REPORT
DESIGNING NATURE BASED SOLUTIONS FOR THE AA OF WEERIJS

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Contents

1. Introduction

Climate change is a severe problem, causing sea level rise, higher temperatures, more drought and also more intense rainfall which is also the case in the Netherlands. This study is about dealing with these problems – mainly drought - in a part of the Dutch province of Noord-Brabant, using so-called nature-based solutions. With regards to that, the Province wants to achieve these goals based on the Dynamic Implementation Agenda PMWP in collaboration with regional partners (1). Climate changes have many essential effects on Noord-Brabant, like all around the Netherlands. The need for water has crucial importance especially for agriculture and nature which rely on water. The province sets the frameworks for clean, safe and sufficient water in Brabant. But the problem is how to manage the water system under all circumstances and this kind of uncertainties bring lack of enforcing instruments and complexity of the need for integrated approaches (2).

On the one hand, this interference deficiency results in a lack of willingness to take responsibility and possibly throw away their money for this uncertain situation like what is going to happen about climate change. Because all climate models and scenarios have been struggling with uncertainties which gives some hesitation to make the decision about handling with climate change by spending a lot of money. On the other hand, climate change has a crucial impact on the Breda such as drought. In this report instead of focusing on all challenges caused by climate change, drought problem is prioritized as finding solutions for it. All these climate impacts lead to difficulties in realising sustainability due to the uncertainty of the future. The availability of sufficient water in the area is under pressure due to increasing demand from agriculture (tree nurseries and fruit production) and increasing drought due to climate change. A regional approach must offer both solutions for adaptation to climate change, preserving the quality of the environment and enhancing sustainable economic supports.

In the provincial environmental plan (omgevingsvisie), the emphasis is laid upon restoring and strengthening the soil-water-nature system as a basis for working towards climate-resilient regions (3). It means that preferred measures are not based on hard engineering but so-called nature-based solutions.

In this research, the study area is Aa of Weerijs, which is located in the Western part of the Brabant. Many landscapes in the research area have been covered by tree nurseries and greenhouses which have more effect than grassland on the resilience of hydrological systems and nature. Due to this enormous effect of land-use on the hydrological system, many measures are relevant to land-use changes or making room for water in the suitable areas of tree nurseries land.

The aim in these areas is to balance the demand for water from the various useful functions with the available water. This is achieved through measures by using nature-based solutions that reduce water demand, retain water in the area and improve the sponge action of the soil and it will be necessary to adapt to or accept the effects of drought and to prevent droughts effect on are due to making more resilient for future.

In this report, challenges of water availability and water usage related by land use are considered to solve and to make new strategies depending on them. Due to finding solutions for the future management plan, firstly general information of the research area is defined, and secondly, challenges of the area are defined, and climate change effects are defined. After determining all of them, relevant measurements which are nature-based solutions are specified based on the identified tipping points between 2035 and 2050. Then, adaptation pathways are made by using all tipping points and more suitable measures for the area by based on different scenarios and timelines.

Description of the study area:

Brabant can be roughly divided into two types of areas which are polders and higher sandy soils. In the polder parts; here, we can actively regulate the supply and drainage of water (level-controlled areas). We can make up for shortages by leaving water in the polder from (large) rivers. In the sand soil parts which is the research area; water supply is not possible, but where we can buffer and conserve the water (for example with weirs) (4). This way the water remains available for as long as possible in the event of drought. For consideration of responsibilities, the province is responsible for the deep groundwater that we use for drinking water. It measures the quality of groundwater and groundwater levels throughout Brabant. The province determines the biological and chemical quality of the ground and surface water. Consider the concentrations of nitrogen or the types of fish in a stream. Municipalities and water boards often manage the ponds, canals and other waters in the built environment together. The wastewater in the sewers goes to sewage treatment plants, where the water boards purify the water. Water boards and municipalities measure groundwater levels in specific areas and also the quality and quantity of wastewater. To properly manage the water system, all these organizations work closely together. With each other and with others, such as residents and nature managers.

Due to making a more precise solution for this approach, researching area is decided to narrow down to work on Aa of Weerijs catchment. The Aa or Weerijs is a stream and downstream a river that originates in Belgium, where it originates from the confluence of the Grote Aa (in Wuustwezel) and the Kleine Aa (in Brecht). Subsequently, the brook has several names, namely Kleine Aa or Weerijsbeek and Grote Beek, and then flows further from the border with the Netherlands as Aa or Weerijs. At Breda (= wide Aa) the river enters the canals of this city, to continue to flow together with the Bovenmark under the name Mark. The width of the Aa or Weerijs varies from 5 meters at the border with Belgium to 15 meters at Breda. The stream valley is approximately 3 kilometres wide. The catchment area of the Aa or Weerijs covers a large area (approx. 19,000 ha) and is mainly in Belgium (approx. 12,000 ha). The streams flow globally from the southwest to the northeast and are generally deeply incised. Important residential areas in the area are Zundert, Klein Zundert and Wernhout, Effen and Rijsbergen. The Aa or Weerijs passes these residential areas on the east side (4).

The management area of the Brabantse Delta water board is located on the south side on the relatively draining, higher sandy soils and then gradually descends to the Maas in the north and the Scheldt-Rhine canal and the Volkerak-Zoommeer in the west. The polders lie along this north and west edge (4). The area is intersected from east to west by the rivers Mark and Dintel and by the Vliet. The polders mostly consist of sand and clay soils and peat soils occur on the transition between the sand and clay. The polders are largely used for agriculture (5).

The research area is characterized by sandy soils. The water flows from the higher-lying sandy soils to the polders under free fall and there are several measuring areas. Therefore, water is also let in from this to keep the watercourses up to standard and to make irrigation possible (4). The drain determines together with the depth and width and any obstacles, such as weirs, the flow speed. The hydrology in the river basin has changed for agriculture with strong dewatering and active water level management with weirs. The weirs and water level management deemed irreversible due to agricultural interests in the river basin (5).

Throughout this research, a specific part of the Netherlands part of Aa of Weerijs is chosen which is from the border of Belgium to Zundert. Various dilemmas come together in the area around upstream of Aa of Weerijs. There is a high economic pressure (tree cultivation and high-quality horticulture, in particular, strawberry cultivation) that places high demands on the area. But from a climate adaptation perspective that is not sustainable. At the same time, the demands of the market are also increasing. To be able to grow more efficiently, more and more cultivation-supporting facilities are being used. The cultivation is therefore increasingly "free from the ground".

The general structure of research area (the current situation with the channelised river) is shown in figure-1 to see water structure of the area and in figure-2 is illustrating the combination of the old version (1900) of Aa of Weerijs river flow with current river flow which is vital to know historical changes on the area.

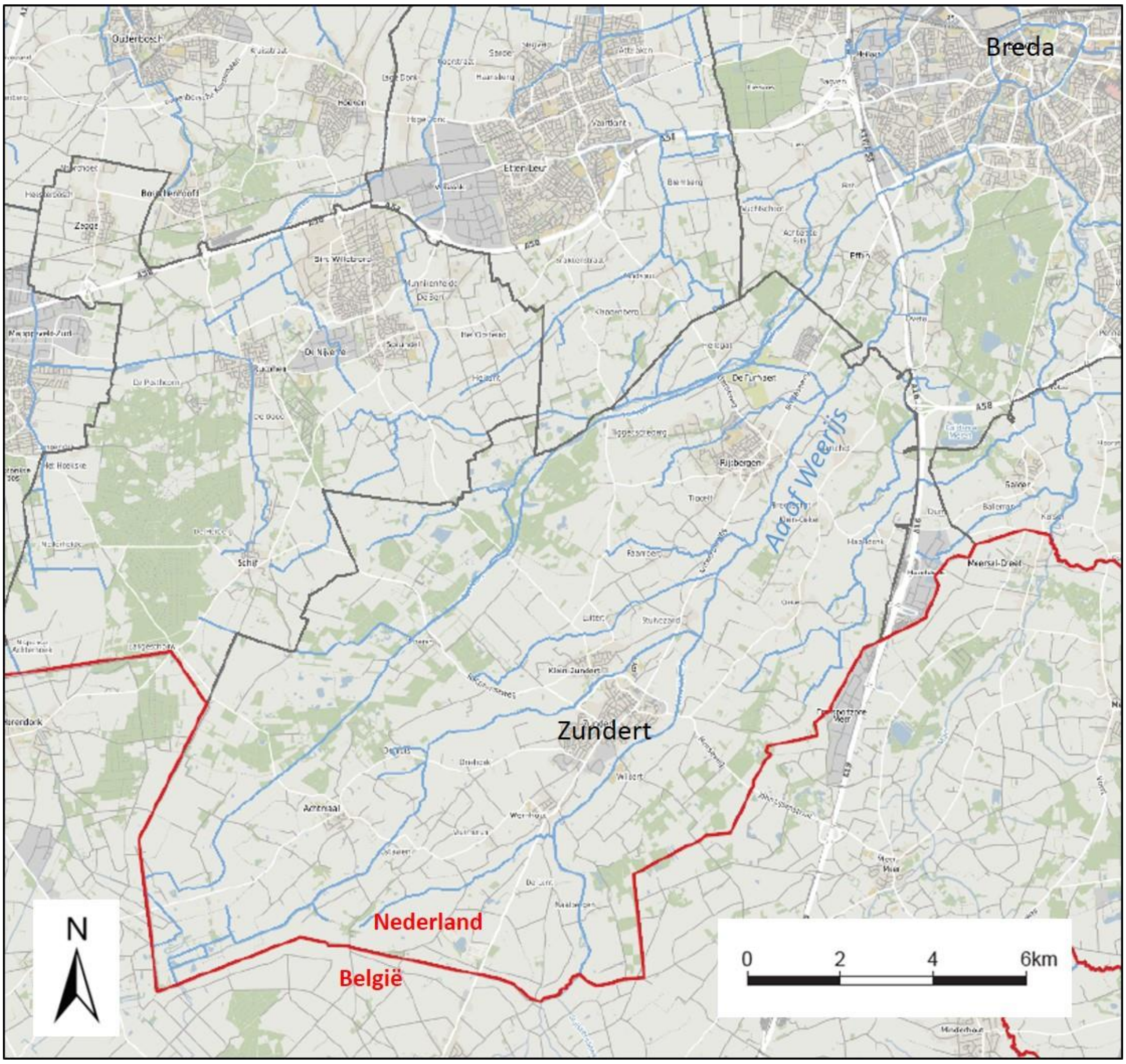


Figure-1: ***General structure of research area*** *-The Aa or Weerijs arises in Belgium from the confluence of the Great Aa 'and' Kleine Aa. The stream flows into the canals of Breda. As the stream is combined with the "Top Mark 'and flows as' Mark' to the Westerschelde.*

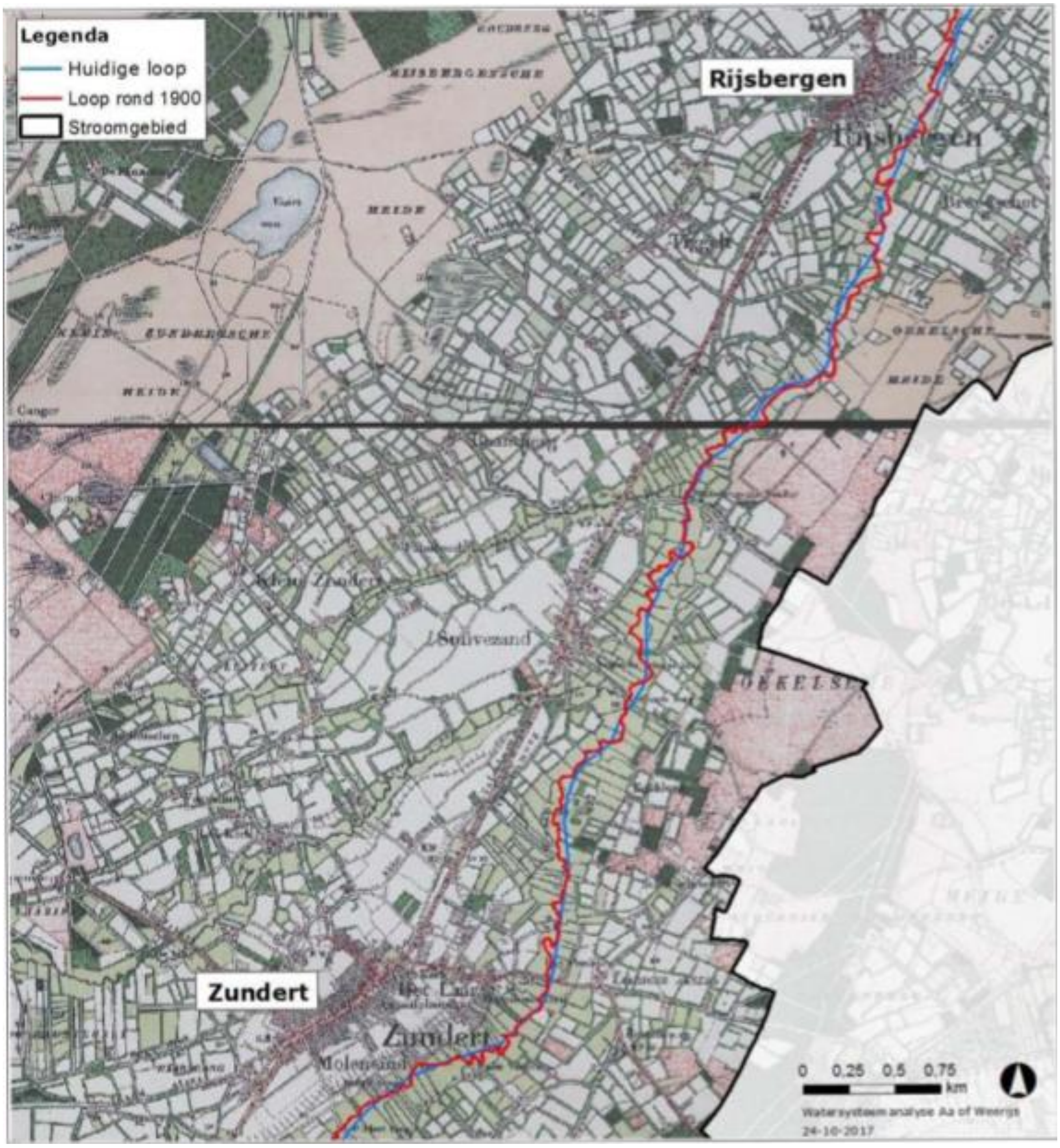


Figure-2: *Cut out of a historical map of 1900 with the then course (red) and current course (blue) of the Aa or Weerijs between Rijsbergen and Zundert (4).*

2. Challenges

The changing climate may have significant consequences for the high sandy soils area. In addition to the fact that more adjustments are likely to be able to cope with large amounts of precipitation in a short time, it is also necessary to anticipate longer and extreme periods of drought. Whereas the anticipation of extreme precipitation can often be done by taking water management measures and the effects on user functions are mainly local in nature, drought has larger-scale consequences for the entire area. Long-term droughts can have a direct impact on the income of the agricultural sector, can cause considerable damage to current nature and also have effects on water extraction from groundwater. In the event of drying out, an area has a low groundwater level or the inflow of groundwater (seepage) is too small or of insufficient quality. Through being mainly sandy soils in the research area, a small amount of water can be retained which run the risk of becoming so dry in the longer term that much damage will occur to both nature and agriculture.

Before defining all challenges, first climate change effects and essential, relevant information about the area such as infiltration capacity and land use is explained.

Climate change effects and features of the area

- Assessing climate effects
    - *Types of expected effects*

The impacts of climate change are often distinguished between primary and secondary effects. Under primary effects, change in sea level, precipitation, and temperatures wind are sortable. Secondary effects, such as salinization, water surpluses, deficit, flood risk, heat stress arise dependent on physical and geographical aspects of an area, such as elevation, soil type hydrological properties (6).

In this research, we generally have been focusing on the secondary effects of climate change caused by some primary effects such as temperature and precipitation changes. These predictions can be made based on climate scenarios that KNMI made specifically for the Dutch situation based on the data from the Intergovernmental Panel on Climate Change in 2006. In addition to the variation in airflow, the KNMI also distinguishes the degree to which the temperature rises. However, the temperature rise seems to be going faster than initially thought, making the warm scenarios increasingly likely. The consequences of the increase in temperature and changing precipitation patterns for the municipality of Breda depend on the local circumstances of the municipality and finally also on the vulnerability of the functions in the places where effects occur.

According to KNMI'14 scenarios and Climate Effect Atlas predictions about climate changes, the temperature is likely increasing; precipitation deficiency is likely growing, amount of extreme rainfall is going to increase, and the amount of evaporation is rising. The average temperature rises. In addition to temperature rise, the precipitation deficit is defined as precipitation minus potential evaporation. Index G+ and + W Scenario is a significant decrease of summer rain days and summer precipitation evaporation increases; in this scenario, the dryness increases. In the W and W + scenarios the growing season begins later. The year-on-year variation is known, the presumption that it is summer deviation between consecutive years becomes larger. It maximizes the shortage of the harvest: in the spring it is less rain and more radiation. Maximum precipitation deficit does not indicate when in the growing season the precipitation deficit is made. The scenario in 2050 is reasonably comparable with now, there is not much difference, but there is more precipitation deficit.

- *Climate model results*

Due to the prediction of drought possibility, some CMIP5 ensembles can be helpful. By using research area' coordinates which are 51.4707 N, 4.6624E and by using different 24-42 models and 48-108 ensembles, we looked at ALTCDD (Dry spell length), TR (tropical nights), GSL(growing season length), TX90 (hot days), temperature, precipitation and evaporation. For each CMIP5 ensembles, on the left, for each scenario one line per model is shown plus the multi-model mean, on the right percentiles of the whole dataset: the box extends from 25% to 75%, the whiskers from 5% to 95% and horizontal line denotes the median(50%) (Figure-3).

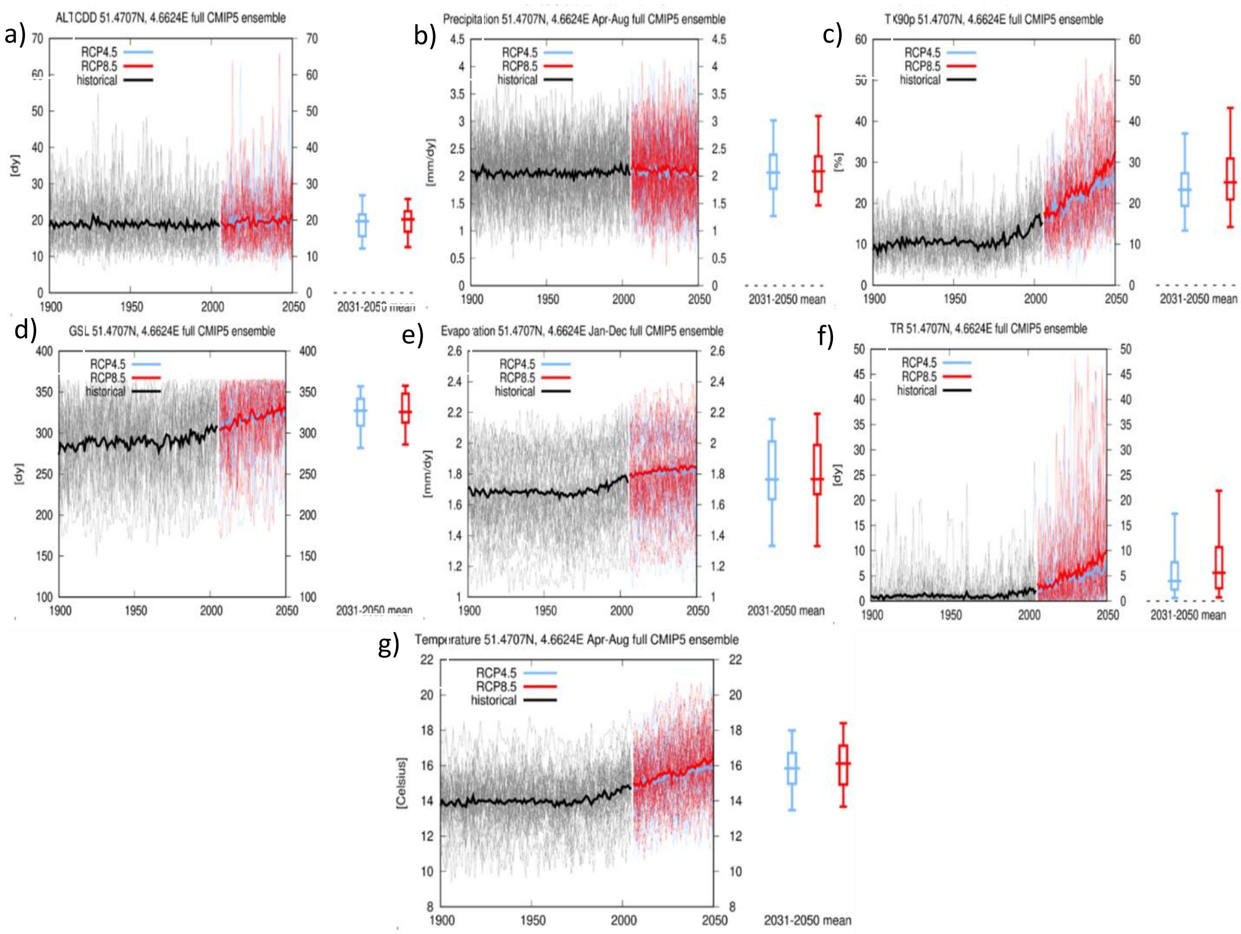


Figure-3: Relevant CMIP5 climate ensembles according to predictions of drought

For the ensemble median: (a) dry spell length (ALTCDD) increases by 2-3 days by 2050, while (c) hot days (TX90P) increase by 20% by 2050. Projected changes in drought-related indices are also distinct at different warming levels. Specifically: (b) projected mean annual precipitation decreases but not much to point out and (g) temperature indicates increases approximately 2 degrees which is higher than global temperature increase predictions. In addition, all these, the evaporation level is getting raise. Combinations of all ensembles show that possibilities of drought are getting increase by 2050 in the research area.

- *Climate effect atlas*

The climate scan is a methodology developed within the climate impact atlas (https: // climateeffectatlas.wur.nl) that makes the effects of climate change area-specific and combines it with the vulnerability of the functions in a specific area. This climate scan uses climate effect data for the W and W + scenario in 2050.

- Precipitation deficit and summer precipitation level

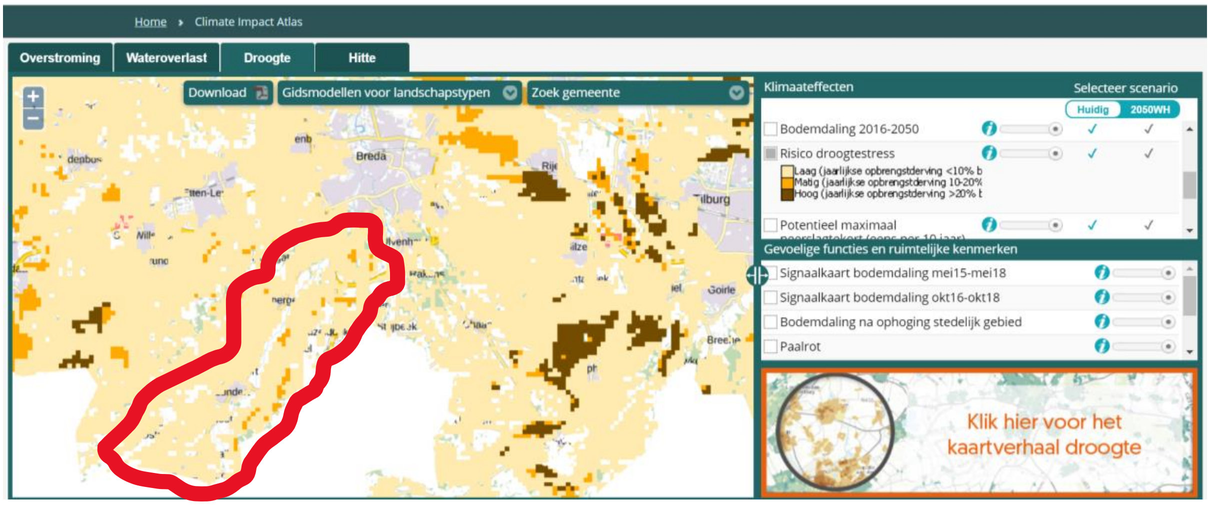
Potential maximum precipitation deficit (once every 10 years) is expected to increase from 210-240 mm range (current situation) to the 270 -300mm range by 2050 and summer amount of precipitation is expected to decrease from 250-275 mm range (current situation) to 150-175mm range by 2050 which is shown by climate effect atlas maps in Annex-1.1.

- Annual reference evaporation

According to climate effect atlas predictions (in Annex 1.2), the annual evaporation rate is getting increased from 560 mm to 600 mm by 2050 which is essential ensembles when it is combined with the temperature rising and precipitation deficit.

- Drought stress

Current:



2050:

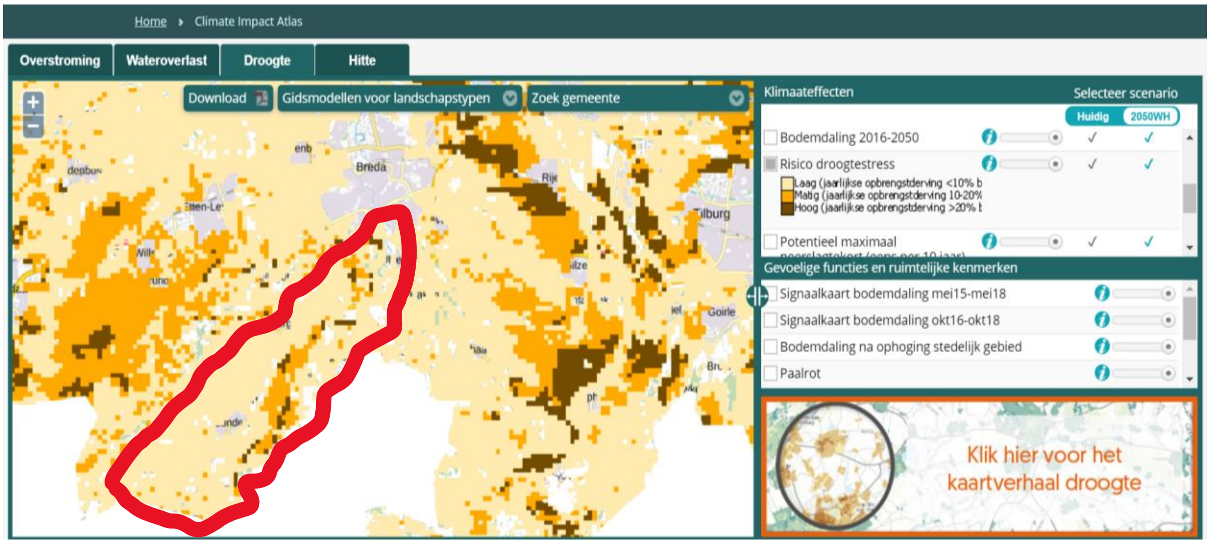


Figure-4: *Current drought stress map and prediction of future drought stress map in research area by using climate effect atlas. Legend of the map is cream means low (annual revenue loss < 10%), orange means moderate (annual revenue loss is between 10 and 20%), and brown means high (annual revenue loss > 20%).*

Figure 4 illustrates that the risk of drought stress is expected to go up especially nearby the riverside and natural wet areas from low to high which has an important impact on the economic situation.

- Expected effects in the study area

During Dutch summers, more water generally evaporates than precipitation falls. This creates a potential precipitation deficit, usually around 100 mm. The year 2018 was historically dry. In the summer half-year, much less rainfall fell than usual. It was also exceptionally warm and very sunny. Because of this, the evaporation was high. The potential precipitation deficit in Brabant rose to well above 300 mm in 2018 and thus came close to the drought record of 1976. The map below shows the highest value of the potential precipitation deficit in 2018 (KNMI) for each location in Brabant.

Climate change affects the soil-water system, and these effects can lead to many problems caused by insufficient water availability. Therefore, a large part of Brabant consists of (high) sandy soils. Characteristic of these areas is that no or only limited water supply is possible from the main water system: there are often no channels or large pipes through which water can be supplied from elsewhere (Annex 2, 2.1). For their water supply, these areas are entirely dependent on the "own" precipitation and groundwater. It means that if there is not enough water in the water system or if there is not enough precipitation, there is no another area to get water from.

According to climate effect atlas results, the precipitation deficit in an arid year in the current climate, and shows how this increases in the WH scenario in 2050. An extremely dry year occurs on average once every 10 years in the current climate, with a precipitation deficit of 210 –240 mm in most of Brabant. In the WH scenario, the precipitation deficit that occurs once every 10 years increases to 270-300 mm in the majority of Brabant with outliers at the edges. Moreover, due to climate change, the maximum temperatures during extremes rise faster than the average temperatures. This means that days above 30 degrees will occur more often. The lens shows how the number of tropical days in Brabant per year is increasing from 2-9 days now, to 9-18 days in 2050 in scenario WH. These two significant changes in areas climate lead to a high level of evaporation and evapotranspiration.

Drought stress mainly occurs on soils with a deep groundwater level below ground level and with a coarse texture, such as coarse sand. The potential drought stress is therefore also highest on the higher sandy soils in the province. We see that these areas can dry up extra due to climate change. The result is that the rainwater can reach the soil poorly and often drains quickly through drainage systems. As a result, the soil can no longer always fulfil its maximum water-storing function.

Infiltration, drainage, water run-off and soil quality have an important role in keeping water in the system in case of drought. 2018 and 2019 were recorded as the driest year and because of this water board was prohibited pumping water from surface water due to insufficient water.

According to last researches (4), the area was examined in terms of groundwater level changes between 1950 and 2010 (figure -5). Figure 5 shows the average difference in the piezometric head in the topmost aquifer. The most significant decrease in groundwater level from 1950 to 2010 due to land-use changes and changes in crop yield is simulated in areas with little surface water. The decline in groundwater recharge is most pronounced in the growing season and therefore causes a more considerable drop in low groundwater levels than in high groundwater levels. Even though these research years were not the extremely dry years, the groundwater level has been dropping (Annex-2, 2.2.).

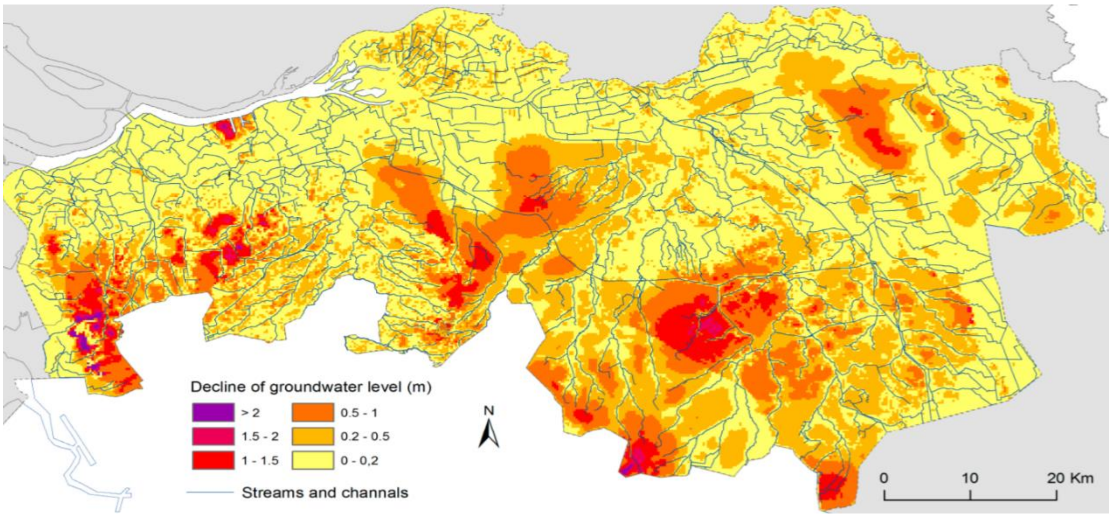


Figure-5*: Simulated decline in groundwater level due to change in land use and increase of crop yields between 1950 and 2010.*

In the future, drier summers may occur much more frequently. In the most extreme KNMI'14 climate scenario of 2050 (W), the dry summer of 2018 is twice as common. The effects of drought can vary significantly from place to place. With a large precipitation deficit, the groundwater levels in these areas will decrease relatively quickly. We also saw that happen during the 2018 drought: sometimes the groundwater even dropped to 1 meter below the average level.

In addition to groundwater level changes, surface water has been getting lower and precipitation amount is getting decrease which leads to water scarcity and water availability problem in the research area. Also, a low GLG (average lowest groundwater level) in combination with drier summers can lead to water shortages. Water shortage and lack of water availability have a crucial impact on agriculture and nature.

Apart from the large groundwater abstractions, there are also smaller licensed irrigation wells. In the catchment area of the Aa or Weerijs, 576 wells have been licensed to 421 permit holders. These figures do not include the permits for the Bijloop-Turfvaart sub-basin, because this area only drains on the Aa or Weerijs in Breda and therefore only influences the discharge of this stream from that point. Every permit holder reports annually to the water board how much groundwater farmers have extracted from all licensed wells. A license holder may have more wells, part of which may be in a different (sub) catchment area. As a result, the sum of the reported volume gives an approximation of the groundwater extraction with wells from the catchment area of the Aa or Weerijs. The reported withdrawals were collected for 2012, 2013 and 2014. The amount of groundwater that has been extracted varies per year and depends on the amount of precipitation and the distribution of rainfall over the summer. In the wet summer of 2014, the total reported volume was 1.1 million m3, and in the drier summer of 2013, the extraction with 2.6 million m3 was more than twice as large. In 2012, the extraction with 1.6 million m3 was in between (4).

Agriculture suffered considerably during the dry summer months. The average gross income of a farmer decreased by around 30,000 euros compared to 2017. Arable farmers had higher costs due to additional irrigation of the crops. The cultivation of greenhouse vegetables was not only less in terms of numbers but also in terms of quality. Not all farmers had the option to irrigate. In many areas, the Brabant water boards imposed a ban on pumping up surface water and groundwater.

With this, they hoped to save the vulnerable nature and prevent damage to banks and quays. Due to climate change, more extended periods of drought are possible, especially in the summer. This is particularly important for Brabant because more than three-quarters of the province is on the sand and there is often little water available during dry periods. Besides, grasses, shrubs, and trees became more abundant in nature areas, partly under the influence of atmospheric nitrogen deposition and cuts on nature management. Those plants evaporate more than the original vegetation.

Overall, climate model results and climate effect atlas predictions show that temperature is getting increase during the summer season, precipitation deficit is getting raise throughout the summer season which leads to high evaporation level. Based on these predictions; soil quality and water quality and quantity may have critical decline which is going to have an impact on not just agricultural area and nature-area but also an urban area in case of water demand in the research area.

3. Solutions/Measures

During this research, we focus on nature-based solutions (NBS) instead of looking for a technical solution.

Before explaining Nature-Based Solutions, we need to know which layer we are going to make interventions. The layered approach emphasises the space in three layers (Figure 6). The first layer consists of the physical substrate, the water system and the biotic system. The next layer contains networks of infrastructure including roads, railways and waterways. Finally, the segment with human activities such as living, working and recreation and the physical fallout thereof (7).

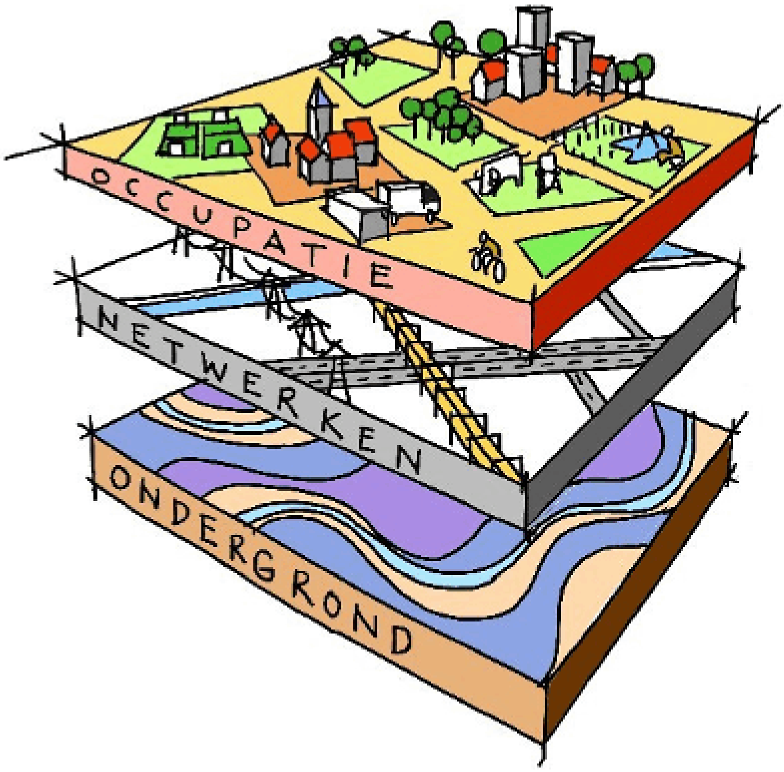


Figure-6: *Pictures of three different layers*

All those layers are subject to change. The speed with which they change varies per layer. Some layers have a long history. Changes determine the future for a long time. Others are more volatile and change within a few years. We apply the following rule: the slower the speed of change, the more carefully you handle it.

Based on the timeline, we are going to work on the first layer which is the occupation layer (Annex-3, 3.1.). The occupation layer has a high rate of change. Changes often occur within one generation (10 to 40 years). The occupation layer consists of the usage patterns that arise from the human use of the subsurface and the networks. When planning the occupancy layer, account must be taken of the characteristics and functions of the subsurface and the networks and the requirements that these layers impose on the use of space. Areas with a similar usage pattern form an area type (7).

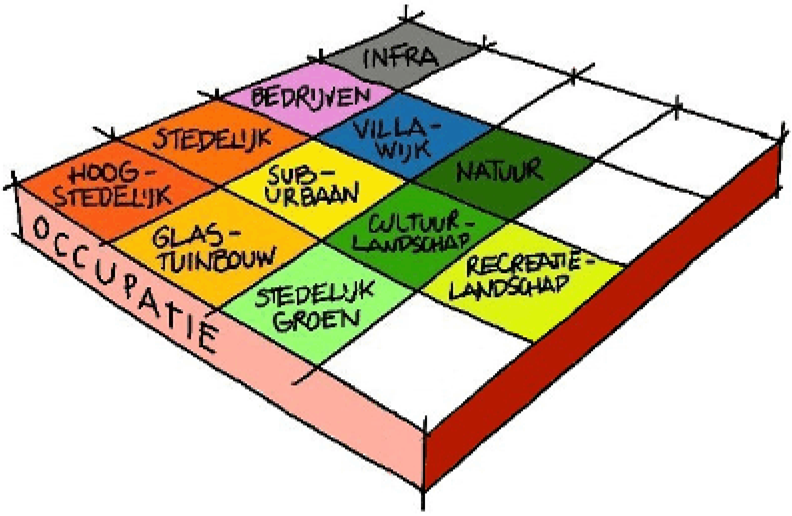


Figure-7: Land use in occupational layer

What are Nature-based solutions:

The original definition of Nature-Based Solutions (NBS) which is defined by International Union for Conservation of Nature (IUCN) is *"actions to protect, sustainably manage, and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.".* NBS are actions inspired by, supported by or copied from nature to deal with challenges both by using and by enhancing the existing solutions (7,8,9). In this research, NBS mainly address significant climate-related challenges which are drought in this case. The primary aim is to prevent drought impacts by using NBS as water storage, improving soil moisture and soil quality, improving soil infiltration capacity and groundwater discharge etc.

We will use NBS as to mimic natural processes to enhance water availability (e.g., soil moisture retention, groundwater recharge), improve water quality (e.g., natural and constructed wetlands, riparian buffer strips), and reduce risks associated with water-related disasters and climate change.

There are many NBS based on the challenges, land use, soil type and area etc. In this case, our NBS are relevant with sandy soil area, upstream of the catchment, agricultural land use, nature and wetland areas to store water, to improve soil quality, to enhance the quality of water.

1. Buffer strips and hedges:

Buffer strips are areas of natural vegetation cover (grass, bushes or trees) at the margin of fields, arable land, transport infrastructures and watercourses. They can have several different configurations of vegetation found on them varying from simply grass to combinations of grass, trees, and shrubs. Due to their permanent vegetation, buffer strips offer the right conditions (Annex-3,3.2.) for effective water infiltration and slowing surface flow; they, therefore, promote the natural retention of water. They can also significantly reduce the number of suspended solids, nitrates and phosphates originating from agricultural run-off. Moreover, buffer strips can increase the sustainability of agriculture and nature (10).

2. No-till:

No-till is an agricultural technique which increases the amount of water that infiltrates into the soil and increases organic matter retention and cycling of nutrients in the soil. Among other benefits of no-till (Annex-3,3.2.), the most potent benefits of no-till are to improve the quality of soil, which makes more resilient soil (11).

3. Low till agriculture:

Low till agriculture is another alternative solution for conservation or reduced till applies to arable land. It consists of a combination of a crop harvest which leaves at least 30% of crop residue on the soil surface, during the critical soil erosion period and some surface work (low till). Low till agriculture is more suitable for other crops land in the study area (in the land use map figure 11). There are many benefits of this measure (Annex-3, 3.2.) such as increase soil retention, but this measure is most effective on the protection for the ecosystem (11).

4. Riparian buffers:

Riparian buffers are treed areas alongside streams and other water bodies. While most associated with set-asides following forest harvest, riparian buffers can also be found in urban, agricultural and wetland areas. By preserving a relatively undisturbed area adjacent to open water, riparian buffers can serve several functions related to water quality and flow moderation. The trees in riparian areas can efficiently take up excess nutrients and may also help to increase infiltration. A riparian buffer is more useful in wetland and regions with a low infiltration capacity to capture water in the area (11).

5. Detention basins and ponds:

Detention basins and ponds are water bodies storing surface water to prevent run-off. A detention basin is free from water in dry weather flow conditions, whereas a pond (e.g. retention ponds, flood storage reservoirs, shallow impoundments) contains water during dry weather, and is designed to hold more when it rains (11).

6. Wetland restoration:

According to the Convention on Wetlands (1971), a wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. It provides water retention, biodiversity enhancement or water quality improvement (11).

7. River meandering:

A river meander is a U-form taken by the river, allowing it to decrease water velocity. In the past, rivers have been straightened by cutting off meanders (11). Most significant benefits of re-meandering are groundwater/aquifer recharge, water storage, sustainable agriculture, and preventing surface water deterioration among the others (Annex-3,3.2.).

8. Artificial Groundwater Recharge:

Groundwater is the part of infiltrated water which composes the water resource for population and human activities. Previous modifications of the landscape have reduced the infiltration capacity of many European soils, thereby limiting the rate at which precipitation can infiltrate and recharge groundwater aquifers. Restoration of natural infiltration to groundwater enables a lowering of run-off from surrounding land and enhances the condition of groundwater aquifers and water availability. The natural cleaning processes associated with infiltration can improve water quality. This measure can also be known as “Artificial Groundwater Recharge” in the engineering literature. Mechanisms to restore or enhance natural infiltration capacity include: (i) surface structures to facilitate/augment recharge (such as soakaways and infiltration basins); (ii) subsurface indirect recharge – infiltration capacity is enhanced through wells drilled within the unsaturated zone; and (iii) subsurface direct recharge – infiltration and recharge of the groundwater aquifer is accomplished through wells reaching the saturated area (11).

9. Intercropping and crop rotation:

Intercropping is the practice of growing two or more crops in proximity. The most common goal of intercropping is to produce a higher yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop or planting a tall crop with a shorter crop that requires partial shade. Numerous types of intercropping, all of which vary the temporal and spatial mixture to some degree, have been identified: mixed intercropping, row cropping, relay cropping, etc. (11).

Crop rotation is the practice of growing a series of dissimilar/different types of crops in the same area in sequential seasons. Judiciously applied (i.e. selecting a suitable crop) crop rotation can improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants. In turn, this can reduce erosion and increase infiltration capacity, thereby reducing downstream flood risk. It gives various benefits to the soil. A traditional element of crop rotation is the replenishment of nitrogen through the use of green manure in sequence with cereals and other crops. Crop rotation also mitigates the build-up of pathogens and pests that often occurs when one species is continuously cropped. However, as crop rotation has been traditionally practiced for agronomic reasons rather than to achieve environmental and water objectives, new practices may be required to ensure water retention benefits can be achieved. Some crops such as potatoes carry more significant risks of erosion due to the formation of ridges and the greater area of bare soil (see for example http://publications.naturalengland.org.uk/file/5925127770341376). Crop rotation can be used in combination with other measures when these are compatible with crop choice (11).

10. Meadows:

Meadows are areas or fields whose primary vegetation is grass, or other non-woody plants, used for mowing and haying. Pastures are grassed or wooded areas, moorland or heathland, generally used for grazing. Due to their rooted soils and their permanent cover, meadows and fields provide suitable conditions for the uptake and storage of water during temporary floods. They also protect water quality by trapping sediments and assimilating nutrients. The measure offers the potential for temporary flood storage, increased water retention in the landscape and runoff attenuation. Soil cover is maintained at all times with rooted vegetation; this reduces the surface flow of water and allows more significant infiltration to the soil. Rates of soil erosion are considerably lower than arable land with potential benefits for water quality (11).

11. Mulch:

Mulch is a layer of material applied to the surface of an area of soil. Its purpose is any or all of the following:

- to conserve moisture
- to improve the fertility and health of the soil

- to reduce weed growth
- to enhance the visual appeal of the area

Mulching as NWRM is using organic material (e.g. bark, wood chips, grape pulp, shell nuts, green waste, leftover crops, compost, manure, straw, dry grass, leaves etc.) to cover the surface of the soil. It may be applied to bare soil, or around existing plants. Mulches of manure or compost will be incorporated naturally into the soil by the activity of worms and other organisms. The process is used both in commercial crop production and in gardening, and when applied correctly, can dramatically improve the capacity of soil to store water (11).

12. Sand dams:

Professor Pieter van der Zaag and Annelieke Duker shared an example of nature-based water storage in dry rivers in Africa. They explain the use of so-called 'sand dams' (walls across the river in the sand) which increases the thickness of the sediment layer in the river (through heightening the dam in stages), thus increasing both the volume of water stored and its accessibility.

Professor McClain mentions the US Conservation Reserve Program, which aims to remove environmentally sensitive private land from agricultural production and to re-establish grass and trees to protect water quality (12).

In addition to all these NBS interventions, there are other interventions which are easier to apply and generally they are more for short-term solutions such as detention tank (improving rainwater harvesting tank capacity for horticultural area – greenhouses)(Annex-3,3.2.), infiltration trench (between meanders and current situation, stone trench – for infiltration which is shallow to create an underground reservoir) and water consumption and soil ventilation.

4. Adaptation pathways

What is the pathway approach?

‘Pathways’ concerning adaptation is an approach created to schedule adaptation decision-making: it defines the decisions that need to be taken now and those that may be taken in future. The approach supports strategic, flexible and structured decision-making. The pathways approach allows decision-makers to plan for, prioritise and stagger investment in adaptation options. Tipping points and thresholds help them identify when to revisit decisions or actions (13).

The tipping point or tipping point is described as a point when global climate changes from one stable state to another steady state. After the tipping point has been passed, a transition to a new state occurs. A turning point is different from a decisive moment. A decision moment goes to one pivot point in advance in time and depends on many factors such as obtaining social and political, support for a decision, the lead times of the planning phase and implementation phase, etc.

Before making an adaptation pathway by using regional scenarios, as a first step, tipping points should be described. In the research area, tipping points are defined by using climate scenarios, areas research and past experiences in the following sentences;

- surface water level (last two years water board forbidden to pump water because of low surface water level)

- groundwater level (current groundwater level is still not under the risk but according to the last years' groundwater level measurements and according to climate effect atlas predictions, the groundwater level is getting decrease)

- soil water capture capacity/ soil quality (current soil quality and water capture capacity is already in a bad situation and it is getting worse because of the land use)

These are used as tipping points for areas challenges description and these are relevant with water scarcity problem which is caused by drought. There is no specific data to use numbers for tipping points, but in the scenarios, we refer to the past occurrence and future expectations as a tipping point. After defining tipping points, which strategy is followed, and which measures/management are deployed to meet the Province objectives are filled in the adaptation pathway. Aim of making adaptation pathways with different scenarios is to make them more resilient area under climate change.

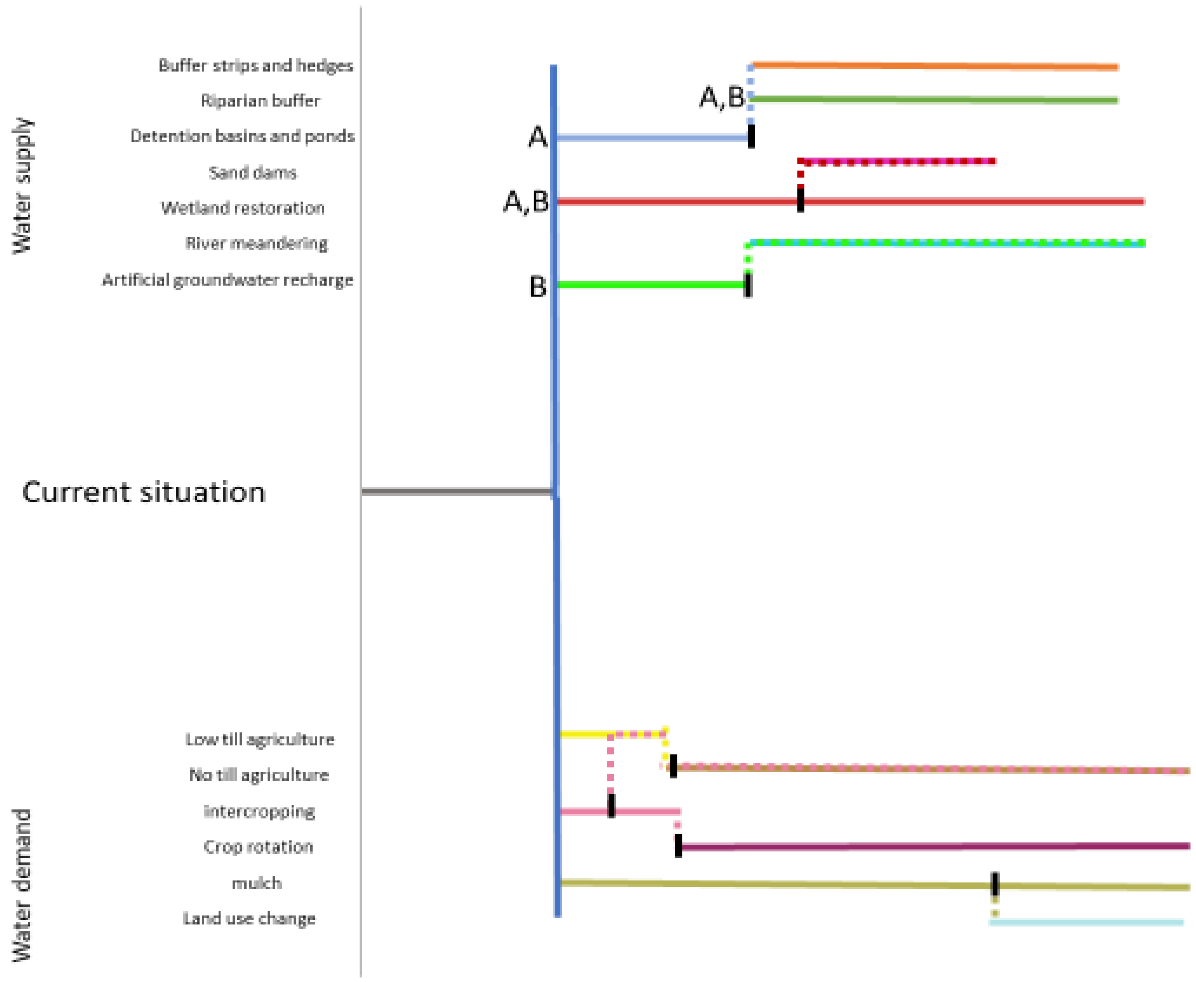


Figure-8: *It is an example adaptation pathway to show which NBS can be useful for which condition. For the detailed adaptation pathway, specific tipping points are needed such as groundwater level, surface water level, soil moisture level etc. A: when surface water level reaches 2018's level B: when groundwater level gets lower than past 10 years groundwater level*

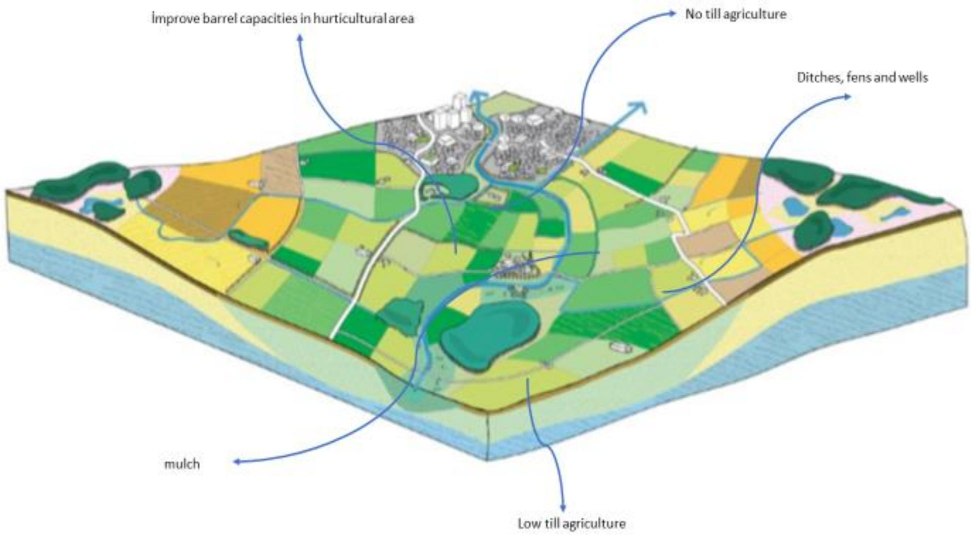
There are 4 scenarios which explain that based on different measure usage what can be happen and what it looks like in the research area.

Scenario 1 – doing nothing: remain with current management strategies, current land use, current laws

What can be happen:

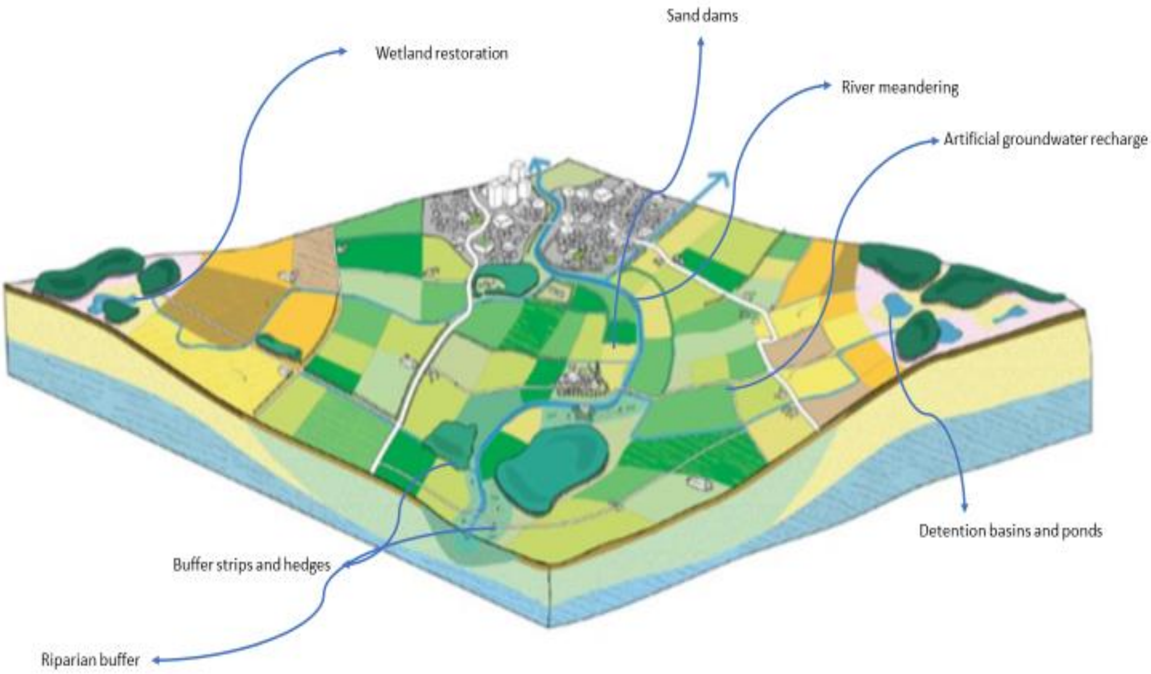
- There will not be available groundwater and surface water – water scarcity
- Agriculture will be harmed – because of water deficiency and low soil quality
- The soil will be more damaged
- Economic effects
- Nature – loss biodiversity
- Losing resilience

Scenario 2 – using NBS in current land use and water system layout



In this scenario, we just use water storage and infiltration related measures and agriculture related measures without land use change. It can work for short-term but still system works as same way as current situation. Just improve some current system like ditches, wells and water storage capacity of horticultural system.

Scenario 3 – Combining NBS with water system restoration (downscaling river engineering)



In addition to the first scenario, in this scenario we suggest using some river engineering system and instead of improving current system works, adding new structure to change water flows in the system is the main idea.

Scenario 4 – combining NBS with large scale land-use change

"New models: water farms, energy production, recreation, wide agriculture ''

groundwater and soil improvement

“Sponge Operation return by improving the quality of the soil’’

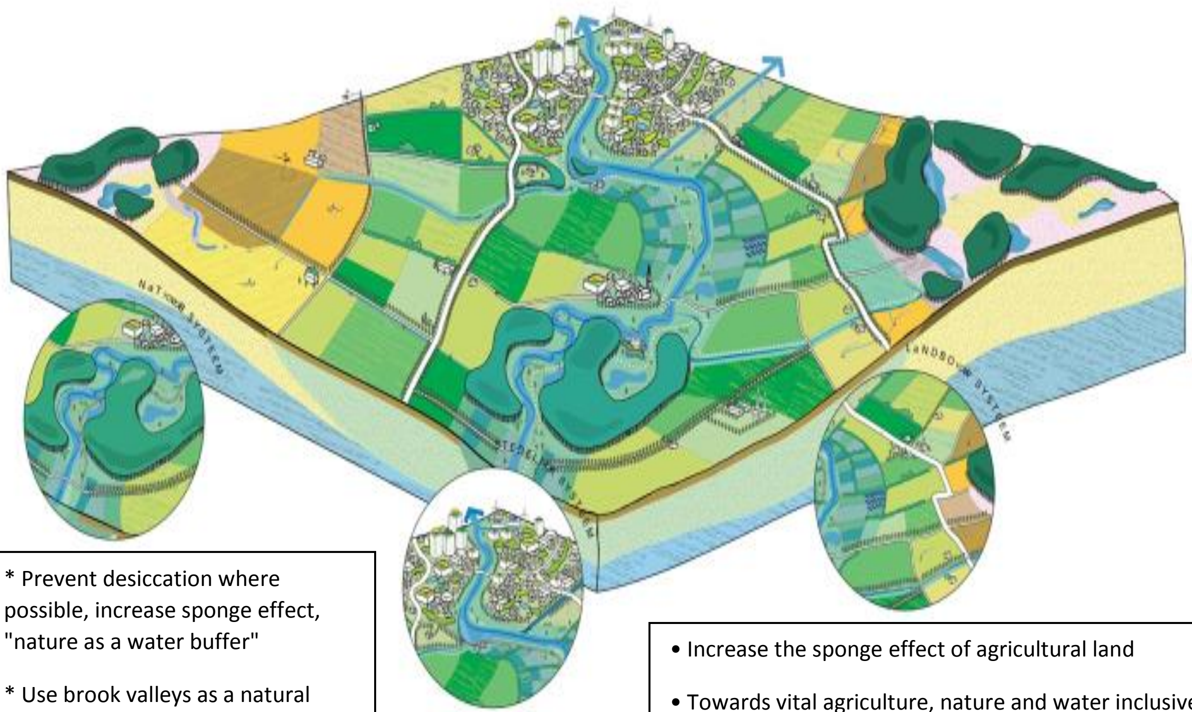
"Sensible use of irrigation wells, replenishment of groundwater resources and soil improvement"

" Locks, utilizing channels for water storage"

"Water buffers around nature areas"

"Sometimes (dug) brooks shut on the high ground"

"The stream gets as much space as possible"



* Prevent desiccation where possible, increase sponge effect, "nature as a water buffer"

* Use brook valleys as a natural connecting zone

* Giving room to natural processes in the stream

• How do we deal with periodic drought, eutrophication from agriculture and water scarcity?

• Increase the sponge effect of agricultural land

• Towards vital agriculture, nature and water inclusive agriculture, taking into account the capacity of the area.

• Towards a differentiated manure and soil policy per area?

• Vital soil: in balance with fertilizer application, good organic matter content, ecologically healthy soil life

• Use new cultivation / supportive facilities for good yield potential

This scenario is the most improved scenario when we compare with other scenarios because every NBS which are relevant to landscape structure is suggested with changing landuse and to show how it works and what it changes in the area to reach our goal.

5 Regional adaptation scenarios'

After defining NBS and giving possible scenarios for research landscape as a general idea, if we look at the studied area in detail, some important points should be made more explicit. In this chapter, we are going to give some detail information about solutions to relate to the research area.

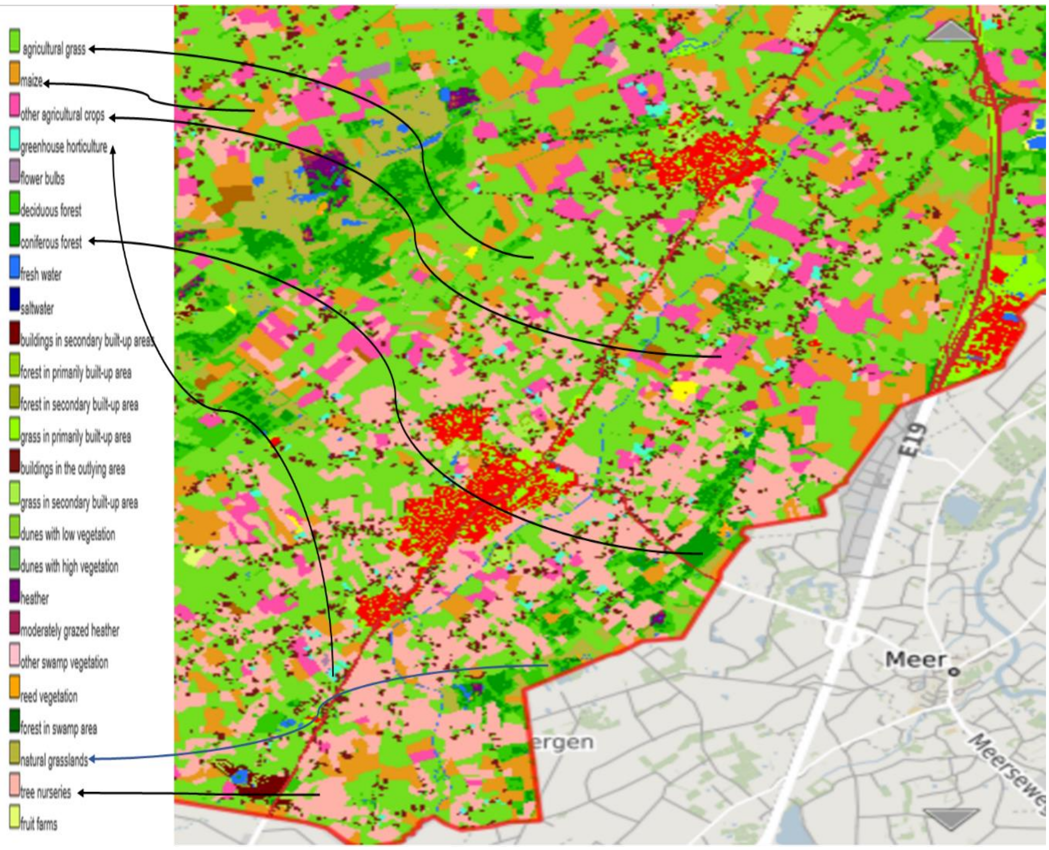


Figure-9: *Land use map according to the Alterra Landelijk Land Usesbland (LGN6). Land use has a significant influence on the water system.*

Figure 9 shows that tree nurseries and grassland dominate land use in the research area, and other necessary land-use units are maize, other agricultural crops and coniferous forest. Land use is vital to decide about which kind of NBS could be more feasible in the area because land use influences the water system both quantitatively and qualitatively. Concerning quantitative influence, consideration can be given to the influence of land use on the size of the precipitation surplus, on the feeding of the (more in-depth) aquifers, on the dewatering requirements required for specific crops and on the drainage dynamics. In urban areas, a relatively large proportion will drain quickly in the event of intensive rainfall. This also applies to areas where there is a dense drainage system due to land use. The land use in the stream valley of the Aa or Weerijs consists of the most of agriculture and the water management is adapted to this. At the end of the 1960s, the stream was normalised, widened and deepened and provided with weirs. Along the over-dimensioned main course, there are chimney paths on both sides that border on agricultural parcels. Due to drainage of agricultural lands, intensive dewatering and the limited natural storage capacity, water is drained faster during wet periods and the basic drainage during dry periods is shallow, an effect that is further enhanced by abstractions. In the summer, this leads to meagre flow rates in the main run. Agriculture-related NBS could be adapted based on the agriculture type. For example, no-till agriculture and crops exchange can be most useful in the other crops area. Also, types of tree changes can make relevant with crops exchange, and as changing types of tree, water usage could be decreased.

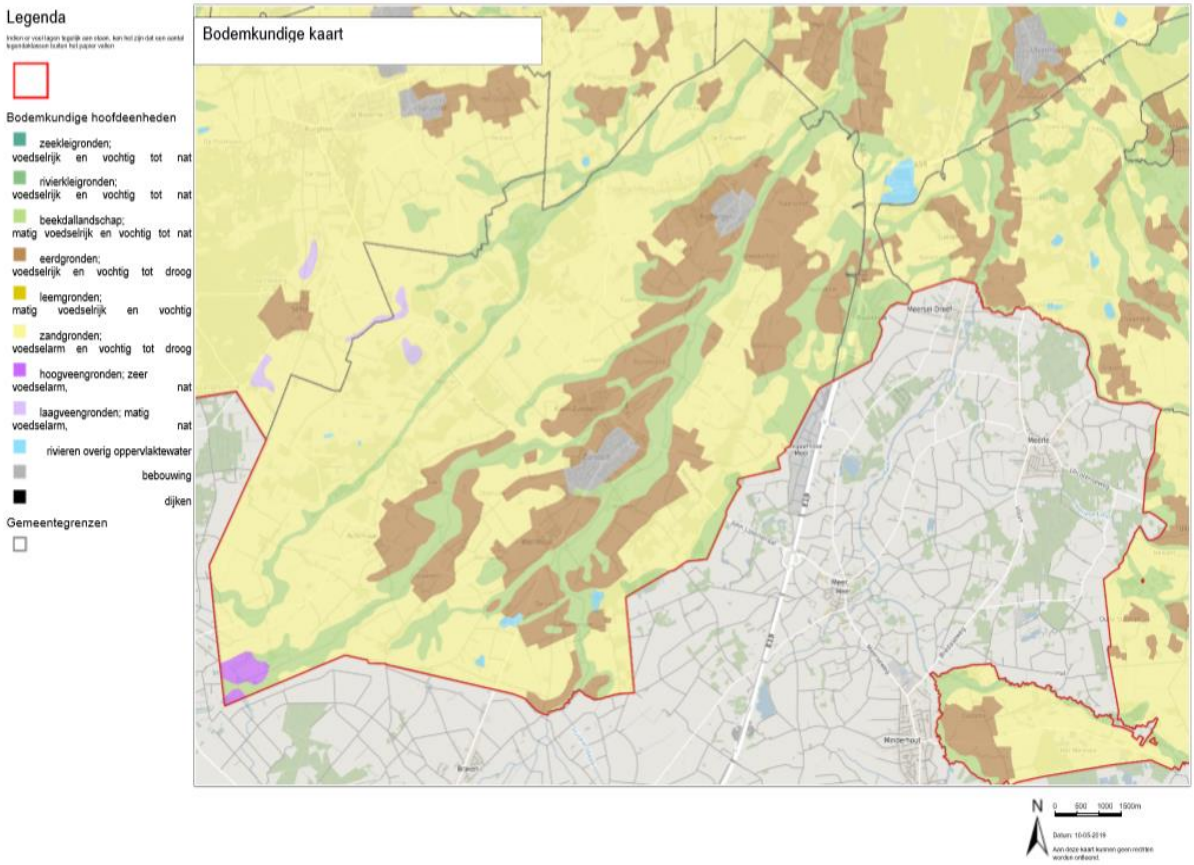


Figure -10: *Soil characteristics map shows which area is moisture, which area is wet or dry*

Figure 10 shows which area is more suitable for water storage and buffering. Brown parts show soils which is nutrient-rich and moist-dry, the yellow section shows sandy soil areas which low quality for agriculture and dry, green part shows river clay which nutrient-rich, moist and wet. When we combine this map with the land use map, it is obvious to see that intensive agricultural area and other agricultural crops area have low-quality soil and sensitive soil under the drought. These areas need to be improved their soil quality and need to have enough water to keep the system working during the dry season. Therefore, some NBS in section 4 which helps to improve soil water capturing capacity and improve soil quality could be more useful in these areas like a meadow, crop rotation, artificial groundwater recharge etc.

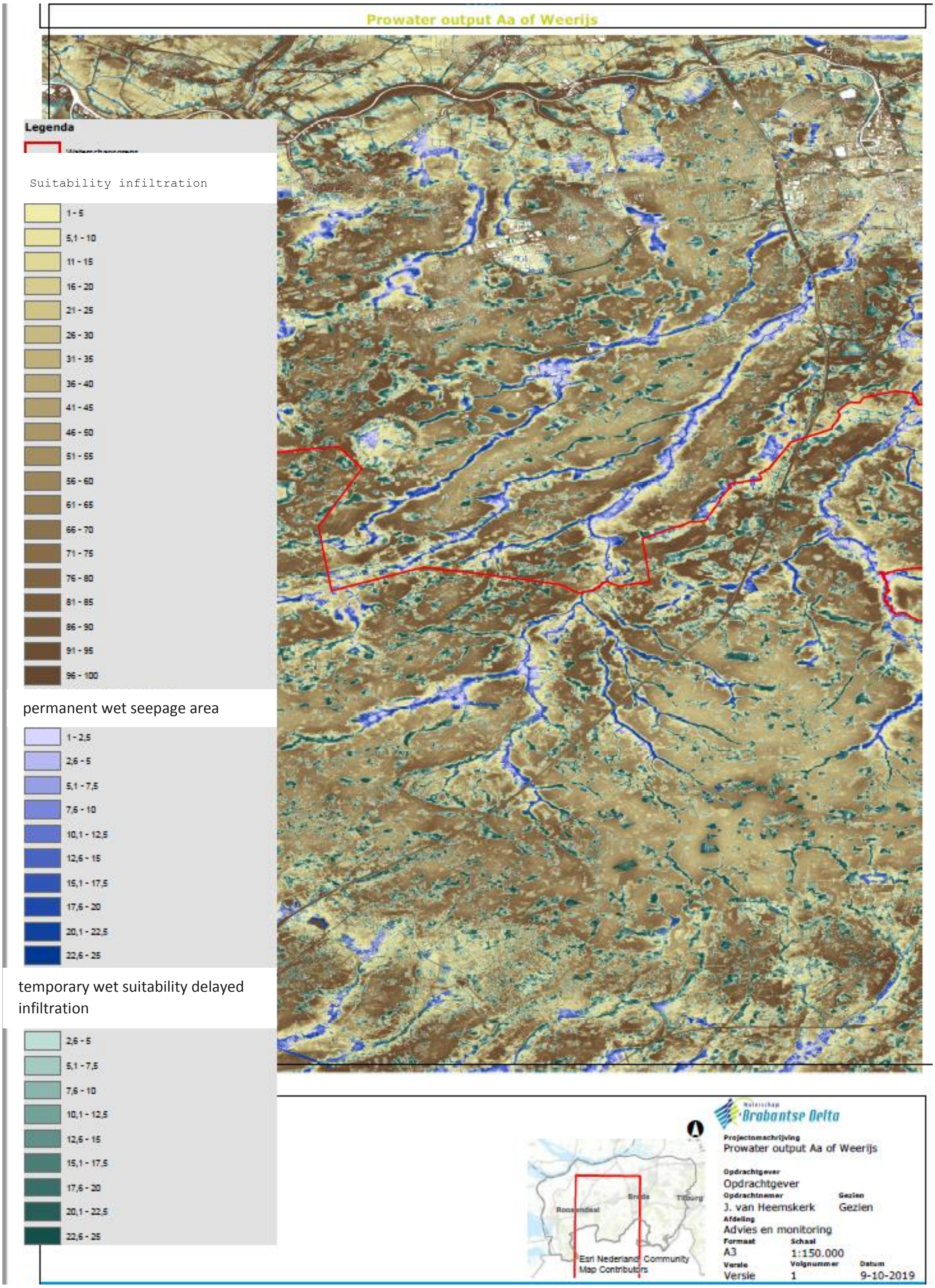


Figure-11: *Infiltration map which shows that where can be suitable infiltration area, where wet seepage area*

In the catchment areas of the Aa or Weerijs, the groundwater flow in the more in-depth packages is generally directed to the north. The flow pattern is locally influenced by the watercourses present. The shallow groundwater has a much more erratic pattern and drains globally in the direction of the lower watercourses. The seepage water in the stream valleys of the Aa or Weerijs and the Kleine Beek is plentiful of regional origin, with forest and heath areas in Flanders as infiltration areas. In the other watercourses in the area, the seepage often has a more local source and is often infiltrated in the forest areas in the immediate vicinity.

Figure 11 is a map which was made by Brabantse Delta to figure out infiltration areas and seepage areas. According to this map, suitable areas for infiltration (dark brown) could be useful to create water storage and make artificial groundwater recharge system to restrain water run-off. Also, seepage area is the area that one of the significant sources of water loss from the surface system and based on the seepage area we could now where irrigation level should reduce, where we need to reduce soil permeability. This map could be useful to decide which measures can suit where. Majority of the measures are relevant to improve soil quality and soil water capture capacity, water storage and keeping water in the system. When we combine this infiltration map with the land use map, it is obvious to see tree nurseries cover that majority of the seepage areas. It means irrigation capacity of the tree nurseries companies and landowners should be controlled by waterboard and province. Also, measures which are more focusing on improving water capture capacity of the soil and soil quality are more suitable for seepage areas.

In addition to all these, meandering also another option to keep water in the system and prevent the area from drought. According to watersystemanalysis of Aa of Weerijs report, there are some areas where extra meanders could be possible to make (figure- 12).

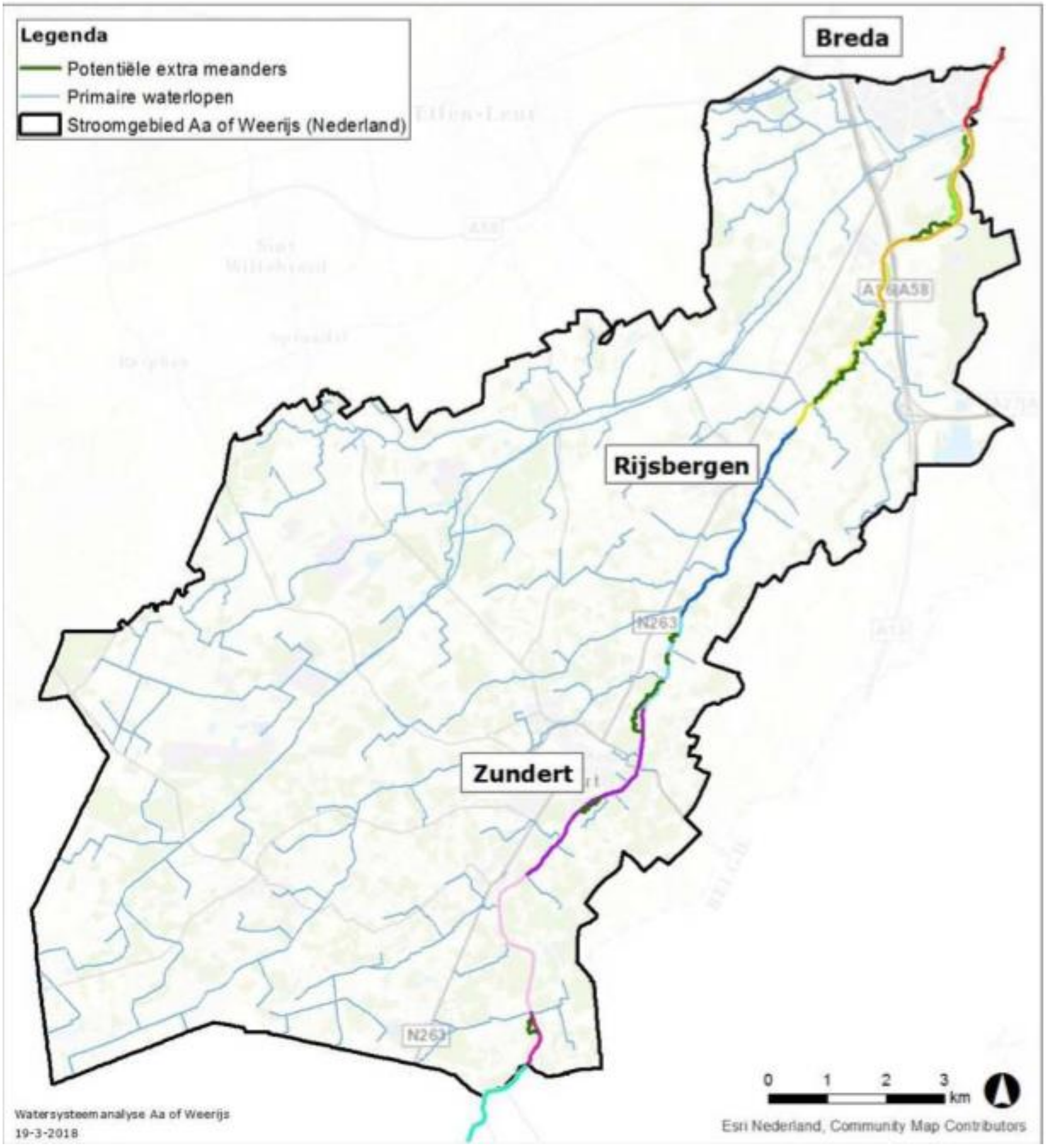


Figure-12: *Potential extra meanders map; dark green lines illustrate potential extra meanders areas*

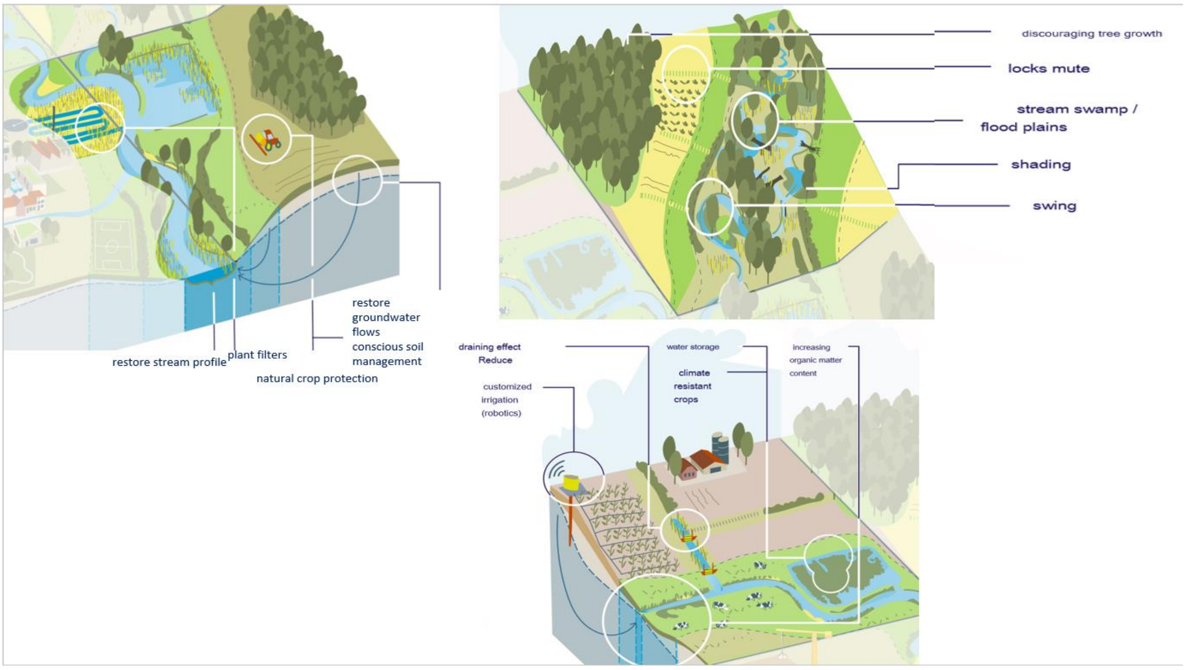


Figure-13: *This figure shows which kind of changes depending on challenges make system more climate-proof in Aa of Weerijs stream valley (Stowa_naar een klimaatbestendig beekdal)*

In this chapter, we try to show more areas characteristic and needs. Based on these needs and challenges which farmers have been facing caused by climate change, we try to explain which solutions could be applied in where. Also, as an example, according to STOWA map (figure -13), we can see what the area needs and which perspective we need to look for it.

6 Conclusions and recommendations

In recent years, there have been many problems caused by climate change and water shortage due to drought has been one of the critical challenges. The purpose of this report is to eliminate or minimise existing challenges relevant to water management and soil quality by using nature-based solutions. We explained the challenges throughout this report and tried to show what solutions/measurements/scenarios can be beneficial and feasible for the research area. This chapter first presents a description of the current state, and this is followed by an explanation for scenarios related by nature-based solutions. Finally, the recommendations from the analysis are given.

Current situation:

Land use in the Aa or Weerijs brook valley mainly consists of agriculture and water management has been adjusted accordingly. The stream has been widened and deepened and provided with weirs. Due to intensive dewatering and the limited natural storage capacity, water is drained faster during wet periods and the primary drainage during dry periods is shallow, an effect that is reinforced by abstractions. In the summer, therefore, the flow is deficient, and the body of water looks more like a stagnant system than a flowing stream.

Majority of agricultural land use consists of tree nurseries and tree nurseries, especially growing-up season, need much more water than other periods. Soil quality is not enough to grow up trees in the research area, and because of that, farmers use a different kind of techniques such as covering the land with some plastics and growing trees in small plastic pots to improve the quality and efficiency of trees which has an essential effect on scaling down of soil quality. Soil quality has been decreasing because of the lack of ventilation and lack of fertilisation. When soil quality decrease, it affects the water storage capacity of the soil. It turns to kind of loop and with the current management plan, land use style and increasing climate change effects it is getting worst.

The current water management system is not enough to prevent drought effects on Aa of Weerijs catchment and to control discharge capacity- water flow, to improve soil and water quality, store water in the appropriate areas.

Measures and scenarios:

Due to minimising drought-related challenges, NBS interventions recommended to use, and how to implement these measures in different situations has been showed. NBS interventions were wide and varied. Each intervention has its particularity regarding the geographic location and geomorphological characteristics, political context, and stakeholder involvement. NBS is a flexible concept that covers a wide range of techniques and policies that vary in the degree of intervention in the functioning of ecosystems.

Each part of the catchment has different requirement depending on their land-use type, infiltration capacity, distance to water sources and soil type. Considering these features of the area and their requirements to prevent challenges, NBS's can be defined and be implemented. Because of that, it could be easy to identify which measures can be feasible in where. Implementation time relies on tipping points which show when intervention is needed and till when it can be achievable. Combination of tipping points and timeline give us to make a clear adaptation pathway to see when we can apply which measures and which measures can be combined at the same time. Interconnections between measures should be taken into account based on the benefits of measures and which area they can be implemented. Depending on tipping points, all information from maps and area requirements, the various scenarios could be both runs parallel to each other and run as interpenetrating each other. Because of that, it is imperative to understand location needs and tipping points. Figure 14 illustrates changes in 50 years that the current land use-water system and old (1965) land use-water system. Dramatical changes of water system draw the attention which transformed from meandering river system to the canalised river system.

Moreover, the landscape has been changed throughout time, and it keeps changing, such as the size of natural areas, agricultural land use, improving some urbanisations area which has impacts on water consumption. The map in figure 14 is essential to understand changes through the time and it is crucial to see what we want. One hand we want to solve the problems and this map shows us original land usage and water system like meandering and ponds in the area, on the other sides for the natural transformation we are not going to back to past but also we are trying to create some improved version of the area. So, these NBS are new elements to constitute the developed more sustainable and resilient areas under the drought.

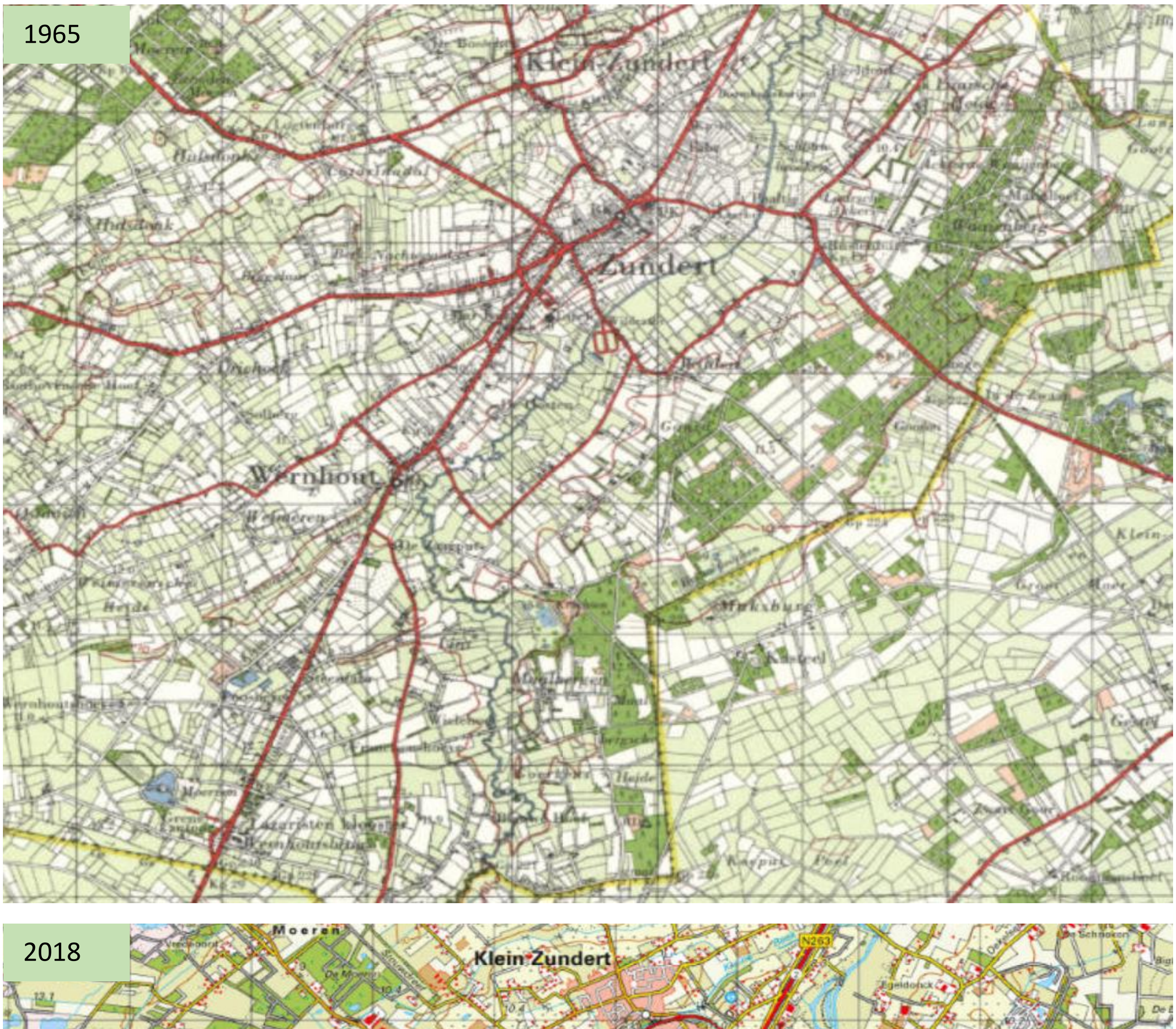


Figure-14: *Comparison between historical map and current map about areas land changes and watercourses changes*

Recommendation:

As a follow-up to the present analysis, the targets should be determined, and the necessary choices should be made with the partners in line with these goals. The chosen variant must then be further elaborated and supplemented with proposals for (technical) goal adjustment. Given the cross-border nature of the Aa or Weerijs, this is preferably done together with Flemish partners.

Besides, the present analysis makes the following recommendations:

- Whatever measures are chosen should suit on nature of the landscape, and landscape characteristic should be taken into account
- Type of trees and their water consumption level should be explored, and other alternatives should be considered,
- Collaboration with farmers should be improved and depends on their necessity, implementations could be regulated such as ditches and weirs -where they should be (area slope and distance to water resource should calculate), and it should be some regulation of controlling water usage
- It is, therefore, advisable to intensify coordination and cooperation with Flemish partners.
- Current management and land-use need to change. While some changes take a long time, others are very effortless and do not require a long time to change. So, depending on urgency, measures should be chosen carefully.
- Tipping points could calculate carefully with taking into climate change account and depends on tipping points solutions can be applied step by step – this helps to understand what is happening in the area and how we can handle with the problems.
- Implementation of measures depends on urgency, and this urgency can be defined by using climate adaptation pathways and tipping points. Due to defining tipping points, some critical information could be defined carefully such as soil moisture, limit level of water sources and water usage
- Scenarios rely on when measures should apply, where they should apply in and how many of them should be implemented as interaction with each other. Because of that, understanding the benefits of measures and implementation areas are connected to use scenarios with different tools in the landscape because measures are work very well as individuals, but they work even better together.
- Tree nurseries have an essential role in making everything right, and because of that, collaboration with stakeholders is crucial to convince them about challenges and changes requirements. Land-use changes seem impossible in the current situation, but from 1900 till now, land use has been changing, and it keeps changing again. Because water demand/supply relation has more relation to land use, therefore, if we want to have more water, we need to decrease our water demand, and also, we need to keep water in the system in case of drought.

Besides, all these, during research, there are some knowledge gaps which did this research hard to reach its goal. These deficiencies are lack of information about moisture level of soil, lack of data about the availability of water usage in the area which is also relevant to lack of communication with stakeholders, and differences between Flemish law and Dutch law. For effective approach in the whole catchment this should be expanded with downstream (Breda) and upstream areas (Flanders). These gaps make it hard to be keeping on track, especially throughout defining the tipping points. We try to present a sort of system to show how to design adaptation pathway like this. But lack of information made our adaptation pathway very superficial. As a province, waterboard or government, if you want to reach your goal or if you want to do something to deal with challenges, you should gather all needed information to define where or what the tipping points are.

Moreover, responsibilities of water management were divided into waterboard and province such as dipper part of groundwater is under the province' responsibility and surface water is under the waterboard responsibility, but there is still some misunderstanding between them like about deciding water level for prohibition. Maybe, it could be useful and helpful to be more interconnecting in the regional process even though each of them has their responsibilities and their strategies to handle challenges. In addition to this, the environmental quality of the Aa or Weerijs must be considered in the broader context of the transboundary river basin, and an inventory must be made of any conflicts and linkage opportunities with other functions and developments.

In conclusion, measures for dealing with challenges need detailed information, and in this research, there are some limitations. These limitations and information deficiency make this research fragmentariness. Due to providing missing points and information; understanding the old system, understanding changes, understanding characteristics of the area, defining real challenges and their reasons and collaborations are crucial. Collaboration and interconnection between both regional management system (province, waterboard and stakeholders) and national management system (Dutch government and Flemish government) are essential to reach all goals. In this report, we look at the system at the climate adaptation approach, and we look at the different layers, landscape, hydrological information, toolbox and measures. That is all about technics to use for applying measure; however; governance, legislations, budget, and so on make this report real and useful for the real world. Aa of Weerijs is a catchment area, and in the catchment, area working by yourself is pointless. Because of that, a co-creation process could be needed to implement measures and to make people (landowners and other stakeholders) realise that in the real world, a governance approach is needed.

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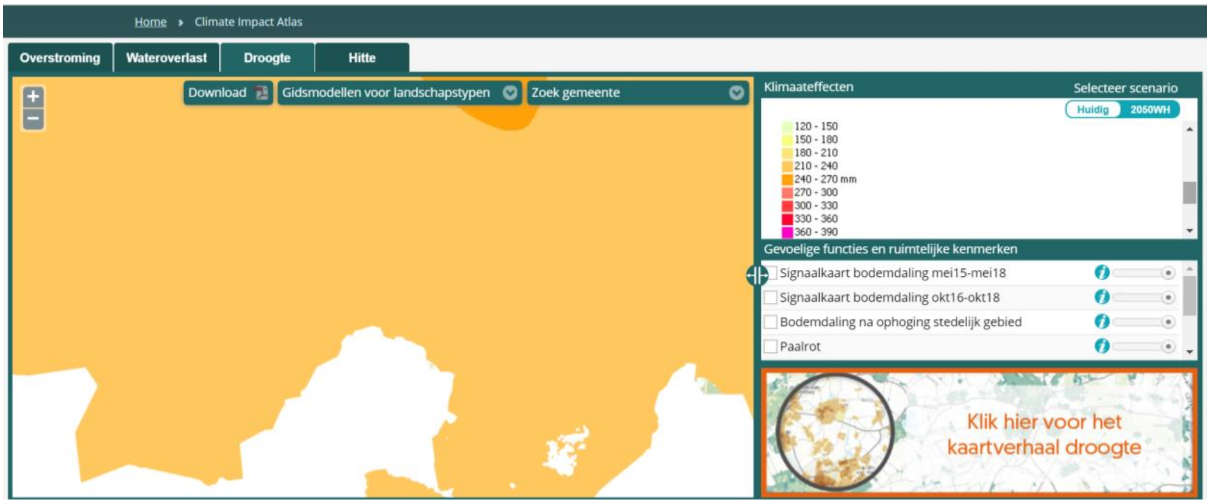
Annex:

Annex- 1: Climate Effect Atlas

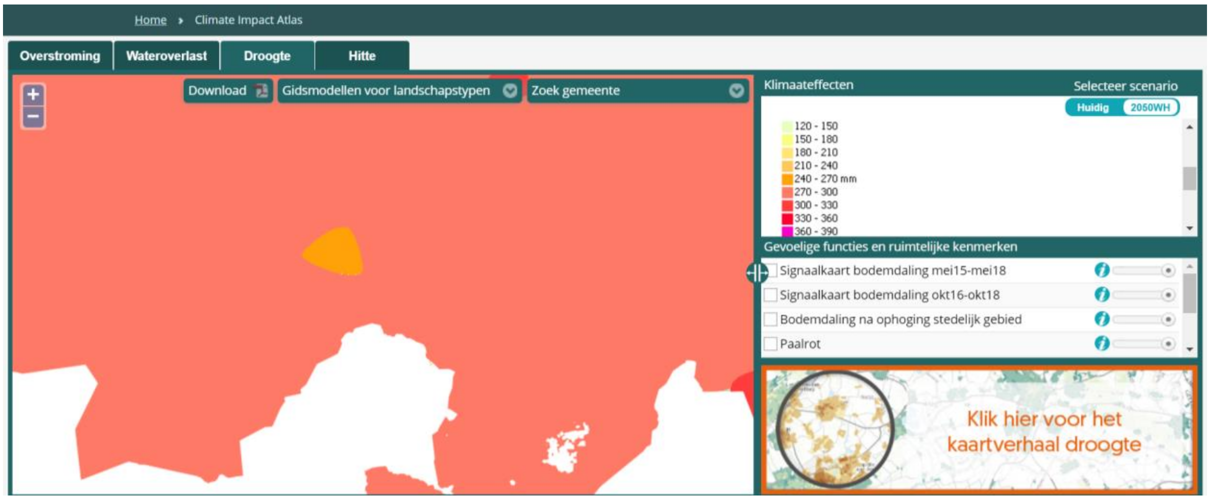
1.1. Precipitation deficit and summer precipitation

Precipitation deficit:

Current:

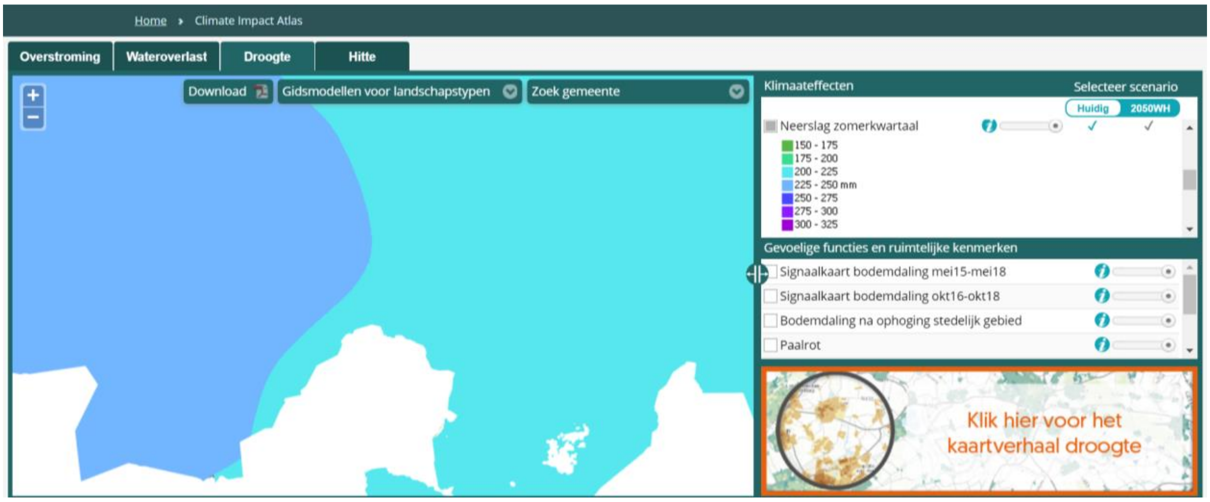


2050:

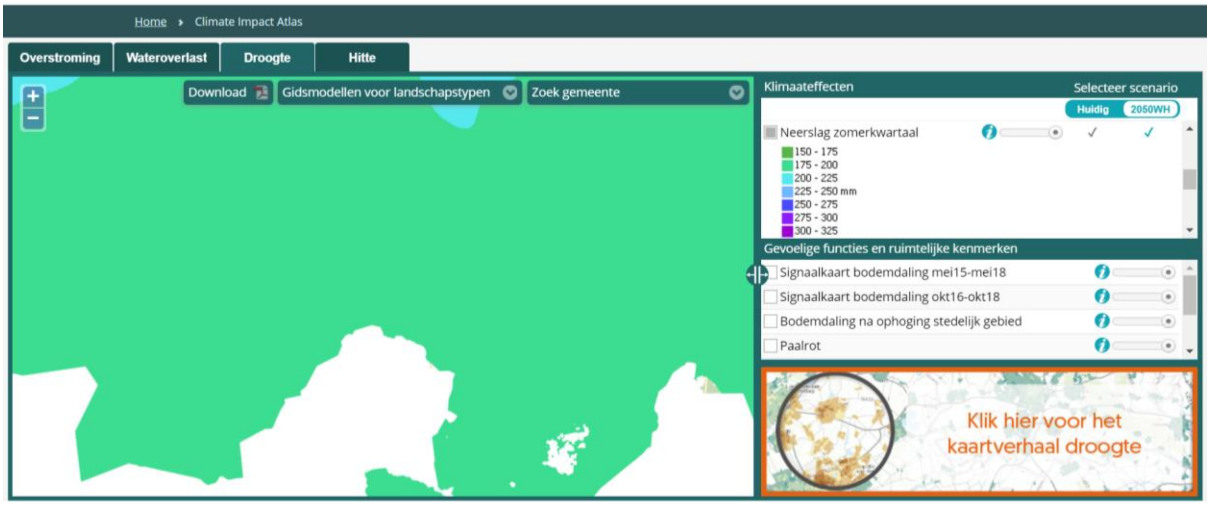


Summer precipitation

Current

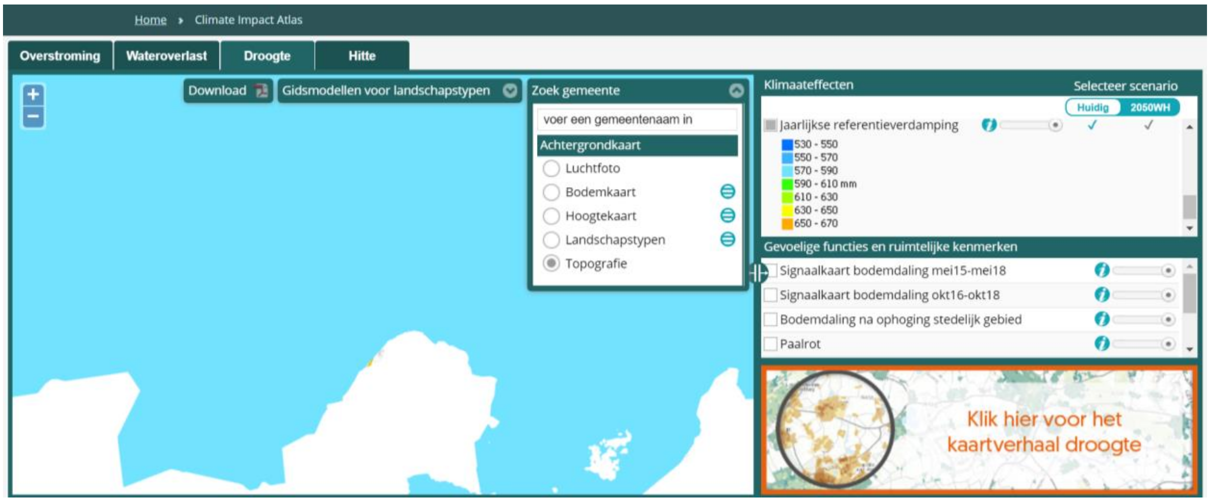


2050



1.2. Annual reference evaporation

Current



2050

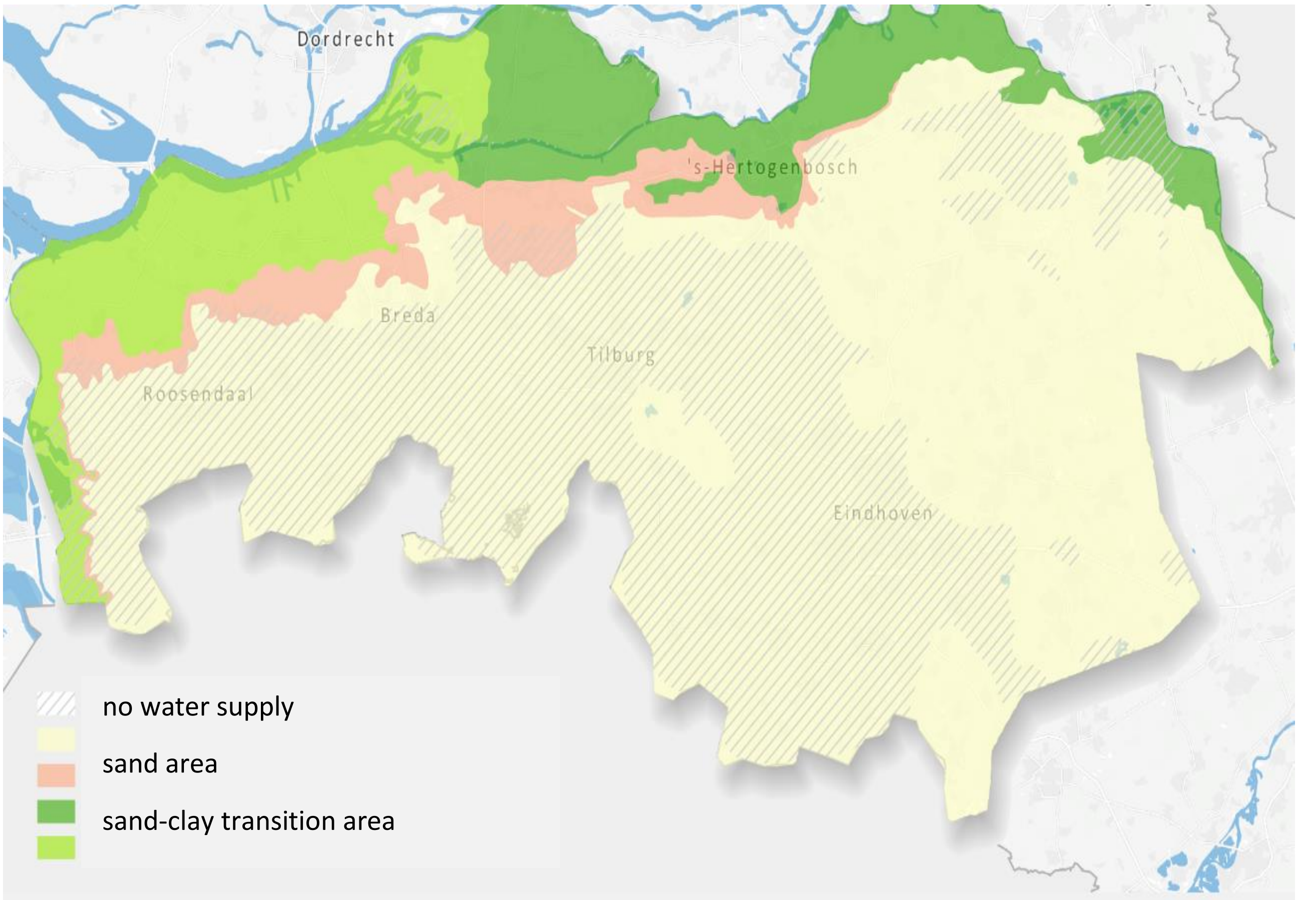
Annex-2: Climate effects on region

2.1. Water supply map

The effects of drought can vary greatly from place to place. A large part of Brabant consists of (high) sandy soils. Characteristic of these areas is that no or only limited water supply is possible from the main water system: there are often no channels or large pipes through which water can be supplied from elsewhere. For their water supply, these areas are completely dependent on the "own" precipitation and groundwater.

An exception to this is the northeastern part of Brabant, where water can be supplied from the Maas. The Maas is a rain-dependent system that itself is also vulnerable to dry periods. Deltares, an independent research institute in the field of water and subsurface, calculated that the current level of water supply from the Maas will come under pressure around 2050 due to climate change.

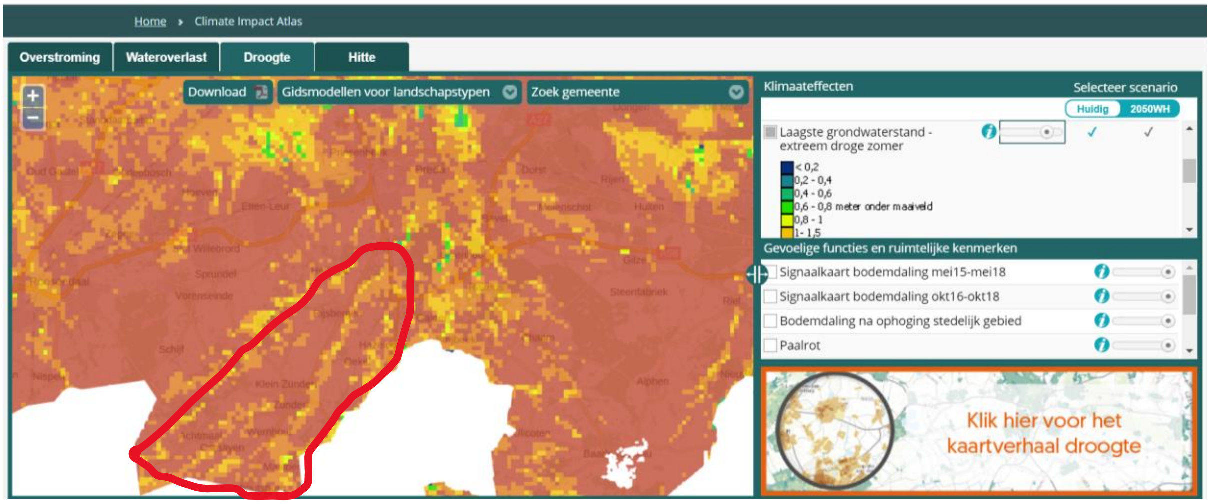
The map below shows the high sandy soils in Brabant. The sandy soils where no water can be supplied from the Maas are extra sensitive to drought.



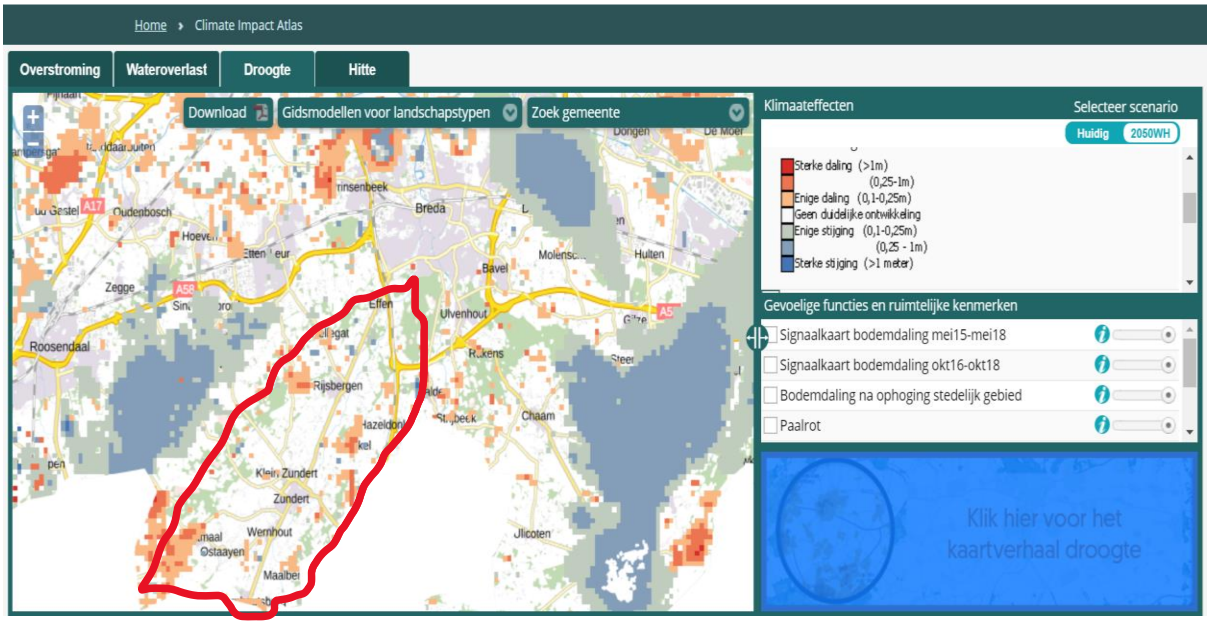
2.2. Other relevant effects

lowest groundwater level - extremely dry summer

Current:

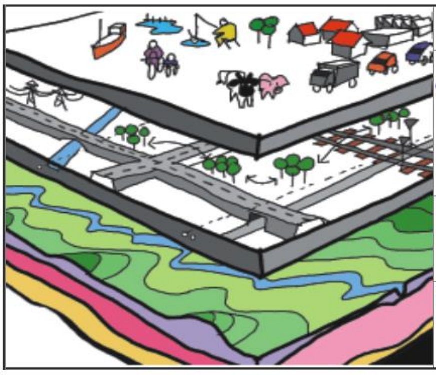


2050:



Annex-3: Nature Based Solutions

3.1. Characteristics of Layers

	low	characteristic
	Occupation layer	High change speed; changes usually occur within one generation (10 to 40 years).
	Network layer	High start-up costs and long start-up times; major changes last around 20 to 80 years.
	Base layer	Long history and vulnerable; major changes soon take more than a century.

3.2. Ranking Impacts of Measures

1- Buffer strips: Buffer strips can be sited in riparian zones, or away from water bodies as field margins, headlands or within fields (e.g. beetle banks). Hedges across long, steep slopes may reduce soil erosion as they intercept and slow surface run-off water before it builds into damaging flow, particularly where there is a margin or buffer strip alongside (16).

Possible benefits with level:

Benefits	Level
BP2 - Slow runoff	High
BP10 - Reduce erosion and/or sediment delivery	High
ES7 - Flood risk reduction	High
ES8 - Erosion/sediment control	High
ES9 - Filtration of pollutants	High
PO7 - Prevent surface water status deterioration	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
PO12 - More sustainable agriculture and forestry	High
PO14 - Prevention of biodiversity loss	High
BP6 - Increase infiltration and/or groundwater recharge	Low
BP11 - Improve soils	Low
ES3 - Natural biomass production	Low
ES4 - Biodiversity preservation	Low
PO1 - Improving status of biology quality elements	Low
PO2 - Improving status of physico-chemical quality elements	Low
PO4 - Improving chemical status and priority substances	Low
PO5 - Improving quantitative status	Low
PO6 - Improving chemical status	Low
PO10 - Protection of important habitats	Low
PO13 - Better management of fish stocks	Low
BP5 - Increase evapotranspiration	Medium
BP7 - Increase soil water retention	Medium
BP9 - Intercept pollution pathways	Medium
BP14 - Create terrestrial habitats	Medium
BP17 - Absorb and/or retain CO_2	Medium
ES5 - Climate change adaptation and mitigation	Medium
ES6 - Groundwater/aquifer recharge	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO8 - Prevent groundwater status deterioration	Medium

Illustration: Hedgerow (UK) Source: http://www.bbc.co.uk/nature/habitats/hedge

Illustration : Buffer strips Source: https://en.wikipedia.org/wiki/Buffer_strip

2- No-till :

Possible benefits with level:

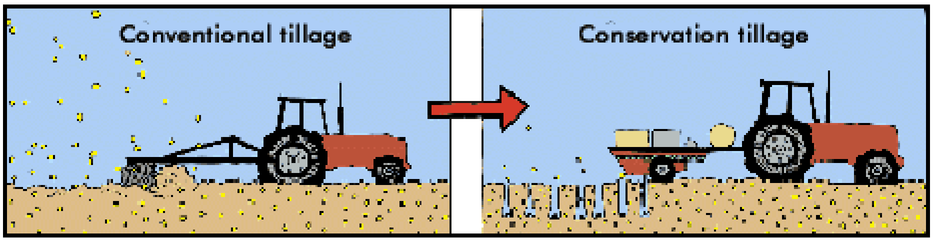
Benefits	Level
BP8 - Reduce pollutant sources	High
BP11 - Improve soils	High
BP17 - Absorb and/or retain CO_2	High
ES8 - Erosion/sediment control	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
PO12 - More sustainable agriculture and forestry	Low
PO14 - Prevention of biodiversity loss	Low
BP6 - Increase infiltration and/or groundwater recharge	Low
BP7 - Increase soil water retention	Medium
BP10 - Reduce erosion and/or sediment delivery	Medium
ES5 - Climate change adaptation and mitigation	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES9 - Filtration of pollutants	Medium
PO2 - Improving status of physico-chemical quality elements	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Medium
ES4 - Biodiversity preservation	Medium
PO5 - Improving quantitative status	Medium

Illustration: No till Source: Gábor Ungvári's presentation, NWRM Workshop 1

3. Low till agriculture: This slows water movement, which reduces the amount of soil erosion and potentially leads to greater infiltration (18).

Possible benefits with level:

Benefits	Level
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
ES1 - Water storage	Low
ES5 - Climate change adaptation and mitigation	Low
ES10 - Recreational opportunities	Low
PO12 - More sustainable agriculture and forestry	Low
PO14 - Prevention of biodiversity loss	Low
BP7 - Increase soil water retention	Medium
BP10 - Reduce erosion and/or sediment delivery	Medium
BP11 - Improve soils	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES9 - Filtration of pollutants	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Medium



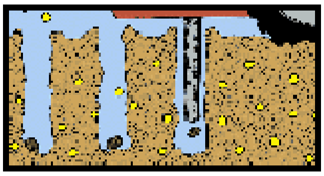


Illustration of conservation tillage Source: nwrm.eu/measure/low-till-agriculture

4. Riparian buffers serve to slow water as it moves off the land. This can decrease sediment inputs to surface waters (19).

Benefits	Level
BP10 - Reduce erosion and/or sediment delivery	High
BP13 - Create riparian habitat	High
ES4 - Biodiversity preservation	High
ES8 - Erosion/sediment control	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
BP5 - Increase evapotranspiration	Low
BP6 - Increase infiltration and/or groundwater recharge	Low
BP7 - Increase soil water retention	Low
BP11 - Improve soils	Low
BP14 - Create terrestrial habitats	Low
BP17 - Absorb and/or retain CO_2	Low
ES1 - Water storage	Low
ES3 - Natural biomass production	Low
ES7 - Flood risk reduction	Low
ES11 - Aesthetic/cultural value	Low
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Low
BP4 - Slow river water	Low
ES6 - Groundwater/aquifer recharge	Low
ES10 - Recreational opportunities	Low
ES12 - Navigation	Low
PO4 - Improving chemical status and priority substances	Low
PO6 - Improving chemical status	Low
PO8 - Prevent groundwater status deterioration	Low
BP1 - Store runoff	Medium
BP2 - Slow runoff	Medium
BP8 - Reduce pollutant sources	Medium
BP9 - Intercept pollution pathways	Medium
BP12 - Create aquatic habitat	Medium
BP16 - Reduce peak temperature	Medium
ES9 - Filtration of pollutants	Medium
PO1 - Improving status of biology quality elements	Medium
PO2 - Improving status of physico-chemical quality elements	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO10 - Protection of important habitats	Medium
PO12 - More sustainable agriculture and forestry	Medium
PO13 - Better management of fish stocks	Medium
PO14 - Prevention of biodiversity loss	Medium
ES2 - Fish stocks and recruiting	Medium

Illustration; riparian buffer source : http://www.flatheadwatershed.org/watershed/floodplains.shtml

5. Basins and ponds

Possible benefits with level:

Benefits	Level
BP1 - Store runoff	High
BP6 - Increase infiltration and/or groundwater recharge	High
ES1 - Water storage	High
ES6 - Groundwater/aquifer recharge	High
ES7 - Flood risk reduction	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	High
BP2 - Slow runoff	High
BP7 - Increase soil water retention	Low
BP10 - Reduce erosion and/or sediment delivery	Low
BP12 - Create aquatic habitat	Low
ES2 - Fish stocks and recruiting	Low
ES3 - Natural biomass production	Low
ES4 - Biodiversity preservation	Low
ES8 - Erosion/sediment control	Low
PO1 - Improving status of biology quality elements	Low
PO5 - Improving quantitative status	Low
PO7 - Prevent surface water status deterioration	Low
PO11 - Better protection for ecosystems and more use of Green Infrastructure	Low
PO13 - Better management of fish stocks	Low
PO14 - Prevention of biodiversity loss	Low
PO2 - Improving status of physico-chemical quality elements	Low
PO3 - Improving status of hydromorphology quality elements	Low
PO4 - Improving chemical status and priority substances	Low
PO6 - Improving chemical status	Low
PO12 - More sustainable agriculture and forestry	Low
BP9 - Intercept pollution pathways	Medium
ES9 - Filtration of pollutants	Medium
ES10 - Recreational opportunities	Medium
ES11 - Aesthetic/cultural value	Medium
PO8 - Prevent groundwater status deterioration	Medium

Illustration a pond and basins Source : http://nwrm.eu/measure/basins-and-ponds

6. Wetland restoration and management can involve: technical, spatially large-scale measures (including the installation of ditches for rewetting or the cutback of dykes to enable flooding); technical small-scale measures such as clearing trees; changes in land-use and agricultural measures, such as adapting cultivation practices in wetland areas. They can improve the hydrological regime of degraded wetlands and generally enhance habitat quality. Creating artificial or constructed wetlands

in urban areas can also contribute to flood attenuation, water quality improvement and habitat and landscape enhancement (21).

Possible benefits with level:

Benefits	Level
PO10 - Protection of important habitats	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
PO13 - Better management of fish stocks	High
PO14 - Prevention of biodiversity loss	High
ES2 - Fish stocks and recruiting	High
ES4 - Biodiversity preservation	High
BP1 - Store runoff	High
BP2 - Slow runoff	High
BP12 - Create aquatic habitat	High
BP13 - Create riparian habitat	High
BP17 - Absorb and/or retain CO_2	High
PO1 - Improving status of biology quality elements	High
PO3 - Improving status of hydromorphology quality elements	Low
PO12 - More sustainable agriculture and forestry	Low
ES8 - Erosion/sediment control	Low
BP10 - Reduce erosion and/or sediment delivery	Low
BP11 - Improve soils	Low
BP14 - Create terrestrial habitats	Low
PO2 - Improving status of physico-chemical quality elements	Medium
PO5 - Improving quantitative status	Medium
PO7 - Prevent surface water status deterioration	Medium
PO8 - Prevent groundwater status deterioration	Medium
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Medium
ES1 - Water storage	Medium
ES3 - Natural biomass production	Medium
ES5 - Climate change adaptation and mitigation	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES7 - Flood risk reduction	Medium
ES9 - Filtration of pollutants	Medium
ES10 - Recreational opportunities	Medium
ES11 - Aesthetic/cultural value	Medium
BP3 - Store river water	Medium
BP4 - Slow river water	Medium
BP6 - Increase infiltration and/or groundwater recharge	Medium
BP7 - Increase soil water retention	Medium
BP9 - Intercept pollution pathways	Medium

Illustration ; wetland in a forest Source : http://nwrm.eu/measure/wetland-restoration-and-management

7.Re-meandering

Many rivers in northern and western Europe have been straightened and channelized to, for example, facilitate log floating and/or speed up the drainage of water and control/limit the river bed movements. Channelizing was also a way to gain land for cultivation. River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders, therefore slowing down the river flow. The new form of the river channel creates new flow conditions and very often also has a positive impact on sedimentation and biodiversity. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals (22).

Possible benefits with level:

Benefits	Level
PO1 - Improving status of biology quality elements	High
PO2 - Improving status of physico-chemical quality elements	High
PO3 - Improving status of hydromorphology quality elements	High
PO7 - Prevent surface water status deterioration	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	High
PO10 - Protection of important habitats	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
PO12 - More sustainable agriculture and forestry	High
PO13 - Better management of fish stocks	High
PO14 - Prevention of biodiversity loss	High
ES3 - Natural biomass production	High
ES4 - Biodiversity preservation	High
ES6 - Groundwater/aquifer recharge	High
ES7 - Flood risk reduction	High
ES8 - Erosion/sediment control	High
ES10 - Recreational opportunities	High
ES11 - Aesthetic/cultural value	High
BP4 - Slow river water	High
BP9 - Intercept pollution pathways	High
BP10 - Reduce erosion and/or sediment delivery	High
BP12 - Create aquatic habitat	High
BP13 - Create riparian habitat	High
BP17 - Absorb and/or retain CO_2	Low
BP5 - Increase evapotranspiration	Low
BP8 - Reduce pollutant sources	Low
PO4 - Improving chemical status and priority substances	Medium
PO5 - Improving quantitative status	Medium
PO6 - Improving chemical status	Medium
PO8 - Prevent groundwater status deterioration	Medium
ES2 - Fish stocks and recruiting	Medium
ES5 - Climate change adaptation and mitigation	Medium
ES9 - Filtration of pollutants	Medium
BP3 - Store river water	Medium
BP6 - Increase infiltration and/or groundwater recharge	Medium
BP7 - Increase soil water retention	Medium
BP14 - Create terrestrial habitats	Medium
BP16 - Reduce peak temperature	Medium
ES1 - Water storage	Medium
BP1 - Store runoff	Medium
BP2 - Slow runoff	Medium
BP11 - Improve soils	Medium

8.

Possible benefits with level:

Benefits	Level
ES13 - Geological resources	High
BP6 - Increase infiltration and/or groundwater recharge	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Low
ES5 - Climate change adaptation and mitigation	Low
ES7 - Flood risk reduction	Low
ES8 - Erosion/sediment control	Low
BP1 - Store runoff	Low
BP9 - Intercept pollution pathways	Low
BP10 - Reduce erosion and/or sediment delivery	Low
PO5 - Improving quantitative status	Medium
PO8 - Prevent groundwater status deterioration	Medium
ES1 - Water storage	Medium
ES6 - Groundwater/aquifer recharge	Medium
BP7 - Increase soil water retention	Medium
BP2 - Slow runoff	Medium

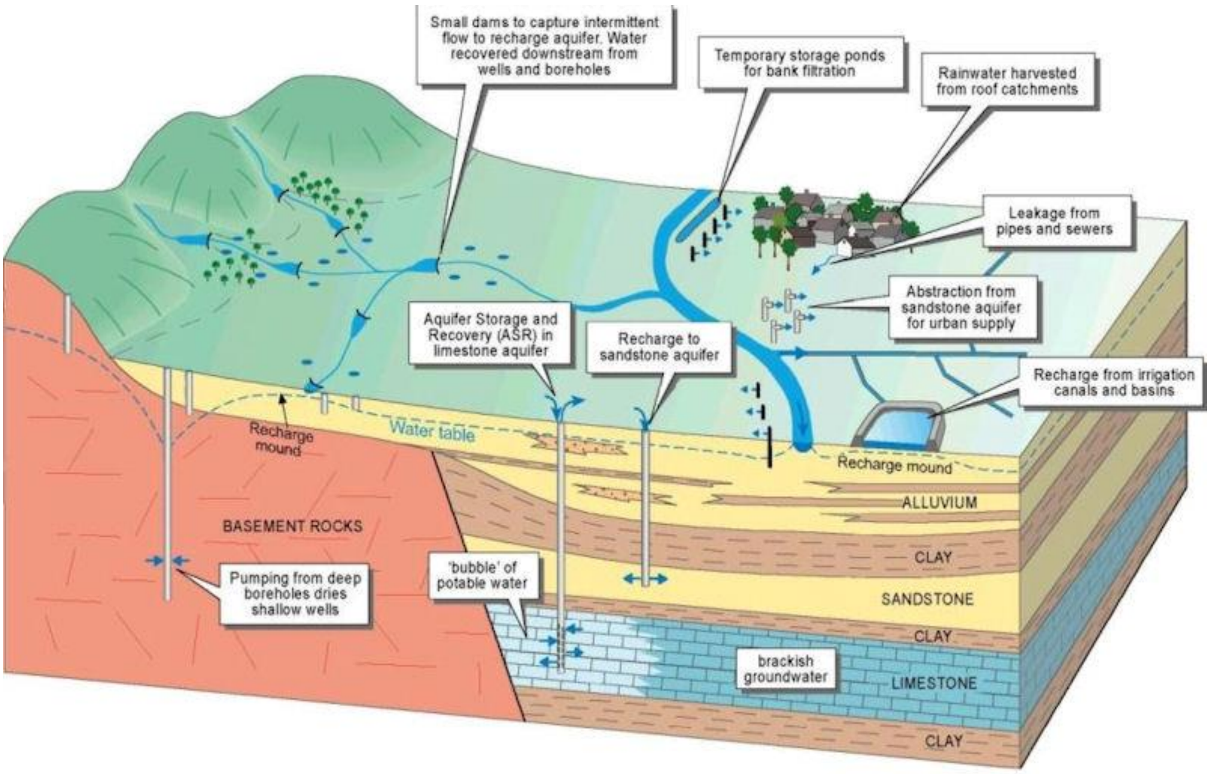


Illustration ; Explicative scheme of enhanced infiltration (UK) Source: http://www.bgs.ac.uk/research/groundwater/agrar.html

9. Intercropping and crop rotation:

Intercropping benefits;

Possible benefits with level:

Benefits	Level
BP6 - Increase infiltration and/or groundwater recharge	High
BP10 - Reduce erosion and/or sediment delivery	High
BP15 - Enhance precipitation	High
ES9 - Filtration of pollutants	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
BP2 - Slow runoff	High
BP7 - Increase soil water retention	Low
ES1 - Water storage	Low
ES5 - Climate change adaptation and mitigation	Low
BP11 - Improve soils	Medium
ES7 - Flood risk reduction	Medium
ES8 - Erosion/sediment control	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO12 - More sustainable agriculture and forestry	Medium
PO14 - Prevention of biodiversity loss	Medium
ES4 - Biodiversity preservation	Medium

Intercropped cereals with soybeans Source: Gábor Ungvári's presentation, NWRM Workshop 1

Crop rotation benefits;

Possible benefits with level:

Benefits	Level
BP9 - Intercept pollution pathways	High
BP11 - Improve soils	High
ES7 - Flood risk reduction	Low
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Low
ES8 - Erosion/sediment control	Low
BP10 - Reduce erosion and/or sediment delivery	Low
PO4 - Improving chemical status and priority substances	Low
ES4 - Biodiversity preservation	Low
BP2 - Slow runoff	Medium
BP6 - Increase infiltration and/or groundwater recharge	Medium
BP7 - Increase soil water retention	Medium
BP8 - Reduce pollutant sources	Medium
BP17 - Absorb and/or retain CO_2	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES11 - Aesthetic/cultural value	Medium
PO2 - Improving status of physico-chemical quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO11 - Better protection for ecosystems and more use of Green Infrastructure	Medium
PO12 - More sustainable agriculture and forestry	Medium
ES9 - Filtration of pollutants	Medium

10.Meadow

Possible benefits with level:

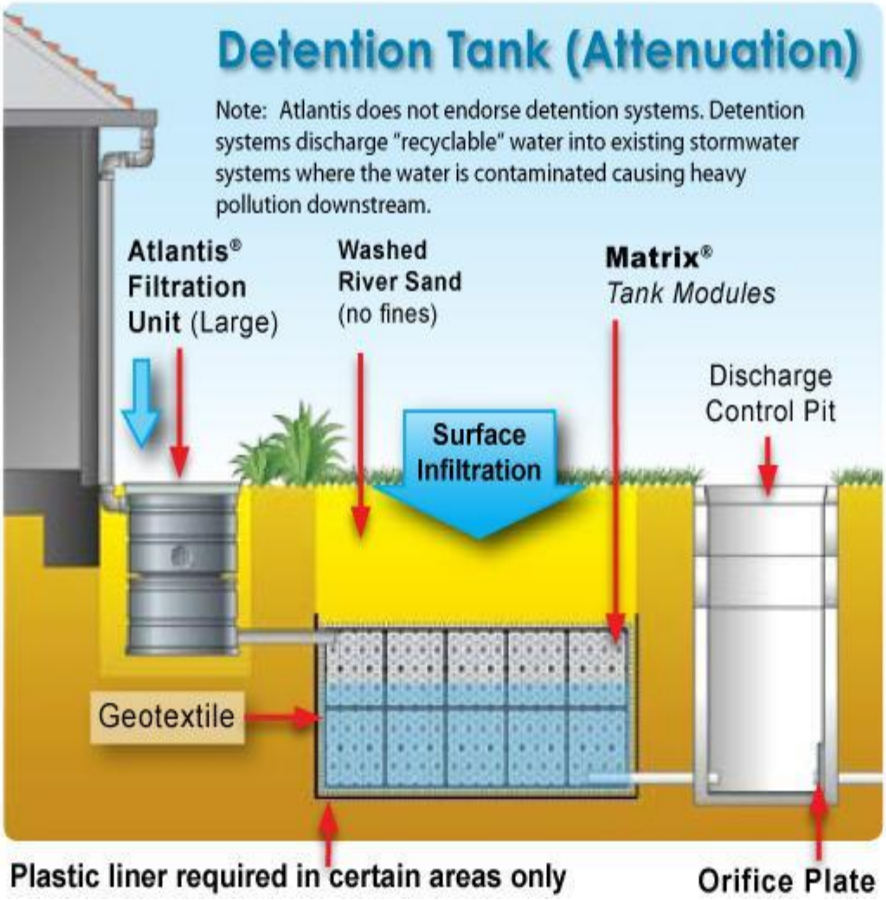
Benefits	Level
BP2 - Slow runoff	High
BP10 - Reduce erosion and/or sediment delivery	High
ES7 - Flood risk reduction	High
ES8 - Erosion/sediment control	High
PO9 - Take adequate and co-ordinated measures to reduce flood risks	High
PO11 - Better protection for ecosystems and more use of Green Infrastructure	High
BP6 - Increase infiltration and/or groundwater recharge	Low
BP11 - Improve soils	Low
PO5 - Improving quantitative status	Low
PO8 - Prevent groundwater status deterioration	Low
BP5 - Increase evapotranspiration	Medium
BP7 - Increase soil water retention	Medium
BP17 - Absorb and/or retain CO_2	Medium
ES5 - Climate change adaptation and mitigation	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES9 - Filtration of pollutants	Medium
PO3 - Improving status of hydromorphology quality elements	Medium
PO7 - Prevent surface water status deterioration	Medium
PO12 - More sustainable agriculture and forestry	Medium
PO14 - Prevention of biodiversity loss	Medium

11. Mulch

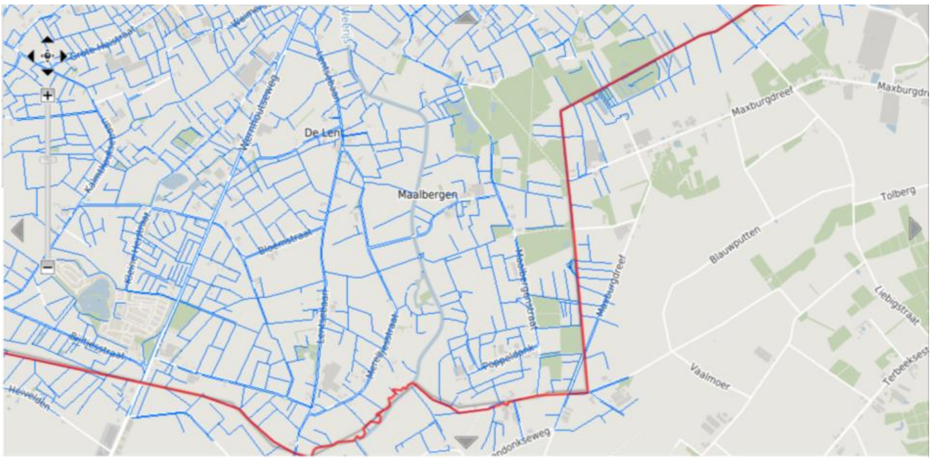
Possible benefits with level:

Benefits	Level
BP2 - Slow runoff	High
BP6 - Increase infiltration and/or groundwater recharge	Low
PO5 - Improving quantitative status	Low
PO8 - Prevent groundwater status deterioration	Low
BP7 - Increase soil water retention	Medium
ES6 - Groundwater/aquifer recharge	Medium
ES7 - Flood risk reduction	Medium
PO9 - Take adequate and co-ordinated measures to reduce flood risks	Medium
BP10 - Reduce erosion and/or sediment delivery	Medium

Detention Tank:

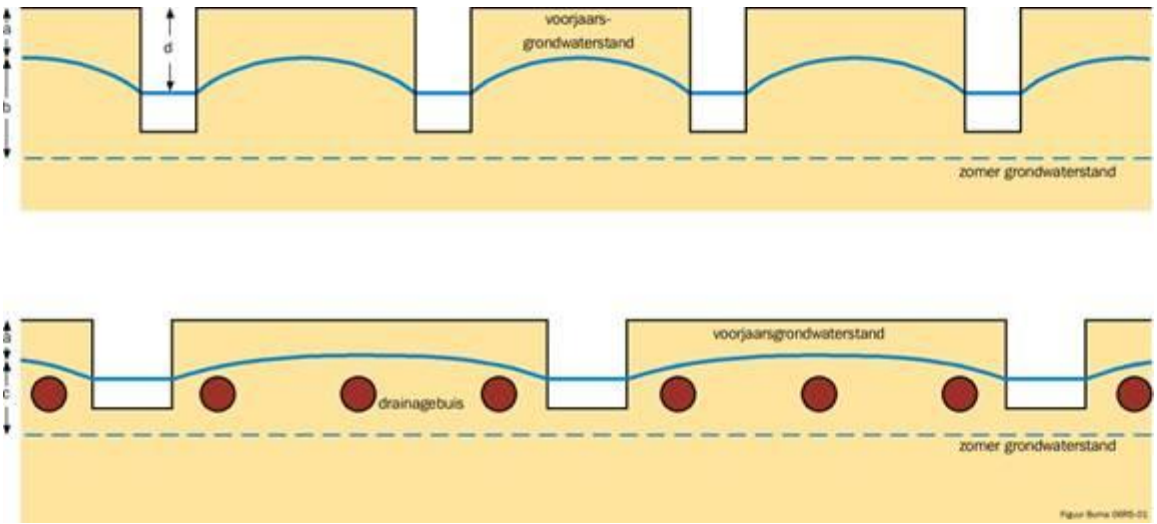

Detention Tank (Attenuation)
Note: Atlantis does not endorse detention systems. Detention systems discharge "recyclable" water into existing stormwater systems where the water is contaminated causing heavy pollution downstream.
Atlantis® Filtration Unit (Large)
Washed River Sand (no fines)
Matrix® Tank Modules
Discharge Control Pit
Surface Infiltration
Geotextile
Plastic liner required in certain areas only
Orifice Plate

Annex-4: Information about the location of the ditches and locks



This map shows the location of the ditches and locks. Locks and ditches are called the 'capillaries of the water system'. Together, all these ditches and ditches determine an important part of the drying out in Brabant, and they cause flooding due to high peak discharges. The map shows how much has been dug in recent centuries to get dry feet and crops. Conversely, the map can serve as an entry point for the recovery of water systems.

The map of ditches and locks shows in which areas water conservation is promising. This concerns measures such as deepening and widening ditches, often in combination with deepening of pipe drainage (see figure below) and raising the level with weirs. The drain function is thus retained while reducing the unnecessary drainage of groundwater.

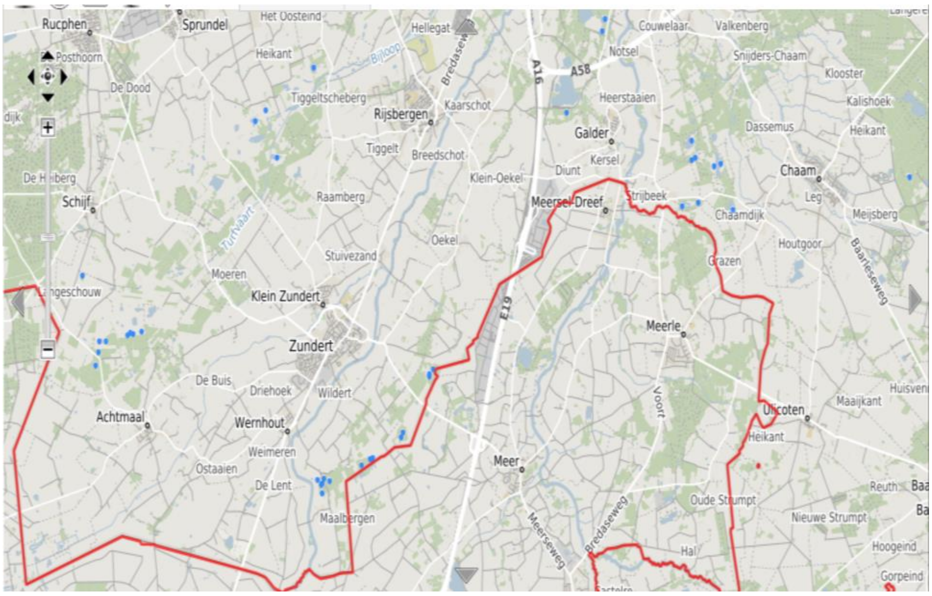


Water conservation: Locks are widened and deepened and the drainage system is deepened. As a result, the groundwater level drops less deep in the summer (distance c is smaller than b). The spring groundwater level (a) remains the same.

The areas with the most ditches lie in the Roerdalslenk around Boxtel, in the western Langstraat near Waspik and Waalwijk, and in West Brabant on the transition from the sandy area to the polder area (The Seam of Brabant). The wetness in these areas was, or still is, caused by a combination of poorly permeable, shallow soil layers and incoming seepage water.

Human intervention has changed the entire water system greatly in the last hundred years. These changes are reflected in the map with historic ditch patterns .

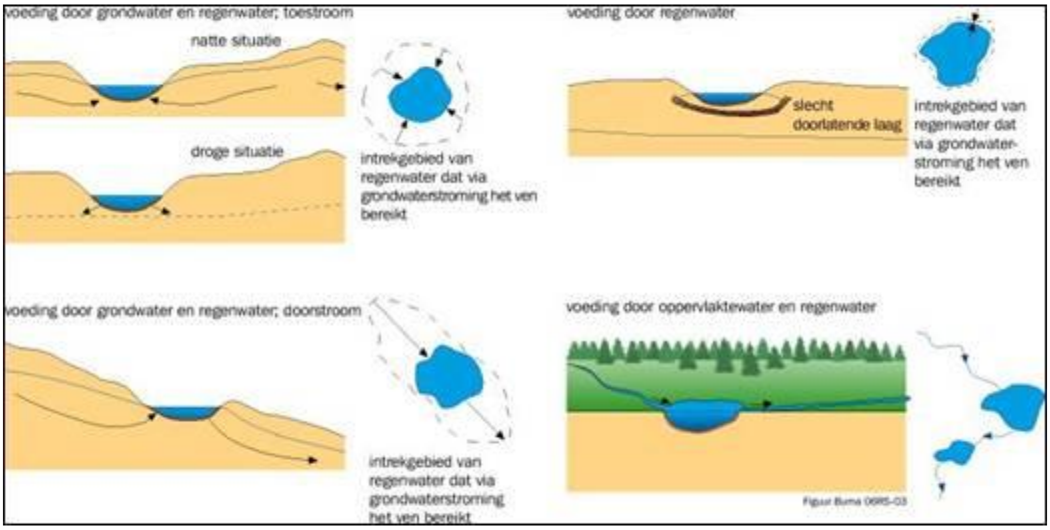
Annex-5: Information about the watercourses of the area



In total there are around 600 fens in Brabant; in the past there were many more, an estimated 2000. Of those 600 fens, around 280 have the function of nature in provincial water policy. These are indicated on the map. With the function water nature, we indicate that we as a province consider it important that these ponds are in good ecological and hydrological order. The fens are home to many rare plant and animal species. Brabant therefore has a major responsibility for maintaining the biodiversity of these fens.

Annex-6:Information about rainwater collection

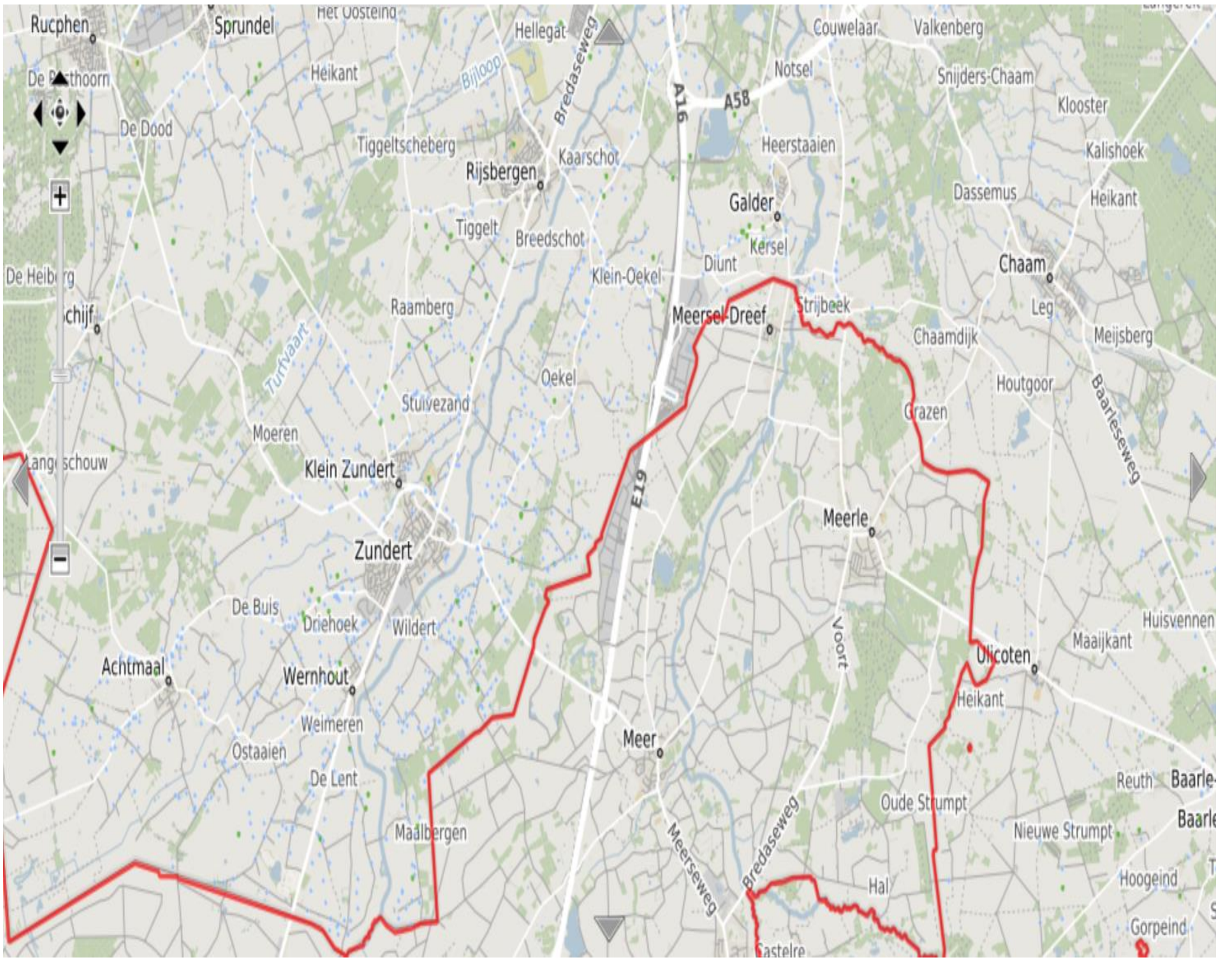
Fens are fed by rainwater, but can also be fed by groundwater or surface water (see figure below). The fens that are only fed by rainwater occur on water divisions or on shallow, poorly permeable layers that isolate the groundwater system. The rainwater determines the water quality, so that this type of fens is always unbuffered (acid). If the water level does not fluctuate too much, peat formation can occur. Fens fed by groundwater or surface water are usually buffered; the degree of buffering depends on the composition of the nourishing ground or surface water. With this type of fens, a distinction can be made between inflow and flow fens.



Different types of fens

Many fens have been filled up or drained over time. The number of fens in Brabant has therefore fallen sharply. Drained fens can still be recognized on the map or in the terrain by their round shape. Due to their low location, it was usually necessary to dehydrate them intensively for use as agricultural land. This is disadvantageous for both nearby wet nature and for peak discharges in wet periods.

Annex-7: Information about groundwater measurement of the area, groundwater abstraction and irrigation map



Groundwater abstractions- irrigation map

The presence of a (large) groundwater extraction is an important factor in spatial planning. In the withdrawal area of the groundwater abstraction, the groundwater must be clean; this can sometimes conflict with land use. The presence of a withdrawal can also influences the opportunities for nature restoration or development. Finally, the presence of a groundwater extraction must be included in urban development; it is possible that the groundwater level has now been lowered as a result of the abstraction, but that the groundwater level will rise in the future upon closure.

The map shows the distribution and the size of the groundwater abstractions. The total annual amount withdrawn is approximately 400 million m3. An estimated 25% of this is due to irrigation for agriculture.

With regard to the spread of larger withdrawals, a few patterns stand out. There are hardly any extraction sites in the northwest because the groundwater here is often brackish to salt. In the east too, there are few catches, because there is only shallow fresh groundwater that is often strongly influenced by eutrophication. Concentrations of extraction are visible around the larger cities, Eindhoven, Den Bosch, Tilburg and Breda. There are also many withdrawals on the Brabantse wal. Here water is extracted for the water supply of a large part of the province of Zeeland.

Groundwater is extracted from various aquifers. The smaller groundwater abstractions, up to and including one million m3 / year, mainly extract from the first aquifers. The larger withdrawals (also) extract from the deeper aquifers. In addition to the groundwater abstractions in the province of Noord-Brabant, the map also shows extraction in Limburg and Flanders.

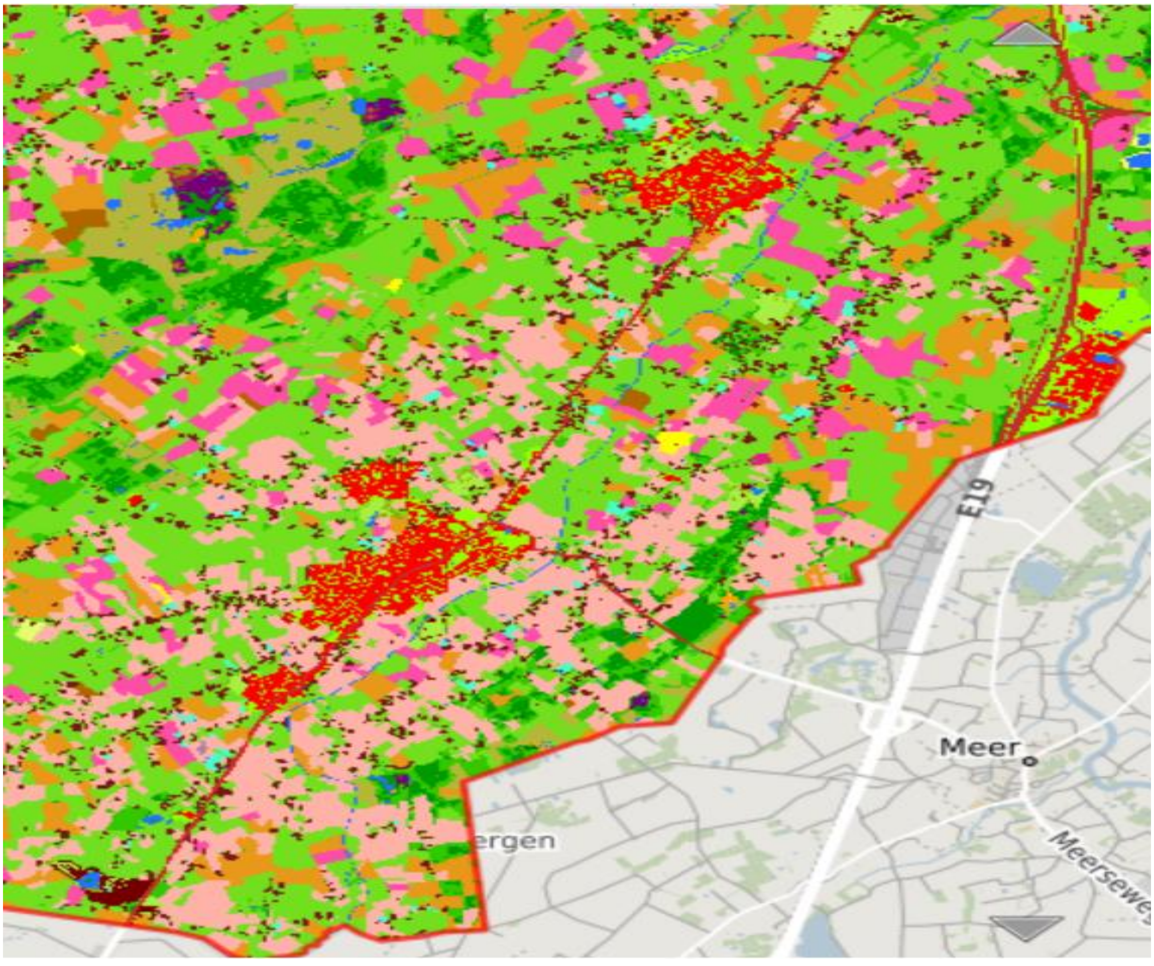
Groundwater protection areas have been established around all pumping stations for drinking water supply. Homes, roads and businesses are permitted within these areas, but legal rules apply to prevent groundwater pollution (see groundwater protection areas map).

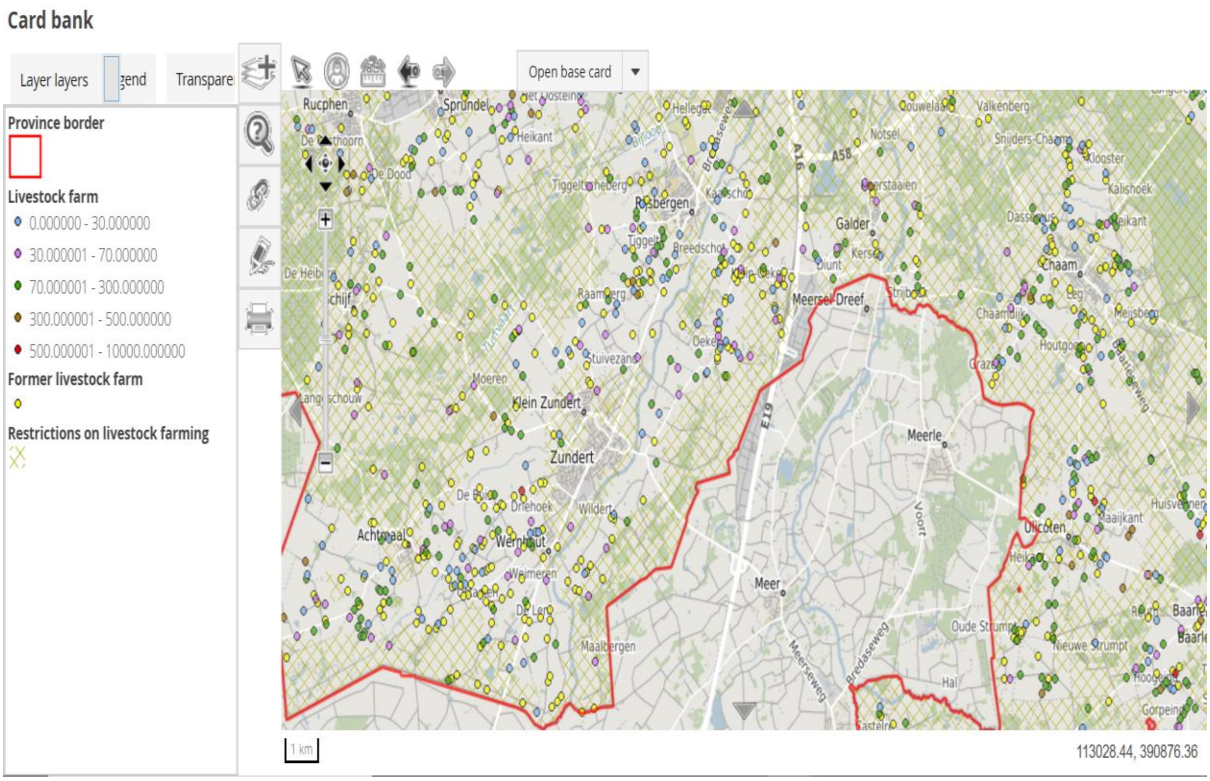
Annex-8: Land use information about the area

Land use

This map shows the land use according to the Alterra Landelijk Land Usesbland (LGN6). Land use has a major influence on the water system. Land use influences the water system both quantitatively and qualitatively. With regard to quantitative influence, consideration can be given to the influence of land use on the size of the precipitation surplus, on the feeding of the (deeper) aquifers, on the dewatering requirements required for certain crops and on the drainage dynamics. In urban areas, a relatively large proportion will drain quickly in the event of intensive rainfall. This also applies to areas where there is a dense drainage system due to land use. In a qualitative sense, each type of land use has a specific load,

The map shows a large difference in plot size between the sandy area and the river area with the sea clay area. Much larger plots are found in the sea clay area. It must be borne in mind that in the sea clay area, alternating culture takes place with potatoes, beets and grains. Land use on the sandy area is dominated by grassland and maize with a coverage ratio (for the entire province) of 27% and 10% respectively. In current business operations, grass plots are often converted to maize or vice versa. The two most important other large land use units are buildings (9%) and coniferous forest (6.5%).





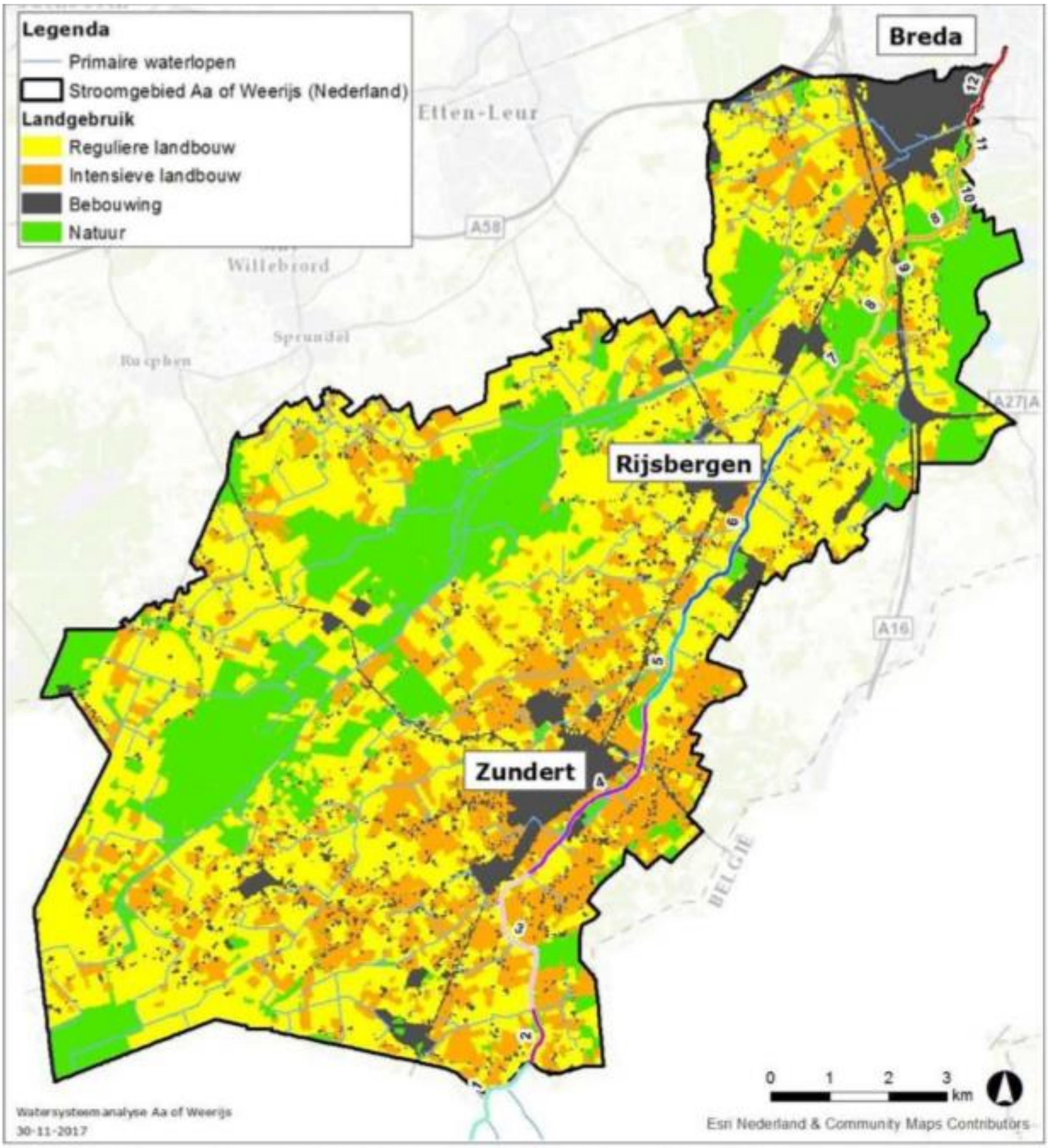
The ecological value of streams is determined by, among other things, the land use within a river basin. In general, the more nature, the lower the human influence (“pressure") and the greater the chance of high EKRs. Conversely, with a large area of (intensive) agriculture, it is to be expected that a brook will be more heavily loaded with nutrients, pesticides and rinsing sludge and will therefore have lower EKRs. That is why land use within the catchment area has been determined within the Aa or Weerijs water system analysis.

In addition, the area of pipe drainage can influence the EKRs. With an intensively drained basin, the basic drainage will be lower, and the peak drainage will be higher. As a result, the flow velocity in the stream will be on average lower in the summer, which will have a negative effect on flow-loving species and the flow velocity will be higher in the winter, which can cause drift (washing away) of (juvenile) fish and macrofauna. That is why the area (pipe) drainage within the Dutch part of the catchment area of the Aa or Weerijs has also been determined.

Method The LGN5 file (from 2003) is combined with the cadastral property of the water board, Staatsbosbeheer, Natuurmonumenten, Brabants Landschap, the province of Noord-Brabant (incl. Former BBL lands) and some nature parcels of the municipalities of Zundert and Breda. These plots can be expected to be managed as a nature reserve. The different categories are then subdivided into "nature", "agriculture", "intensive agriculture" and "buildings". A disadvantage of this method is that any grassland in private nature management is counted as agricultural land. However, this area is expected to be limited. Another disadvantage is that land use in the Belgian part of the river basin is not determined.

In addition, a file with pipe drainage (Massop and Schuiling, 2015 / reference date 2012) was used to determine the area of agricultural plots with pipe drainage. A distinction has been made between traditional pipe drainage and level-controlled pipe drainage.

Results the Dutch part of the catchment area of the Aa or Weerijs is approximately 14,700 ha. This part of the river basin consists of 23% from nature, 65% from agriculture (of which 45% regular agriculture and 20% intensive agriculture, mainly tree cultivation) and 12% from buildings (see figure 1).



Land use within the Dutch part of the catchment area of the Aa or Weerijs.

Approximately 2,400 ha of drained agricultural land is found in the Dutch part of the catchment area of the Aa or Weerijs. This means that 16% of the catchment area is provided with pipe drainage, or

25% of the agricultural land. Of the drained agricultural lands, 5% is equipped with level-controlled drainage.

By comparing the above numbers with land use in other river basins, the distribution of land use can be better explained (see Table 1). In comparison with the catchment areas of the Chaamse Beken and 't Merkske, the catchment area of the Aa or Weerijs consists of relatively much agriculture and relatively little nature.

Land use	River basin Aa or Weerijs	Chaamse Beken river basin	The Merkske river basin
Nature	20%	47%	38%
Agriculture	65%	42%	52%
Grassland	47%	62%	38%
Building	12%	11%	10%

Fraction calculations of the drain

Fraction calculations: A fraction calculation was performed to gain insight into the composition of the different drains of the Aa or Weerijs. With a fraction calculation, the distribution of water from different sources can be analyzed at every time step of the calculation and at every location of the model.

Drainage situations: Drainage is measured at several locations in the Aa or Weerijs, from upstream to downstream at weir Wielhoef (1982 to the present) and at Oranjeboombrug (also 1982 to the present). The discharge from the Flemish part of the catchment area of the Aa can be determined at weir Wielhoef. The measured discharges have been analyzed to gain insight into the frequently occurring discharge situations. A number of the characteristic discharges from the Oranjeboombrug are presented below, see table (x.1).

repeat time	drain m3 / s	95% reliability interval of the drain (m3 / s)	theoretical% of normative discharge (T1)	calculated% of normative discharge (T1)
T25 (once every 25 years)	45	40-50		
T10 (once every 10 years)	40	35-45		
T1 (once a year)	23	20-27	100	100
half normative discharge (2-3 weeks / year)	10		50	43
spring drain (3 months / year)	3		20	13
Median (average) drain	2		10	9
Driest month drain	0.6		~2	2
Driest week drain	0.3		~1	1

A few characteristic discharges as measured at Oranjeboombrug

To gain insight into the distribution of water in different seasons and drainage situations, the fraction calculation was calculated for a spring drainage, a median (average) drainage and a driest month drain. For this, the normative drain (specific drain (l / s / ha) * area) has been scaled to 13, 9 and 2% respectively.

The sources per drainage unit (10-50 ha) are determined on the basis of the LGN5 (LandGebruik Nederland). Per drainage unit, the largest percentage of land use present is allocated to the drainage unit.

Hydrology

In the water system analysis of the Aa or Weerijs it is investigated whether WFD objectives are being achieved and if not, why not. A few explanatory factors for the ecological functioning of a stream are the flow velocity, water depth and water level width. These can be made transparent with a Sobek model. That is why the Sobek model of the "Toetsing flooding test" (Witteveen + Bos, 2014) is made suitable for modeling some frequently occurring drainage situations. This memo describes the model construction and elaborates model outcomes.

Share of the discharge from Belgium In addition to the Oranjeboombrug discharge measurement point, the discharge is also measured at the Wielhoef weir. The discharge over the Wielhoef weir is almost entirely from Belgium. By comparing the measured discharge at Wielhoef with the discharge at Oranjeboombrug, the share of Belgian discharge from the Aa or Weerijs can therefore be determined. Figure 1 shows that on average around 40-5007o of the discharge at Oranjeboombrug comes from Belgium. During dry periods, however, relatively more water comes from Belgium, probably because a lot of water is extracted from the Aa or Weerijs for irrigation. During 1-20 of the measured days the discharge from Belgium is even greater than the discharge measured at Oranjeboombrug (see figure 1: share ^ 000 / b). The number of irrigation withdrawals from surface water is unknown, partly because withdrawals smaller than 100 mVuur do not require a permit.