Sustainable water use at the Wageningse Eng

Report

Wageningen University

Project: Sustainable water use at the ‘Wageningse Eng’: can you help bringing the different interests together?

Report

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Summary

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The Wageningse Eng is an area to the East of Wageningen, where water is used for activities such as farming, allotment gardening, and animal keeping. Seasonal weather variability and climate change introduce problems with water availability for the land users on the Wageningse Eng, now and in the future. Therefore, the objective of this project is to study the current water use on the Wageningse Eng and assessing its sustainability, so in the future, the various activities can still take place in a sustainable manner. The current water use was investigated by mapping land use and different water access points, and a water balance for the Wageningse Eng area has been set up. Furthermore, the social and environmental sustainability will be assessed with a sustainable water use framework.

We found that for an average year the water balance is closing during the growing season. However, precipitation cannot meet the water demand during the growing season and therefore large quantities of ground- and drinking water are used for irrigation. If more water is needed besides precipitation, the usage of drinking water is found to be more sustainable than using groundwater for irrigation energy wise.

From the stakeholder analyses, consisting of interviews, a questionnaire and small talks, we found that the largest problems land users experience encompass are: not having water available at their plot, strict guidelines regarding buildings, and prolonged droughts due to climate change. Therefore, solutions which increase the soil water holding capacity in the topsoil, such as increasing organic matter, should be further investigated.

The current sustainability has been assessed using the sustainability framework. We concluded that in general the Wageningse Eng is slightly unsustainable. Both the environmental aspects as well as the social aspects of sustainability can be considered slightly unsustainable. Regarding the environmental aspects, irrigation with water from a different source than precipitation should be minimized in the future to increase the sustainability. As to social aspects, the willingness of current people in Wageningse Eng is at a high level, however, it is difficult for them to implement applications to upgrade sustainability since the adaptivity scores low compared to other criteria.

Thus, considering all these conclusions, this report suggests using the principles of Trias Aquatica (TA) to guide future research. Improving stakeholder awareness on water use quantity consequently reduces water consumption. Wageningse Eng can implement technical methods for collecting and storing precipitation to minimize the water demand from outside sources. In addition, future research also needs to consider the financial aspects of implementing sustainable solutions and applications.

1. Introduction

1. Introduction

The Wageningse Eng is an area to the East of Wageningen where varying land uses, such as housing, farming, horse keeping, allotment gardening, nature and recreation, tie together in a unique landscape (Bulkens et al., 2015). Within this area, precipitation, groundwater, and drinking water are used as inputs for these activities. However, water supply and demand of these different sources fluctuate strongly due to seasonal weather variations and climate change, which is coupled with increasing periods of drought, declining groundwater levels, and increasing scarcity of drinking water (Liu et al., 2019).

As sustainable water use is necessary to upkeep the various activities in the area, achieving sustainable use of the available water for all land users on the Wageningse Eng is highly essential to the commissioner in the next few years. However, there is currently no overview of the water use of different land users and of water sources within the area. Therefore, there is a lack of knowledge regarding the current sustainability of the water system on the Wageningse Eng.

This sustainability is generally defined as meeting our own needs without compromising the ability of future generations to meet their needs (WCED, 1987, p. 43). Sustainability has three different components: environment, economy and society (Gidding et al., 2002; Purvis et al., 2019). Within our project we are focusing only on the environmental and societal aspects of water use. For the social part, we take into consideration the problems, needs and interests of stakeholders on the Wageningse Eng regarding water use. Regarding the environmental component, we define sustainability using system thinking, including aspects that are located within the area as well as the inputs and outputs of the water system (Shahrokni et al., 2015). Sustainability will be defined more precisely in this project through the process of developing an integrative framework that can be used to assess the sustainability of the current water use.

The overall project is a collaboration between the Wageningen Science shop and the 'Stichting Wageningse Eng' (A foundation which will hereafter be referred to as 'the foundation'). The foundation is committed to ensure the richness and diversity of values and functions of the Eng. They strive towards sustainable management and development of the area (Stichting Wageningse Eng, n.d.). The Wageningen Science shop is an organisation which collaborates with non-profit groups in society by organising research projects that find answers to their questions. Their goal is to empower groups in society by engaging them in scientific research and create a direct, positive change together (Wageningen University and Research Science shop, n.d).

The foundation, being a point of contact for many stakeholders, has indicated the need for advice on a sustainable water management plan. This project was outsourced to the Wageningen Science Shop, which means they are the direct commissioner. Our team will collaborate with the Wageningen Science Shop by providing interdisciplinary knowledge on social and environmental issues on the Wageningse Eng. Although the larger project involves many aspects such as water quality, finances, ecology, ethics, and legislation, our team will mainly focus on hydrology, hydrogeology and technology, as well as on social aspects. Considering the background of the team, the key issues that are going to be addressed are water use management, different water sources, the assessment of the extent to which the current water system is sustainable, and the different interests and needs of the stakeholders that are relevant for environmental or social aspects of water use.

1.1 Project objective and research questions

The goal of this project is to investigate the current water use on the Wageningse Eng by creating a water balance for the area and developing a water sustainability framework to quantitatively assess the sustainability of the water use on the Wageningse Eng. Additionally, we will map the current system, including water access points, water types, and problems stakeholders have related to water use. Our role is to collect data and provide academic knowledge to the commissioner and the foundation.

In order to achieve this goal, we have formulated a main research question:

To what extent is the current water use on the Wageningse Eng sustainable?

To answer this question, we formulated three sub-questions:

1. What is the current water use on the Wageningse Eng?
    a. Where are the current water sources located?
    b. What is the current water balance of the Wageningse Eng?
    c. What are the problems and needs of the different stakeholders regarding current water use?
2. What can be considered sustainable water use on the Wageningse Eng?
    a. What is sustainable water use according to the stakeholders?
    b. What indicators should be included in a sustainable water use framework for the Wageningse Eng?

To what extent is the current water use on the Wageningse Eng sustainable according to the framework?

To answer these questions, a sustainability framework needs to be developed based on a literature review. This literature review will be elaborated upon in chapter 2, which contains the theoretical framework of the project. In chapter 3, the methodology is explained, followed by the results in chapter 4. These results will then be discussed in chapter 5, and finally, a conclusion will be given with the answers to the research questions in chapter 6.

2. Theoretical framework

2. Theoretical framework

As described in the introduction, this research project needs a sustainability framework specific to the Wageningse Eng in order to assess the sustainability of the area. As it needs to be specific for the study area, a new framework needs to be developed. For that, it is necessary to know how to create such a framework. This section therefore includes a literature review on how to create a framework which includes both quantitative and qualitative aspects. This section also includes research on the geological formation of the study area of the Wageningse Eng because the Eng is a very dry area (dry soil and deep groundwater levels), which is part of the problem because precipitation infiltrates to the groundwater instead of staying in the top layer of the soil. This means the land users need more water for their activities such as farming on the Eng. Since this research aims at understanding the current situation and its problems, it is also relevant to understand how the area came to be and why it is so dry. First, this section goes into the geological formation and then it will explain how to create a framework.

2.1 Geological description of study area of the Wageningse Eng

The presence of deep groundwater tables and sandy soils can be explained by the formation history of the Wageningse Eng. During the penultimate glaciation in the Saalian (at the end of the Middle Pleistocene, 200.000 - 125-000 years ago) a continental ice cap extended over Scandanavia and large parts of North-Western European lowlands, including half of the Netherlands. Ice tongues scoured out and intruded pre-existing river valleys and pushed up the gravelly and sandy alluvial sediments, forming hills, basins and ridges (ISRIC World Soil Information, 2017).

The glacier used an existing valley system (Gelderse Vallei), north of Wageningen. This valley was formerly a part of the Rhine valley. By the flow of the glacier, materials accumulated and were pushed upwards along the flanks. This resulted in the formation of the Wageningen-Ede push moraine on the eastern side, parallel to the Utrechtse Heuvelrug on the western side. The glacier came to a standstill near Wageningen. In the following interglacial stage, the relief was levelled through erosion. However, the remnants of the glacial valleys and push ridges are still recognized in the present-day landscape (ISRIC World Soil Information, 2017).

The Weichselian (last glaciation) was characterized by a renewed advance of the Scandinavian ice sheet. However, this time the ice sheet only reached the North of the Netherlands. The area in front of the glacier was influenced by periglacial conditions. In the arctic desert, large parts of the landscape became covered with Eolian sands with a homogenous grain size distribution. These cover sands are still present in the area around the push moraines (ISRIC World Soil Information, 2017). The Wageningse Eng is located on the flank of the Wageningen-Ede push moraine and therefore the dominant soil material on the Wageningse Eng is sand. The sand causes the precipitation to quickly infiltrate into the soil and flows towards the groundwater. Due to the elevated position in the landscape, the area is dominated by dry and sandy soils with deep groundwater tables (TNO, 2019).

2.2 How to develop a framework to assess the level of sustainability

As mentioned in the introduction, the current water use on the Wageningse Eng is unknown. Taking into consideration the number of activities (housing, farming, horse keeping, allotment gardening, nature, recreation, etc.) being practiced in the area and the amount of water needed for those activities, it is important to have a sustainable water use framework to help assess the sustainability of water in the area. A Multi-Criteria Analysis (MCA) is suitable to develop a sustainable water use framework which is explained in the next paragraphs.

Multi-Criteria Analysis, as a tool, can assess, evaluate and quantitively measure complex problems of high uncertainty, conflicting purposes, and stakeholders with multiple perspectives (Mendoza et al., 1999; Mateo, 2012). Thus, the advantage of an MCA framework is that it has the ability to include indicators for both these quantitative and qualitative aspects (Department for Communities and Local Government, 2009) which is why an MCA seems a good fit for this study area. Generally, five steps are included in MCA, they respectively are: defining the problem and creating criteria, assigning weight for each criterion, constructing the evaluation matrix, selecting the appropriate method, and ranking the alternatives (Mateo, 2012). There are various ways to apply an MCA, but the end results of the analysis in each case should be robust, transparent, and defensible. This robustness can be checked by conducting a sensitivity analysis (Infrastructure Australia, 2021).

Sustainable water use should be assessed by multiple dimensions (Diaz-Balteiro et al., 2017). However, through combining water availability and source issues with different stakeholders' interests, it becomes a complex and critical problem. That is the current situation on the Wageningse Eng. The multiple dimensions of this problem needs to be divided into several perspectives (both environmental and social) to create a sustainable water use framework with different indicators (Diaz-Balteiro et al., 2017). Figure 1 shows the steps required to create an MCA framework.

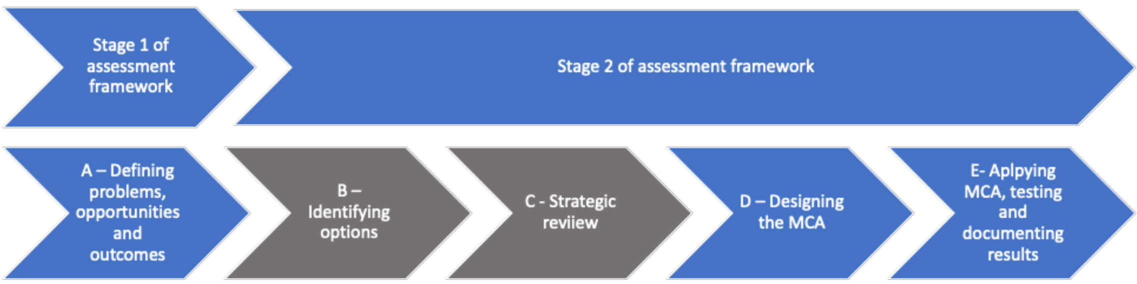

Figure 1 Inputs and key steps in conducting a Mult-criteria analysis (MCA). Adapted from Infrastructure Australia (2021)

A. *Defining problems and opportunities and intended outcomes*. This involves defining the problems and opportunities and intended outcomes driving the project. However, it is critical that there is clarity about outcomes and priorities and sufficient evidence to comprehensively analyse the problems and opportunities that need to be addressed by the project. Stage 1 provides detailed guidance on these activities (Infrastructure Australia, 2021). For the Wageningse Eng, the problems include the water availability on the Eng and the conflicting stakeholder views. These problems are both quantitative (e.g. water quantity) and qualitative (e.g. conflicting views).
B. *Identifying options*. The second step is to develop different options or solutions that can be implemented to solve the identified problems and achieve the desired outcomes. It is usually a long list (Infrastructure Australia, 2021). In this report, this step is omitted as the goal of this project is to assess and analyse the current situation on the Wageningse Eng. Looking into solutions for the future and what their effect would be is beyond the scope of the project.
C. *Strategic review*. This step filters out unfeasible options which means that a more rigorous analysis can focus on options that have the best potential in subsequent steps. This is intended to form an initial view of each option and can be conducted informally with less effort than is

required for a qualitative analysis (Infrastructure Australia, 2021). As Step B is beyond the scope of this project, this also goes for filtering out the options from step B in step C.

D. *Designing the MCA*. This step includes developing the MCA framework by determining the criteria that relate to the desired outcomes identified in step A. This includes the scoring scales and indicators for analysing each criterion as well as the weights given to each indicator and/or criterion (Infrastructure Australia, 2021). Usually, a framework has different criteria which are each measured by multiple indicators. For example, regarding sustainability, you could have an environmental, social and economic criterion. Then, to measure each criterion, multiple indicators can be used to measure the performance on that criterion. For environmental, indicators could potentially be about groundwater pollution, emissions, biodiversity but together they determine the environmental sustainability.

E. *Applying the MCA.* This step includes scoring the current situation (baseline) as well as the identified alternative options from step C against each of the criteria. However, in this study, only the current situation will be scored as testing solutions is beyond the scope of this project. This step also involves documenting the results and providing sufficient commentary to understand how the relative scores of options are connected to the underlying, quantitative evidence and any qualitative analysis. Providing a reasoned narrative for the MCA framework, the scoring and the options taken forward is essential for justifying the outcomes of the MCA (Infrastructure Australia, 2021).

A very important step is assigning weights to the different criteria and indicators. This can be a difficult aspect which is why this literature review also goes into this specific part. The criteria and indicators of the designed framework differ from each other in level of importance. Generally, weight assessment on each indicator helps to determine differences in how important the different indicators are to assess the final sustainability of the Wageningse Eng. There are multiple tools for weight assessment, one of them the Analytical Hierarchical Process (AHP). It is introduced by Saaty (1987) and is the most popular tool to solve complicated questions and in decision making. Normally, AHP is done by identifying the options and criteria, conducting pairwise comparisons, scaling the importance of each indicator, and checking the consistency.

This technique applies pairwise comparisons (Ramanathan, 2004). The main step for pairwise comparisons is to compare the relative importance of each pair of indicators, one to one. Using the values from Table 1 this relative degree of importance between two indicators can be assigned. By doing this for all pairs of indicators in the framework, the formulas discussed below calculate the final weight of each indicator.

Table 1 Pairwise comparison scale with different importance degree

scale	Degree of importance
1	equal importance
3	moderate importance of one factor over another
5	strong or essential importance
7	very strong importance
9	extreme importance
2,4,6,8	values for inverse comparison
reciprocal	If the importance between element i and element j is Wij, then the importance between j and i would be Wji=1/Wij

The scores from Table 1 are filled out for the different criteria in Table 2 which shows the pairwise comparison for the relative importance. As you can see, the relative importance between indicator.1 and indicator.1 equals 1. This means, as you can see in Table 1 that they are of equal importance. To illustrate how it works, W_{21} indicators the relative importance of indicator.2 relative to indicator.1. If this value is 3, this means indicator.2 is moderately more important compared to indicator.1.

Table 2 Pairwise comparison

Group A	indicator.1	indicator.2	indicator.3
indicator.1	$W_{11} = 1$	W_{12}	W_{13}
indicator.2	W_{21}	$W_{22} = 1$	W_{23}
indicator.3	W_{31}	W_{32}	$W_{33} = 1$

In AHP, Linear algebra is the mathematical tool always used to calculate the weight of each indicator by using matrixes after scaling their importance (Jagoda et al., 2020; Bunruamkaew, 2012). The concrete steps for how to obtain the weight are as follows:

1. The scale of each pairwise couple is a vector in a matrix, which shows in the following equation.

$$A = \begin{vmatrix} W_{11} & W_{12} & W_{13} \\ W_{21} & W_{22} & W_{23} \\ W_{31} & W_{32} & W_{33} \end{vmatrix}$$

2. Applying geometric average in each vector and normalizing the results of this step. Take this matrix (3 × 3) as an example, to calculate the weight of first indicator.

$$weight = \frac{(W_{11} \times W_{12} \times W_{13})^{\frac{1}{n}}}{(W_{11} \times W_{12} \times W_{13})^{\frac{1}{n}} + (W_{21} \times W_{22} \times W_{23})^{\frac{1}{n}} + (W_{31} \times W_{32} \times W_{33})^{\frac{1}{n}}}$$
$$n = 3$$

3. Check the consistency index (CI) and consistency ratio (RI), the random index is determined as soon as knowing the order of a matrix.

   CI equation:

$$\mathrm{CI} = \frac{\lambda_{\max} - \mathrm{n}}{\mathrm{n} - 1}$$

   CR equation:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

   RI is decided by the matrix order, and Table 3 is different RI in each matrix order.

   Table 3 Random Index in different matrix order

Matrix order (n)	3	4	5	6	7	8
RI	0.58	0.9	1.12	1.24	1.32	1.41

4. If the CR is less than 0.01, then the weight is perfectly consistent, and we can use those weights for the analysis.

In the research methodology section, we will discuss how to develop and apply such a framework for this project.

3. Research Methodology

3. Research Methodology

This chapter will describe the different methods that were used in order to answer the research questions. The main objective of this project is to access the sustainability of the current water use on the Wageningse Eng. In order to fulfil this objective, firstly, an overview of the current water use had to be developed by mapping the current land use, by setting up a water balance and by executing a Material Flow Analysis. The methods used for the land map are described in section 3.1, the methods used in the water balance are described in section 3.2 and the Material Flow Analysis is described in section 3.3. Secondly, an overview of the needs, problems and views of the different stakeholders on the Wageningse Eng had to be developed using interviews and a questionnaire, as is further elaborated on in sections 3.4 and 3.5. Finally, section 3.6 describes how the sustainability framework was developed and how the results from the previous section were used as input for this framework.

3.1 Land-use mapping

As explained before, we first needed to map different land use types as well as the presence of groundwater wells and drinking water taps on the Wageningse Eng. The study area is shown below in Figure 2. We decided to distinguish three different land use types: grassland, agricultural land and allotment gardens. These three land use types were covering most of the area on the Wageningse Eng. In addition, these plots of land provided were the most interesting concerning the accessibility of water and water usage. By using a Google maps satellite image from 2021 and conducting three days of field observations, the different plots on the Wageningse Eng were mapped. For each plot we mapped we made notes on land use type, animal species, number of animals, type of crop, water type and water availability (taps or no taps present). The collected data was processed using QGIS-LTR version 3.22.7 Tisler to make a digital map.

Figure 2 Research area, the Wageningse Eng. The southern area is considered the open area, and the northern area the closed area (forestry). Map based on Visie Wageningse Eng (Gemeente Wageningen, 2020) .

3.2 Water balance and groundwater levels

To assess the current situation regarding to the water flows on the Wageningse Eng, a water balance has been developed. The water balance gives an overview on the incoming and outgoing water fluxes on the Wageningse Eng.

3.2.1 Description of water balance

To calculate the water balance, we considered the water system on the Wageningse Eng as a box with water inputs (sources) and water outputs (sinks). The sources consisted of precipitation (P) and irrigation (I). Irrigation consisted of two components, irrigation with drinking water ($I_{Drinking\ water}$) and irrigation with groundwater ($I_{Groundwater}$). The sinks only had one component, namely evapotranspiration (ET). Transpiration, evaporation of intercepted water, and soil evaporation extract water from the soil and release it in the air. The sum of these three fluxes is called evapotranspiration (ET) (Moene & van Dam, 2014 p.7). In addition, we had a special term, namely the groundwater extraction (E). The extracted groundwater was used to irrigate the land and therefore will be partly used by plants and partly drain back to the groundwater **Fout! Verwijzingsbron niet gevonden.**. The different sinks and sources, and how all necessary data was collected will be further elaborated on later in the next section.

The difference between the sinks and the sources represented a change in water storage (ΔS) in the box described before. The change in storage was equal to the change in groundwater level and was calculated by: $\Delta S = P + I_{Groundwater} + I_{Drinkingwater} - ET - E$

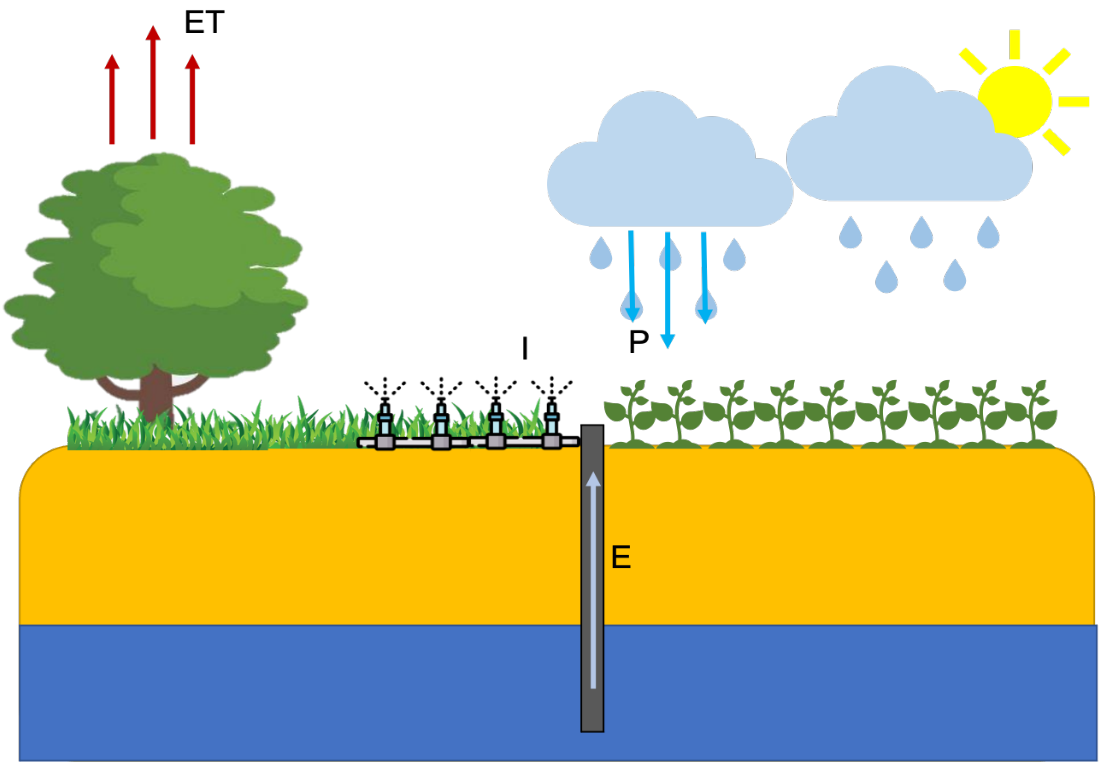

Figure 3 Visual representation of the water balance of the Wageningse Eng. Inputs are precipitation (P) and irrigation (I). Outputs are extraction (E), Evapotranspiration (ET).

Important to note is that with this balance, we were solely looking at factors which change the groundwater levels in the area, during the growing season (April 1st to September 30th). Therefore, we were not investigating the total water use of the Wageningse Eng. A large component which was not considered in this water balance was the inputs of water for animals to drink. We chose to exclude this from the water balance because the water that animals drink did not affect the groundwater level too much unless they were drinking groundwater. The total water use, including the amount of water the animals use will be further elaborated on in the Material Flow Analysis.

3.2.2 Data collection

Precipitation (P)

The precipitation data was downloaded from the Dutch meteorological institute KNMI (KNMI, 2022). We used the daily precipitation data from weather station de Veenkampen near Wageningen between 2010 and 2021. This precipitation data was summed for each year and for each growing season (between April 1st and September 30th) to obtain the total amount of precipitation.

Evapotranspiration (ET)

The reference evapotranspiration (ET) differs per year and is higher for wet years with a lot of sunshine and lower for dry years (Teuling, 2018). The reference ET for Dutch grassland for different months is obtained from Moene & van Dam (2014, p. 286) (Table 4).

Table 4 Monthly values for the reference evapotranspiration (Eref) during the growing season according to Moene & van Dam (2014, p286).

	April	May	June	July	August	September
Eref (mm)	54.5	82.9	86.7	91.5	80.2	48.2

The ET differs per land use type. The ET for each land use type was calculated by multiplying the reference ET for grassland with a crop factor, a method that was developed by Makkink (Moene & van Dam, 2014). A higher crop factor means that a crop will evaporate more than the reference crop. The different crop factors in a growing season for the Netherlands were obtained from Moene & van Dam (2014, p.326) and are summarised in the Table 5.

Table 5 Monthly crop factors for the different crops according to Moene & van Dam (2014, p.326). Crop factors have been estimated based on Moene & van Dam (2014, p.326) for allotment gardens, diverse, cemetery and the campsite.

Crop Factors	**April**	**May**	**June**	**July**	**August**	**September**
Grass land	1	1	1	1	1	0.9
Maize	0	0.8	1.2	1.2	1.2	1.2
Allotment gardens	0.7	0.9	0.9	1.1	1.1	1
Grain	0.9	1	1.2	0.8	0	0
Forest	1.04	1.04	1.04	1.04	0.96	0.96
Lupine	0.7	1	1.2	0	0	0
Potato	0	0.9	1.2	1.1	1.1	0
Aspargus	0	0.7	1.2	1.2	1.2	1.2
Diverse	0.7	0.9	0.9	1.1	1.1	1
Cemetry	1.04	1.04	1.04	1.04	0.96	0.96
Camping	1.04	1.04	1.04	1.04	0.96	0.96

For the allotment gardens, an estimation for the crop factor was made by averaging crop factors for different types of vegetable crop factors. This same procedure was applied for the cemetery and the camping by averaging the crop factors for grassland and deciduous forest. For the agricultural fields it was known from the land use mapping, which type of crop they are growing, and therefore the corresponding crop factor could be directly used. For agricultural fields that were used to grow multiple different crops, the crop factor was calculated by combining the crop factors of the different crops.

Irrigation (I)

Agricultural fields, allotment gardens and some pastures were irrigated using either drinking or groundwater. The amount of water that land users used to irrigate the land was obtained from the interviews and questionnaire. We distinguished between irrigation with drinking water and irrigation with groundwater. Irrigation from precipitation had already been accounted for in the water balance by considering the yearly and seasonal sums of precipitation. An average amount of irrigation per square meter of allotment garden and agricultural field was used in the water balance. In addition, we looked at irrigation amounts for wet and dry years for both allotment gardens and agricultural field.

Groundwater extraction (E)

It was not possible to know exactly how much water was extracted, but an estimation could be made based on the area of land which was irrigated by groundwater. This was done by multiplying the area of land irrigated by groundwater with the average amount of water used to irrigate this. Regarding the amount of groundwater extraction, we looked at dry and wet years since we expected groundwater extraction to be higher for dry growing seasons and lower for wet growing seasons.

3.3 MFA

A Material Flow Analysis (MFA) is an assessment tool used to describe matter mass flow within a well-defined system (Cencic & Rechberger, 2018). In this report, it is used to visually present the flow of water on the Wageningse Eng. It includes the water flows into the area, water use within the area and water flows that leave the area. As such, it is comparable to the water balance and the MFA is strongly based on the water balance. This means that the influxes of precipitation and irrigation and the output of evapotranspiration use in the water balance are also included in the MFA. However, it does differ from the water balance in one aspect. In the water balance, water that is given to animals was excluded because it does not affect groundwater. In the MFA, this influx is included, meaning that the MFA provides a complete overview of the total water supply and water demand on the Wageningse Eng. This overview was needed in order to be able to assess the sustainability of the current water use on the Wageningse Eng.

Data on the precipitation, irrigation and evapotranspiration were gathered for the water balance and could be directly used for the MFA. Data for the extra input of water provided to animals was collected through interviews, the questionnaire and land-use mapping. The number of animals was counted during field observations and additional data was collected in interviews with animal owners and through the questionnaire. Not all animals were present on the parcels during the field observations and to ensure the number of animals was not underestimated, the assumption was made that two animals lived on empty parcels. Data on the water use of animal owners was gathered in the interviews and the questionnaire. If the animal owners were not able to provide sufficient information, data from other studies was used as a reference.

The MFA figure was produced using the software STAN.

3.4 Interviews

To analyse the current situation and problems related to water on the Wageningse Eng, it is relevant to know what the stakeholders think about it. We therefore conducted interviews, questionnaires and talked to land users while in the field. This section goes into the data collection and analysis of the interviews.

3.4.1 Data collection

The interviews were used to ask stakeholders about their water demand, the water source(s) that they use, possible water-related problems, solutions for these problems and their views on sustainability. A semi-structured interview form was chosen to ensure that all necessary data was collected. This from leaves room for follow-up questions and changing the order of questions based on the responses of the interviewee (Gray, 2014). The interviews started with quantitative introductory questions about the water use and water sources of the different stakeholder groups. This data was needed to answer research question 1 regarding the current water use on the Wageningse Eng. Thereafter, it focused on their experiences regarding water use, problems and solutions as well as their view on sustainable water use through exploratory questions. The answers to these questions provided the inputs that are necessary for the sustainability framework. Next to this, the insights gained from these questions are of great importance for the larger project of the Wageningen Science Shop. Before we conducted the interviews, an interview guide was developed to assist the interviewers during the interviews and to minimize the difference in interview techniques and styles between different interviewers. This guide is included in Appendix B of this report.

A short list of stakeholders was drawn up to provide an overview of the stakeholders that were most important to interview. This list was created based on the long list. The long list and the explanation of how we determined the short list is included in Appendix D. This list included:

- Allotment garden users
- Parcel owners
- Foundation Wageningse Eng
- Horse owners
- Other animal owners
- Commercial Farmers
- Hobby and semi-commercial farmers
- Plant nursery owners
- Local environmental organisations

We interviewed at least one person from each stakeholder group on our short list except for the local environmental organisation. They were contacted but did not reply. In total, we spoke to 18 stakeholders. We got the contact details through the foundation or by walking around on the Wageningse Eng to approach stakeholders for an interview. Since we wanted to interview at least one individual from each stakeholder group, this can be considered quota sampling, which is a non-probability sampling method (Gray, 2014). In total, we spoke to 18 stakeholders. Of these 17 stakeholders, 11 stakeholders were formally interviewed, and 7 stakeholders were asked questions during in-person conversations or other personal communication forms. An overview of all interviewees can be found in Table 6. All interviewees received a code name for privacy reasons. Our main interest concerned the water use on the Wageningse Eng and therefore we interviewed mainly stakeholders that used land on the Wageningse Eng for one of their activities. Next to this, we interviewed two landowners and one resident to capture their points of view. Finally, we interviewed the water company Vitens, which provides the drinking water on the Wageningse Eng, about their activities and views on sustainability.

Interviews were conducted in Dutch to avoid language barriers and to ensure that stakeholders experienced no difficulties regarding language. The interviews lasted on average around 30 to 40 minutes. All interviews were recorded to enable a precise transcription. Interviewees were asked to sign an informed consent form to formally approve the recording of their interview, the storage of the data in a secured online environment and the use of anonymised interview data in this report.

After the interviews and conversations were conducted, a transcription was made to enable further analysis. The method of intelligent verbatim transcribing was used. In this method, certain elements are omitted if they add no meaning, such as for example “ums”, “errs” and repetitions (Summa Linguae, 2021). This transcription method was chosen to ensure that no relevant data was lost while also enabling an easier analysis of the data. After the transcribing was finished, the transcriptions were sent to the interviewee for approval. When they were formally approved, the audio recordings of the interviews were deleted.

Table 6 Overview of the different interviews, type of stakeholder and type of contact.

Interviewee	Type of stakeholder	Type of contact
1	Horse owner A	Phone conversation
2	Animal owner	Interview
3	Nursery owner A	Interview
4	Hobby farmer	Interview
5	Commercial farmer A	Interview
6	Allotment gardener	Interview
7	Horse owner B	Interview
8	Cow owner	Interview + emails
9	Nursery owner B	Interview
10	Kitchen gardener	Interview + emails
11	Resident	Emails
12	Commercial farmer C	Interview
13	Landowner A	Interview
14	Vitens employee	Meeting MS Teams
15	Landowner B	Emails
16	Commercial farmer C	Emails
17	Beekeeper	Meeting on Eng
18	Foundation member	Meeting on Eng

3.3.2 Data analysis

To analyse the data that was collected from the interviews, thematic analysis was used. This is “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke, 2006). According to Maguire and Delahunt (2017), there are many different approaches that fall within the method of thematic analysis. For our analysis, we decided to follow the method that was developed by Braun and Clarke (2006). This method consists of six phases:

1. Familiarizing yourself with your data by reading the transcriptions and noting down initial ideas.
2. Generating initial codes by coding fragments from the interviews.
3. Searching for themes and gathering codes that belong to a certain theme.
4. Reviewing themes by checking if the themes work in relation to the codes.
5. Defining and naming themes.
6. Producing the report.

According to Braun and Clarke (2006), two important decisions must be made before starting with the thematic analysis. Firstly, we chose to code and analyse only the fragments of the interviews that were relevant for our research questions and objectives instead of providing a rich description of the entire data set. Secondly, we choose to combine a theoretical and an inductive approach in the thematic analysis. From the theoretical approach, we explicitly addressed our research questions in the initial codes. From the inductive approach, we used a bottom-up approach with themes, patterns and codes arising from the interview data itself.

The first part of the interview with quantitative questions was coded using codes from the data theme. The data theme includes codes related to the data for the water balance. These codes were then used to provide descriptive information that could be used for the water balance, as input for the sustainability framework and to describe the current situation of stakeholders. The second part of the interview with qualitative questions was coded with codes from the non-data theme. This theme relates more to the problems, solutions and perspectives mentioned by the stakeholders. An overview of all codes can be found in Appendix F. In total 99 different codes were developed and in total 604 quotes from the interviews were analysed. All interviews were coded by two coders to ensure there are no differences arising from different coding styles.

3.5 Questionnaire

3.5.1 Data collection

The main focus of the questionnaire was collecting quantitative data on water demand and water sources from the land users of the Wageningse Eng. This data was required to provide the inputs for the land-use map, the water balance and the application of the sustainability framework.

At the start of the questionnaire, respondents were asked to check a box to formally approve the storage of the data in a secured online environment and the use of anonymised questionnaire data in this report. The first part of the questionnaire included mostly closed and quantitative questions regarding water use and water sources. Respondents were asked whether they performed a certain activity on the Wageningse Eng. If the answer to this question was negative, they were directed to the next activity and if they did perform a certain activity, follow-up questions on their water use, water sources and location were asked. The activities that were included in the questionnaire were allotment gardening, farming, animal keeping and plant nursing. The second part of the questionnaire included three open questions regarding problems related to water and possible solutions for these problems. In the final part of the questionnaire, the stakeholders' views on sustainability were collected by asking their agreement to four statements regarding their own sustainability, sustainability of the Wageningse Eng, sustainability of different water types and the importance of environmental and social aspects of sustainability. The complete questionnaire is included in the report in Appendix A.

The questionnaire was distributed amongst as many individuals from the stakeholder groups as possible. We distributed the questionnaire through the foundation and their contacts. Therefore, this sampling method can be classified as convenience sampling as they are easily accessible respondents (Gray, 2014). In total, 85 respondents started the questionnaire. 15 respondents that started the questionnaire did not answer any questions and 1 respondent filled in the questionnaire twice. These respondents were deleted before the data was analysed, meaning that in total 69 responses were used for the data analysis. Out of the 69 respondents, 62 respondents had an allotment garden, 9 respondents kept animals, 7 respondents conducted farming and 1 respondent owned a plant nursery. Since some respondents perform multiple activities on the Wageningse Eng, the number per activity type add up to more than 69.

3.5.2 Data analysis

The data from the first part of the questionnaire with quantitative questions regarding activities, water use and water sources was used to provide the necessary input for the land-use map, the water balance and the sustainability framework. The open questions from the second part of the questionnaire were analysed using the same method of thematic analysis that was used for the interview analysis and the codes and themes that were developed in the interview analysis were directly used. In total, 42 quotes from the questionnaire were analysed. All questionnaires were coded by two coders to ensure there are no differences arising from different coding styles. The final part of the questionnaire, consisting of four statements about sustainability was summarised with some descriptive statistics, such as percentages of respondents that chose a certain answer and mean and median values.

3.6 Framework development and application – MCA

In order to answer the main research question of our report, how to measure the current sustainable water use of Wageningse Eng, we needed to create an assessment tool with which we could efficiently analyse the sustainability level of the Wageningse Eng. After obtaining an overview of the current water use in the research area by creating a water balance and stakeholder analysis the next step for us is to create a sustainable water use framework.

The steps of the methodology of how we created the framework for this project is in Figure 4. This methodology is based on the steps to create and MCA from Infrastructure Australia (2021). Those steps are explained in Chapter 2: Theoretical Framework. The Theoretical framework also represents Step 0 from Figure 4 below.

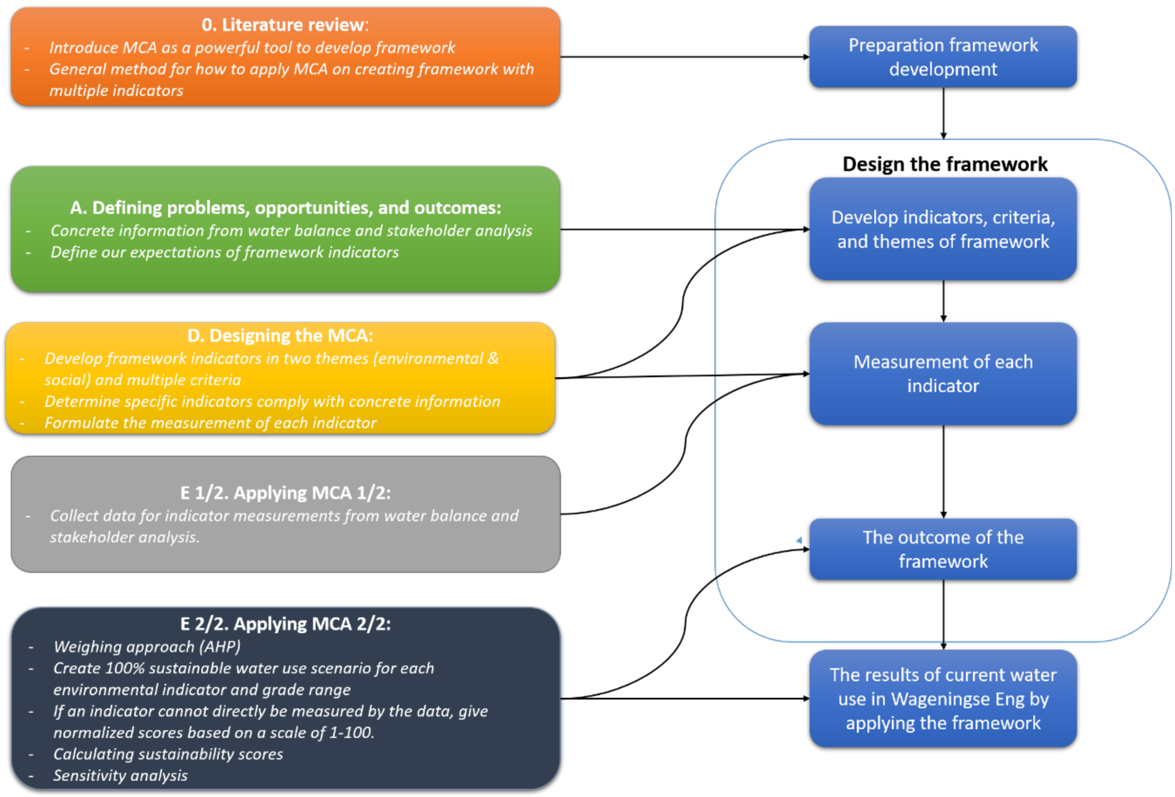

Figure 4 Research methodology of sustainable water use framework

3.6.1 Step A: Defining problems, opportunities and outcomes.

The first step is to define the problem, the opportunities and the desired outcomes. The problems can be identified from the water balance and the stakeholder analysis. The opportunities and desired outcomes can be determined based on the stakeholder analysis. The information from the water balance and stakeholder analysis (interview and questionnaire) offers guidance on what could be relevant criteria and indicators for the framework.

3.6.2 Step D: Designing the MCA

The information from the water balance and stakeholder analysis by itself is not enough to create a sustainable water use framework with specific measurable indicators. Thus, the literature review is to research possible indicators to evaluating water-related sustainability on the Wageningse Eng. The database that was used is Google Scholar. Search terms included “indicators” OR “criteria” AND “sustainable” OR “sustainability” AND “water demand” OR “water supply” OR “water use”.

3.6.3 Step E 1/2: Applying MCA part 1

After Step A and D 1/2 are completed, and the criteria and indicators have been developed, data is required to fill in the values for each of the indicators. This data needs to be collected. Data on water supply, demand and use as well as stakeholder views on problems, solutions, and environmental and social sustainability are required. This is done by fieldwork, where activities were mapped, and questions were asked to land users. Data was also collected through formal interviews, the questionnaire and the water balance data.

3.6.4 Step E 2/2: Apply MCA part 2

After the framework development (Step A and D) and the data collection (Step E 1/2) were completed, the framework can be applied to the case study of the Wageningse Eng. This includes 1) weighing the themes, criteria and indicators, 2) scoring the environmental indicators relative to a 100% sustainable description, 3) scoring the social indicators based on stakeholder input, 4) calculating the final sustainability scores which are the output of the framework, and 5) do a sensitivity analysis to test the robustness of the results.

Weighing

The first step for us is to weigh their importance on how they can influence sustainability by the weighting approach. As mentioned before, we utilize the AHP which introduce before in the literature review chapter to get the weight of each indicator with acceptable consistency.

Scoring the environmental indicators

We created the 100% sustainable description of each environmental indicator based on our expertise combined with stakeholder input. Ranges of 1-19, 20-39, 40-59, 60-80, and 79-100 were created with a definition of what a score in that range means (see Appendix E). Since it is difficult to directly score the quantitative indicators in the framework for the Wageningse Eng, as detailed sufficient data is often not available, we need such a standard as an explanation of how we score the different environmental indicators. This step is for ensuring us to get a justified score depending on a standard (the 100% situation). The advantage of this method for scoring the indicators, is that the indicators become unitless. To be able to compare the scores across indicators, they need to be unitless. After all, it is impossible to compare values for mm/year with Euro’s.

Scoring the social indicators

The social indicators are mostly qualitative. For the social scores, this score is given based on what stakeholders told us in the stakeholder analysis. If most of the stakeholders were happy regarding a certain indicator, it got a higher score. The justifications for each score can be found in Appendix E.

Determining the sustainability by calculating the final sustainability scores

The score of each indicator is multiplied by the weight of each indicator. These weighted scores ae then summed up per criteria. That summed up value is multiplied by the weight of the criteria to create the weighted score per criteria. The same calculation is used to scale up from the criteria to the themes and from the themes to the final sustainability score of the whole Wageningse Eng. Appendix E gives more details on these calculations.

$$Final\ score = \sum_{indicator\ i}^{n} score_{indicator\ i} \times weight_{indicator\_i} \times weight_{criteria(indicator\_i)} \times weight_{theme(indicator\_i)}$$

There are n indicators, each indicator belongs to one sort of criteria, and each criterion is in one type of theme.

Sensitivity analysis

The last step is to check robustness of the scores in MCA approach with sensitivity analysis. The easiest way to do a sensitivity analysis, is to see how the final score of the MCA changes if the weights for each of the criteria and/or indicators change. Then you see how sensitive the outcome is to the assigned weights. This can be done by making all weights equal as well as by making the weights very unequal.

4. Results

4. Results

In this chapter, the results of the research are given, which will help answer the research questions. Section 4.1 will elaborate on the current water use on the Wageningse Eng, including the land-use mapping, a water balance of the area, and a material flow analysis. In section 4.2, the results of the stakeholder analysis are described. These include a description of the current situation of the stakeholders, their problems and possible solutions, and their views on sustainability. Lastly, in section 4.3, the results of the water sustainability framework are given.

4.1 Current water use on the Wageningse Eng

To get an overview of the current water use on the Wageningse Eng, first the land use is mapped. This land-use mapping is then used to make a water balance for the area.

4.1.1 Land use of Wageningse Eng

The results of the land-use mapping are shown in Figure 5. We managed to map the different types of land use and indicate the locations of groundwater wells and drinking water access points (Figure 5). In total, we mapped an area of approximately 140 ha (1404837 m2). The land-use type with the largest surface area on the Wageningse Eng is grassland for animals (around 70 ha). The second largest area is used for agricultural farming (30 ha) and the allotment gardens use the smallest surface area (11 ha). Additionally, there are three important parties on the Wageningse Eng that may have a large water demand. These are the gardening centre 'de Oude Tol', the cemetery, and campsite 'de Wielerbaan'. Through verbal communication, we learned that 'de Oude Tol' has its own groundwater well to water their plants and drinking water access for use of toilets, sinks, and other domestic uses.

The campsite does not irrigate their grassland, and they use drinking water to fill the pool. The cemetery is using groundwater to maintain the scenery.

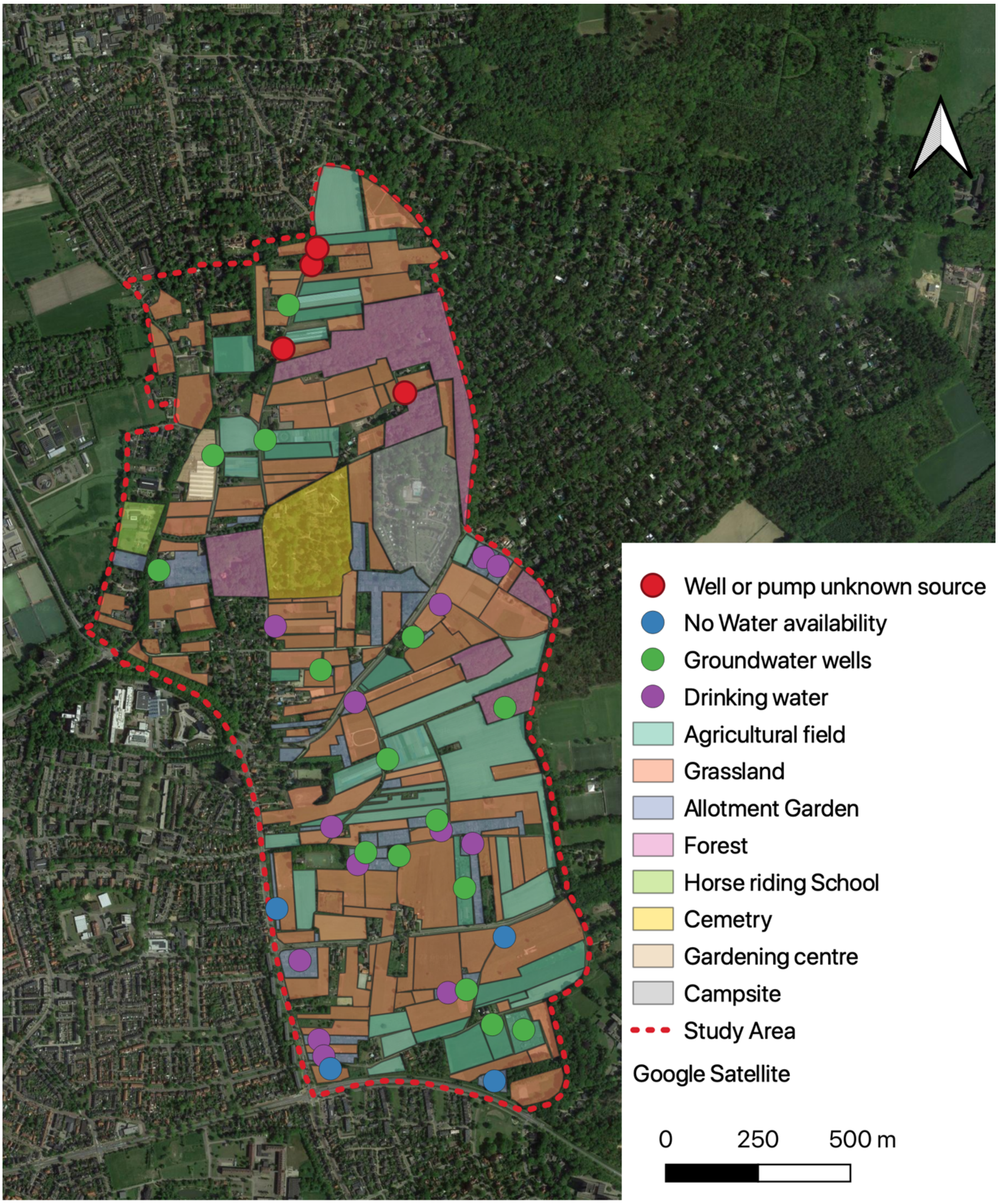

Figure 5 Map with the different land use types of the Wageningse Eng, including location of (ground)water wells and drinking water taps.

4.1.2 Water balance and groundwater levels

For the water balance, precipitation and irrigation are used as sources, and evapotranspiration and groundwater extraction as sinks. The results of the different quantities for the sources and sinks are shown in Table 7 and 8.

Table 7 Calculated volumes of precipitation and irrigation as sources for the water balance

Input	Amount	Unit
Average Precipitation	607493664	L
Maximum precipitation	794154356	L
Minimum precipitation	469637009	L
Average irrigation (drinking water)	1533506	L
Maximum irrigation (drinking water, dry periods)	3479879	L
Minimum irrigation (drinking water, wet periods)	589810	L
Average irrigation (ground water)	1064048	L
Maximum irrigation (ground water, dry periods)	4031193	L
Minimum irrigation (ground water, wet periods)	772355	L

Table 8 Calculated volumes of groundwater extraction and evapotranspiration for the sink of the water balance

Output	Amount	Unit
Average extraction	1064048	L
Maximum extraction (dry periods)	4031193	L
Minimum extraction (wet periods)	772354	L
Evapotranspiration	607936844	L

Table 9 Change in the groundwater storage according to the different sources and sinks

Change in groundwater storage (mm)	Amount	Unit
average	0,77612268	mm
high (dry season)	-95,968398	mm
low (wet season)	132,974375	mm

In Table 9 it is visible that on average, the water balance is approximately closing. A closing water balance means that the amount of water leaving the system is the same as the amount of water coming into it, and the change in groundwater storage is thus zero. In dryer periods, when there is more irrigation and a higher ET, there is a shortage of water, and the groundwater level is expected to drop. During wetter periods, there is an excess of water entering the ground, causing a rise in the groundwater table.

Groundwater levels according to Dinoloket

Unfortunately, only limited data is available on groundwater levels on Dinoloket. There are two piezometers available in our study area, and only one of them has been operating during our study period (2010-2021). The measurement data for this piezometer are shown in Figure 6. It is visible that the groundwater levels have a seasonal fluctuation, with higher groundwater levels in the winter and lower groundwater levels in the summer. There is no decreasing or increasing trend visible in the groundwater levels from the period between 1972 and 2020. In other words, when comparing 1972 and 2020, the groundwater level has neither risen, nor fallen.

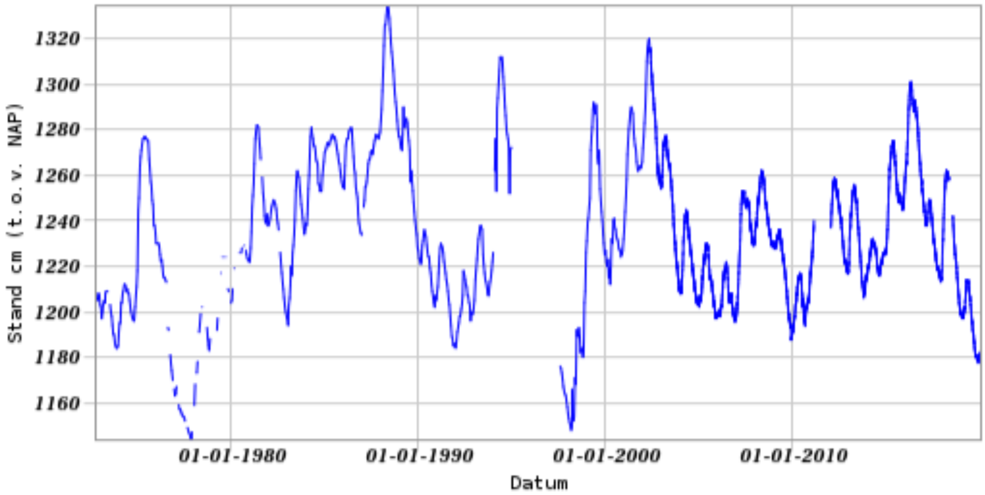

Figure 6 Groundwater level for a piezometer 20.28 m above NAP (identification number B39F0607). Groundwater levels between 1972-2020

4.1.3 Material Flow Analysis

For the Material Flow Analysis (MFA), the data used is shown in Table 10. The specific data on the amount of drinking water used by animals is given in Appendix C. Some of this data was taken from the interviews with stakeholders. However, not all animal types were covered in the interviews, so for these animal types, water consumption is taken from literature. This is also discussed in Appendix C.

A visualisation of the MFA, with the different import and export streams, as well as the groundwater extraction, is given in Figure 7.

Table 10 Water flow quantity in MFA

Water use	Water quantity	Unit
Import	/	/
Precipitation	1232042.05	m^3 /a
Allotment garden irrigation (drinking water)	1533.51	m^3 /a
Animal drinking water	2712.57	m^3 /a
Export	/	/
Evapotranspiration	814877.11	m^3 /a
Total import	1236288.13	m^3 /a
Total export	814877.11	m^3 /a
Δstock	421411.02	m^3 /a
Groundwater extracted	1064.05	m^3 /a
Groundwater irrigation	1064.05	m^3 /a

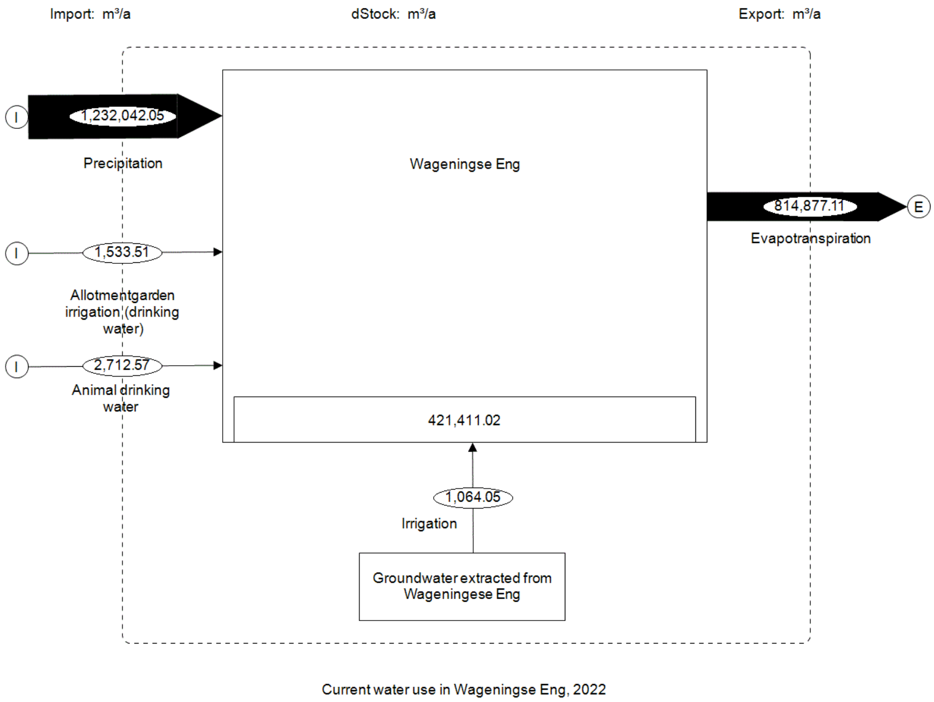

Figure 7 Visual overview of current water inputs and outputs in Wageningse Eng

4.2 Stakeholder analysis

4.2.1 Description of current situation stakeholders.

To get an overview of the current situation of the stakeholders of the Wageningse Eng, interviewees were asked about the water type they currently use. Of the 17 interviewees, 3 mentioned using drinking water for all their activities (Cow owner, Horse owner B, Nursery owner B), and 6 only used groundwater (Hobby farmer, Commercial farmer B, Kitchen gardener, Horse owner A, Nursery owner A, Landowner B). For the groundwater users, they either had a groundwater well on their land, or they shared a groundwater well with (one of) the neighbouring plots of land. One interviewee mentioned using stored precipitation (Beekeeper), and another interviewee (Commercial farmer C) uses no water at all. Three of the interviewees mentioned that more than one water type is used, e.g., both groundwater and precipitation (Allotment gardener), both drinking water and precipitation (Animal owner), and both groundwater and drinking water (Commercial farmer A). Three interviewees were either not land users on the Wageningse Eng (and thus used no water within the study area) or did not specify which water type they use.

For some interviewees, their current water type did not match with their preferred water type. Two interviewees indicated that they preferred using stored precipitation (Animal owner, Horse owner B). Some interviewees preferred to use drinking water, because they only need small amounts of water. Others preferred groundwater, and many of those interviewees have taken switching to groundwater into serious consideration. A few interviewees also mentioned that they would prefer to not use any water.

When asked about the optimal situation regarding water use, some interviewees indicated that their situation was already optimal, at first. However, many of them would then continue to provide possible improvements to their situation. These improvements mainly consisted of using different irrigation methods, wanting to use different water types (e.g., precipitation, water from the Rhine), improving precipitation collection and storage, improving the water retention in the soil, and finding solutions for problems caused by the recent high temperatures. One interviewee mentioned that the situation would be optimal if everyone on the Wageningse Eng has reliable access to water (through a pipeline network), and that the water type would not matter to them as long as the quality is good (Animal owner).

4.2.2 Problems stakeholders mentioned

Of the 69 answers we got from the questionnaire, we find that only 16 land users (23%) are experiencing problems regarding their water use and the water availability.

The results of the interviews show that most interviewees are satisfied with the water type they are using, whether this is groundwater or drinking water. The users of groundwater trust that the water is of good quality. However, the interviewees who are using groundwater are going to analyse the groundwater for the presence of toxicants and residues of pesticides (Allotment gardener). The interviewees using drinking water are also satisfied with the water quality. This is an obvious finding since the quality of drinking water is strictly regulated by Vitens (nursery owner B, Animal owner). Most users seem to be satisfied with the water pressure on the taps. The drinking water taps have a standard pressure of 4.5 bar, which is sufficient for all interviewees. However, problems occur for people whose groundwater tap is far away from the water access points they are using. This is especially a problem for the allotment gardens and Horse owner B. The water pressure is rather low, and if many other people are using the water, hardly any water is coming out of the tap. Besides this problem, the users of the allotment garden complex and horse owner B are not unsatisfied with the low pressure. They are okay with the water troughs and barrels taking longer to fill and do other things while the water is filling up.

In general, the results show that the problems are not arising from the water type, quality or pressure, but rather from the availability, weather influences, and policies and regulations.

The first problem concerning water availability is that, due to the sandy soil and the higher position in the landscape, the precipitation is not retained in the topsoil for a long time. Therefore, the soils are dry, and extra water is needed for irrigation compared to other locations around Wageningen (Animal owner, Allotment gardener, Nursery owner B, Hobby farmer, Landowner A, Kitchen gardener).

A second category of problems is more socially related. These problems occur due to policies and regulations in the area, and social conflicts or friction. Regarding policy related problems, a much occurring problem is that the land users have to follow strict building rules according to the 'Visie Wageningse Eng'. Land users are not allowed to build higher than 1.5 m in the open area, and in the soil not deeper than 30 cm (Hobby farmer). Therefore, land users experience problems with the collection of rainwater with shelters, and retention troughs in the ground. Besides building regulations, allotment garden users have additional regulations to follow. Depending on the complex of your allotment garden, you are not allowed to use sprinklers and/or must collect the water manually with buckets and watering cans (Horse owner B).
A frequently occurring social conflict entails jealousy from land users without water access, arising from land users/residents excessively irrigating their gardens (Animal owner).

Problems concerning labour intensity are mainly occurring for animal owners, who have no access to a water point in their pasture. Bringing water from home to your animals is a labour-intensive task (Horse owner A and kitchen gardener). Next to this, if you are ill or on holidays, you have to find someone who can do it for you instead (Horse owner A).

The last main category of problems is climate related. The most prominent problem is the prolonged droughts which seem to be occurring more often, according to hobby farmers, animal owners, and allotment garden owners. For farmers the main problem is that if you do not irrigate your crops, the harvest will fail (Commercial farmer C). But if you do decide to irrigate your crops, it is not financially feasible anymore due to the high cost of water (Commercial Farmer A, Commercial farmer C). For allotment garden owners, due to the drought extra water is needed to irrigate their plants (Allotment gardener). For animal owners the problem is, when the grass dies due to lack of precipitation, the animals need extra food and water to compensate for the missing grass (Animal owner).

A miscellaneous problem mentioned by Horse owner B, Landowner A, and the Animal owner is that for using groundwater, you need electricity to feed your groundwater pump. Most plots of land are not connected to the electricity network, and therefore would need diesel generators to generate electricity for a groundwater pump. As a result, the before mentioned interviewees find it too complex, besides the financial aspect, to install a groundwater pump.

4.2.3 Individual solutions

This section describes solutions proposed by interviewees or questionnaire respondents that can be implemented by individuals land users.

The first individual solution that can be identified from the interviews and questionnaire entails improving the water retention of the soil by increasing organic matter. This solution was mentioned very often, and it was mentioned by allotment gardeners, farmers, nursery owners and to a lesser extent by animal keepers. Many different methods were proposed to increase organic matter. For example, the Hobby farmer explained how they use the method of mulching to increase matter and plant nursery owners, animal keepers and allotment gardeners explained how they use compost, fertiliser or weeds to increase the thickness of the organic matter soil layer.

Closely related to this solution, the allotment gardener suggested to plant more hedges between plots of land to reduce wind, and as such reduce evaporation and increase water retention in the soil (Allotment gardener).

The next solution entails increasing precipitation storage on the Wageningse Eng. Methods to achieve this were proposed by different land users and can be summarized into two main categories. The first method, proposed by multiple allotment gardeners through the questionnaire and multiple interviewees (Allotment gardener, Horse owner B, Kitchen gardener and Cow owner), entails increasing precipitation storage on houses and sheds. For example, an animal owner explained how precipitation was stored from a large shed and how storage can be further increased in the future (Animal owner). A horse owner highlighted that there are many houses and sheds on the Wageningse Eng that currently do not store precipitation and that this is a solution that can easily be implemented (Horse owner B). The second method, proposed by the Kitchen gardener, involves placing new water buckets or tanks to increase precipitation storage.

Next to this, increasing the availability of groundwater on the Wageningse Eng is proposed as a possible solution. Questionnaire respondent 1 (animal keeper), respondents 5 and 12 (allotment gardeners) and the Beekeeper proposed to dig more groundwater wells. Questionnaire respondent 15 (allotment gardener) suggested to install more water pipes to increase groundwater availability.

Furthermore, several interviewees suggested solutions about the methods used to water their crops or plants. Not giving water at all unless it is absolutely necessary and checking whether the plants or crops need water was proposed by Nursery owners A and B. However, they do acknowledge that some knowledge is needed to be able to execute this. Commercial farmer A suggested that allotment gardeners should give water at night-time using an automated system to reduce evaporation. Another method that was suggested by multiple interviewees and questionnaire respondents entails making gullies or small pits close to plants or crops (Hobby farmer, Nursery owner B, questionnaire respondent 6 (allotment gardener)). Finally, drip irrigation was proposed by Commercial farmers B and C.

The final individual solution entails the sustainable management of crops or plants. Regarding the timing of planting, crops should be sowed in a timely manner in the spring when there is enough water available for the seedlings (Commercial farmer A). Furthermore, plants should not be planted in a dry period, but only when the weather conditions are favourable for seedlings and enough water is available (Nursery owner B). Next to this, drought resistant crops and plants that use water efficiently should be chosen (questionnaire respondent 6 (allotment gardener), nursery owner B), such as perennials in allotment gardens that do not need as much water as other plants (Allotment gardener).

Furthermore, trees can be planted which pull up water to the surface that can be used by other nearby plants (Allotment gardener). Finally, Commercial farmer A and Nursery owner B explained how they increase the drought resistance of their crops or plants by not giving much water and using natural selection to maintain the most drought resistant crops and plants.

4.2.4 Collaborative solutions

This section describes solutions proposed by interviewees or questionnaire respondents that can only be implemented through cooperation and collaboration between different land users. There are five collaborative solutions that were identified. Firstly, land users can share already existing groundwater pumps or drinking water access points, or they can cooperatively build new ones (Commercial farmer A, Landowner, questionnaire respondent 11 and 16 (allotment gardeners) and questionnaire respondent 13 (animal owner). Secondly, questionnaire respondent 6 (allotment gardener) proposed to provide education about sustainable water use in the newspaper. Thirdly, precipitation storage should be further stimulated and awareness about the importance of precipitation storage should be raised (Allotment gardener). Fourthly, since organic matter is essential for water retention, Horse owner B suggested that multiple land users collect soil samples that can be brought to a laboratory to assess the quantity and quality of organic matter on the Wageningse Eng. Finally, Commercial farmer B suggested that new regulations or guidelines should be made about methods to give water to avoid water wastage.

4.2.5 Perceptions of stakeholders on sustainability

In an area with as many stakeholders as the Wageningse Eng social sustainability is very important. Through the interviews we conducted and the questionnaire we distributed, we collected different perspectives on several aspects of social sustainability. In this report we found three main aspects of social sustainability, as well as some additional views and opinions. The main aspects are awareness, willingness, and adaptability, which all encompass a group of views and opinions that relate to each other. The first aspect we found is awareness. Awareness was brought up by many interviewees in different ways. There were many instances in the interviews in which people showed awareness about their own water use, mentioning things such as limiting their water use, choosing the most effective way to water their garden or crops, and growing crops that need less water. One interviewee, who keeps their horses on the Wageningse Eng, commented about how people shouldn't assume that there is unlimited water for them to use (Horse owner A). The stakeholders that we interviewed often associated a lack of awareness with easily accessible water sources, such as private water pumps. One interviewee mentioned that the people who invest in these pumps often lack awareness about their water use since it does not cost them a lot of effort or money to use the water. A second aspect of social sustainability can be summarized with the term willingness. This indicates people's willingness to improve the sustainability of their water use. One interviewee mentioned explicitly that they are willing to make changes to become more sustainable. They say that if you want to be sustainable, you have to accept that you need to change certain things about how you work (Commercial farmer A). In contrast, another interviewee said that sustainability measures generally involve more maintenance and practical difficulties. So even if you want to be sustainable, it stops somewhere. However, if there is a big demand for sustainable change, they are willing to adapt (Landowner A). The third aspect of social sustainability that we will discuss in this report is adaptivity. The aspect adaptivity encompasses all statements about an interviewees' ability to change the water type or water source that they use. Two interviewees stated that there were practical barriers that prevented them from being able to switch to groundwater even if they would have a desire to do so, a stakeholder who keeps bees on the Eng mentioned financial aspects as a barrier (Beekeeper), and another stakeholder indicated that the electricity needed to operate a groundwater pump was a problem (Landowner A). Besides the three main aspects that we found during our research, we also came across some additional statements on social sustainability. This included several mentions of a landscape management collective aimed at producing and selling local products, called De Korenschoof, of which two of the interviewees are a member, and the view that one person's water use should not come at the expense of others. One interviewee mentioned that excess use of groundwater could reduce the groundwater availability for other land users (Animal owner), and another interviewee mentioned that it could negatively affect the availability of drinking water (Kitchen gardener).

Environmental sustainability is another important part of our sustainability assessment. An important aspect of the environmental sustainability is the sustainability of different water types. During the interviews we encountered many statements on the sustainability of groundwater and drinking water use. For groundwater, several interviewees mentioned concerns about private groundwater pumps leading to excess water use (Animal owner; Hobby farmer; Horse owner B). One of those interviewees also stated that the increased use of groundwater could lead to a lower level of groundwater in the area (Hobby farmer). However, one interviewee expressed that it is less wasteful to use groundwater instead of drinking water for irrigation and animal keeping, since the groundwater quality is good enough for this (Cow owner). For drinking water, the opinions were similarly varied. Concerns about using drinking water included the need for the water to be cleaned (Nursery owner A; Beekeeper) and transported (Nursery owner A; Cow owner) and the energy that is needed for these processes (Commercial farmer C). The sustainability of using stored precipitation was discussed very few times, in comparison to groundwater and drinking water, but was always considered as a sustainable option for the future (Cow owner; Horse owner B; Landowner A). Some interviewees expressed uncertainty about the sustainability of the different water types. In one interview a horse owner stated to see both the pros and cons of both groundwater and drinking water (Horse owner A). Another interviewee expressed doubts about the differences between water types because: "The groundwater and drinking water in this area come from the same source." (Hobby farmer). When asked about the sustainability of water types, many interviewees brought up that limiting excess water use, regardless of water type, is the most important thing for water use to be sustainable (Horse owner A; Nursery owner A; Commercial farmer A; Hobby farmer; Nursery owner B; Allotment gardener). Other opinions that stood out included the statement of a resident that the right type of water needs to be used for the right purposes, drinking water to drink and cook and groundwater for irrigation, and the view, expressed by two interviewees, that to be sustainable you should only pump up as much water as falls as precipitation on your ground (Beekeeper; Commercial farmer C). When asked, drinking water company Vitens stated that it is important to focus on reducing the demand first, before looking at the cascading of water and finally the peak demand (Vitens employee). Besides the sustainability of water use, many of the interviewees also brought up other aspects of environmental sustainability. Multiple interviewees stated that they practice, or would like to practice, organic farming. Reasons for this ranged from ecological considerations, and the large amounts of pesticides that are already used in the Netherlands, to being able to supply to organic animal husbandry businesses. Several interviewees were Skal certified (Nursery owner A; Commercial farmer A; Hobby farmer). Two interviewees, who keep their animals on the Wageningse Eng, expressed concerns about large amounts of fertilizer that are being used by others on the Eng. Both worried that these fertilizers might make the groundwater unsafe to use for their animals (Animal owner; Horse owner B. Another aspect of environmental sustainability that was mentioned several times was biodiversity. Some of the farmers we interviewed explained how they grow specific crops or flowers that contribute to the biodiversity of the area (Commercial farmer A; Hobby farmer).

In the interviews, we also asked about people's personal views on sustainability. This included questions about the importance of sustainability and a person's view on their own sustainability and that of others. Overall, people seemed to think sustainability was important to consider. Although one interviewee notably had an opposing view, stating: "Sustainability just isn't so important to [me]" (Landowner A). When asked about their own personal sustainability many interviewees, but especially the stakeholder that keep animals on the Wageningse Eng, brought up using very little water (Horse owner A; Horse owner B; Animal owner; Cow owner). A commercial farmer even stated in their interview that they might be too sustainable (Commercial farmer A). But there was also some uncertainty about personal sustainability, with one interviewee expressing that they do not have enough knowledge on groundwater levels to know if their use of groundwater is sustainable (Kitchen gardener). Another interviewee expressed feeling guilty about the amount of water they use, even though they try to be conscious about this amount (Hobby farmer). Finally, the interviewees were asked about the sustainability of others on the Wageningse Eng. There were a few who did not think they could not, or should not, comment on the sustainability of others, but there were many more interviewees who did express their opinion. Many of the interviewed stakeholders, as well as one respondent to the questionnaire brought up comments other users wasting water by using sprinklers (Horse owner A; Hobby farmer; Commercial farmer B; questionnaire respondent 6 (allotment gardener)), washing their horses a lot (Horse owner A), having too many animals in a field (Commercial farmer A), or growing crops unsuitable for the area (Hobby farmer). Additional comments were made by several interviewees about people watering their plants and crops in unsustainable ways (Hobby farmer; Commercial farmer B), and commercial farmers using too much water (Horse owner B; Allotment gardener). The use of certain water types was also commented on, with one interviewee being critical about the many groundwater wells on the Wageningse Eng (Hobby farmer) and two interviewees who were critical about people using 'clean' drinking water for the irrigation of their plants or crops (Landowner C; Commercial farmer B). Several interviewees also had opposing views on others' sustainability and commended other users on the Wageningse Eng on their irrigation methods (Animal owner; Commercial farmer B; Allotment gardener), their methods of watering animals (Commercial farmer B), or water retention methods (Animal owner; Horse owner B).

In the questionnaire, four statements were graded by the respondents on a likert scale from 'Completely disagree' to 'Completely agree'. As can be seen in Figure 8, most respondents consider their current water use sustainable. However, when looking on the Wageningse Eng as a whole, they are not as positive. In addition, most land users believe that using groundwater is more sustainable than using drinking water. Finally, most respondents think that ecological sustainability is more important than social sustainability.

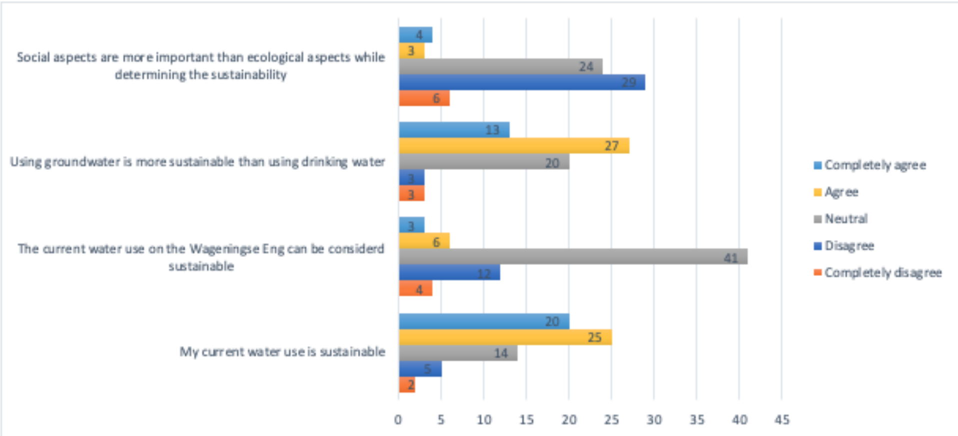

Figure 8 Results from the sustainability statements of the questionnaire.

4.3 Sustainable water use framework

As described in the methodology, this research both creates the framework as well as applies it to the current situation on the Wageningse Eng. Therefore, this results section therefore also includes these two parts.

4.3.1 Creating the sustainable water use framework

We create the framework with three dimensions, including themes, criteria and indicators. According to the water balance and stakeholder analysis, indicators should be concluded into environmental and social themes. Then, we present three criteria on the environmental side, including water supply, water demand, and water use. Meanwhile, adaptivity, willingness, and satisfaction satisfy expectations on the social side. And each indicator of these criteria is shown in Table 11. See Appendix E for the descriptions of each indicator, criteria and theme as well as the justifications for why they were chosen to be included in the framework.

Table 11 Sustainable water use framework

Sustainable water use framework			
Environmental theme		**Social theme**	
Criteria	Indicators	**Criteria**	Indicators
Water supply	Precipitation (mm/year)	**Adaptivity**	Community adaption
	Groundwater (m^3/year)		Flexibility
	Drinking water (m^3/year)		
Water demand	Water demand per animal (m3/per stock/year)	**Willingness**	Participation and ownership
	Irrigate rate (m^3/ha)		
	Water self-sufficient index (%)		Awareness
Water use	Crop water use efficiency (kg/m^3)	**Satisfaction**	Water availability
	Soil water holding capacity (inches/foot of soil)		Water pressure
			Water quality
	Field application efficiency (%)		Water type

4.3.2 Applying the sustainable water use framework

The final framework with grades is shown in Table 12. Figure 9 compares the final scores with maximum possible score it could have gotten. Depending on the grade given to each indicator, we calculated the score of each criterion. We can then also compare these criteria scores with their full mark possibility in Figure 9. Justifications for the grades given to each indicator can be found in Appendix E. As is visible in Figure 9, the final sustainability score is 58.28 out of 100. If we look at the two themes separately, the environmental theme scored 58,17 and the social theme scored 58,49.

Table 12 Sustainable water use framework with scores

Criteria	Score	Indicators	Grade
Water supply	4.45	Precipitation	60
		Drinking water	50
		Groundwater	40
Water demand	7.73	Animal	70
		Irrigation rate	40
		Water self-sufficient index	50
Water use	26.60	Crop water use efficiency	50
		Soil water holding capacity	65
		Field application efficiency	65
Adaptivity	3.00	Community adaptation	70
		Flexibility	20
Willingness	4.67	Participation and ownership	50
		Awareness	80
Satisfaction	11.83	Water availability	40
		Water pressure	60
		Water quality	80
		Water type	50
Final score	58.28		

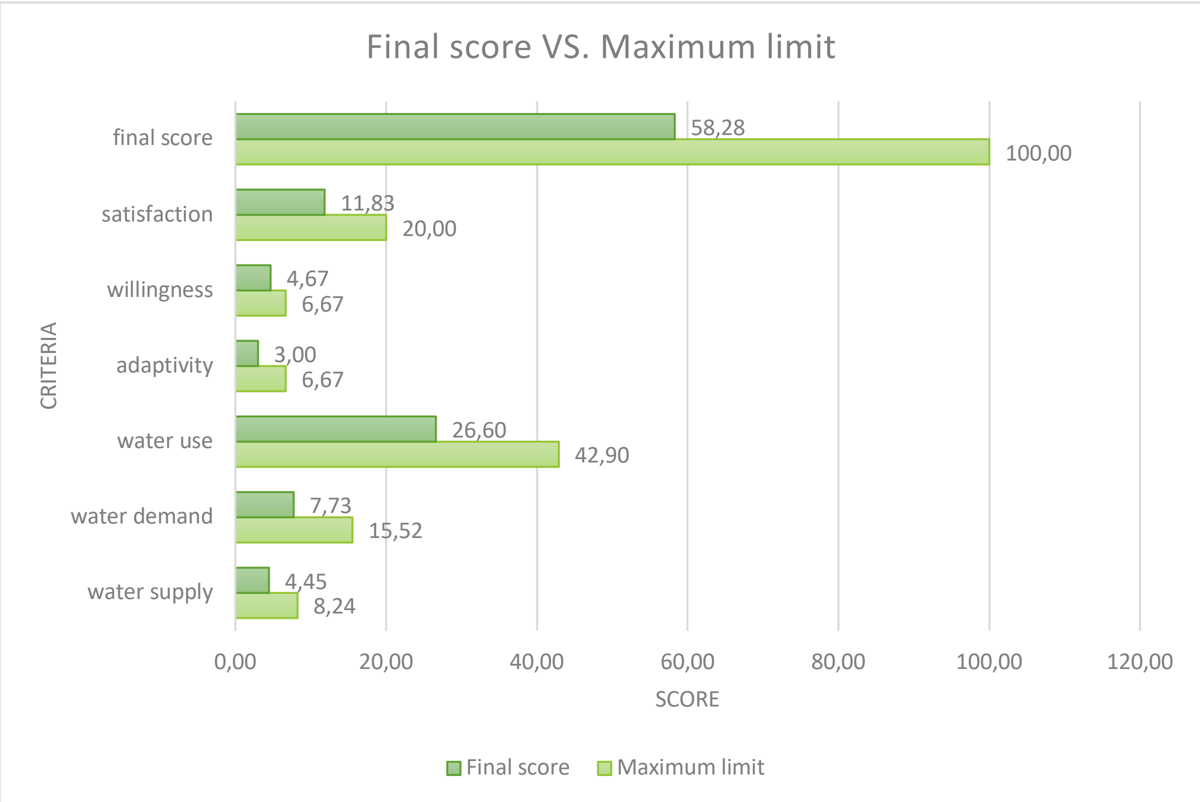

Figure 9 Final score VS. maximum limit

Sensitivity analysis

The score with the justified weights was 58,28/100. When the themes, criteria and indicators all get assigned equal weights, the score becomes 55,14. This shows that changing the weights has quite an impact on the score, with 3,14/100 difference in sustainability while keeping the sustainability scores constant.

We also distorted the weights very unequally to see what would happen. This meant that if a criterium has three indicators, the first two indicators get a 0.1 and the last one a 0.8 so that they together still add up to 1 and thus together weigh 100% for that criterium. These unequal weights resulted in a score of 54/100 which is 4,28/100 difference compared to the justified weights.

This sensitivity analysis shows that the sustainability score is indeed somewhat sensitive to the weights as changing the weights, changes the sustainability score by around 3-4 percentage points without even changing the assigned scores to the indicators.

5. Discussion

5. Discussion

This chapter will discuss the results chapter four and the methods that were used in this research project. Section 5.1 will provide an overview of the main results and the implications of these results on sustainable water use on the Wageningse Eng. Section 5.2 will then reflect on the different methods used in this project. Finally, section 5.3 will provide recommendations on future research.

5.1 Discussion on results

In this section, the main results of the project are discussed. Section 5.1.1 will elaborate on results related to the water balance, groundwater, and the Material Flow Analysis. The sustainability of the different water types will be discussed in section 5.1.2. Thereafter, section 5.1.3 will describe the problems, needs and solutions mentioned by stakeholders. Finally, section 5.1.4 will discuss the results of the sustainability framework.

5.1.1 Water balance, groundwater, and Material Flow Analysis

As became clear from the results, during an average growing season the water balance is closing. However, it is important to note that a significant amount of water is brought into the system with drinking water from the tabs and groundwater from the wells. Without the drinking water irrigation, the average water balance is slightly negative, and excluding any type of irrigation the average water balance is far from closing during the growing season. Therefore, there is more water leaving the system through evapotranspiration than it enters the system via precipitation during the growing season (Table 8). Without the input from water sources from outside the Wageningse Eng, this system is not able to sustain itself because the water demand is higher than the water supply through natural recourses (precipitation) during the growing season.

Furthermore, interesting insights can be gained from the water balance if we look at it on a yearly basis. We then see that there is enough incoming precipitation on yearly basis (848 mm, equal to a total volume of around 1.2 million m3) to supply for the evaporation demand for plants during the growing season (0.61 million m3). Therefore, we can conclude that the shortage of water only exists during the growing season, when demand is high and the supply through rainfall relatively low. For future solutions, it might be worth investigating possibilities to collect and retain precipitation on a large scale, which can then be used during the growing season to irrigate.

From Dinoloket we gathered the information on groundwater levels. The groundwater levels naturally fluctuate throughout the year, with higher groundwater levels during the winter when there is more precipitation than evapotranspiration, than in summer when there is more evapotranspiration than precipitation. From Figure 6 we did not identify an increase or decrease in groundwater levels over the whole timespan between 1972 and 2020. Therefore, we can conclude that, on average, the groundwater does not drop due to for example pumping activities where some stakeholders were concerned about (Figure 6). This is supported by the calculation of the average water balance from the previous section, which is also approximately closing. What does have an influence on the groundwater levels is a lack of precipitation during dry summers. For example, we can see that the groundwater level is dropping very fast after 2017. This is caused by the extremely dry summers of 2018 and 2019 in which we had a precipitation shortage of around 300 mm (Kennisportaal Klimaat Adaptatie, 2021). From the information and calculations on groundwater levels, we can conclude that there is no direct risk for a systematically decreasing groundwater table in the near future.

The amount of water given to the animals as drinking water was left out of the water balance on the grounds that animals do not influence the change in water storage, and therefore do not influence the groundwater level. However, the animals do drink significant amounts of drinking water throughout the year. Therefore, the Material Flow Analysis was established to get an overview on how much water, in total, is brought into the water system of the Wageningse Eng. An important assumption we made is that all animals are given drinking water. Therefore, all water for the animals is brought into the system from outside the system.

The drinking water brought into the system for the animals is estimated at a quantity of 2717 m3 per year. Compared to the sum of all the water influxes this only accounts for 0.2%. Nevertheless, comparing the amount of drinking water used by the allotment garden owners with the amount of drinking water used by the animal owners, we see that animal owners almost use twice as much drinking water. Even if the amount of groundwater used by allotment garden owners is added to this, the animal owners still use much more water.

An important factor to explain why we might find this, is that parcels for animals take up the largest space on the Wageningse Eng (70 ha grassland vs 11 ha allotment garden). On a spatial scale, much more allotment gardens fit on a certain area than animals. Hence, we can calculate the water intensity per area. For animal keeping we find 3.8 l per m2, for allotment garden users we find 22.4 l per m2. This concludes that allotment gardening is a way more water intensive activity than keeping animals on the Wageningse Eng.

From the analyses on the water balance, groundwater levels and the MFA we can conclude that on an average year, the groundwater balance is closing for a growing season. However, large quantities of water are brought from outside the system to inside the Wageningse Eng system during the growing season. Excluding irrigation, the water balance is not closing. On a yearly basis, the water balance is slightly positive, meaning that there is more water input than output. Therefore, the groundwater levels have not changed over the years, except for natural seasonal variation. Finally, we found that significant amounts of water are brought into the system for animals to drink. However, comparing the water use intensity per area for animal keeping and allotment gardens, we find that allotment gardening is much more intensive than animal keeping.

5.1.2 Sustainability of different water types

In general, three different water types are used on the Wageningse Eng namely, precipitation, drinking water and groundwater. The question arises, which of these water types is most sustainable? From the interviews and questionnaire, it became clear that the different users of the Wageningse Eng have various visions on using groundwater, drinking water and precipitation. Land users want to use as much precipitation as possible, since they consider this the most sustainable water source. Based on a study from Hofman & Paalman (2014), we conclude that precipitation is indeed the most sustainable source for irrigation (Hofman & Paalman, 2014). Unfortunately, it is complicated to collect and retain the rainwater because building 'large' structures are prohibited in the open area of the Wageningse Eng (Gemeente Wageningen, 2020). As an example, building a shed over 2 meters high and use this to collect precipitation on the roof is not allowed since this is against the vision of the Wageningse Eng. Besides this, it is also not allowed to build structures into the ground to ensure the safety of the archaeological area (Gemeente Wageningen, 2020). Therefore, an additional source of water, either drinking water or groundwater, besides precipitation is needed to fulfil the water demand on the Wageningse Eng.

A dichotomy was found between land users who are pro groundwater, and land users who are pro drinking water. Reasons for land users to use groundwater are for example that the use of groundwater is more sustainable energy wise as no treatment by Vitens is needed (Personal communication Foundation member, 17-05-2022). On the other hand, we have land users who rather use drinking water. They argue that the drinking water is coming from the same source as the groundwater that is pumped by individual users, the groundwater might be contaminated (personal communication Allotment gardener, 03-06-2022), and the groundwater levels might drop too much if everyone starts pumping groundwater for themselves.

However, we found that it does not matter whether you use drinking water or groundwater. Both water types have pros and cons, and neither of them are bad in a sense that they do not damage humans or the environment, if used wisely. The use of drinking water is more sustainable energy wise as it costs less energy to produce 1m3 of drinking water by Vitens than to pump 1m3 of groundwater by private users (0.23 kwh vs 1 kwh per m3) (Personal communication Vitens employee, 15-06-2022; personal communication Resident, 08-06-2022). However, there is one important drawback on the use of drinking water. Drinking water companies struggle to deliver enough water during peak demands (e.g., during the summer when the water demand is high). During these times, drinking water companies ask people to use the water wisely and not fill swimming pools, wash cars or irrigate gardens when the water demand is high (Personal communication Vitens employee, 15-06-2022). Therefore, for the drinking water company it would be better to use your own groundwater rather than the drinking water provided by de drinking water companies.

To conclude, both drinking water and groundwater have positive and negative aspects. This is where we can introduce the 'Trias Aquatica' as best way of water usage on the Wageningse Eng (Hydroscan, n.d.). The first step is to limit your water use, the second step is to use sustainable water sources, such as precipitation, as much as possible. The last step is cost-effective water infrastructures. There will be further elaborated on the Trias Aquatica in the recommendation for future research section.

5.1.3 Other problems, needs and solutions mentioned by stakeholders

As mentioned in the results section, the main problems stakeholders have are related to water availability, policies and regulations, and weather and climate. Most of these problems are straightforward and do not need to be discussed in great length, such as the dry sandy soil, the policies and regulations preventing land users from building structures to collect precipitation, the longer and more frequent periods of drought, and the electricity needed for a groundwater pump.

The stakeholders also mentioned solutions that they had already implemented or wanted to implement. One of these solutions was to increase the organic matter content of the soil to increase the water retention in the topsoil. Organic matter does indeed increase the water retention of the soil (Dexter, 2004), and is thus a valid solution to retain water in the soil in dry periods. Another solution that was mentioned to retain more water in the soil, was to plant trees to increase capillary rise. This would then increase the water availability for plants with smaller rooting depths. However, according to Moene & Van Dam (2014, p. 164), capillary rise hardly occurs in sandy soils if the groundwater level is more than 65 cm below the root zone. Trees have an average rooting depth of 2.6 meters for a deciduous temperate forest (Canadell, 1996), while the groundwater level is at 20 to 30 meters deep on the Wageningse Eng. Thus, planting trees will not increase capillary rise and is not a sufficient solution to increase the water retention capacity of the soil.

5.1.4 Sustainability framework

In the results, the sensitivity analysis of the MCA showed that the result is somewhat sensitive to the weights assigned to the indicators, criteria and themes. This is interesting because it means that without changing the sustainability scores for the indicators, the final sustainability score for the Wageningse Eng can increase or decrease just by changing the weights. This means you have to take care in interpreting the results. Since the weights were derived by the research team, based on communications with stakeholders, the weights might not completely correspond to the actual weight the stakeholders on the Wageningse Eng collectively would give to the themes, criteria and indicators. If the final sustainability score would not have been sensitive to the weights, the results would be more robust and easier to interpret.

The overall sustainability score is 58,28/100. This means the water system on the Wageningse Eng is slightly unsustainable but can be improved a lot. Thus, there can be many improvements made to increase the sustainable score. The framework can be used to assess how much the water system on the Eng will improve if certain measures are implemented. As previously shown in Figure 1 in the Theoretical Framework chapter, this research omitted step B and C, which includes identifying measures to implement. By assessing how the scores for each of the indicators would change if, for example, measure X, Y and/or Z are implemented, you can compare the new sustainability scores for the whole Wageningse Eng.

Furthermore, it is interesting to discuss the differences in scores between themes, criteria and indicators. Combining the scores for the indicators gives a score of 58,17 for the environmental theme and 58,49 for the social theme. The difference is thus not high, suggesting that the environmental and social sustainability are around the same level of sustainability. While the indicators average out between the two themes, the scores for the indicators themselves do differ substantively, with Flexibility getting 20/100 and Awareness and Water quality both getting 80/100. Thus, the framework can show what aspects on the Wageningse Eng specifically can be improved the most to become more sustainable. In this case, the Flexibility or, in other words, ability to switch water types, needs the most improvement. Other indicators that need the most improvement, all with a 40/100 score, include the supply of Groundwater, a lower Irrigation rate, and an increase in Water availability.

5.2 Discussion on methods

In this section, the internal and external validity will be discussed. Section 5.2.1 will elaborate on the limitations and assumptions of the methods used. Section 5.2.2 discusses the bias in the sampling of stakeholders for the interviews and questionnaire.

5.2.1 Internal validity

In this section, the internal validity of the methods is discussed. With regards to the water balance, it can be concluded that it provides a good indication of the current situation. However, due to several assumptions that had to be made and difficulties with the data collection, it is an indicative rather than a completely reliable overview of the current water use on the Wageningse Eng. The precipitation component could be determined very precisely, but the amounts of evapotranspiration and irrigation were more difficult to determine. Therefore, they were estimated based on data from other research as was explained in the methodology chapter. Next to this, many interviewees and questionnaire respondents had difficulties with estimating their own water use and were only able to provide rough estimates.

Regarding the mapping of land use, two limitations can be recognised. Firstly, there might be some water access points that are missing on the land use map. We did not have access to private properties so we could base the location of water access points only on observations from publicly accessible roads or areas or on data from the interviews or questionnaire. Secondly, the land use map is only valid for the current situation, as land use can change quite rapidly, for example when farmers use crop rotation.

The results of the questionnaire showed how only 23 percent of the questionnaire respondents indicated that they experience problems regarding their water use and water availability. Important to notice is that in many interviews, interviewees first answered that they did not experience any problems. However, through follow-up questions, certain problems or nuisances often arose. This can indicate that in the questionnaire, there might be an underestimation of stakeholders on the Wageningse Eng that experience problems.

With regards to the sustainability framework, the development of the MCA might be biased, since the criteria, indicators, and weights are determined and defined by the project team. Therefore, the scores of the sustainability framework are likely subjective. This also followed from the sensitivity analysis, which showed that the final sustainability score is somewhat sensitive to the assigned weights. Therefore, it might be wise to explicitly consult the different stakeholders and ask them to weigh the themes, criteria and indicators. Per indicator, the average weight of all the different stakeholders can then be used in the framework. This is more reliable as it would be the actual weights by users on the Eng instead of the interpretation of the researchers on what the stakeholders said.

Despite this bias, there are several advantages of effectively applying a well-constructed MCA as part of a decision-making tool, such as structural clarity, efficiency, flexibility, risk, and consistency (Infrastructure Australia, 2021).

Finally, we were not able to gather all necessary data for a quantitative analysis of the environmental part of the sustainability framework. Instead, qualitative scores have been assigned to the indicators. Due to time constraints, the sustainability framework was developed while simultaneously conducting the interview and developing and distributing the questionnaire. This means that it was not possible to ask questions that were specifically designed to provide the quantitative data for the environmental part of the framework. Future research should ensure that the framework is fully developed before starting with the gathering of data.

5.2.2 External validity

In this section, the external validity of the research is discussed. As part of the research, a lot of information was gathered from interviews, the questionnaire and short conversations with land users in the field.

The questionnaire was sent out to (almost) all land users on the Wageningse Eng. We got a total of 69 responses on the questionnaire. However, out of the 69 respondents, 62 respondents had an allotment garden, 9 respondents kept animals, 7 respondents conducted farming and 1 respondent owned a plant nursery. Therefore, in the results of the questionnaire, the allotment garden stakeholder group is disproportionally represented compared to other stakeholder groups.

The same issue occurred regarding the conversations in the field. During the mapping of the area, we spoke to relatively many allotment gardeners because these were the land users present in the field during the day. Therefore, the allotment gardeners are overly represented.

For the interviews, the different stakeholder groups that we identified as important, were included (allotment gardeners, (commercial and hobby) farmers, plant nursery owners, animal owners and residents). However, only one or two persons from each stakeholder group were interviewed. Therefore, the results of the interviews might not completely represent the situation on the Wageningse Eng. As the interviews were used to give scores in the sustainability framework, this will also result in a generalisation of the sustainability assessment. For example, four interviewees were satisfied with their current water type and four of them mentioned they would like to use a different water type. Therefore, the score that was assigned in the sustainability framework was 50/100. However, this was based on only eight interviewees, and is thus a generalisation of the sustainability on the Wageningse Eng.

To finalize, while all important stakeholder groups are represented in the research, the allotment gardeners are overrepresented.

5.3 Recommendations

The recommendations in this section all relate to suggestions for future research. Suggestions to improve the sustainability of the Wageningse Eng is not part of the recommendations as this is beyond the scope of the research project. This first part includes recommendations related to the Trias Aquatica, which was previously mentioned in the results. The second part of the recommendations covers recommendations unrelated to the Trias Aquatica.

5.3.1 Trias aquatica

As introduced before, investigation on Trias Aquatica (TA) might be interesting for future research. The TA consists of three steps, namely: limit water consumption, maximize the use of sustainable water sources (precipitation) and cost-effective water infrastructure (Figure 10) (Hydroscan, n.d.). The TA can be used as a guideline for recommendations for solutions and future research.

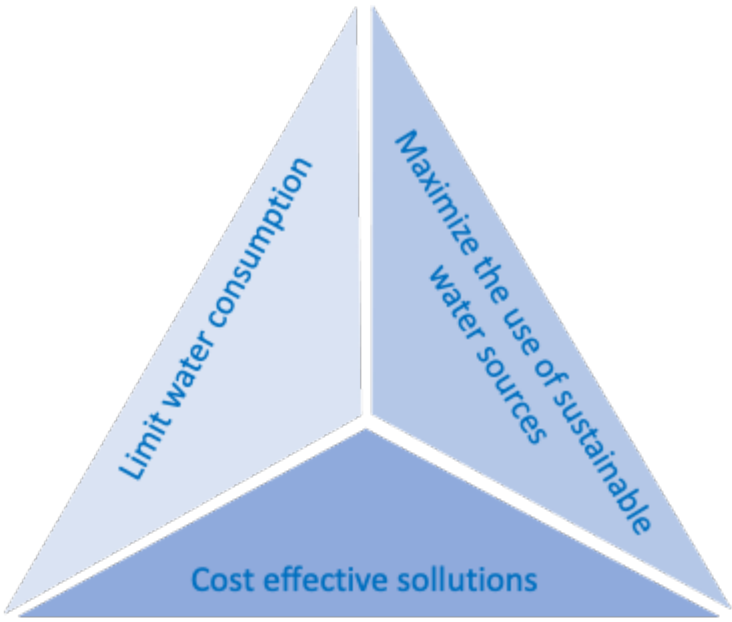

Figure 10 Trias aquatica: limit water consumption, maximise the use of sustainable water sources and cost-effective solutions.

Limit water consumption

From the interviews, it became clear that land users on the Wageningse Eng are conscious about the water they use and that they try to waste as little water as possible. However, from the questionnaire we also found that most land users do not have any clue on how much water they are using approximately. This raises the question whether they are as conscious about their own water use as they stated they are. Creating more awareness on the amount of water they are using might help the people on the Wageningse Eng be more conscious of their water use. Consequently, this might also reduce the overall water consumption (Kappel & Grechenig, 2009).

Maximise the use of sustainable water sources

Maximising the use of sustainable water sources would be worth studying. Most interviewees, and people we met in the field, would like to make more use of precipitation (Personal communication with allotment gardeners 01-06-2022). However, as stated before, the collection and storage of precipitation is complicated due to strict building guidelines in the vision of the Wageningse Eng e.g., no building under the ground, no building higher than 1.5 m above the ground (Gemeente Wageningen, 2020). Therefore, finding solutions for collection and storage of precipitation, or altering some of the policies and regulations to facilitate this would be highly valuable.

Cost-effective solutions

Finally, financial considerations play an important role in the different water usage types on the Wageningse Eng. For the usage of drinking water, you have to pay water company Vitens. However, digging a groundwater well is expensive as well (Personal communication Resident 08-06-2022). An investigation on cost effective solutions is very important in this area. Since most people are only individual users and might not have the same financial resources as large companies, the solutions should be cheap and easy to implement. A suggestion made by stakeholders was to increase the organic matter content to improve the water holding capacity of the soil.

5.3.2 Other recommendations

Several different suggestions on what to investigate within the Wageningse Eng area in the future have been made. The first and most frequently mentioned suggestion is to do an analysis on the quality of the groundwater to see whether there are any toxins and pesticides left in the groundwater from previous activities (Personal communication Allotment gardener, 03-06-2022). This is highly important because people want to carry out organic farming. If the groundwater they are using to irrigate their land is full of pesticides, their farming activity cannot be considered organic anymore. Soil quality is another interesting aspect to look into, both in organic matter content around the area, as well as for local pollutions (Personal communication Horse owner B, 03-06-2022). In the past, there was a gas station on the Wageningse Eng. This might have caused local soil pollution. This pollution can leak towards the groundwater and affects its quality.

6. Conclusion

6. Conclusion

The goal of our research was to investigate the current sustainability of the water use on the Wageningse Eng.

From the analysis on water use, we find a closed water balance during the growing season for an average year. However, the average amount of precipitation is not enough to meet the water demand for the different activities on the Wageningse Eng. Therefore, large quantities of drinking water are brought into the Wageningse Eng for irrigation during the growing season and to supply animal water intake. Equally large quantities of groundwater are extracted and applied as irrigation on agricultural fields and allotment gardens.

During the stakeholder analysis, we came across different opinions on the social and environmental sustainability on the Wageningse Eng. Amongst the different stakeholders on the Wageningse Eng, we saw some level of awareness and willingness already being demonstrated by their self-described efforts to limit their water use. However, there was also still a large group of people who was unable to estimate their own water use, indicating that the general awareness about sustainable water use could still be improved. Generally, people on the Wageningse Eng also had an opinion about the sustainability of different water types, such as groundwater and drinking water. Many agreed that precipitation is the most sustainable source of water. Unfortunately, in the current situation, the amount of precipitation that is collected and stored is not enough to meet the demands on the Wageningse Eng. Therefore, another water source is needed in addition to precipitation, which can be either groundwater or drinking water. We found that there was a slight preference for the usage of groundwater over drinking water, since this is viewed as the more sustainable water type of the two. However, in the case of the Wageningse Eng, the usage of drinking water is more sustainable with regards to energy use. Therefore, we can conclude that whenever precipitation cannot be used, drinking water is considered the most desirable alternative with regards to sustainable water use.

Based on the sustainable water use framework we created, the sustainability score of current water use in Wageningse Eng is 58. This shows that the current water use is slightly unsustainable. Though the willingness to improve of the land users on the Wageningse Eng is at a high level, it is difficult for them to implement solutions to improve the sustainability since the adaptivity is lower than the other criteria. The environmental sustainability could be improved by decreasing the amount of irrigation with drinking water and groundwater.

We can conclude that the water use is slightly unsustainable on the Wageningse Eng. The most important aspect of social sustainability, awareness, is present among the land users. Therefore, in the future, the focus should be on collaborative solutions to improve the sustainability on the Wageningse Eng.

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Appendices

Appendix A. Questionnaire

Introductie

Wij zijn zeven studenten aan de Wageningen Universiteit (WUR). Wij doen onderzoek naar het watergebruik op de Wageningse Eng en hebben hiervoor informatie van de landgebruikers en –eigenaren nodig. Dit onderzoek is onderdeel van het vak Academic Consultancy Training (ACT) en wordt uitgevoerd voor onze opdrachtgever De Wetenschapswinkel WUR. Met deze enquête willen we graag informatie over watergebruik op de Wageningse Eng verkrijgen en we willen de meningen en visies van alle landgebruikers en -eigenaren in kaart brengen. Uw antwoorden zijn daarbij van groot belang en we zouden het zeer waarderen als u de vragen zou willen beantwoorden.

De enquête duurt tussen de 5 en 10 minuten. Uw deelname aan deze enquête is volledig vrijwillig en u kunt de enquête op elk moment beëindigen. Uw antwoorden zullen worden opgeslagen in een beveiligde omgeving. Uw antwoorden worden anoniem verwerkt. Alle gegevens worden vertrouwelijk behandeld en alleen gebruikt voor dit onderzoek. Alleen de zeven leden van ons ACT team, onze coach en academische adviseur hebben toegang tot deze data tot en met 1 juli 2022. De data wordt daarna overgedragen naar de Wetenschapswinkel en zij slaan de data op tot en met december 2023.

Als u vragen hebt over deze enquête kunt u een mail sturen aan: robin.martens@wur.nl
Alvast hartelijk dank voor uw medewerking en tijd!

ACT groep 2881
Wageningen Universiteit

1. Toestemmingsverklaring

Als u onderstaande knop “Akkoord” aanklikt, betekent dit dat:

- U bovenstaande informatie hebt gelezen
- U vrijwillig deelneemt

a. Akkoord
b. Niet akkoord

2. Wat is uw voor- en achternaam? Uw naam zal alleen gebruikt worden ter identificatie voor de onderzoekers. Alle antwoorden worden anoniem verwerkt.

Vragen activiteiten en watergebruik

3. Bent u woonachtig op de Wageningse Eng?
a. Ja
b. Nee

4. Bent u landeigenaar op de Wageningse Eng?
a. Ja
b. Nee

5. Bent u gebruiker van land op de Wageningse Eng?
a. Ja
b. Nee

6. Heeft u een volkstuin op de Wageningse Eng?
a. Ja
b. Nee

Vraag 7 tot en met vraag 14 worden alleen weergegeven mits het antwoord op vraag 6 ja is.
7. Wat is de oppervlakte van uw volkstuin? Vermeld a.u.b. de eenheid (m2, hectare, etc.)

8. Geef door te klikken op de kaart de locatie van uw volkstuin aan.

9. Bent u eigenaar van het land dat u gebruikt voor uw volkstuin?
a. Ja
b. Nee

10. Hoeveel water gebruikt u gemiddeld per jaar op uw volkstuin? Vermeld a.u.b. de eenheid (m3, liters etc.)

11. Welk type(s) water gebruikt u?
a. Drinkwater (aansluiting drinkwater aanwezig op volkstuinen(complex))
b. Drinkwater (aansluiting drinkwater NIET aanwezig op volkstuinen(complex))
c. Grondwater (grondwaterput aanwezig op volkstuinen(complex))
d. Grondwater (grondwaterput NIET aanwezig op volkstuinen(complex))
e. Regenwater

Vraag 12 wordt alleen weergegeven mits het antwoord op vraag 11 b is.
12. Waar haalt u het drinkwater vandaan?

Vraag 13 wordt alleen weergegeven mits het antwoord op vraag 11 d is.
13. Geef door te klikken op de kaart de locatie van de grondwaterpomp aan die u gebruikt.

14. Op welke manier geeft u water op uw volkstuin? (bijv. sproeiinstallatie, gieters, tuinslang, geultjes, etc.)

15. Houdt u dieren op de Wageningse Eng?
a. Ja
b. Nee

Vraag 16 tot en met vraag 24 worden alleen weergegeven mits het antwoord op vraag 15 ja is.
16. Welke dieren houdt u op de Wageningse Eng?

17. Hoeveel dieren heeft u per soort?

18. Geef door te klikken op de kaart de locatie aan waar u dieren houdt

19. Bent u eigenaar van het land dat u gebruikt om dieren te houden?

a. Ja
b. Nee

20. Wat is de oppervlakte van het land dat u gebruikt om dieren te houden? Vermeld a.u.b. de eenheid (m2, hectare etc.)

21. Hoeveel water gebruikt u gemiddeld per jaar voor het houden van dieren op de Wageningse Eng? Vermeld a.u.b. de eenheid (m3, liters etc.)

22. Welk type water gebruikt u?
a. Drinkwater (aansluiting aanwezig op locatie)
b. Drinkwater (aansluiting NIET aanwezig op locatie)
c. Grondwater (Grondwaterput aanwezig op locatie)
d. Grondwater (Grondwaterput NIET aanwezig op locatie)
e. Regenwater

Vraag 23 wordt alleen weergegeven mits het antwoord op vraag 22 b is.
23. Waar haalt u het drinkwater vandaan?

Vraag 24 wordt alleen weergegeven mits het antwoord op vraag 22 d is.
24. Geef door te klikken op de kaart de locatie van de grondwaterpomp aan die u gebruikt.

25. Verbouwt u agrarische gewassen op de Wageningse Eng? Volkstuinen, pluktuinen en kwekerijen vallen niet onder deze categorie
a. Ja
b. Nee

Vraag 26 tot en met vraag 34 worden alleen weergegeven mits het antwoord op vraag 25 ja is.
26. Welke gewassen verbouwt u?

27. Wat is de oppervlakte van het land dat u gebruikt voor ieder gewas? Vermeld a.u.b. de eenheid (m2, hectare etc.)

28. Geef door te klikken op de kaart de locatie aan waar u agrarische gewassen verbouwt

29. Ben u eigenaar van het land dat u gebruikt voor het verbouwen van gewassen?
a. Ja
b. Nee

30. Hoeveel water gebruikt u gemiddeld per jaar voor het verbouwen van gewassen op de Wageningse Eng? Vermeld a.u.b. de eenheid (m3, liters etc.)

31. Welk type water gebruikt u?
a. Drinkwater (aansluiting aanwezig op locatie)
b. Drinkwater (aansluiting NIET aanwezig op locatie)
c. Grondwater (Grondwaterput aanwezig op locatie)
d. Grondwater (Grondwaterput NIET aanwezig op locatie)
e. Regenwater

Vraag 32 wordt alleen weergegeven mits het antwoord op vraag 31 b is.
32. Waar haalt u het drinkwater vandaan?

Vraag 33 wordt alleen weergegeven mits het antwoord op vraag 31 d is.
33. Geef door te klikken op de kaart de locatie van de grondwaterpomp aan die u gebruikt.

34. Op welke manier geeft u water aan uw gewassen? (bijv. sproeiinstallatie, gieters, tuinslang, geultjes, etc.)

35. Heeft u kwekerij, pluk- of oogsttuin op de Wageningse Eng? Volkstuinen vallen NIET onder deze activiteit
a. Ja
b. Nee

Vraag 36 tot en met vraag 44 worden alleen weergegeven mits het antwoord op vraag 35 ja is.
36. Welke planten, bloemen of groenten kweekt u?

37. Wat is de oppervlakte van het land dat u gebruikt voor iedere soort? Vermeld a.u.b. de eenheid (m2, hectare etc.)

38. Geef door te klikken op de kaart de locatie aan waar u planten, bloemen of groenten kweekt

39. Bent u eigenaar van het land dat u gebruikt voor het kweken van planten, bloemen of groenten?
a. Ja
b. Nee

40. Hoeveel water gebruikt u gemiddeld per jaar voor het kweken van planten, bloemen of groenten op de Wageningse Eng? Vermeld a.u.b. de eenheid (m3, liters etc.)

41. Welk type water gebruikt u?
a. Drinkwater (aansluiting aanwezig op locatie)
b. Drinkwater (aansluiting NIET aanwezig op locatie)
c. Grondwater (Grondwaterput aanwezig op locatie)
d. Grondwater (Grondwaterput NIET aanwezig op locatie)
e. Regenwater

Vraag 42 wordt alleen weergegeven mits het antwoord op vraag 41 b is.
42. Waar haalt u het drinkwater vandaan?

Vraag 43 wordt alleen weergegeven mits het antwoord op vraag 41 d is.
43. Geef door te klikken op de kaart de locatie van de grondwaterpomp aan die u gebruikt.

44. Op welke manier geeft u water aan u planten, bloemen of groenten? (bijv. sproeiinstallatie, gieters, tuinslang, geultjes, etc.)

45. Houd u zich bezig met andere activiteiten op de Wageningse Eng?
a. Ja
b. Nee

Vraag 46 tot en met vraag 53 worden alleen weergegeven mits het antwoord op vraag 45 ja is.
47. Wat is uw activiteit op de Eng?

48. Wat is de oppervlakte van het land dat u gebruikt voor uw activiteit? Vermeld a.u.b. de eenheid (m2, hectare etc.)

49. Geef door te klikken op de kaart de locatie van uw activiteiten aan.

50. Hoeveel water gebruikt u gemiddeld per jaar voor deze activiteit(en)? Vermeld a.u.b. de eenheid (m3, liters etc.)

51. Welk type water gebruikt u?
a. Drinkwater (aansluiting aanwezig op locatie)
b. Drinkwater (aansluiting NIET aanwezig op locatie)
c. Grondwater (Grondwaterput aanwezig op locatie)
d. Grondwater (Grondwaterput NIET aanwezig op locatie)
e. Regenwater

Vraag 52 wordt alleen weergegeven mits het antwoord op vraag 51 b is.
52. Waar haalt u het drinkwater vandaan?

Vraag 53 wordt alleen weergegeven mits het antwoord op vraag 51 d is.
53. Geef door te klikken op de kaart de locatie van de grondwaterpomp aan die u gebruikt.

Vragen problemen omtrent water
54. Ervaart u problemen betreffende het watergebruik op de Wageningse Eng?
a. Ja
b. Nee

Vraag 55 wordt alleen weergegeven mits het antwoord op vraag 54 ja is.
55. Welke problemen ervaart u betreffende het watergebruik op de Wageningse Eng?

Vraag 56 wordt alleen weergegeven mits het antwoord op vraag 54 ja is.
56. Hoe kunnen deze problemen verholpen worden?

Vragen duurzaamheid

57. Geef aan in hoeverre u het met de volgende stellingen eens bent (see Table 13):

Table 13 Statements on sustainability for the questionnaire.

	Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
Mijn huidige watergebruik is duurzaam	o	o	o	o	o
Het huidige watergebruik op de gehele Wageningse Eng is duurzaam	o	o	o	o	o

Het gebruik van grondwater is duurzamer dan het gebruik van drinkwater	o	o	o	o	o
In het bepalen van duurzaamheid zijn sociale aspecten belangrijker dan ecologische aspecten	o	o	o	o	o

Einde

58. U bent bijna aan het einde gekomen van de enquête. Mocht u nog toevoegingen/opmerkingen hebben, dan kunt u ze hieronder plaatsen.

U bent hierbij aan het einde van de enquête gekomen. Uw antwoorden zijn opgeslagen. Hartelijk dank!

Appendix B. Interview guide

Praktische punten

- Print het geïnformeerde toestemmingsformulier 2x uit om te ondertekenen, en vul ons eigen deel al vast in.
- Neem een geprinte kaart mee.
- Neem verschillende kleuren pennen mee.
- 2x telefoon mee voor opname gesprek.
- Notitieboek voor aantekeningen.
- Zoek interviewee op, verzamel informatie over ze.
    - Vragen toevoegen aan de guide specifiek voor deze persoon?
- Print 2x interview guide en neem mee.

Als het een online interview is:

- Zet de automatische transcriptie van Teams aan en zet de gesproken taal op Nederlands.
- Voor de kaart
    - Download van tevoren het bestandje 'Complete Eng', waarop ingetekend moet worden.
    - Deel de kaart via Share en Microsoft Whiteboard.
    - Deel het bestand en laat mensen hierop intekenen.
    - Download de ingetekende kaart

Introductie Interview (5 minuten)

- Wij zijn [namen].
- Project waar we aan werken: Wij doen onderzoek naar het watergebruik op de Wageningse Eng en hebben hiervoor informatie van de landgebruikers en –eigenaren nodig.
- Affiliatie: Wij doen dit onderzoek vanuit een vak van de Wageningen University & Research en onze opdrachtgever is de Wageningen Science Shop.
- Waarom u: U bent een landgebruiker/eigenaar op de Wageningse Eng en kan daarom informatie over het watergebruik met ons delen.
- Hoe aan naam gekomen: via de Stichting Wageningse Eng.
- Duur interview: ±30 minuten.
- Structuur interview: openingsvragen, vragen over uw watergebruik en problemen en behoeften met betrekking tot het watergebruik. We eindigen met wat eindvragen en sluiten daarna het interview.
- Geïnformeerde toestemming:
    - Formulier bespreken
    - 2x FORMULIER LATEN ONDERTEKENEN. Éen formulier meegeven en één zelf houden.
- Vraag of alles duidelijk is en of de geïnterviewde nog vragen heeft voordat we beginnen.
- **Begin met opname op 2 telefoons.**

Openingsvragen (5 minuten)

1. Wat doet u op de Wageningse Eng?
    a. Welke activiteiten bijv. graanteelt, paarden houden, volkstuinder, landeigenaar.
    b. Voor dierhouders:
        i. Welke dieren?
        ii. Aantal per diersoort?
    c. Voor boeren/telers:
        i. Welke gewassen/planten?
        ii. Oppervlakte per gewas/plant?
2. Bent u eigenaar van land op de Wageningse Eng?
3. Gebruikt u land waarvan u niet de eigenaar bent?
    a. In het geval dat dit zo is, vraag van wie de grond is.
4. **Per activiteit**, geef op de kaart aan wat de omvang is van het land dat u gebruikt en/of in het bezit heeft?
    a. Ze moeten op de kaart het land waar ze eigenaar van zijn/ gebruik van maken omlijnen.
    b. Als ze zowel land in het bezit hebben als ander land gebruiken, moet dit beide aangegeven worden.
    c. Zorg dat het duidelijk is welke omlijning bij welke activiteit hoort.
5. **Herhaal vraag 4 voor elke activiteit.**

Hoofdvragen (15 minuten)

Thema A. Huidig watergebruik (5 minuten)

Per activiteit, stel vraag 7 en 8.

6. Voor stakeholders die iets verbouwen/telen, op welke manier geeft u water aan de gewassen en/of planten? (Sproei installatie, etc.)
7. **Per activiteit**, hoeveel water gebruikt u per jaar? (m3 of L)
        i. Als ze dit niet weten, vraag naar watergebruik gemiddeld per week **EN** of ze dit per jaar kunnen uitzoeken en later kunnen doorgeven aan robin.martens@wur.nl
    a. Verschilt dit watergebruik per jaar?
    b. Wat is het gemiddelde watergebruik per jaar van de afgelopen ±10 jaar?
        i. Eventueel minder jaar als ze het niet weten.
    c. Hoeveel verschilt dit watergebruik per seizoen? (met voorkeur in m3 of L)
    d. Wat is de oppervlakte (m2 of ha) van het gebied dat u gebruikt voor deze activiteit?
8. **Per activiteit**, welk type water gebruikt u? (drinkwater, grondwater, regenwater)
    a. Waar haalt u het water vandaan?
        i. Geef aan op de kaart waar het waterpunt is.
    b. In het geval dat grondwater gebruikt wordt: is de put/pomp in uw bezit of is die van iemand anders?
        i. Zijn er afspraken en/of contracten over de relatie en rechten van de eigenaar en andere gebruikers met betrekking tot het watergebruik uit deze put?
            1. Wat houden die in?
    c. In het geval dat er geen pomp in uw bezit is: heeft u plannen om een put te laten slaan?
    d. In het geval dat de pomp uw bezit is: gebruiken andere mensen de put/pomp ook?
        i. Zo ja, wie?
        ii. Voor welk land? Geef weer aan op de kaart.
        iii. Voor welke activiteiten?
        iv. En hoeveel water per stuk land? (m3 of L)
9. **Herhaal vraag 7 en 8 per activiteit.**

Thema B. Huidige problemen en behoeften (5 minuten)

10. Bent u tevreden over de beschikbaarheid van water?
    a. Bijv. kwantiteit, kwaliteit, type water, waterdruk.
11. Ervaart u problemen betreffende het watergebruik? Bij ontevredenheid bij vraag 10, vraag welke problemen.
    a. Welke problemen?
    b. Bijv. kwantiteit, kwaliteit, type water, waterdruk.
12. Denkt u dat andere gebruikers op de Wageningse Eng vergelijkbare ervaringen hebben betreffende watergebruik?
    a. Bijv. kwantiteit, kwaliteit, type water, waterdruk.
13. Hoe kunnen deze problemen verholpen worden?
    a. Is er iets geprobeerd om de genoemde problemen op te lossen?
        i. Door uzelf, door anderen?
        ii. Hoe?
        iii. Heeft het geholpen?
    b. Als het niet heeft geholpen, wat heeft u zelf nog nodig om deze problemen te verhelpen?

14. Hoe zouden de watervoorzieningen eruit moeten zien om uw activiteiten optimaal uit te voeren?

Thema C. Duurzaam watergebruik (5 minuten)

15. Wat ziet u als duurzaam watergebruik op de Wageningse Eng?
    a. En hoe ziet u de sociale duurzaamheid? Impact op belanghebbenden, betaalbaarheid, etc.
16. Hoe duurzaam denkt u dat het huidige watergebruik op uw land/ het land dat u gebruikt is?
17. Hoe duurzaam denkt u dat het huidige watergebruik in het open deel van de Wageningse Eng in het algemeen is?

Eindvragen (1 minuut)

18. Zijn er mensen waarvan u denkt dat wij daarmee moeten praten over deze onderwerpen?
    a. Zo ja, heeft u contactinformatie voor ons?

Einde interview (2 minuten)

- Geef aan dat alle vragen zijn gesteld. Bedank de geïnterviewde voor hun input en tijd.
- Vraag of de geïnterviewde nog opmerkingen of vragen heeft.
- Geef een korte samenvatting van wat er is gezegd in het interview
- Vraag hoe de geïnterviewde het interview ervaarde.
- Bedankt nogmaals de geïnterviewde en sluit af.
    - Optioneel: geef bedankje zoals bijv. een chocoladereep.

Appendix C. Data on water balance and MFA

Water balance

The water balance and the corresponding data is with Viola Benning from the WUR science shop.

MFA

The animal drinking water consumption in the MFA is shown in Table 14. The data about the water consumption of the different animal types was gathered from the stakeholder interviews, as well as from literature. Since only a small amount of goats is kept on the Wageningse Eng, we decided to estimate the water consumption of the sheep/goats animal type based solely on sheep water consumption (Fischer er al., 2017). The water consumption of horses, donkeys and cows were based on stakeholder interviews. The water consumption of the deer was based on literature on water intake of Fallow Deer (Mcgregor, 1986).

Table 14 Animal drinking water amount in MFA

Animal types	**Animal amount**	**Water consumption per animal (L/d)**	**Data source**	**Water consumption per animal (m^3/a)**
Sheep/goats	66	1.45	Fischer et al. (2017)	95.70
Horses	190	35	Personal communication animal owner, 10-06-2022	6650
Cows	22	20	Personal communication cow owner, 13-06-2022	440
Donkey	6	35	Estimation based on horse water consumption	210
Deers	18	2	Mcgregor (1986)	36
Total animal drinking water amount (m^3/a)				7431.70

Appendix D. Stakeholder long list

The Wageningse Eng has many people and organizations related to the broad problem, some of them strongly impact the problem, while others are not that involved. Therefore, it was necessary to do a stakeholder-analyse in which we estimate the interests and power of all stakeholders.

Firstly, we created a stakeholder long list (Table 15) with every person, business, and group that could possibly have a stake in our project. Then we determined their interests and power with regards to sustainable water management on the Wageningse Eng and plotted them on a Power Interest Matrix which you can see in Figure 11. Finally, we analysed this grid in order to create our short list of stakeholders, with only those stakeholders that we determined had the most interest.

Figure 11 Influence-interest matrix.

Table 15 Stakeholder longlist

Stakeholder in long list		Interest	Power	Short-list stakeholder components
No.	**Name**			
1	Allotment garden users	High	Low	Yes
2	Parcel owners	Medium	High	Yes
3	Board foundation Wageningse Eng	High	High	Yes
4	Horse owners.	High	Low	Yes
5	Sheep owners	High	Low	Yes
6	Deer owners	High	Low	Yes
7	Commercial Farmers	High	Medium	Yes
8	Hobby and semi-commercial farmers (e.g. De Nieuwe Ronde)	Medium	Medium	Yes

9	Gemeente Wageningen	Low	High	No
10	Provincie Gelderland	Low	High	No
11	Vitens	Low	Medium	No
12	Waterschap Vallei en Veluwe	Low	Medium	No
13	WUR	Low	Low	No
14	Recreational users (strollers, cyclists)	Low	Low	No
15	Residents	Medium	Low	No
16	Pluktuin ‘Bloemrijk’	High	Low	Yes
17	Pluktuin ‘De bosrand’	High	Low	Yes
18	Local environmental organisations	High	Medium	Yes
19	TAWE	High	High	No
20	Klankbordgroep sustainable water use Wageningse Eng	Medium	Medium	No
21	Klankbordgroep Vision Wageningse Eng	Medium	Medium	No

Appendix E. Overview indicators justification and detailed description

E.1 Justification of choosing themes, criteria, and indicators

This section justifies why the various themes, criteria, and indicators were chosen for the creation of the framework.

Themes justification

Based on the information from the water balance and stakeholder analysis, we formulated themes for the framework. Usually, sustainable water use should be assessed by environmental, social, and economic, these three dimensions (Purvis, Mao & Robinson, 2019)). In our project, the main activities are related to the water balance and stakeholder analysis. Thereout, we can figure out the water use on the nature side by current water balance. Stakeholder analysis also helps us address the sustainable situation on the social side. Furthermore, we don't have enough information from economic information on current water use. Moreover, we can't get economic facts from stakeholders due to privacy limitations. We thereby prefer to evaluate sustainable water use from environmental and social themes in our project.

We justify the criteria and indicators in both themes separately.

Environmental criteria and indicators justification

The environmental theme has three criteria in the framework, and each of them has three indicators.

In creating MFA, we conclude the water flow with import, export, and stock in the system (Wageningse Eng). Each of them is a critical component of the water balance. The import water flow is the water supply to the system. Also, water supply depends on water demand which is also essential and decided by the activities in Wageningse Eng. Moreover, the activities in the boundary determine the performance of water use. And if using water efficiently, then it should reflect on the water quantity of export. So, we take water supply, water demand, and water use as criteria to overview the current water situation of Wageningse Eng.

Water supply: There are three flows of water supply based on the water import in MFA. They are separately precipitation, drinking water for irrigating the allotment gardens, and groundwater, which are all be analysed in the water balance section. The results of water balance supply enough data and information on their water quantity. Thereout, we take these three water types as indicators in water supply criteria, precipitation, drinking water, and groundwater.

Water demand: Wageningse Eng consists of different land-use types, basically, these are farms that need irrigating. And through the stakeholder analysis and land mapping, we notice there are amounts of animals (more than 150) here that need feeding water. Both activities, irrigating and feeding, determine the water demand in Wageningse Eng. From the land-use mapping and stakeholder analysis, the water quantity of animals as an indicator can be addressed. Irrigation rate can reflect water quantity on irrigating demand in Wageningse Eng (Olgarenko & Tsekoeva, 2012). Considering the extracted groundwater from Wageningse Eng directly irrigates the farm, it thus can improve sustainability because this action decreases the water demand from the outside. The water self-sufficient index (WSSI) as an indicator can measure how this harvested water influences the sustainable situation (da Silva et al., 2016). In conclusion, water quantity of animals, irrigation rate, and WSSI are indicators of water demand criteria.

Water use: From interviews and questionnaires, we conclude three indicators which can reflect how they use water. The methods on how they irrigate the farm is different in Wageningse Eng which can influence their water use performance. Field application efficiency as an indicator can measure this problem, if the efficiency is high which means irrigation water is lost more (Irrigation Engineering, n.d.) of this irrigating method. Through collecting information from water balance and interviews, the soil type can also affect water use and there are already some implementations for decreasing water loss. To specify this, we apply soil water holding capacity as an indicator (Plant & Soil Science eLibrary, n.d.). If the capacity is high, then it means the soil needs less water, and decreases water demand either. Furthermore, Wageningse Eng now has different plants and farmer would like to plant the crop expended less water. Crop water use efficiency as an indicator to reflect the water amount of crop growth (Trimble, 2021). Afterall, field application efficiency, soil water holding capacity, and crop water use efficiency consist of water use criteria

Social criteria and indicators justification

The social theme consists of three (3) criteria (adaptivity, willingness, and satisfaction), each criterion at least consists of two (2) indicators that will be discussed in below. Over the last decade, literature on water management has included social aspects in indicators of sustainability and resilience, recognizing that human behaviour greatly influences water use (Polonenko et al., 2020). Though it is obvious that human behaviour is of course more difficult to measure due humans' behaviour being unpredictable and not be controlled during environmental research (Nesselroade and Molenaar, 2016). However, individuals and households always comprise the units of analysis (Polonenko et al., 2020).

Firstly, the adaptation criterion consists of two indicators: community adaptation and flexibility these were choosing as a result of stakeholder responses from the interviews conducted by the team. Secondly, for the willingness criterion, it consists of participation & ownership and awareness, and they were choosing based on the assumption was made that willingness can be used as an overarching criterion for the indicators, willingness and participation and ownership. A study in Sweden has shown how civic participation increases the willingness to contribute to environmental protection (Marbuah, 2019). Next to this, we assumed that willingness to adapt or to change increases if stakeholders are more aware of problems or of the importance of sustainability.

Lastly, the satisfaction criterion consists of three indicators: water availability, water pressure, water quality, and water type. These were also choosing based on stakeholders' response from the interviews conducted. Because not all stakeholders have access to water, also some of those that have access to water complained of the water pressure, while few were concerned about water quality.

E.2 Description and measurement of indicators

Table 16 describes each indicator with their measurement.

Table 16 Overview indicators and description

Theme	Criteria	Indicators	Description	Indicator Measurement
Environmental	Water supply	Precipitation (mm/year)	The total precipitation per year	Measured by using the daily precipitation data from Wageningen Veenkampen from 2010 and 2021 to get the yearly amount of precipitation.
		Groundwater (m^3/year)	The total amount of groundwater per year	Estimation based on the area of land which is irrigated by groundwater.
		Drinking water (m^3/year)	The total amount of drinking water per year from the water tap and water access point in Wageningse Eng.	Stakeholders analysis through interviews and questionnaires.
	Water use	Crop water use efficiency (kg/m^3)	Refers to the response of crops to soil water availability. (Trimble, 2021) (Casson et al., 2019) (Irmak et al., 2011)	Data from literature review.
		Field application efficiency (%)	To express what percentage of irrigation water is lost or evaporated, the term irrigation efficiency is used. Usually, irrigation efficiency is divided into two sub-indicators: conveyance efficiency and field application efficiency. In the framework, we only consider field application efficiency to analyse different irrigation methods applied in our studied area. Because the most amount of water is supplied from the outside, which we do not consider it in our project. (Brouwer, Prins & Heibloem, 1989) (Howell, n.d.)	Data from literature review

		Soil water holding capacity (inches/foot of soil)	Refers to the ability of the soil to retain water. (Plant & Soil Science eLibrary, n.d.) (Curell, 2011)	Stakeholders engagement through interviews, questionnaires, and literature review
	Water demand	Irrigation rate(m^3/ha)	The irrigate rate is water quantity for the crop growth in the growing seasons in Wageningse Eng. It supplies the deficiency between natural replenishment (precipitation) and the total water consumption of crops in the growing season. (Olgarenko & Tsekoeva, 2012)	Estimation from stakeholder analysis via interviews and questionnaires
		Water demand per animal (m3/per stock/year)	The water consumption per animal per year for different stocks.	Stakeholders' engagement through interviews and questionnaires.

		Water self-sufficient index (%)	The SSI index regards to calculate the efficiency of water harvested treatments, using harvested water to divide the water demand which can reflect the self-sufficiency of water demand of Wageningse Eng. (da Silva, V. et al, 2016)	Following formula: $\mathrm{SSI} = \frac{\text{Harvest water quantity}}{\text{Water demand in Wageningse Eng}} \times 100\%$ Data from information of stakeholder engagement and water balance.
Social	Satisfaction	Water quality	The condition of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or swimming (National Marine Sanctuaries, n.d)	Measured by conducting physiochemical analysis of the available water as well as doing interviews of relevant stakeholders in the project area.
		Water availability	The quantity of water that can be used for human purposes without significant harm to the environment and its constituents (Sustainable Summit, 2013)	Measured by conducting field survey and doing interviews in the study area.
		Water pressure	This determines the flow of water from the tap. The amount of pressure at your tap can depend on how high the service reservoir or on how much others are using (Ofwat, n.d)	Measured by doing interviews and questionnaires in the project area.
		Water types	This refers to the different water types (precipitation, groundwater, and tap water) use in the research area. Different activities, diverse needs for the water available in the study area.	Measured by doing interviews and questionnaires in the project area.
	Adaptivity	Community adaptation	This indicator relates to measures taken by citizens of wageningse Eng in response to	This indicator can be assessed by measuring water access in the in the community (Wageningse Eng).

			insufficient water use services in the study area (Polonenko et al., 2020).	And, by measuring the active response of the community to insufficient services (Krueger, Rao & Borchardt, 2019).
		Flexibility	Ability of stakeholders to change the type of water they have been using due to unforeseen circumstances (water stress).	Measured by interpreting quotes of interviewees in the study area.
	Willingness	Awareness	The community's knowledge and understanding of issues related to water that are of importance to that community (Polonenko et al., 2020).	Has to do with percentage and number of community members responding accurately to a survey with knowledge bearing questions in a 5-point Likert Scale (Dean, Fielding & Newton, 2016).
		Participation and ownership	The extent to which community members are actively engaged in water-related activities (Polonenko et al., 2020).	It is measured by the involvement of the community in data collection and analysis process; an adaptive learning process is followed that creates and measures indicators with direct community involvement (Reed, Fraser & Dougill, 2006).

E.3 Weighing justification

We do pairwise comparisons three times, separately themes, criteria, and indicators in Excel based on the AHP method. The specific method and formulas are mentioned in the literature review chapter. This E.3 appendix starts with the theme weighing justification, and then continues with the environmental criteria and indicator justifications, and ends with the social theme criteria and indicator justifications.

Theme weighing justification

Environmental theme can more influence the sustainable water use based on the statement of stakeholder analysis, and we mainly focus on the environmental aspect in Wageningse Eng rather than social (Figure 10).

theme comparison					
theme	environmental theme	social theme	multiplication	power n times	weight (wi)
environmental theme	1	2	2	1.414213562	0.6666667
social theme	0.5	1	0.5	0.707106781	0.3333333
				2.121320344	

Figure 10 Theme weight

Then we compare the criteria in both themes separately.

Environmental theme weighing justification

On the environmental side, water supply depends on the outside which is less related to the research system. We consider water use as the most important criteria since the whole project is related to the water use in Wageningse Eng. As to water supply and water demand, water supply is from the outside of the research system, and it depends on the demand of the system. So, we take water supply as less important than water demand (Figure 11).

criteria comparisons										
Environmental aspect										
criteria	water supply	water demand	water use	multiplication in line	power n time	weight(wi)	Awi	Awi/wi	CI	CR
water supply	1	0.33	0.14	0.047619048	0.467138	0.12	0.293151	2.37185	-0.2588	-0.2876
water demand	3	1	0.20	0.6	0.8801117	0.23	0.732359	3.14504		
water use	7	5	1	35	2.4322993	0.64	2.673024	4.15361		
										TRUE
					3.779549					

Figure 11 Environmental criteria weight

Till indicators on the environmental side, we discuss them in different criteria we develop.

Water supply: Within water supply there are three categories: precipitation, drinking water and groundwater. Drinking water and groundwater are equally weighted. They have essentially the same source (the ground), only the drinking water has one extra treatment step. Precipitation is weighted heavier than drinking water and groundwater, this because the interviewees found this an important factor for sustainability (Figure 12).

E.water supply										
indicators	precipitation	drinkingwater	groundwater	multiplication in line	power n time	weight(wi)	Awi	Awi/wi	CI	CR
precipitation	1	3	3	9	2.0800838	0.6	1.8	3	0	0
drinkingwater	0.333333333	1	1	0.333333333	0.6933613	0.2	0.6	3		
groundwater	0.333333333	1	1	0.333333333	0.6933613	0.2	0.6	3		
					3.4668064					TRUE

Figure 12 Water supply indicator weight

Water demand: Within water demand we have the three categories, animals, irrigation rate and self-sufficiency index. The water self-sufficiency index is most important because it gives an indication of the amount of water coming from outside the system (Wageningse Eng). The animals are not affecting the water balance and are therefore determined to be least important in assessing sustainability. Irrigation rate is moderately important in determining sustainability, because it is only unsustainable when drinking water or groundwater is used (Figure 13).

E.water demand

indicators	animal	irrigate rate	water self-su	multiplicatior	power n tir	weight(wi	Awi	Awi/wi	CI	CR
animal	1	0.5	0.2	0.1	0.464159	0.12827	0.38552	3.00554	0.00277	0.00477
irrigation rate	2	1	0.5	1	1	0.27635	0.83058	3.00554		
water self-sufficient index	5	2	1	10	2.154435	0.59538	1.78943	3.00554		
					3.618594					TRUE

Figure 13 Water demand indicator weight

Water use: Within the water use we have the three different categories, soil water holding capacity, water use efficiency and the field application efficiency. The soil water holding capacity is most important because this is wat interviewees found that this is an important factor for determining sustainability. The field application and crop water use efficiency are equally important (Figure 14).

E.water use

indicators	crop water use efficie	soil water holdin	field applicati	multiplication in line	power n time	weight(wi)	Awi	Awi/wi	CI	CR
crop water use efficiency	1	0.333333333	1	0.333333333	0.6933613	0.2	0.6	3	0	0
soil water holding capacit	3	1	3	9	2.0800838	0.6	1.8	3		
field application efficienc	1	0.333333333	1	0.333333333	0.6933613	0.2	0.6	3		
					3.4668064					TRUE

Figure 14 Water use indicator weight、

Upon social aspect, we first discuss criteria comparison same with the environmental aspect. Then comparing indicators in different criteria.

Social theme weighing justification

This section explains the logic for the weights given to the social theme criteria and their indicators. The three criteria from the social sustainability theme include Adaptivity, Willingness and Satisfaction. In relation to each other, Satisfaction is weighed as most important. For a system to be socially sustainable, while the social pillar of sustainability represents the people (Purvis, Mao & Robinson, 2019), it is important that the people on the Wageningse Eng are happy and thus satisfied. Therefore, in the matrix to determine the weights, Satisfaction was filled out as more important compared to Adaptivity and Willingness. Adaptivity and Willingness were filled out as equally important for social sustainability, as both are required to enable a stakeholder to change or improve their situation (Figure 15).

criteria comparisons

social aspect

criteria	adaptivity	willingness	satisfaction	multiplication in line	power n time	weight(wi)	Awi	Awi/wi	CI	CR
adaptivity	1	1	0.33333333	0.333333333	0.6933613	0.2	0.6	3	0	0
willingness	1	1	0.33333333	0.333333333	0.6933613	0.2	0.6	3		
satisfaction	3	3	1	9	2.0800838	0.6	1.8	3		
					3.4668064					TRUE

Figure 15 Social criteria weight

Within the criteria Adaptivity, there are two indicators: Community adaptation and Flexibility. While Flexibility indicators the ability of stakeholders to switch water type if necessary (for example, they could switch to drinking water if the groundwater level drops too far), Community adaptation indicates the active response to insufficient or unsustainable water services and measures taken to improve the situation. Thus, one is about whether they have the option to change their water type while the other indicator is about what has actually happened already in the community. They are equally important since the changes and improvements themselves (Community adaptation) are important, but you also need to have the option to change something (Flexibility) (Figure 16).

S.adaptivity					
indicators	community adaption	flexibility	multiplication	power n times	weight(wi)
community adaption	1	1	1	1	0.5
flexibility	1	1	1	1	0.5
				2	

Figure 16 Adaptivity indicator weight

Within the Willingness criteria, there are also two indicators: Participation and ownership, and Awareness. Throughout the interviews, Awareness was mentioned a lot (Horse owner A, Animal owner, Commerical farmer A, Hobby farmer, Nursery owner B, Allotment gardener) while participation and ownership did not come up when asked about social sustainability in the area of the Wageningse Eng. Therefore, even though Participation and ownership is gaining ground as being important in the urban planning discipline (Galende-Sánchez & Sorman, 2021), Awareness is entered in the weight matrix as moderately more important compared to Participation and ownership (Figure 17).

S.willingness					
indicators	participation and own	awareness	multiplication	power n times	weight(wi)
participation and ownerst	1	0.5	0.5	0.707106781	0.3333333
awareness	2	1	2	1.414213562	0.6666667
				2.121320344	

Figure 17 Willingness indicator weight

Within the Satisfaction criterion, there are four indicators: Water availability, Water pressure, Water quality, and Water type. Water quality got the relatively lowest importance and weight because, even though stakeholders brought it up as a possible issue, it was not a problem to them. Water availability is the most important because without water, activities on the Eng cannot occur. Moreover, some interviewees mentioned they or others not having access to water on the Eng and having to bring it from home which was a big hassle for most of them (Allotment gardener, Commercial farmer C, Hobby farmer, Commercial farmer A, Animal owner, Kitchen gardener, Landowner A, Horse owner A) At the same time, the water has to be of good enough Water Quality that is safe so that the land users can use the available water. One interviewee even mentioned that she did not care about the water type (groundwater, rainwater, drinking water), as long as the water was safe and of good enough quality to use for drinking water for her animals (Animal owner). Therefore, the indicators Water Quality and Water Availability both got equal high relative importance scores compared to the other two indicators. Lastly, Water Type is relatively important as many stakeholders mentioned they would like to switch to a certain type of water (Horse owner B, Allotment gardener, Animal owner, Cow owner) or that they made a very conscious choice for a certain type of water (Animal owner). It therefore got a higher relative weight than the Water pressure but a lower relative importance score in the weight matrix compared to Water availability and Water quality (Figure 18).

S.satisfaction											
indicators	Water availability	Water pressure	Water quality	Water type	multiplicatior	power n time	weight(wi)	Awi	Awi/wi	CI	CR
Water availability	1	4	1	2	8	1.68179283	0.356064	1.42792	4.01028	0.00584	0.00648
Water pressure	0.25	1	0.25	0.5	0.03125	0.42044821	0.089016	0.35698	4.01028		
Water quality	1	4	1	3	12	1.86120972	0.39405	1.58879	4.03195		
Water type	0.5	2	0.33333333	1	0.3333333	0.75983569	0.16087	0.64828	4.02986		
						4.72328644	1				TRUE

Figure 18 Satisfaction indicator weight

E.4 Scoring justification

Environmental indicators scoring justification

The results of each environmental indicator are quantity number then we need 100% sustainable situation to score them with a reliable standard. This section we determine the 100% sustainable situation in each indicator under the same criteria group. According to the 100% situation, we develop the grade range. We can define how sustainable each indicator is by comparing it with 100% situation and determine a score according to the grade range.

Water supply: In the 100% situation, limited amounts of water are coming from outside the Wageningse Eng. For all water uses, except drinking water for humans and animals, the water should all come from rainwater collection. For animals and humans, drinking water should be used as most sustainable water source.

Water demand: In the 100% situation the water demand is brought down to its minimum. Water demand should not exceed precipitation + water needed for animals. In this case the water self-sufficient index is 100 and the irrigation amount should not exceed the precipitation amount.

Water use: In the 100% situation mainly drought resistant crops are grown, people actively apply measure to improve soil water holding capacity and point irrigation (or no irrigation) is applied everywhere.

0 – 19: Situation is far from sustainable. No active measures are taken to improve the sustainability.

20 – 39: Situation is far from sustainable, but the users are aware of it. No measures are taken to improve sustainability.

40 – 59: Situation is not sustainable, but the users are aware of it. Measures are taken to improve the sustainability.

60 – 79: Situation is sustainable, however, could still be improved.

80 – 99: Situation is sustainable now and for the future.

100: The perfect situation has established (100% situation)

Precipitation: At the moment, land users are collecting limited amounts of precipitation to use for their allotment gardens, however, this could definetly improve. They wish to collect more, but this is complicated due to building restrictions from the 'Visie Wageningse Eng'. **60/100**

Drinking water: Drinking water is used to irrigate mainly allotment gardens and for animals on the Wageningse Eng to drink. Using drinking water is more sustainable energy wise, however, we would still like to see that the amount of water from outside the Wageningse Eng is limited. **50/100**

Groundwater: Land users are cooperatively digging groundwater wells. However, from research we found that groundwater usage is energy wise less sustainable than drinking water. The drinking water here is from the same source as the groundwater individual user's pump. Therefore, the usage of groundwater should be limited more to get a higher grade. **40/100**

Animals: Animals just need a certain amount of water to stay alive. From the analysis we found that the water use intensity is rather low for animals compared to, for example, allotment gardens. In addition, animal owners are already aware of the amount of water they are using for their animals and how to minimize this. **70/100**

Irrigation: At the moment, (hobby and commercial) farmers are not/ only limited, irrigating their land, because it is not financially feasible. However, the allotment garden owners are using large quantities of water to irrigate their gardens (20 l per m2), even though they think they are being very sustainable. Water used to irrigate is now mainly consisting of groundwater and drinking water. This should be shifted towards collected precipitation. **40/100**

Water self-sufficiency index: In the area, precipitation and large amounts of groundwater is used. Therefore, the area is not dependent on the drinking water provided by Vitens. To a certain extent they are quite self-sufficient at the moment. **70/100**

Crop water use efficiency: Land users know that the area of the Wageningse Eng is dry. Farmers account for this by growing more drought resistant crops, and a plant nursery owner especially experiments with the use of drought resistant crops. However, allotment gardeners grow mainly what they wat to grow in their vegetable gardens. Therefore, the plants they grow have not a high water use efficiency. **50/100**

Soil water holding capacity: The different land users are aware that the water holding capacity of the soils on the Wageningse Eng is low. People started to implement solutions to improve the water holding capacity. However, it can still be implemented on larger scale. **65/100**

Field application efficiency: Some farmers are using large sprinkler installations and are not taking the effort to point irrigate their crops due to the large scale of their agricultural lands. On the other hand, allotment garden owners are trying their best to in finding solutions and easy applications for point irrigation. **65/100**

Social indicators scoring justification

This section justifies the scores for each of the indicators in the social theme of the framework.

Community Adaptation: Interviewees from all stakeholders group indicated that currently many measures are taken in response to insufficient water availability. Many interviewees increase their organic matter level to improve water retention (Hobby farmer, nursery owners, Allotment gardener). Next to this, two interviewees explained how they adjusted the timing of planting crops or plants and how they used natural selection to increase the drought resistance of their crops or plants (Commercial farmer A, Nursery owner B). However, not many measures are taken to increase rainwater storage and there is room for improvement in for example the sharing of water access points or in the methods used to give water to crops or plants. Therefore, the score is **70/100.**

Flexibility: Two interviewees (Beekeeper, Landowner A) explicitly mentioned the ability to change water type. However, both said that because of money or other practicalities, the ability is often not that high. Therefore, the score is pretty low with **20/100**.

Participation and ownership: different stakeholders were involved in creating a Vision for the Wageningse Eng (Gemeente Wageningen, 2020). However, stakeholders also indicated that many things are not allowed even if it would help them. Examples include building a shed or planting a tree so that animals can have shade or collect rainwater (Animal owner, Allotment gardener, Horse owner B, Hobby farmer). Thus, there has been proper participation in creating the vision but land users or owners often did not get a say in what they can and cannot do in the area, even for small things like planting a tree. The score is therefore in the middle with **50/100**.

Awareness: interviewees generally seemed very aware about the issues regarding water use and how to improve their sustainability. Some interviewees showed through their responses that they themselves are very aware (Horse owner A, Animal owner, Hobby farmer, Nursery owner B, Allotment gardener). Others mention that other users on the Eng are aware (Commercial farmer A, Nursery owner B, Landowner A).

However, some also mention others not being aware of what they use and because of that use too much water (Horse owner B). One interviewee even mentioned trying to make others more aware (Allotment gardener). In general, the level of awareness we noticed while talking to and interviewing land users on the Eng seemed quite high. However, as there are also some people less aware, the score could be higher. It is now **80/100**.

Water availability: from the interviews, eight interviewees mentioned they are satisfied with the water availability (Horse owner A, Nursery owner A, Commercial farmer A, Commercial farmer B, Nursery owner B, Allotment gardener (about own activities), Cow owner, Kitchen gardener) while five interviewees mentioned they are not satisfied (Animal owner, Hobby farmer, Beekeeper, Landowner (about other people), Allotment gardener (about other people)). Five interviewees mentioned they themselves or other people on the Eng have to bring water from home because they have no access to water on the Eng (Horse owner A, Animal owner, Hobby farmer, Landowner A). Additionally, three interviewees specifically mentioned not having access to water on their own land or the land they use (Commercial farmer C, Allotment gardener, Hobby farmer). Moreover, from the questionnaire, three respondents who are allotment gardeners are not satisfied with water availability. Furthermore, an allotment gardener and an animal owner said they have no water access point. It thus seems many interviewees say they are satisfied. However, as quite a lot of people on the Eng (including survey respondents and other users mentioned by interviewees) do not have access to water, the water availability score cannot be high. It is therefore given **40/100.**

Water pressure: when in the field, some land users we encountered mentioned that the water pressure can be an issue when using groundwater. This is because one groundwater pump supplies water to multiple tabs on a piece of land and the last tab will have lower water pressure than the first, especially if multiple people are using it at once. In the interviews, some said the pressure was fine (Nursery owner A, Nursery owner B) while others think it could be better (Allotment gardener, three questionnaire respondents who are allotment gardeners). For some the water pressure is not that high but they do not see it as a problem because they can still do their activity (Horse owner B). Given that the water pressure is not a problem to most and to those for whom the pressure is lower, it is not preventing them from doing what they do on the Eng, it gets a relatively higher score of **60/100**.

Water quality: five interviewees indicated that they are happy with the water quality, of which some mainly use drinking water and some mainly use groundwater. One interviewee mentioned that rainwater contains contaminants (Horse owner) and another one indicated the groundwater quality has not been an issue but that they are looking into it (Allotment gardener). Thus, generally, the people on the Eng seem to be satisfied with the water quality. It therefore gets a high score of **80/100**.

Water type: four interviewees explicitly mentioned to be satisfied with the water type they use (Nursery owner A, Nursery owner B, Commercial farmer B, Kitchen gardener). Others mention it can be improved, as the Horse owner B and Allotment gardener would like to use more precipitation and the Animal owner and Cow owner would like to work with groundwater if possible and feasible. Thus, it seems from the interviews that there is a pretty even split. The score **50/100** was assigned.

E.5 Calculating the final sustainability scores

The step for calculating the final score is shown in the following steps according to the results of weight approach and score on each indicator:

$$water\ supply = 0.67 \times (60 \times 0.6 + 50 \times 0.2 + 40 \times 0.2) = 4.45$$

$$water\ demand = 0.67 \times (70 \times 0.12 + 40 \times 0.28 + 50 \times 0.60) = 7.73$$

$$water\ use = 0.67 \times (50 \times 0.2 + 65 \times 0.6 + 65 \times 0.2) = 26.60$$

$$adaptivity = 0.33 \times (70 \times 0.5 + 20 \times 0.5) = 3.00$$

$$willingness = 0.33 \times (50 \times 0.33 + 80 \times 0.67) = 4.67$$

$$satisfaction = 0.33 \times (40 \times 0.36 + 60 \times 0.09 + 80 \times 0.39 + 50 \times 0.16) = 11.83$$

$$final\ score = 4.45 + 7.73 + 26.6 + 3 + 4.67 + 11.83 = 58.28$$

Appendix F. Overview of codes

Table 17 shows an overview of the codes used for the coding and their descirptions.

Table 17. Overview of codes and description.

Theme	Subtheme	Code Nr	Code Name	Additional	Description of the code
Data	Water Type Used	1a	Use precipitation		Mention of a specific person or plot of land that uses collected precipitation (excluding direct precipitation)
		1b	Use drinking water		Mention of a specific person or plot of land that uses drinkingwater
		1c	Use groundwater		Mention of a specific person or plot of land that uses groundwater
		1d	Use no water		Mention of a specific person or plot of land that does not use water (excluding direct precipitation)
	Water Source Access	2a	Groundwater access point on terrain		Mention of a specific person or plot of land that has a groundwaterpump on their terrain
		2b	Shared groundwater access point		Mention of multiple people or plots of land using water from the same groundwaterpump
		2c	Drinking water access point on terrain		Mention of a specific person or plot of land that has a drinking water access point on their terrain.
		2d	Water brought from home	Water type(s)	Mention of a specific person bringing water from home.
		2e	Precipitation storage		Mention of a specific person storing precipitation.
		2f	No water access point		Mention of a specific person or plot of land that does not have access to water (excluding direct precipitation)
		2g	Shared drinkingwater access point		Mention of multiple people or plots of land using water from the same drinking water point

	Agreements shared water sources	3	Agreements shared water sources		Mention of agreements regarding shared water sources.
	Water Quantity	4a	No water quantity estimation		Not able to make or not willing to give an estimation of the quantity of water they use
		4b	Water quantity estimation		Any estimation regarding quantity of water used
	Watering methods plants	5a	Garden hose		Mention of a specific person using a garden hose to water plants
		5b	Sprinkler		Mention of a specific person using a sprinkler to water plants
		5c	Watering can		Mention of a specific person using a watering can to water plants
		5d	Gullies		Mention of a specific person using gullies to water plants
		5e	Drip irrigtion		Mention of a specific person using drip irrigation to water plants.
	Method for giving water to animals	6a	Drinking trough		Mention of a specific person using a drinking trough to give water to their animals
		6b	Showering animals		Mention of a specific person showering or washing their animals.
	Activity	7a	Allotment gardens	Reason for having allotment garden	Mention of a specific person or plot of land having or being an allotment garden
				Plant type(s)	/
		7b	Animal keeping	Animal type(s)	Mention of a specific person or plot of land having animals.
		7c	Farming	Crop type(s)	Mention of a specific person or plot of land having or being a farm.
		7d	Plant/flower nursery	Plant type(s)	Mention of a specific person or plot of land having or being a plant/flower nursery
	Fluctuation water use	8a	Seasonal		Mention of seasonal fluctuation in water use
		8b	Yearly		Mention of yearly fluctuation in water use

		8c	Dependent on weather		Mention of fluctuation in water use dependent on the weather
	Surface area	9	Surface area		Mention of the surface area of a specific plot of land
	Land ownership situation	10a	Owner		Mention of a specific person owning a specific plot of land
		10b	Tenant or leaseholder		Mention of a specific person renting or leasing a specific plot of land.
		10c	Using land of someone else		Mention of a specific person using a specific plot of land they do not rent/lease or own.
		10d	Unclear ownership		Unclear ownership of plot of land.
Non-data	Preference water type	11a	Prefers precipitation		Mention of a specific person preferring precipitation as water type to use.
		11b	Prefers drinking water		Mention of a specific person preferring drinking water as water type to use.
		11c	Prefers groundwater		Mention of a specific person preferring groundwater as water type to use.
		11d	Prefers no water		Mention of a specific person preferring to use no water.
		11e	Prefers combination water types		Mention of a specific person preferring a combination of water types to use.
		11f	No preference water type		Mention of a specific person not having a preference regarding water type to use.
	Water type satisfaction	12a	Satisfied with water type		Interviewee mentioning being satisfied with water type currently used.
		12b	Not satisfied with water type		Interviewee mentioning being unsatisfied with water type currently used.
	Water quality satisfaction	13a	Satisfied with water quality		Interviewee mentioning being satisfied with water quality.
		13b	Not satisfied with water quality		Interviewee mentioning being unsatisfied with water quality.

		13c	Uncertain about water quality		Interviewee mentioning being uncertain about water quality.
	Water pressure satisfaction	14a	Satisfied with water pressure		Interviewee mentioning being satisfied with water pressure.
		14b	Not satisfied with water pressure		Interviewee mentioning being unsatisfied with water pressure.
	Water availability satisfaction	15a	Satisfied with water availability		Interviewee mentioning being satisfied with water availability.
		15b	Not satisfied with water availability		Interviewee mentioning being unsatisfied with water availability.
	Optimal situation	16a	Situation needs no improvements		Interviewee mentioning being satisfied with current situation.
		16b	Situation could be improved		Interviewee mentioning being unsatisfied with current situation.
		16c	Optimal situation description		Interviewee talking about their ideal situation.
		17a	Lack of water retention		Interviewee mentioning lack of water retention.
		17b	Lack of surface water		Interviewee mentioning lack of surface water.
		17c	Policies and regulations		Interviewee mentioning problems regarding policies and regulations.
		17d	Labour intensive		Interviewee mentioning labour intensity of their activity.
		17e	Health consequences		Interviewee mentioning health consequences as a problem.
		17f	Technical difficulties		Interviewee mentioning technical difficulties.
	Problems	17g	Cannot do preferred activity		Interviewee mentioning they cannot do their preferred activity (or grow desired plants)

			(or grow desired plants)		
		17h	Climate change		Interviewee mentioning climate change or changes in climate- or weather conditions in the future (does not include mentioning drought or a hot summer if it is not related to the future).
		17i	Drought		Interviewee mentioning drought as a problem.
		17j	Frost		Interviewee mentioning frost as a problem.
		17k	Social conflicts or friction		Interviewee mentioning social conflicts or friction as a problem.
		17l	Miscellaneous problems		Interviewee mentioning problems that do not fall under any of the other categories
	Solutions	18a	Water retention measures		Interviewee mentioning water retention measures, including everything regarding organic matter.
		18b	Individual solutions		Interviewee mentioning individual solutions, excluding water retention measures
		18c	Collaborative solutions		Interviewee mentioning collaborative solutions
	Reasons for not watering plants	19a	Do not like the job of watering plants		Interviewee does not like the job of watering plants.
		19b	Plants do not need water		Interviewee mentions the plants do not need water.
		19c	Not watering plants is sustainable		Interviewee mentioning that not watering plants is sustainable.
	Social sustainability	20a	Considering needs of other users		Interviewee mentions the importance of considering the needs of other users.
		20b	Awareness		Interviewee shows or mentions awareness regarding sustainability or water use.

		20c	Willingness		Interviewee shows or mentions willingness to improve sustainability.
		20d	Participation in initiatives and creating visions for the area		Interviewee mentioning an individual participating in initiatives and creating visions for the area.
		20e	Adaptivity		Interviewee shows (in)ability to adapt.
		20f	Provides opportunities for others		Interviewee mentions providing opportunities for others.
		21a	Sustainable if precipitation is used		Interviewee sees precipitation as a sustainable water type.
		21b	Sustainable if drinking water is used		Interviewee sees drinking water as a sustainable water type.
		21c	Sustainable if groundwater is used		Interviewee sees groundwater as a sustainable water type.
		21d	Sustainable if no water is used		Interviewee sees using no water as sustainable.
		21e	Sustainable if no excess water is used		Interviewee sees using no excess water as sustainable (= using exactly what is required and no more)
		21f	Sustainable if a combination of water types is used		Interviewee sees a combination of water types as sustainable.
	Sustainability of water use	21g	Unsustainable if precipitation is used		Interviewee sees precipitation as an unsustainable water type.

		21h	Unsustainable if drinking water is used		Interviewee sees drinking water as an unsustainable water type.
		21i	Unsustainable if groundwater is used		Interviewee sees groundwater as an unsustainable water type.
		21j	Unsustainable if a combination of water types is used		Interviewee sees a combination of water types as unsustainable.
		21k	Uncertain about sustainability of water types		Interviewee is uncertain about the sustainability of water types.
		21l	Other opinions on sustainable water use		Interviewee gives opinion about sustainable water use unrelated to a specific water type.
	Environmental sustainability	22a	Organic farming		Interviewee mentions no pesticides or artificial fertiliser are used (Some organic farms have Skal certification).
		22b	Selling locally		Interviewee mentions 'de Korenschoof' or selling locally.
		22c	Biodiversity and nature		Interviewee mentions biodiversity and nature.
		22d	Considers other users not sustainable		Interviewee mentions other users not being sustainable.
		22e	Considers other users sustainable		Interviewee mentions other users being sustainable.
	No comment on other land users	23	No comment on other land users		When an interviewee say they have no comment or knowledge about other land users.
	Sustainability importance	24a	Sustainability is important to me		Interviewee mentions sustainability is important to them

		24b	Sustainability is not important to me		Interviewee mentions sustainability is not important to them.
	Personal sustainability	25a	Considers themselves very sustainable		Interviewee considers themselves very sustainable.
		25b	Considers themselves mostly sustainable		Interviewee considers themselves mostly sustainable.
		25c	Considers themselves not very sustainable		Interviewee considers themselves not very sustainable.
		25d	Uncertain about own sustainability		Interviewee is uncertain about their own sustainability.