall, hydroponics fits the trend in policies.

### Agroforestry

In this feasibility check, the focus will be on agroforestry with the use of nuts (hazelnut, walnut), grasses (wheat, ryegrass), fruit trees (apples, sweet cherries), berries (blueberries, raspberry), and vegetables (onion, potatoes). These are just examples of options farmers could apply and farmers can adapt the design to their own preferences. To check the suitability of these crops on the different soils in the area, the information was obtained from PFAF (n.d.).

**Area characteristics**

- Soil:
  - Walnuts tree (*Juglans regia*) is suitable for any type of soils: light-sandy soils, medium-loamy soils, and heavy-clay soils, and prefers moist but well-drained soils.
  - Hazelnut (*Corylus colurna*) can be grown in light (sandy), medium (loamy) and heavy (clay) soils. It grows best on moist soils.
  - Wheat (*Triticum aestivum*) can grow on light (sandy), medium (loamy) and heavy (clay) soils and prefers moist, well-drained soils.
  - Apple tree (*Malus domestica*) prefers well-drained soils and can be grown in light (sandy) soils, medium (loamy) soils as well as heavy clay soils. Moist soils are the most suitable for the growth of apple trees.
  - Sweet cherry (*Prunus avium*) is suitable for light (sandy), medium (loamy) and heavy (clay) soils and prefers well-drained but moist soils.
  - Blueberry (*Vaccinium corymbosum*) can be grown in light (sandy) and medium (loamy) soils. It prefers moist, well-drained soils.
  - Raspberry (*Rubus idaeus*) is suitable to be grown in light (sandy), medium (loamy) and heavy (clay) soils. It also prefers moist soils that are well-drained.
  - Onion (*Allium cepa*) can be grown on light (sandy) and medium (loamy) soils. It prefers well-drained but moist soils.
  - Potato (*Solanum tuberosum*) is suitable for growth on light (sandy), medium (loamy) and heavy (clay) soils and prefers moist, well-drained soils.
  - Grass (*Lolium perenne*) is suitable for light (sandy), medium (loamy) and heavy (clay) soils and prefers moist, well-drained soils.

  Overall, most crops seem to be suitable for the soils in the municipality of Brummen.

- Upwelling water: Almost all of the previously mentioned crops grow best in well-drained soils. This means that none of these crops is suitable in areas with a lot of upwelling water. An examination of crops that perform well in wetter areas needs to be performed. Blueberries are able to grow in soils with high water tables (up to 40 cm) (Blommers, 1979). Furthermore, sweet cherries have shallow root systems as well and prefer to grow in deep moist soils (PFAF, n.d.). In areas with little upwelling water, the abovementioned crops are suitable. Thus, if a proper design is made in which the local circumstances are taken into account, the business practice is likely to work.

- Topography: It is important to consider that obtaining results of the implementation of agroforestry is going to take a while since the trees grow slowly. Therefore, it is recommended for farmers to implement this practice when having a successor or when having a long-term plan for the farm to actually obtain the benefits.

- Geography: Crops and trees that cannot handle wet soils very well can best be grown in the higher areas of Brummen to the west. Other crops need to be considered that can be grown in wetter areas. If this is done, the business practice is suitable for the area of Brummen.

**Climate parameters**

- Precipitation:
  - Walnuts tree (*Juglans regia*) needs about 890 mm of annual precipitation. This means the growing circumstances in Brummen regarding precipitation will be sufficient (USDA, 2002). The tree especially requires water during the months July & August to prevent the growth of small walnuts. However, in the future, the amount of wet days and precipitation is expected to increase for these months (Wertheim, 1981).
  - Hazelnut (*Corylus colurna*) requires water during its growing season. In most months, an increase in precipitation can be observed. Furthermore, in July and August, an increase in wet days is expected. This can create favourable growing conditions.
  - Wheat (*Triticum aestivum*) is susceptible to droughts. This means the trend of more rain will probably turn out well for wheat (PFAF, n.d.).
  - Apple tree (*Malus domestica*) needs about 1000 to 1250 mm of precipitation through the year (NHB, n.d.). In the future, the precipitation in Brummen is expected to be about 892 mm. Therefore, there might be a slight shortage.
  - Sweet cherry (*Prunus avium*) grows best in precipitation ranges of about 500 to 1100 mm (Welk et al., n.d.). This makes the crop suitable for the future climate.
  - Blueberry (*Vaccinium corymbosum*) has a shallow root system. Therefore, they depend on higher groundwater tables and precipitation. Precipitation is likely to increase in the future, making the tree suitable for Brummen (Blommers, 1979).
  - Raspberry (*Rubus idaeus*) is most suitable to grow in areas with an annual rainfall of 800 to 1000 mm (IADK, 2015). Regarding precipitation, raspberry is suitable to grow in Brummen.
  - Onion (*Allium cepa*) requires 350 to 550 mm water. Therefore, the future circumstances in Brummen might be too wet (FAO, n.d.a).
  - Potato (*Solanum tuberosum*) has an optimum precipitation amount of 650 to 800 mm a year. This is a bit lower than the future precipitation in Brummen (Dvorak et al., 2016).
  - Grass (*Lolium perenne*) is susceptible to drought. The crop needs at least 457 mm annually, and in dry summers it needs at least 650 mm (CABI, n.d.).

  Overall, the suitability of the abovementioned crops regarding precipitation depends on the species. Therefore, farmers need to take local circumstances into account when implementing an agroforestry system.

- Temperature:
  - Walnuts tree (*Juglans regia*) requires an average annual temperature of about 13°C (USDA, 2002). The average annual temperature in the future will be about 10.9°C, which means it is a bit low. Furthermore, in the future, more freezing days will be found in the spring. This can damage the flowers (Wertheim, 1981).
  - Hazelnut (*Corylus colurna*) handles frost during flowering well, so an increase in freezing days in the spring will not affect this crop. However, axillary buds cannot handle severe frosts in the spring. Furthermore, low temperatures during the growing seasons cause empty nuts. However, the temperature is

increasing and more days with high temperatures will be observed (Wertheim & Goedegebure, n.d.).

- Wheat (*Triticum aestivum*) grows best in temperatures between 15°C to 20°C. For ripening, a period of 18°C or more is preferred (FAO, 2019). The increase in temperature does thus not seem to be a problem for wheat.
- Apple tree (*Malus domestica*) grows best in summer with temperatures between 21°C and 24°C (NHB, n.d.). According to the climate assessment, the 24-hour average is expected to be around 17°C to 21°C. This means that the temperature during the day will be higher. However, it seems that these temperatures will be suitable for apple trees. In the future, more days with temperatures exceeding 25°C are expected, which might reduce the yield.
- Sweet cherry (*Prunus avium*) grows best in annual average temperatures of 10°C. The annual average temperature found in the climate assessment is 10.9°C, which means the circumstances are sufficient for cherries to grow in. In the future, more days with temperatures exceeding 25°C are expected (Welk et al., n.d.).
- Blueberry (*Vaccinium corymbosum*) has an optimum temperature range of 18°C to 26°C (Retamales & Hancock, 2018). The 24-hour average is expected to be around 17°C to 21°C. This means that the crop is suitable to grow in Brummen.
- Raspberry (*Rubus idaeus*) grows best in temperature from 21°C to 24°C. High temperatures should be avoided. This means that in Brummen, farmers might consider planting the bush in some more shaded areas (SFGATE, n.d.a).
- Onion (*Allium cepa*) has optimum growing temperatures of 15°C to 20°C (FAO, n.d.a). The 24-hour average is expected to be around 17°C to 21°C. This means that the temperature during the day will be a bit higher, but still close to the optimum temperature. Therefore, it is expected that this crop can grow in Brummen as long as the temperatures do not get too high.
- Potato (*Solanum tuberosum*) has an optimum temperature of 20°C to 25°C. A temperature of more than 30°C causes a reduction in growth (Loon et al., 1993). The 24-hour average is expected to be around 17°C to 21°C. This means that the temperature during the day will be a bit higher and thus similar to the optimum temperature. Therefore, it is expected that this crop can grow in Brummen as long as the temperatures do not get too high.
- Grass (*Lolium perenne*) has optimum growing temperatures of 18°C to 20°C, since it is a C3 grass. It is best suited for growing in temperate climates, which means that it should be suitable to grow in Brummen (CABI, n.d.). However, it can be affected by the increasing temperature.

Overall, the suitability of the abovementioned crops regarding the future temperature in Brummen depends on the plant species. Therefore, farmers need to take future local circumstances into account when implementing an agroforestry system.

- Evaporation: Evaporation is likely to increase with the rising temperatures, but more precipitation is available in some of the summer months that could compensate for higher evaporation.

- Water quantity: Spring and summer groundwater tables seem to be the most important for the crops. Many crops cannot properly grow in areas with higher groundwater tables. This could be a problem in spring, where a large part as high groundwater tables. Blueberries are able to grow in soils with high water tables (up to 40 cm) (Blommers, 1979). Furthermore, sweet cherries have shallow root systems as well and prefer to grow in deep moist soils (PFAF, n.d.). However, in summer the groundwater table is much lower and will be expected to reduce even more. Therefore, fewer problems will occur with crops. Overall, as long as the groundwater table is taken into account when choosing the crop species, the business practice is feasible in Brummen.

**Socio-economic parameters**

- Agricultural market trends: Since meat consumption may decrease in the long-term and the dairy sector may suffer from price volatility, it is interesting to either combine cattle grazing between trees (for shade) or change their farm altogether. Combining different crops is a way of risk spreading. Farmers are able to process and/or sell the products (e.g. walnuts, hazelnuts, berries). The consumption of nuts is expected to increase, which would make the growth of this tree feasible.  Overall, agroforestry is suitable regarding the market trends.

- Policies: Carbon sequestration is an important objective of the EU. Subsidies from the CAP post-2020 will be provided for climate change mitigation and adaptation in agricultural practices. There might be an option for farmers to benefit from these subsidies and use them to change their business practice since the trees are a way of sequestering carbon. Furthermore, combining different trees and crops together improves the biodiversity of the area both because of the different crops combined and because of the attraction of wildlife (for which e.g. apple trees are known). In addition, it also improves the appreciation of the area. Overall, agroforestry is suitable in the trends for policy.

## Intercropping

The feasibility check for intercropping will be executed with the combination of the following species: clover, wheat, maize, alfalfa, potato, carrots, onion. To check the suitability of these crops on the different soils in the area, the information was obtained from PFAF (n.d.).

**Area characteristics**

- Soil:
  - Clover (*Trifolium repens*) is able to grow on light (sandy), medium (loamy) and heavy (clay) soils. It prefers well-drained but moist soils. It is able to grow on soils that are poor in nutrition and on heavy clay soils.
  - Wheat (*Triticum aestivum*) grows on light (sandy), medium (loamy) and heavy (clay) soils and it prefers moist, well-drained soils.
  - Maize (*Zea mays*) is suitable for growing on light (sandy), medium (loamy) and heavy (clay) soils, preferably well-drained but still moist.
  - Alfalfa (*Medicago sativa*) can be grown on light (sandy), medium (loamy) and heavy (clay) soils. It is able to grow on poor soils and it prefers well-drained soils. However, it can grow on dry and moist soils.

  - Potato (*Solanum tuberosum*) is suitable for growing on light (sandy), medium (loamy) and heavy (clay). The crop prefers well-drained soils.
  - Carrot (*Daucus carota*) is grown on light (sandy), medium (loamy) and heavy (clay), preferably on moist but well-drained soil.
  - Onion (*Allium cepa*) can be grown on light (sandy) and medium (loamy) soils. It prefers moist, well-drained soil.

  Overall, most crops seem to be suitable for the soil types in Brummen. However, not all crops can grow on wet soils. Therefore, a proper design should be made in which the local circumstances are taken into account.

- Upwelling water: All above-mentioned crops are not very suitable for areas with upwelling water since they required well-drained soils. Therefore, other crops need to be chosen in areas that deal with upwelling water. When this is done, the business practice will be suitable for Brummen. Overall, this parameter suitability depends on the crops introduced.

- Topography: This parameter does not affect intercropping.

- Geography: Crops that cannot handle wet soils very well can best be grown in the higher areas of Brummen to the West. However, as long as the soils are not too wet, the crops can be grown in lower parts of the municipality as well. Overall, this parameter suitability depends on the crops introduced.

**Climate parameters**

- Precipitation:
  - Clover (*Trifolium repens*) prefers moist soils (PFAF, n.d.).
  - Wheat (*Triticum aestivum*) is susceptible to droughts. This means the trend of more rain will probably turn out well for wheat (PFAF, n.d.).
  - Maize (*Zea mays*) needs about 500 to 800 mm annually (FAO, n.d.b). This is close to the future climate predictions.
  - Alfalfa (*Medicago sativa*) can tolerate drought (PFAF, n.d.). Crop water requirements are about 800 to 1600 mm during the growing period, depending on the growing period and the climate (FAO, n.d.). In Brummen, the annual precipitation will be about 890 mm, which means that there might be a slight shortage depending on the length of the growing season.
  - Potato (*Solanum tuberosum*) has an optimum precipitation amount of 650 to 800 mm a year. This is a bit lower than the future precipitation in Brummen (Dvorak et al., 2016).
  - Carrot (*Daucus carota*) requires approximately 900 mm of water during a crop cycle. Therefore, future precipitation amounts come close to the needs of the crop. However, additional irrigation might be necessary (Starke Ayres, n.d.).
  - Onion (*Allium cepa*) requires 350 to 550 mm water. Therefore, the future circumstances in Brummen might be too wet (FAO, n.d.a).

  Overall, not all crops are equally suitable to grow in Brummen. For certain crops, irrigation might be required. However, when selecting the right crops, the business practice is suitable for Brummen.

- Temperature:
  - Clover (*Trifolium repens*) is fully hardy (PFAF, n.d.).
  - Wheat (*Triticum aestivum*) grows best in temperatures between 15°C to 20°C. For ripening, a period of 18°C or more is preferred (FAO, 2019). The increase in temperature does thus not seem to be a problem for wheat.
  - Maize (*Zea mays*) tolerates hot and dry atmospheric conditions as long as enough water is available. Furthermore, temperatures need to stay below 45°C (FAO, n.d.b) Therefore, it will be suitable to grow in Brummen in the future climate.
  - Alfalfa (*Medicago sativa*) is fully hardy and can tolerate drought (PFAF, n.d.) The optimum temperature is about 25°C, but has a growth range between 10°C and 30°C. This makes the crop suitable for the future climatic conditions in Brummen (FAO, n.d.c)
  - Potato (*Solanum tuberosum*) has an optimum temperature of 20°C to 25°C. A temperature of more than 30°C causes a reduction in growth (Loon et al., 1993). In the future, an increase in days with temperatures higher than 25°C will be observed, which could damage the yield.
  - Carrot (*Daucus carota*) grows best in areas with temperatures between 15.6°C and 21.1°C. Temperatures lower than 10°C inhibits the growth of foliage. Temperatures higher than 30°C will cause the production of undesirable flowers (SFGATE, n.d.b). Since the temperature will exceed 30°C in the future more often, this might cause undesirable flowers.
  - Onion (*Allium cepa*) has optimum growing temperatures of 15°C to 20°C (FAO, n.d.a). The temperature seems to be increasing and in the summer higher temperatures will be expected. This may affect the yield.

    The temperature is expected to increase in the future. However, some crops are drought resistant or can tolerate high temperatures. With the proper design, this business practice is applicable in Brummen.

- Evaporation: Evaporation is likely to increase with the rising temperatures, but more precipitation is available in some of the summer months that could compensate for a higher evaporation.

- Water quantity: Spring and summer groundwater tables seem to be the most important for the crops. Many crops cannot properly grow in areas with higher groundwater tables. This could be a problem in spring, where a large part as high groundwater tables. However, in summer the groundwater table is much lower and will be expected to reduce even more. Therefore, fewer problems will occur with crops.

**Socio-economic parameters**

- Agricultural market trends: The trends predict an increase in intake of plant-based proteins, which will make intercropping an interesting business practice if the products are sold for consumption. Furthermore, it is expected that consumers prefer buying products locally to reduce emissions and to know where their food came from. Farmers might be able to sell some of the products, such as carrots, potatoes and onions, to locals, directly on their farm, via supermarkets or to healthcare institutes. Thus, intercropping fits the market trends.

- Policies: Combining different trees and crops together improves the biodiversity of the area both because of the different crops combined and because of the attraction of wildlife (for which e.g. alfalfa is known). Furthermore, it also improves the appreciation of the area. Additionally, clover and alfalfa are nitrogen-fixing plants. If farmers grow these crops on their field, they will be able to use less fertiliser. Therefore, intercropping fits in the trends in policies.

## Permaculture

The feasibility check of permaculture will focus on a design in which sweet chestnut, walnut, linden tree, apricot, apple, elderberry, raspberries, goji berry, strawberry, leek, broccoli, rhubarb, pumpkin, garlic, turnip greens, broad beans, bulrush, reeds, mushrooms. For these crops, the permacultuur Nederland (n.d.) or PFAF (n.d.) are used as a reference. If no site is mentioned it comes from these sites. In this design, it is possible to add cows, chickens, pigs, sheep and bees combined with some grassland.

**Area characteristics**

- Soil:
    - Sweet chestnut (*Castanea sativa*) can grow in all soils, moist or dry.
    - Walnut tree (*Juglans regia*) is suitable for any type of soils: light-sandy soils, medium-loamy soils, and heavy-clay soils, and prefers well-drained soils.
    - Linden tree (*Tilia x europaea*) can grow in all soil types, prefers a moist soil.
    - Apricot (*Prunus armeniaca*) can grow on sandy or loamy soils, not heavy clay and prefers a well-drained soil.
    - Apple (*Malus domestica*) prefers moist soils.
    - Elderberry (*Sambucus nigra*) can grow in all soils, also heavy clay soils that have enough nutrients and is a bit moist.
    - Raspberries (*Rubus idaeus*) is suitable to be grown in light (sandy), medium (loamy) and heavy (clay) soils. It also prefers soils that are well-drained.
    - Goji berry (*Lycium barbarum*) prefers a bit moist soil and can grow in a nutrient-poor soil.
    - Strawberry (*Fragaria*) prefers well-drained soils that are nutrient rich
    - Leek (*Allium porrum*) can grow in all soils as long as it is not to loamy or heavy clay and prefers the ground a bit moist.
    - Broccoli (*Brassica oleracea cymosa*) can grow on all soil types, well drained but still moist and nutrient rich.
    - Rhubarb (*Rheum rhabarbarum*) likes a very nutrient rich moist soil.
    - Pumpkin (*Cucurbita maxima*) likes moist nutrient-rich soil, can also grow on a composting area.
    - Garlic (*Allium sativum*) can handle drought and moist soils but cannot grow on heavy clay soils.
    - Turnip greens (*Brassica rapa*) prefer a moist soil.
    - Broad beans (*Vicia faba*) can grow on all soils, also heavy clay soils.
    - Bulrush (*Typha latifolia*) needs a very moist soil that is nutrient rich.

- Reeds (*Phragmites australis*) needs a very moist soil or part of year completely submerged.
- Mushrooms (*Agaricus bisporus*) can grow in the composting area.

Overall, the Brummen region is suitable for this type of farm, depending on the vegetables chosen there is a need for more or less fertilisation.

- Upwelling water: The walnut, apricot, raspberry, strawberry and broccoli cannot grow in areas where upwelling water is found. The other crops are not that affected by upwelling water.

- Topography: The advantage of permaculture is that it can also be productive in small areas so you can also apply principles of permaculture in gardens.

- Geography: Depending on prefered soil moisture of different crops it is a good idea to choose crops that need a well-drained dry soil on higher locations and moist preferring crops at lower locations. In general, this can be adapted with the design so the Brummen region is suitable for permaculture.

**Climate parameters**

- Precipitation
  - Sweet chestnut (*Castanea sativa*) can deal very well with droughts, especially when it's established. This means that crop is suitable for the trend in which the number of dry days will increase.
  - Walnut tree (*Juglans regia*) can handle droughts, so can grow in the future climate with more dry days.
  - Linden tree (*Tilia x europaea*) can handle future precipitation patterns.
  - Apricot (*Prunus armeniaca*) can also handle droughts and will thus be suitable when the number of dry days increases.
  - Apple (*Malus domestica*) will be suitable for the future climate.
  - Elderberry (*Sambucus nigra*) is a tolerant plant and can grow in future precipitation patterns.
  - Raspberries (*Rubus idaeus*) will be suitable for future precipitation.
  - Goji berry (*Lycium barbarum*) can handle some droughts so the increase in dry days will not be a problem for this crop.
  - Strawberry (*Fragaria*) needs enough water especially in the summer to cool. This means that the amount trend in increasing rain in the summer is good. However, the amount of dry days is increasing so there might be some problems with drought stress (Dijkstra, 1986).
  - Leek (*Allium porrum*) needs quite some water, especially in the summer. This means that the increased amount of precipitation will be good for leek in the summer (Kraker de, 1993).
  - Broccoli (*Brassica oleracea cymosa*) is sensitive for droughts especially in the summer and there will be more dry days and less wet days in these periods, making it a bit risky to cultivate this crop maybe (Everaart, 1993).
  - Rhubarb (*Rheum rhabarbarum*) is sensitive to droughts in the spring this means that the increase in dry days can become a problem. However, in the summer

the roots will be well developed and the crop can handle droughts (Wijk van, 1998).

- Pumpkin (*Cucurbita maxima*) needs not to dry and not to wet conditions. This means that the more wet summer is favourable, however, the increase in dry days can be a problem (Minderhoud & Troost, 2008).
- Garlic (*Allium sativum*) will develop better when the spring is drier. There is an increase in dry days, however in some months there is also more rain and this can become a problem (Teeltaanwijzing knoflook, n.d.).
- Turnip greens (*Brassica rapa*) can be affected by the increase of dry days in the spring. It could be a problem for the development of turnip greens. However, there is no decrease in the amount of rain so it could be compensated (Stek, n.d.).
- Broad beans (*Vicia faba*) needs enough moisture so the increase in rain is positive for this corp (Neuvel, 1991).
- Bulrush (*Typha latifolia*) is not affected by precipitation because it's a plant that grows in ponds.
- Reeds (*Phragmites australis*) is not affected by precipitation because this plant grows in water.
- Mushrooms (*Agaricus bisporus*) is not affected by this parameter since it grows in a greenhouse.

Overall, permaculture is a suitable business practice when looking at future precipitation patterns.

- Temperature:
  - Sweet chestnut (*Castanea sativa*) can be positively affected by the increase in temperature since this is good for the development of fruits.
  - Walnut tree (*Juglans regia*) cannot grow in the shade and prefers full sun. The tree is fully hardy.
  - Linden tree (*Tilia x europaea*) fits in trend.
  - Apricot (*Prunus armeniaca*) is really sensitive to frost so the fact that it becomes warmer in the spring is good. Furthermore, the warmer summers will be beneficial.
  - Apple (*Malus domestica*) can be sensitive to sunburns, so the increasing temperatures in summer can be a problem. However, there are also signs that apples can adapt to these warm temperatures or you can start to grow them in more shade (Bloksma, 2003).
  - Elderberry (*Sambucus nigra*) is a tolerant plant and can deal with sunny conditions. However, it can also grow in the shade.
  - Raspberries (*Rubus idaeus*) can grow in future climate.
  - Goji berry (*Lycium barbarum*) can deal with warmer temperatures so fits in the future climate.
  - Strawberry (*Fragaria*) grows best between temperatures ranging from 16 to 27°C, meaning that the increasing summer temperatures will be favourable (Albert, n.d.a).
  - Leek (*Allium porrum*) grows best in temperatures below 30°C. This means the increase in hot days in the future might be a problem for the leek. However, in

permaculture, it is always an option to grow this crop in the shade (Albert, n.d. b).
  - Broccoli (*Brassica oleracea cymosa*) can best be sown in the fall since it is best in temperatures below 23°C and this will be exceeded more often in the future summer months (Albert, n.d.c).
  - Rhubarb (*Rheum rhabarbarum*) will be suitable in the future warmer summers since it can deal with temperatures up to 32°C before the growth is suppressed (The Rhubarb Compendium, 2010) .
  - Pumpkin (*Cucurbita maxima*) likes the warm weather so the trend that becomes warmer is favourable.
  - Garlic (*Allium sativum*) likes a warmer spring so the increasing spring temperatures will be suitable for this crop.
  - Turnip greens (*Brassica rapa*) will stay suitable since the spring temperatures rise, it can be sown earlier (Chaney, n.d.).
  - Broad beans (*Vicia faba*) might struggle with the warmer summer temperatures since it can grow in temperatures up to 24°C. However, again there is the possibility to grow this crop under another crop to reduce the heat (Albert, n.d.d).
  - Bulrush (*Typha latifolia*) is not affected by temperature since it grows in the water.
  - Reeds (*Phragmites australis*) is not affected by temperature since it grows in the water.
  - Mushrooms (*Agaricus bisporus*) is not affected by temperature since it grows in a greenhouse.

  Overall, permaculture can be a very suitable business practice in the warmer future, especially since the design can be adapted to fit the requirements of certain plants.

- Evaporation: This parameter does not affect permaculture as a business practice

- Water quantity:
  - Sweet chestnut (*Castanea sativa*) needs moist soils, but the groundwater table in the winter should not enter the rooting zone.
  - Walnut tree (*Juglans regia*) needs a well-drained soil so the groundwater table should not be too high. It can even be quite low since this tree can grow in drier conditions as well.
  - Linden tree (*Tilia x europaea*) likes a moist but well-drained soil so the groundwater table should not be too low in the sandy soils. The fact that some sandy soils will get a higher groundwater table can be positive as long as there is no water logging in the rooting zone.
  - Apricot (*Prunus armeniaca*) needs a well-drained soil so the changing climate that some groundwater levels will decrease is positive for this tree.
  - Apple (*Malus domestica*) is affected by a high or very low groundwater levels. Since the groundwater level will drop for almost the whole region some areas will become suitable. However, it should be considered that it is not too low to deliver water to the apple trees (Tuincentrum de Sweach, n.d.).

- Elderberry (*Sambucus nigra*) is quite easy and has no high demands for groundwater level. This means that almost the whole region will stay suitable, only the clay soils near the IJssel might not be suitable due to the fact that they will be to wet.
- Raspberries (*Rubus idaeus*) can deal with high groundwater tables. However, the soil should not be inundated for a long time. The raspberry prefers wetter areas to grow in. This means that in the future climate it should be taken into account that some regions will not be suitable anymore (Groenrijk, n.d.).
- Goji berry (*Lycium barbarum*) requires well drained soils, so the increased water tables in the spring might be a problem in some regions.
- Strawberry (*Fragaria*) needs well-drained soils. However, it does not root that deep so the groundwater level in the spring will only be a problem in some regions. The winter groundwater level does not change that much, however, it should not be too high now for strawberries to grow to be suitable in the future as well.
- Leek (*Allium porrum*) needs a low groundwater table since submerged it will die.
- Broccoli (*Brassica oleracea cymosa*) is affected by a groundwater level that exceeds 80 cm. This means that the winter groundwater table in the municipality might be too high to be suitable for this crop.
- Rhubarb (*Rheum rhabarbarum*) requires a groundwater level to be around 1 m. This means that only a small region will be suitable for this crop. However, the winter groundwater level does not matter for this crop since it is harvested before the winter.
- Pumpkin (*Cucurbita maxima*) requires not too high groundwater levels. There is no large change of groundwater levels in the spring so the regions that are suitable now will probably stay suitable in the future.
- Garlic (*Allium sativum*) has a quite shallow rooting depth so the groundwater level should not be too high, but most regions in Brummen will be suitable for this crop in the future.
- Turnip greens (*Brassica rapa*) has a very shallow rooting system. As long as the groundwater table does not enter the rooting depth it is suitable. This means that areas that are suitable now will stay suitable in the future since the spring groundwater level is not changing that much.
- Broad beans (*Vicia fab*a) needs groundwater levels that stay below 60 cm in clay and 80 cm in more sandy soils. This means that with the drier summer months more regions might become more suitable for this crop.
- Bulrush (*Typha latifolia*) is not affected by the water quantity because it grows in water.
- Reeds (*Phragmites australis*) is not affected by the water quantity because it grows in water.
- Mushrooms (*Agaricus bisporus*) is not affected by the water quantity because it grows in a greenhouse.

Overall, permaculture can be a suitable business practice when the groundwater levels will change. However, the design is very important and good combinations of crops and management practices have to be made to create the right circumstances for some vegetables.

**Socio-economic parameters**

- Agricultural market trends: Meat consumption may decrease in the long-term and EU dairy sector may suffer from price volatility. On the other hand, the consumption of fruits and vegetables is expected to increase, as well as local food preference for consumption. Permaculture will combine different types of crops from which farmers can obtain other products rather than products from cows. This may ensure and stabilise the income of the farmers towards the future.

- Policies: Permaculture fits in the future policies since permaculture will help to retain water and due to the use of renewable energy it will contribute to the goal of being energy neutral in 2030. Permaculture will also use less chemical fertilisers and pesticides which fits in the trend that water pollution will be stricter regulated and that agriculture has to become more nature inclusive.

## Feed production

In this feasibility check a business practice in which cereals, beets, seeds from oily and leguminous plants and forage crops will be studied For most crops and trees characteristics the PFAF.org site was used to get information from. If other sources have been consulted, these are mentioned specifically.

**Area characteristics**

- Soil: For beets, the soil type is not that important, it can grow both in sandy and clay soils, as long as the water management is not to dry or to wet (De Vliegher et al., 2006). Wheat can grow on most soil types as well as long as it is well drained but not to dry (PFAF, n.d.). For legumes you can, for example, go for lupine, this crop can also grow on both soil types however when it is heavy clay, drainage and structure should be guarded (Prins, 2015). Another legume crop that can be used is alfalfa. This crop requires well-drained soils so the clay soils near the IJssel might not be suitable (Praktijkonderzoek voor de akkerbouw en vollegrondsgroenteteelt, 1998). Rapeseed is a crop that requires a soil that has a high capillary rise so sandy soils and droughts are bad for the harvest (‘T Hoff & Sijm, 2006). For maize, it is important that the soils are well drained as well to start sowing in a warm soil earlier (Werkgroep Snijmaïs, 2019). Overall, it can be said that the not too dry more sandy soils of Brummen will be suitable for producing own feed.

- Upwelling water: In some places, there is upwelling water. These areas are not for most of the crops described above. Overall, this means that upwelling water can be a problem for producing own feed.

- Topography:  This parameter does not affect the business practice feed production.

- Geography:  This parameter does not affect the business practice feed production.

**Climate parameters**

- Precipitation: Beets need water in the periods that they are developing their roots. This means that in the growing season it should not get to dry. From the trend in the climate assessment, it can be seen that it does not become drier, so beets can be suitable. There are however more dry days in the spring, this could reduce the yield of beets. Wheat is also susceptible to droughts so the trend of more rain will be good for this crop. However, this crop might even be bothered more by the dry days in the spring due to its shorter growing season. For lupine, the decrease of wet days is suitable since this will reduce the risk of a wet rooting zone, however, there should be enough moisture present so the amount of rain is important and that does increase. The same goes for alfalfa, this crop also can perform well under dry conditions. For rapeseed, there can be a problem with the increase in the number of dry days, since this crop needs enough water and cannot deal with dry sandy soils. For maize, the increase in dry days can become a problem, especially since it also becomes drier in the spring.

- Temperature: For beets to high temperatures can become a problem since especially in the summer more warm days will become a problem for the beets. For wheat, the increase in temperature is not a problem. For Lupine, the increasing temperature, especially in the spring is favourable. For alfalfa, the temperature will also not be a problem. For rapeseed, the increase in summer temperature and the increase in days above 30°C can become a problem since its optimum temperature is not higher than 27°C (PFAF, n.d.). For maize, the increase in temperature will not be problematic, maybe even beneficial due to higher temperatures in the germination phase.

- Evaporation: This parameter does not affect the business practice feed production.

- Water quantity: For all the crops, except for rapeseed the decrease in groundwater level in the spring will be beneficial. In the summer, there is however rain needed to compensate for the lower water table. There are some locations in the region where the groundwater might become higher, this can be a problem, especially for alfalfa. For rapeseed, it is important that the groundwater level does not become so low that the capillary rise is not possible anymore. This means that sandy soils will not be suitable anymore when the groundwater level drops.

**Socio-economic parameters**

- Agricultural market trend: There is a trend towards more local food. This means that, overall, the feed production fits in the trend since it helps to shorten the food chain.

- Policies: There is a demand for crop rotation and increase in diversification. With producing your own feed, there are more crops in the rotation scheme. One should, however, not cultivate rapeseed and beets within three years on the same field with the eye on diseases ('T Hoff & Sijm, 2006).

## Different cow breeds

**Area characteristics**

- Soil: Cows can damage the soils (soil plugging) when the soils are too wet (Eldridge, 2004). Therefore, cows can be kept in Brummen but the exact locations for grazing need to be examined further.

- Upwelling water: If there's too much upwelling water, farmers might consider not to keep farms on those fields because they can damage the fields (Eldridge, 2004).

Farmers can keep cows, but the soil and water characteristics need to be taken into account if farmers want to let the cows graze.

- Topography: This parameter does not affect the diversification of cow breeds.
- Geography: This parameter does not affect the diversification of cow breeds.

**Climate parameters**

- Precipitation: This parameter does not affect the diversification of cow breeds.
- Temperature: Overall, the temperature is going to increase according to the climate assessment. The number of days with temperatures higher than 25°C & 30°C are going to increase. Cows experience heat stress when temperatures are higher than 20°C. Therefore, taking measures against heat stress, such as protection against the sun, is important. When these measures are taken, keeping different cow breeds will be feasible for the future temperature.
- Evaporation: This parameter does not affect the diversification of cow breeds.
- Water quantity: This parameter does not affect the diversification of cow breeds.

**Socio-economic parameters**

- Agricultural market trends: According to the agricultural market trends, consumption of beef is expected to decline. However, there’s also a trend towards local and sustainable food, and buying beef from local farmers is more sustainable. This makes keeping cows for both milk and meat less suitable for this region unless farmers are able to sell their food locally. Furthermore, farmers might want to combine this business practice with another practice to diversify the income since future meat consumption is unpredictable.
- Policies: The most important policy for dairy farmers is the law about phosphate rights. Farmers need to take this law into account, as we expect the law to be in force in 2030.

## Cows in nature & meadows

**Area characteristics**

- Soil: Cows can damage the soils (soil plugging) when the soils are too wet (Eldridge, 2004). Therefore, cows can be kept in Brummen but the exact locations for grazing need to be examined further. However, in nature areas this might not be a real problem, depending on the amount of cows that are planned to be put into a nature area.
- Upwelling water: If there’s too much upwelling water, farmers might consider not to keep farms on those fields because they can damage the fields (Eldridge, 2004). Farmers can keep cows, but the soil and water characteristics need to be taken into account if farmers want to let the cows graze.
- Topography: For citizens, it is nice that the cows are roaming around free and big stables will become less dominant in the landscape which is beneficial as well.

- Geography: This parameter does not affect cows in nature.

**Climate parameters**

- Precipitation: This parameter does not affect cows in nature.
- Temperature: Overall, the temperature is going to increase according to the climate assessment. The number of days with temperatures higher than 25°C & 30°C are going to increase. Cows experience heat stress when temperatures are higher than 20°C. Therefore, protection against the sun is important. However, keeping cows is feasible when looking at the future temperature.
- Evaporation: This parameter does not affect cows in nature.
- Water quantity: This parameter does not affect cows in nature.

**Socio-economic parameters**

- Agricultural market trends: According to the agricultural market trends, consumption of beef is expected to decline. However, there's also a trend towards local and sustainable food, and buying beef from local farmers is more sustainable. This makes keeping cows for both milk and meat less suitable for this region, unless farmers are able to sell their food locally. Furthermore, farmers might want to combine this business practice with another practice to diversify the income since future meat consumption is unpredictable.
- Policies: The most important policy for dairy farmers is the law about phosphate rights. Farmers need to take this law into account, as we expect the law to be in force in 2030.

## A4.2 Water management

### Rainwater storage

**Area characteristics**

- Soil: This parameter does not affect rainwater storage.
- Upwelling water: This parameter does not affect rainwater storage.
- Topography: Rainwater storage ponds require a large space to store sufficient water for irrigation. This means that farmers need to have suitable regions in the neighbourhood, meaning that close to the village or nature areas this option might not be suitable. Furthermore, farmers with small farms might not have the space to add such a tank.
- Geography: The hilly region in the west of the region can be used for the collection and storage of water in tanks, where the slope of the hills can be used for the transport of the water to the lower lying areas through natural gravity. The rest of the area is more useful for water storage in ponds. Overall, the geography of Brummen is suitable for water storage.

**Climate parameters**

- Precipitation: The storage of water in wet periods can create a more robust and reliable water availability for agricultural usage to overcome the more dryer periods of the year. Since some months or become wetter and some other dryer this a more reliable water source besides rainfall is needed in the future.
- Temperature: This parameter does not affect rainwater storage.
- Evaporation: The slight increase in evaporation could result in more water losses of stored water in ponds with an open water surface. This could be overcome by storing the water in water tanks or underground. Overall, the effect of evaporation on water storage depends on the storage place.
- Water quantity: Water storage in and for the summer could reduce the lack of water availability due to a lower groundwater table in the summer.

**Socio-economic parameters**

- Agricultural market trends: This parameter does not affect rainwater storage.
- Policies: National policies on maximum water usage can have an impact on the availability of surface water for agricultural usage. The storage of water can supply farmers in times of surface water usage restrictions. Local policies are also aiming for more water retention and storage in the area. Overall, the storage of water fits the policies.

## On-field water retention

The feasibility check for vegetation buffers will be executed with the combination of the following species: buckwheat, gypsophila, cornflower, goose flower and sunflower.

**Area characteristics**

- Soil: Buckwheat, gypsophila, cornflower, goose flower and sunflower are all suitable to be grown on a variety of soil types like sandy, loamy and clay soils. Overall, the soils of Brummen are suitable for these flowers.
- Upwelling water: Buckwheat, gypsophila, cornflower, goose flower and sunflower do all prefer well-drained soils. Most of the area in Brummen are well drained, but some areas experience upwelling. Overall, the biggest part of the area of Brummen is suitable for these flowers. Specific areas with upwelling could look for flowers that grow better in wetter soils.
- Topography: This parameter does not affect vegetation buffers.
- Geography: Vegetation buffers are suitable to be placed on flat areas as well as on hills. Overall, the geography of Brummen is suitable for vegetation buffers.

**Climate parameters**

- Precipitation: Buckwheat, gypsophila, cornflower, goose flower and sunflower are flowers that can grow in dry or wet soils and can tolerate droughts. They all grow in the summer months. Overall, the precipitation in the growing months of these flowers is suitable for their growth.

- Temperature: Due to the increase in temperature in the whole year, the growth period of the flowers can be lengthened. Overall, the temperature of Brummen is suitable for these flowers.
- Evaporation: All flowers can grow in dry or wet soils and can tolerate droughts and will, therefore, withstand a change in the amount of evaporation. Overall, the amount of evaporation is suitable for its growth.
- Water quantity: All flowers can grow in dry or wet soils and can tolerate droughts and will, therefore, withstand a change in the amount available water. Overall, the available water quantity is suitable for its growth.

**Socio-economic parameters**

- Agricultural market trends: this parameter does not affect vegetation buffers.
- Policies: European, national and local policies are having a trend towards a more environmentally friendly practices and nature inclusive agriculture. Vegetation buffers are a nature inclusive practice. In addition, on-field water retention can also help to deal with pollution. Overall, the policies support vegetation buffers.

## Mulching

**Area characteristics**

- Soil: Mulching can be applied on all soil types, including clay (Longueuil, 2003), which makes it a suitable practice for Brummen regarding this parameter.
- Upwelling water: In areas that experience a lot of upwelling water, the application of mulches might not be very suitable since it can contribute to root and stem rot problems if the soil remains wet (UCONN, 2016). Therefore, the location for the application should be analysed first before implementing this measure. In drier areas with less upwelling, the measure is suitable for implementation.
- Topography: This parameter does not affect mulching.
- Geography: This parameter does not affect mulching.

**Climate parameters**

- Precipitation: Precipitation is overall expected to increase slightly. Mulch can help to temporarily hold rainfall (Ji et al, 2001). This can be especially useful for drier areas. Furthermore, the amount of dry days is expected to increase, which makes it useful to hold rainfall a bit longer. Therefore, this practice can be useful in Brummen.
- Temperature: According to the climate assessment, the temperature is going to increase in the future in most months. This means that there will likely be more evaporation. Mulch can help to keep the soil moist by reducing evaporation (Ji et al., 2001; McMillen, 2013). Therefore, this practice is recommended in Brummen.

- Evaporation: Evaporation is expected to increase. Mulching is effective in reducing evaporation by covering the soil (McMillen, 2013). This makes mulching especially suitable for areas that experience drought.
- Water quantity: In very wet areas, applying a thick layer of mulch is not as suitable since it may cause root and stem rot problems. Therefore, in regions with a lot of upwelling and high groundwater levels, this practice might not be as suitable. However, in dry areas, mulching can help farmers reducing drought. Therefore, it is a suitable measure, dependent on the location of the farm.

**Socio-economic parameters**

- Agricultural market trends: This parameter does not affect mulching.
- Policies: The EU has formed several objectives regarding the environment and climate. One of these objectives it the efficient management of natural resources such as water and soil. Mulching can help to contribute to this by releasing nutrients and minerals as well as holding rainwater. Furthermore, it reduces the growth of weed, which means that fewer pesticides are needed. Therefore, mulching fits with the trends in policies.

## A4.3 Carbon sequestration

### Increasing tree cover

In this feasibility check, the focus will be on the incorporation of trees in pastures. The trees proposed are black poplar *(Populus nigra),* white cedar (*Thuja occidentalis*), sweet chestnut (*Castanea sativa*), the oak (*Quercus robur*), walnuts tree (*Juglans regia*). For most crops and trees characteristics the PFAF.org site was used to get information from. If other sources have been consulted, these are mentioned specifically.

**Area characteristics**

- Soil:
    - Black poplar *(Populus nigra)* grows in most types of soil including light-sandy soils, medium-loamy soils, and heavy clay soils. It also prefers well-drained soils. It rather grows in moist soils than dry soils.
    - White cedar (*Thuja occidentalis*) prefers light-sandy soils, medium-loamy soils, and heavy clay soil. It prefers moist or wet soils.
    - Sweet chestnut (*Castanea sativa*) prefers light-sandy soils, medium-loamy soils, and heavy clay soils. It grows in dry or moist soils and tolerates drought.
    - Oak (*Quercus robur*) grows in loamy and heavy- clay soils. It requires moist and wet soils but it can also tolerate drought, which makes it quite climate resilient.
    - Walnuts tree (*Juglans regia*) is suitable for any type of soils: light-sandy soils, medium-loamy soils, and heavy-clay soils, and prefers moist and well-drained soils.

    Overall, soils present in Brummen are suitable for inclusion of trees in pastures for carbon sequestration, depending on the type of tree that is included.
- Upwelling water:

- Black poplar*(Populus nigra)* It mainly grows next to water bodies such as rivers or water streams, thus suitable in areas with high upwelling water.
- White cedar (*Thuja occidentalis*) prefers well-drained soils, thus upwelling water may not be favourable.
- Sweet chestnut (*Castanea sativa*) can grow in areas where upwelling water is found.
- Oak (*Quercus robur*) can be affected by waterlogging. However, some species are able to withstand some waterlogging and are therefore suitable for growing in areas with upwelling water (Le Provost et al, 2011).
- Walnuts tree (*Juglans regia*) prefers well-drained soils, thus upwelling water may not be favourable.

Overall, upwelling water in Brummen is suitable for inclusion only for some trees in pastures for carbon sequestration, depending on the type of tree that is included.

- Topography:
  - Black poplar (*Populus nigra)* is already present in Central Europe, thus it is more likely to be suitable for the region.
  - White cedar (*Thuja occidentalis*) grows in Eastern North America and not yet in Europe.
  - Sweet chestnut (*Castanea sativa*) already grows in Southern Europe.
  - Oak (*Quercus Robur*) grows in several countries in Europe so planting this tree would not largely affect the aesthetics of the area
  - Walnuts tree (*Juglans regia*) exists in Eastern Europe and South Britain, thus it may be suitable for Northern Europe.

  Overall, the topography of Brummen is suitable for inclusion of trees in pastures for carbon sequestration, depending on the type of tree that is included. The white cedar is not in Europe, further studies for its potential in Europe should be researched. Sweet chestnut should also be considered as it mainly grows in Southern Europe, but it may be suitable for future contexts.

- Geography:
  - Black poplar *(Populus nigra)* cannot grow in the shade which makes it suitable for open pastures. Black Poplar may grow better next to the river Ijssel.
  - White cedar (*Thuja occidentalis*) can grow in semi-shade or no shade, which may be suitable for open pastures.
  - Sweet chestnut (*Castanea sativa*) grows inland and can also tolerate maritime exposure.
  - Oak (*Quercus robur*) can deal with strong winds and grows with or without shade.
  - Walnuts tree (*Juglans regia*) needs to grow in open spaces.

  Overall, all trees proposed can grow in open spaces, thus, they are applicable for growing in Brummen’s pastures.

**Climate parameters**

- Precipitation: Projected precipitation outlines that there will be less wet days over the year. In that sense, sweet chestnut (*Castanea sativa*) and the oak (*Quercus robur*) seem to be more suitable as they resist dry soils. Still, the changes towards 2050 won't be drastic, and therefore the other species can also grow.
- Temperature: Projected temperature is expected to increase over the year. The same as with precipitation, the sweet chestnut (*Castanea sativa*) and the oak (*Quercus robur*) are more resistant to droughts.
- Evaporation: This parameter does not affect the increase in tree cover.
- Water quantity: Water quantity will not be largely reduced. In that sense, all trees will be suitable for the area. It is important to emphasise that black poplar (*Populus nigra*) is largely dependent on water bodies.

**Socio-economic parameters**

- Agricultural market trends: Meat consumption may decrease in the long-term and EU dairy sector may suffer from price volatility. Thus, it may be interesting for farmers to combine their agricultural activities with other practices that may provide income, such as the incorporation of trees in the pastures. The sweet chestnut (*Castanea sativa*), the oak (*Quercus robur),* the walnut tree (*Juglans regia*) for instance, can provide the farmers with chestnuts, walnuts and wood that can be sold in the market and may experience an increase in consumption. The other two, black poplar (*Populus nigra*) and white cedar (*Thuja occidentalis*) can sequestrate high amounts of carbon.
- Policies: At the European level, the improvement of carbon sequestration will be included in the policies and subsidies from the CAP post-2020 for the objective of climate change mitigation and adaptation in agricultural practices. Farmers may have the chance of benefit from these subsidies through including carbon sequestration in their pastures through the grwoth of trees. At the same time, the increase of tree species contributes to increased biodiversity and landscape which is also rewarded at a national and local level.

## Legumes in pastures

The fit of the inclusion of legumes in pastures with the characteristics of the area differs according to the type of legumes. The three legumes that have been proposed are alfalfa, birdsfoot trefoil and white clover. For most crops and trees characteristics the site Naturesseed (2019) was used to get information from. If other sources have been consulted, these are mentioned specifically.

**Area characteristics**

- Soil:
    - Alfalfa legumes will be found in fertile and irrigated soils in a dry climate.
    - Birdsfoot trefoil performs best in areas with poor soil fertility or low pH.
    - White clover is commonly used with other grass species and in any type of soil. Overall, soils are mostly suitable for white clover, while the other two species may vary according to the soil in the pasture.

- Upwelling water:
  - Alfalfa may experience root rot and other diseases when there is a high amount of rainfall and high humidity, thus it is not very suitable for Brummen.
  - Birdsfoot trefoil is good for high water table and areas with drainage issues
  - White clover is quite adaptable to all water conditions but prefers cool moist conditions.

    Overall, water in Brummen is suitable for inclusion birdsfoot trefoil and white clover, while it will not be suitable for alfalfa.

- Topography: This parameter does not affect the selection of legumes in pastures.

- Geography: This parameter does not affect the selection of legumes in pastures.

**Climate parameters**

- Precipitation: As the number of wet days are decreasing over the year, alfalfa and white clover seem to be applicable for Brummen. Still, Birdsfoot Trefoil can be applied in the short-term as the change won't be very drastic.

- Temperature: The average temperature increases over the year, which again, makes alfalfa and white clover more suitable.

- Evaporation: This parameter does not affect the selection of legumes in pastures.

- Water quantity: As the groundwater table may experience an increase in the western area of Brummen, birdsfoot trefoil may be applicable. The rest of the area might not experience such a change, thus the other two species are also suitable.

**Socio-economic parameters**

- Agricultural market trends: Growing demand for dairy products worldwide may increase the production. The combination of legumes and grass is highly nutritious which increases the value and quality of pasture. Further, as consumers will be more aware of the value and origin of their food, adding a sustainability side and a landscape service (i.e. carbon sequestration) may increase its value.

- Policies: At the European level, the improvement of carbon sequestration will be included in the policies and subsidies from the CAP post-2020 for the objective of climate change mitigation and adaptation in agricultural practices. Farmers may have the chance of benefit from these subsidies through implementing this strategy (Gonzalez et al. 2018).

## A4.4 Energy production

### Solar panels

**Area characteristics**

- Soil: This parameter does not affect the installation of solar panels.

- Upwelling water: This parameter does not affect the installation of solar panels.

- Topography: This parameter does not influence the installation of solar panels. However, the solar panels, especially 'Agrivoltaics' may change the aesthetics of the region, characterised by a beautiful landscape. Thus, the extent to which solar panels may not be resisted by the citizens of the Brummen region may be discussed at a local level.
- Geography: The installation of solar panels have to consider the areas where more sun is received in order to increase their efficiency. Open spaces are more suitable for the instalment. Agrivoltaics are very suitable as they are high and catch the solar radiation. Further, the slope of the area needs to be considered.

**Climate parameters**

- Precipitation: This parameter does not affect the installation of solar panels.
- Temperature: This parameter does not affect the installation of solar panels.
- Evaporation: This parameter does not affect the installation of solar panels.
- Water quantity: This parameter does not affect the installation of solar panels.

**Socio-economic parameters**

- Agricultural market trends: Meat consumption may decrease in the long-term and EU dairy sector may suffer from price volatility. In that case, diversifying the practices towards solar energy production can also stabilise the income of farmers in future contexts.
- Policies: Policies are moving towards the decrease of fossil fuel energy and the promotion of renewable energies and low carbon technologies. In the case of energy production from solar energy for self-consumption (i.e. solar panels on the rooftop), farmers will become independent from external energy sources. If farmers decide to sell the energy produced for the common use, they diversify their income, however, large fields of solar panels may be required. The implementation of solar panels will contribute to the European, national and local emission reduction targets, and farmers benefit from the EU subsidies.

## Wind turbines

**Area characteristics**

- Soil: This parameter does not affect the installation of wind turbines.
- Upwelling water: This parameter does not affect the installation of wind turbines.
- Topography: This parameter does not influence the installation of wind turbines. However, the wind turbines may affect the aesthetics of the region according to the size of the turbines. The smaller, the less impact wind turbines may have but also the less energy is produced. Therefore, the extent to which wind turbines may be installed has to be discussed by the citizens of the Brummen region at a local level.

- Geography: The establishment of wind turbines needs to be done in the areas with higher wind speed. Small wind turbines can be installed in the rooftops of houses or agriculture infrastructure to increase its efficiency.

**Climate parameters**

- Precipitation: This parameter does not affect the installation of wind turbines.
- Temperature: This parameter does not affect the installation of wind turbines.
- Evaporation: This parameter does not affect the installation of wind turbines.
- Water quantity: This parameter does not affect the installation of wind turbines.

**Socio-economic parameters**

- Agricultural market trends: Meat consumption may decrease in the long-term and EU dairy sector may suffer from price volatility. In that case, diversifying the practices towards other sources of income, such as energy production from wind, can stabilise the income of farmers in future contexts.
- Policies: Policies are moving towards the decrease of fossil fuel energy and the promotion of renewable energies and low carbon technologies. In the case of energy production for self-consumption, farmers will become independent of external energy sources. if farmers decide to sell the energy produced for the common use, they diversify their income. The implementation of wind turbines will contribute to the European, national and local emission reduction targets, and farmers benefit from the EU subsidies.