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Adaptation Pathways

Development of adaptation pathways for the rural area of municipality Weert

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Author:

Louis Broersma, Renée Swinkels and Joshua van Blaaderen

E-mail address:

Louis.broersma@sweco.nl

Verified by:

Nikéh Booister

Released by:

Tjeerd Dijkstra

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SWECO

Adaptation pathways for the rural area of municipality Weert

SWECO

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1 Introduction

1.1 Motivation and project purpose

The municipality of Weert wants to make the rural area sustainable and future-proof. In view of climate change and the associated uncertainties, the current land use and layout seems to be reaching its limits. This uncertainty is reason to create an adaptation pathway map to shape the strategy for the coming years. This is why the municipality wants to discuss possible measures on the layout of the area together with stakeholders in the rural area. Choices and changes in the layout of the area require stakeholders to adapt.

To explore this together, an adaptation strategy is a solution. Adaptation pathways visualise possible future images of the rural area. Bottlenecks caused by climate change lead to other choices and thus other possible futures. With adaptation pathways, changes can be made negotiable.

From the dialogue, the set of measures can then be established as a joint choice for land use in the rural area of the municipality of Weert. When determining the land use, it is important to have clarity on how long forms of land use are sustainable in relation to (climate) uncertainties and what the lifespan of measures is. These two factors provide insight into optional no-regret choices for land use for the development of the rural area.

Weert's rural area is vulnerable to the effects of climate change due to its location on high sandy soils and the presence of stream valleys. Besides built-up areas, current land use consists largely of nature and agriculture. Nature in the rural areas of Weert consists partly of N2000 areas and areas belonging to the Nature Network Netherlands (NNN) including Natte Natuurparels. Agriculture consists largely of arable farming and (poultry) livestock farming (Municipality of Weert, 2020). Based on the results of the *Limburg Integrated Water System Analysis* (LIWA) (Water Board Limburg, 2022), bottlenecks in the area arising from the effects of climate change have been identified. Increases in temperature, weather extremes and changes in precipitation have effects on agriculture and nature. For instance, lower groundwater levels cause large-scale damage to nature and agriculture and the disappearance of habitats and healthy farm management. More fluctuations in water levels, both dry and wet situations, also cause damage to crops. Extreme weather, in the form of extreme precipitation, causes damage to crops. Intensive land use contributes to emissions in the form of nutrients and crop pesticides. There is also contamination from industry or from areas outside the municipality of Weert (metals). This makes it uncertain whether the WFD targets can be met in 2027. Finally, many different land uses are close together, making it difficult to realise the optimal situation per land use. At borders and transitions of different land uses, conditions are suboptimal for at least one of the land uses.

The purpose of this study is twofold:

- Outlining steps towards a climate-robust design for the rural area of the municipality of Weert. This perspective is a response to the consequences of climate change for the area and responds to the uncertainties of the degree and speed of climate change by incorporating adaptivity. As such, it provides a means to jointly enter into dialogue with stakeholders in the area and further explore the routes.
- To apply the methodology of drawing up adaptation pathways for the High Sandy soils and to examine whether this method is more widely applicable for this part of the Netherlands. As part of Interreg V, a grant has been applied for this by the municipality of Weert and the Limburg Water Board.

1.2 Scope

This study covers the rural area of the municipality of Weert. This includes the area around the stream valleys of the Tungelroyse brook, Leukerbrook, Dijkerpeel and Raam and the surrounding natural and agricultural areas (see Figure 1).

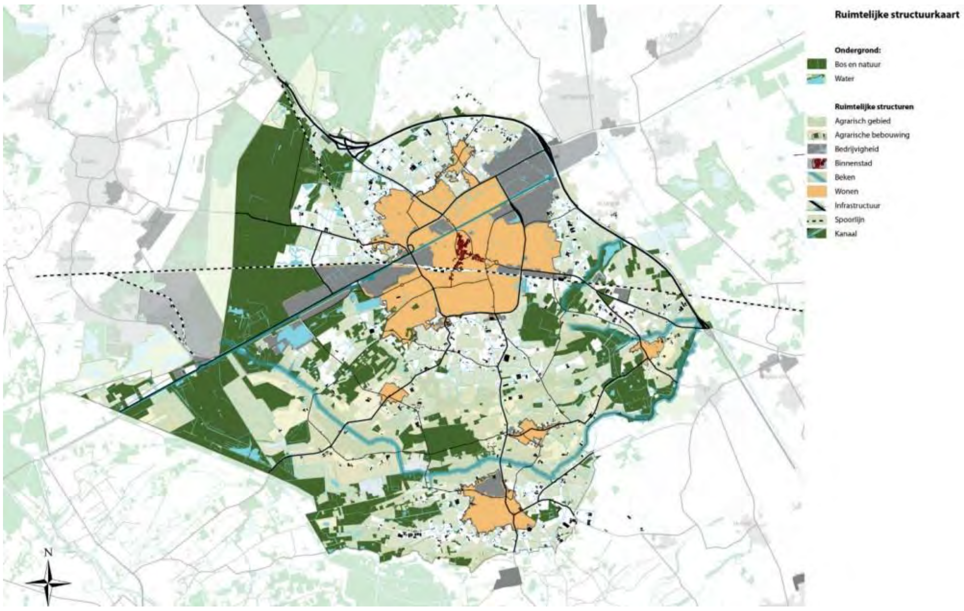

Figure 1: Municipality of Weert, focus on the rural area outside the cores of Weert and Stramproy (Municipality of Weert, 2021)

1.3 Method

The method can be divided into five steps:

- **Step 1 Inventory**: Based on a kick-off meeting with area experts from different sectors, the ambition for the rural area of Weert was formulated. Then, bottlenecks and possible measures were identified by means of a literature study, analysis of existing data (such as LIWA) and additional interviews with area experts.
- **Step 2 Validation bottlenecks and measures**: During a working session, drafted bottlenecks and measures were validated in cooperation with (area) experts and specialists.
- **Step 3 Formulating draft adaptation pathway map:** As a follow-up step, bottlenecks and measures were further elaborated. For this purpose, bottlenecks and measures were timed, arranged by sector (water, agriculture, nature, and urban area) and a timeline was created. In a second working session, a draft version of an adaptation pathway was compiled and validated.
- **Step 4 Final adaptation pathways map and preferred strategies:** The comments from the working session at step 3 were then incorporated into an adaptation pathway map and preferred strategies were drafted. In the third and final working session, the final adaptation pathway map was discussed and a preferred strategy for the area was determined.
- **Step 5 Report:** The present report comprises the results of the study and describes the drafted adaptation pathways map and associated preferred strategy.

1.4 Reading guide

- Chapter 1 describes the problem definition and project purpose, scope and methodology used in this study.
- Chapter 2 describes the area characteristics, the jointly formulated ambition and the effects of climate change on the rural area of Weert.
- In Chapter 3, the effects were translated into the bottlenecks that occur in the area in short-, medium- and long-term. These bottlenecks form the basis of the final adaptation pathways.
- Chapter 4 links these bottlenecks to possible measures, aiming to realise the vision and ambition set in chapter 1. Furthermore, this chapter explains the adaptation pathways map.
- Finally, Chapter 5 reflected on the process and provided recommendations for follow-up steps based on the results.

2 Area analysis

2.1 Area description

The municipality of Weert has about 50,000 inhabitants and consists of the cores of Weert, Stramproy, Laar, Altweerterheide, Tungelroy and Swartbroek. Besides built-up areas with housing and industry, the main land uses are nature and agriculture (see Figure 2).

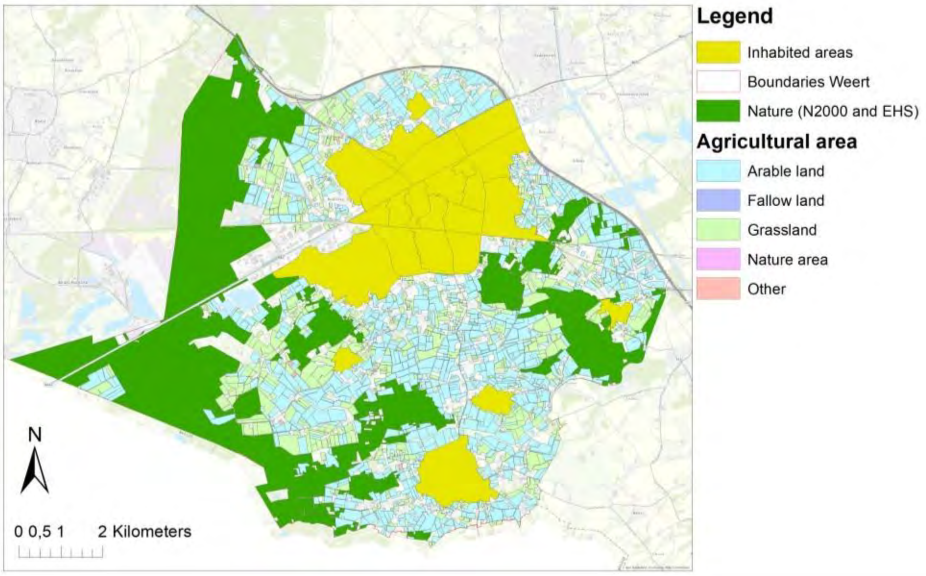

Figure 2: Land use in the municipality of Weert

<u>Agriculture</u>

Arable and (poultry) livestock farming is found in the rural area. Farms are distributed across the rural areas of Weert (see Figure 3). A trend of decreasing number of farms is visible. In 2000, there were about 300 farms in the area, in 2019 this number had decreased to 150 farms. Vacancy of agricultural property is visible in the region as a result. There is currently 25,000 m² of vacant agricultural property. This is forecast to increase by 500% by 2030 (Municipality of Weert, 2020). However, the acreage of agricultural land is not decreasing, the scale of each farm is increasing.

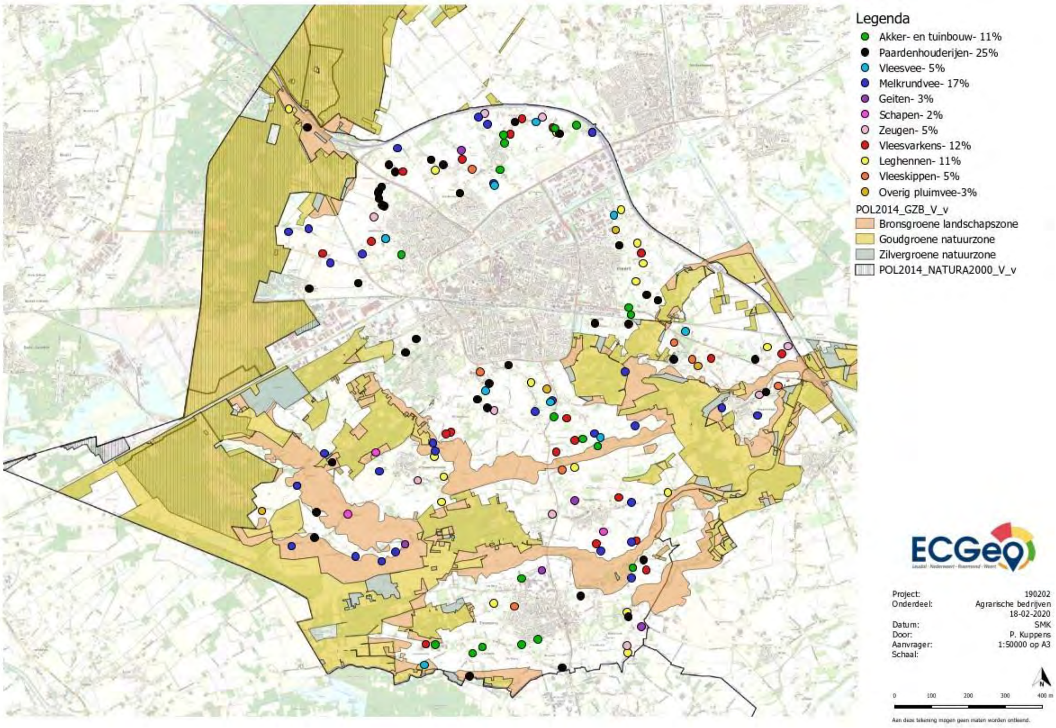

Figure 3: Distribution and type of agriculture (points on map) in municipality Weert (Weert municipality, 2020)

Nature

The rural area of the municipality of Weert partly consists of N2000 areas. The other part of the nature areas is part of Natuur Netwerk Nederland (NNN). These NNN areas are still indicated in Figure 4 with the old name "Ecologische Hoofdstructuur" (EHS). The diversity of nature types is great in the rural areas of Weert. This ranges from dry forests and heathland to wet nature, such as peat and swamp (Figure 4).

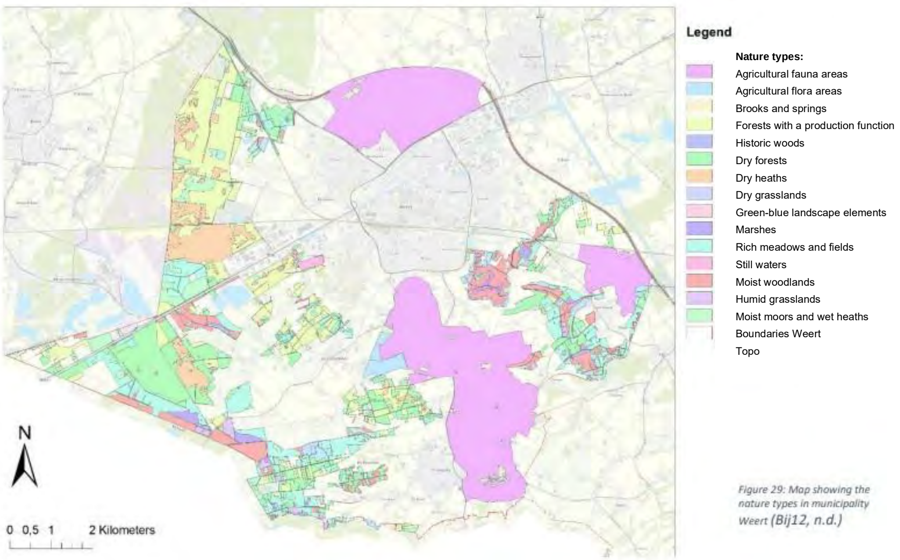

Figure 4: Nature types in Weert municipality (source Bij12.nl)

Soil and water system

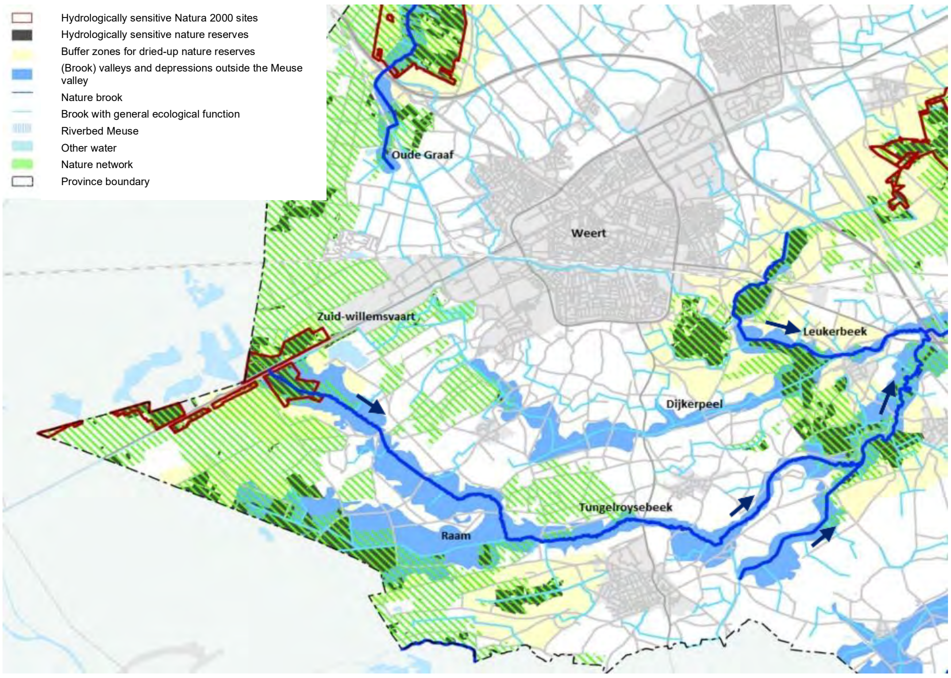

Figure 5: Natural areas and water system Municipality of Weert, (Province of Limburg, 2020)

The main water system consists of several brooks and stream valleys, and the South-Willemsvaart, which cuts through natural systems (see Figure 5). The main water system is the Tungelroyse brook with a total length of 26 km. The Tungelroyse brook drains water from Hamont in Belgium to the Meuse near Hanssum. The Tungelroyse brook has an important function in the water management of northern and central Limburg. The stream has a function in supplying water for agricultural use and discharging rainwater. In addition, the stream and the adjacent stream valley have an important ecological function. Until the year 2000, the Tungelroyse brook lost 20% of its length due to diversion of the natural brook course. Between the year 2000-2012, part (2%) of the old course was restored by rewetting the stream. The Tungelroyse brook is fed from the Hamonterbrook and Ringselven, and in summer from the Nystar. Besides the Tungelroyse brook, the Raam is an important tributary that flows into the Tungelroyse brook. The Raam drains water from the low-lying nature reserve Kettingdijk-Wijffelterbroek and from Belgium. This area is currently being reclaimed so that it can act as a water buffer.

The area has a strong gradient, and the presence of the stream valleys is well reflected in the level of groundwater levels in the area (see figures 6 and 7). The brook valleys are easily recognisable as relatively wet zones with a mean highest groundwater level (GHG) to near ground level and a mean lowest groundwater level (GLG) to a few dozen of centimeters below ground level. At the higher parts of the area, the groundwater levels are much deeper, up to several meters below ground level.

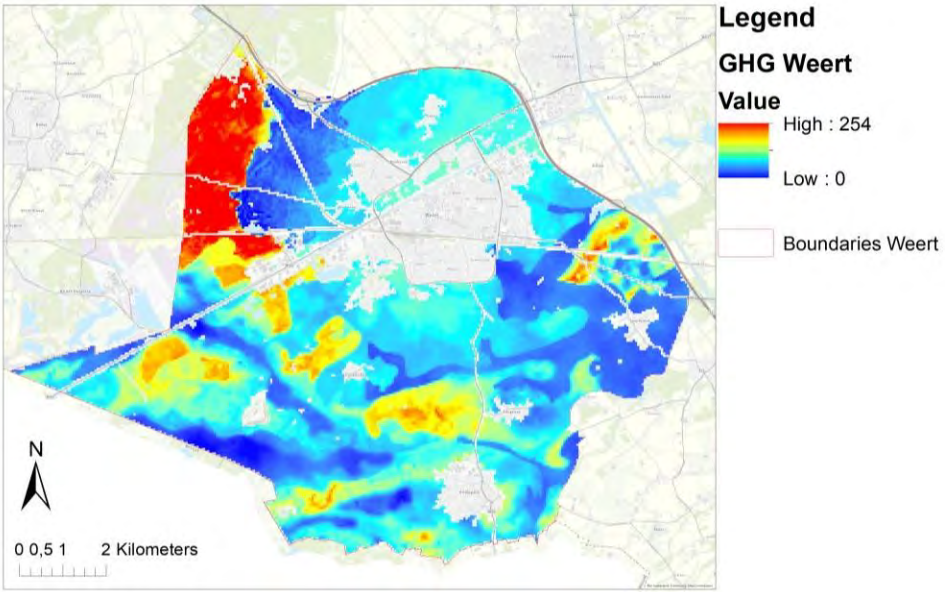

Figure 6: Average highest groundwater level (GHG) in cm above ground level (source: LIWA)

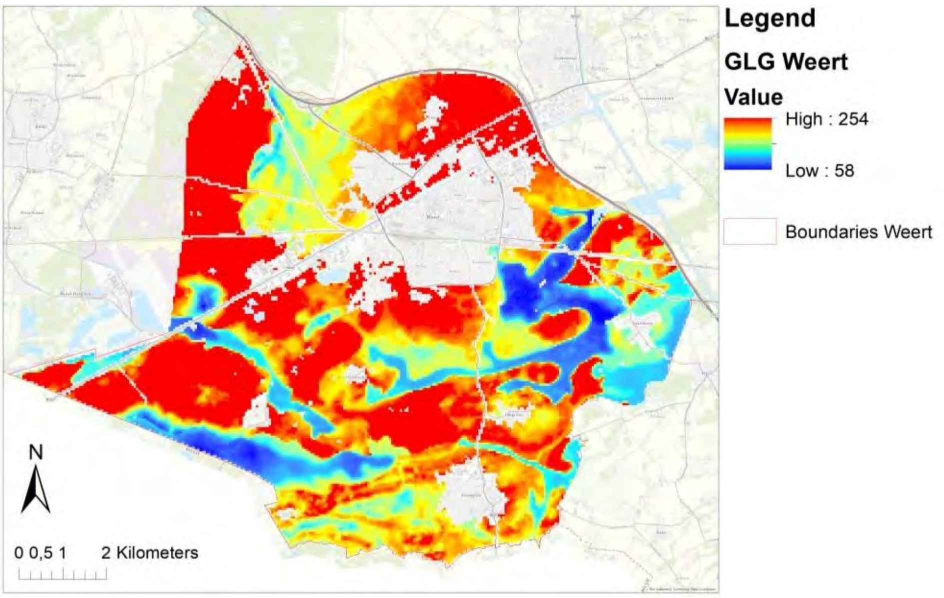

Figure 7: Average lowest groundwater level (GLG) in cm relative to ground level (source: LIWA)

The municipality of Weert is located on the High Sandy soils and increasingly faces drought problems. This is caused by abstractions, water runoff, limited water retention capacity of the soil and an increasingly amount of dry periods.

The soil of the municipality of Weert consists of different soil types (Figure 8). Besides sandy, loamy, eary, marshy, and podzolic soils, there are also some peat soils in the rural areas of Weert, most of which are located in nature reserves and have an important ecological value. Peatlands are vulnerable to climate change and declining groundwater levels.

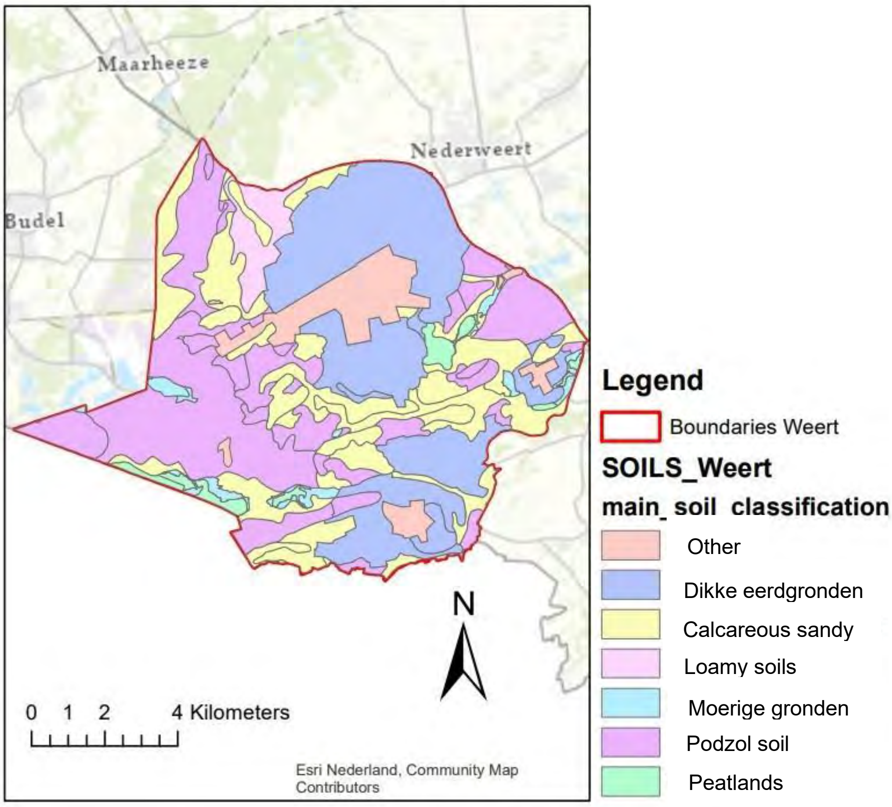

Figure 8: Soil types of municipality Weert (source: PDOK, soil map of the Netherlands)

2.2 Field visit observations

During the field visit on 25 March 2022, a number of locations in the rural areas of Weert were visited where bottlenecks and solutions are tangible and experienceable. These examples provide a good cross-section of what is happening on a broader scale and what interventions are needed and possible.

Site 1: Relocation of The Window

Figure 9: Field visit at the Raam

- The Raam and surrounding nature: At the site visited, the Raam is being diverted, at a greater distance from nature and higher grounds and located against existing agricultural land. The aim of this is to reduce desiccation of nature and to create more opportunities for humidity to ground level around the Raam. Further, the diversion of the Raam ensures that nutrient-rich water no longer flows through the nature area.
- This plan creates tension between stakes from nature and agriculture. The effect of raising the water level affects the neighbouring land of the farmer. Moreover, this farmer suffers from poisonous weeds (Jacob's weed) that mostly originate from the nature areas. This example shows that sectoral solutions do not work out well for all stakeholders in the area. Management must also be properly included so that a workable situation is created for all stakeholders.

Site 2: Tungelroyse brook

Figure 10: Stream restoration Tungelroyse brook

- At this location, the Tungelroyse brook was modified about 15 years ago. A more natural design has been achieved by stream restoration. This is limited because there is not enough space everywhere. There is still a residual task here for more natural design in banks, profiling of the brook and water level management (drought and flooding). This requires adjustments from the adjacent farmers.
- Currently, water retention capacity is relatively limited. Despite all efforts, a wave of runoff has been drained from the system in 1-2 weeks, according to stakeholders from the Weert municipality.
- To make real strides for the various tasks, this requires less intensive use of land along the stream and more integrated approaches with all stakeholders. The space for solution is now too limited.

Site 3: Tungelroyse brook near municipal boundary

Figure 11: Field visit at the Tungelroyse brook stream

- The site has limited space due to the presence of a greenhouse complex immediately adjacent to the stream. This is partly the result of municipal policies that allow for greenhouse complexes in one municipality but not in the municipality of Weert.
- Due to limitation in space on the south side, and high land prices on the north side, the stream cannot be developed in the desired form and tasks for WFD, drought and flooding cannot be realised.
- The desirable scenario at the site is to divert the stream and realise natural banks, stream restoration and more vegetation along the stream with more nature adjacent to the stream and the greenhouse complex at a greater distance from the stream.

Site 4: Dijkerpeellossing and Roukespeel (the Krang)

Figure 12: Dijkerpeellossing and Roukespeel

- At this location the "Natte Natuurparel" (A wet nature reserve where plants and animals live that require sufficient high-quality groundwater) "the Krang" is present, for which Natuurmonumenten has drawn up a plan to further restore the former system of a flow-through marsh by connecting Oude Leukerbrook to the Roukespeelven. At the edges of the stream valley, efforts are being made to strengthen the small-scale cultivated landscape by converting some parcels into wet hay meadows while preserving pools[1].
- The process was designed with nature in mind and as a result of insufficient involvement of surrounding parties, such as farmers, the plan was delayed. Interests such as loss of income were not sufficiently taken into account in the plans.
- An integrated approach and process is needed here. Whereby the challenges and interests from nature, agriculture, climate adaptation and (possibly) nitrogen are simultaneously included in the approach. As a result, smart combinations can be made to tackle tasks together. A zoning approach around the Natte Natuurparel or a more integral approach, in which solutions to the problem of waterlogging and adjacent interests are more interwoven.

[1] Restoration of wet nature Roukespeel (de Krang) | Natuurmonumenten

Location 5: Transition zone city-rural area Weert

Figure 13 Transition zone urban fringe-rural areas

- The ring road south of Weert forms a firm barrier between the city and the rural area. It is difficult for residents of the city to make use of the rural area and it does not provide sufficient opportunities, also for functions such as water collection from the city to the rural area.
- Due to Weert's relatively high elevation, discharge of excess water to the surrounding area can take place under free fall. Better use of water requires inhibition and buffering. Increasing buffer capacity in green surroundings, increasing sponginess to Natte Natuurparels and improving water quality are opportunities for better utilisation of runoff water, such as in urban peripheral redevelopment.
- The transition from city to countryside could also serve to link more green-blue connections and combat heat stress. In the transition area between city and countryside, functions such as small-scale (residential) recreation, (urban) agriculture, visiting nature for walking and cycling fit in. Outside, at a greater distance from the city, nature can serve more as nature for those seeking rest. Zoning of the rural area suits this purpose.

2.2 Joint ambition

At the start of the pilot, a joint working session based on interviews with various stakeholders determined the ambitions of different sectors for the future of the rural area of the municipality of Weert. These ambitions are summarised in Figure 14 below.

Agriculture

- Safe and healthy food
- Healthy soil with organic matter
- Nature-inclusive agriculture
- Healthy revenue model with economic innovations
- Circular agriculture
- Connection between producer and consumer

Urban-Rural area

- Variety in landscape
- Healthy, green living environment
- Nature and water are integrated
- Space for extensive agriculture
- Mix of extensive functions
- Small-scale recreation
- Connecting health care & living

Nature

- Improved biodiversity
- More connection between natural areas
- Nature and agriculture integrated
- Increase of forest (around 20 ha)
- Strengthening N2000
- Restoration of wet landscapes
- Visit nature-experience nature-close to the city
- More connected nature - transboundary

Water

- Robust water system with sufficient buffer capacity
- More space for water and natural stream valleys
- Good soil quality and water retention capacity
- Balance between water retention and water discharge
- Water quality in order, achieving WFD objectives
- Recovery of groundwater level, natural recharge
- Functions fit with water and soil system
- Balance water availability, natural distribution system
- Water basins near fire-prone nature areas (heaths)

Figure 14: Ambition from different sectors

As a follow-up, a joint working session drew up a joint ambition for Weert's rural area. This involved identifying where ambitions overlap from different sectors and where sectors can find each other in an ambition and an appropriate integral approach. This ambition serves as the end point of the adaptation pathway map described in chapter 4. Table 1 summarises the ambition for the rural area of Weert in 2085.

Table 1 Future vision for the rural area of Weert

Future vision outside Weert 2085
The rural area of Weert is a climate robust system that is in balance and can cope with changing conditions. A healthy soil and water system are key to this. The soil is in good condition and can therefore capture and store water. The water system is flexible and can cope with extreme conditions by creating extra space for water. There is a high variation in land use, where different functions are combined. This provides a good connection between city and countryside, creating a rich landscape with strong green-blue networks and good biodiversity. Besides nature managers, farmers are the managers of the rural area and take care of a healthy and high-quality rural area. Alongside conventional agriculture, there is room for nature-inclusive agriculture. Innovative management measures reduce leaching and pollution of natural areas and surface water. All for the benefit of good water quality and an healthy ecosystem.

2.3 Effects of climate change

The climate is changing in the Netherlands, the Climate Signal'21 (klimaatsignal'21) shows that extreme rainfall and periods of drought will also increase in the future (KNMI, 2021). This affects the land use of the rural area of Weert. During the process, through analysis of basic data and interviews, the effects of climate change on the rural area of Weert were identified. These are substantiated in this chapter with data from the *Limburg Integrated Water System Analysis (LIWA)"* (Waterschap Limburg, 2022). We use in this study the mapped future autonomous developments in the area from the LIWA study and other public data. Herein, in line with LIWA, we focus on the most extreme climate scenario: the Wh scenario (Water Board Limburg, 2022). The increase in weather extremes causing drought, flooding and heat problems is used as *changing conditions* in chapter 4.

2.3.1 Change in groundwater levels

Increasing drought and changes in the discharge regime of the Meuse, affect developments of the lowest and highest groundwater levels in the area (see figures 15 and 16)

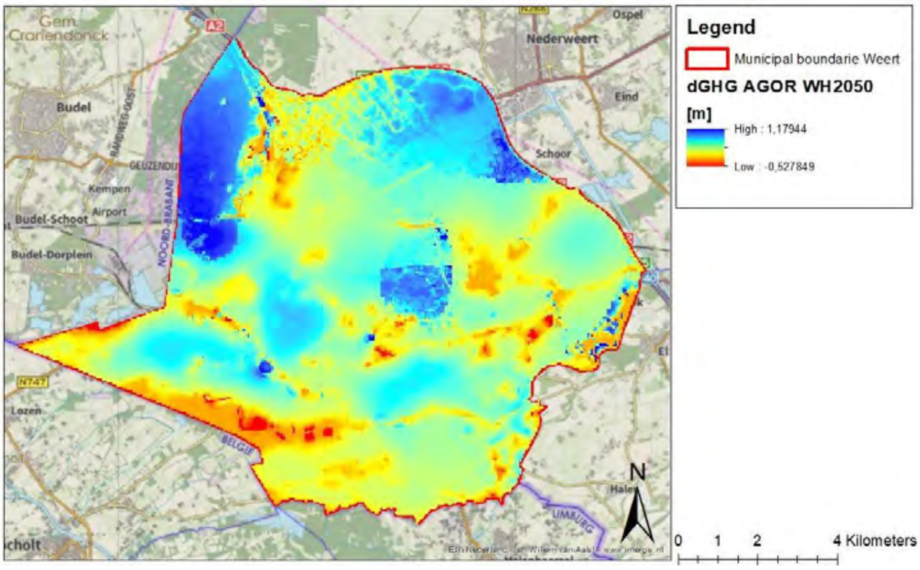

Figure 15: change in mean Highest Groundwater Level scenario WH2050 (GHG) in meters, yellow, orange and red show desiccation and in blue, vernalisation is visible.

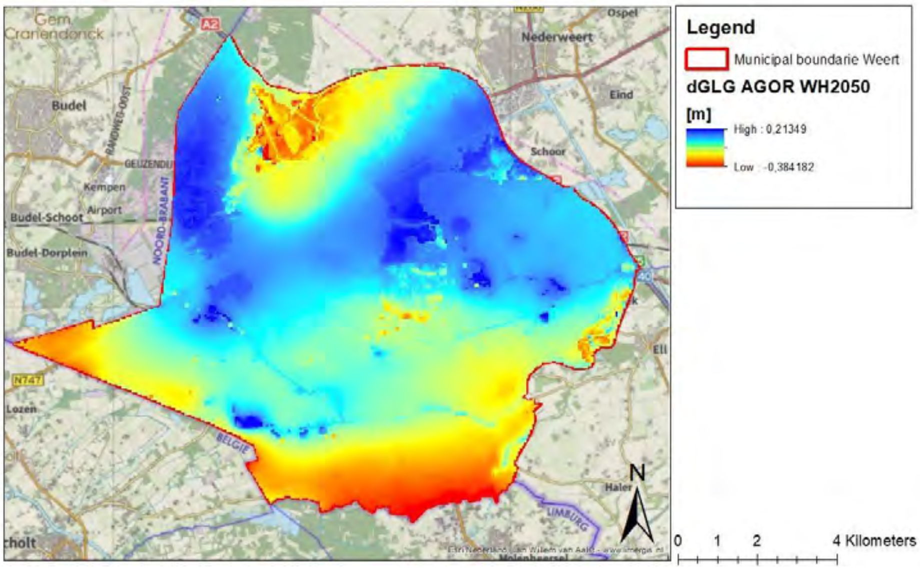

Figure 16: change in mean Lowest Groundwater Level scenario WH2050 (GLG) in meters, yellow, orange and red show desiccation and in blue, vernalisation is visible.

These changes in groundwater levels affect nature and agriculture and can lead to flooding in urban areas. Natte Natuurparels and groundwater dependent N2000 areas are especially vulnerable to changes in groundwater levels. Figure 17 shows the target gap created for different nature management and habitat types (Waterschap Limburg, 2022).

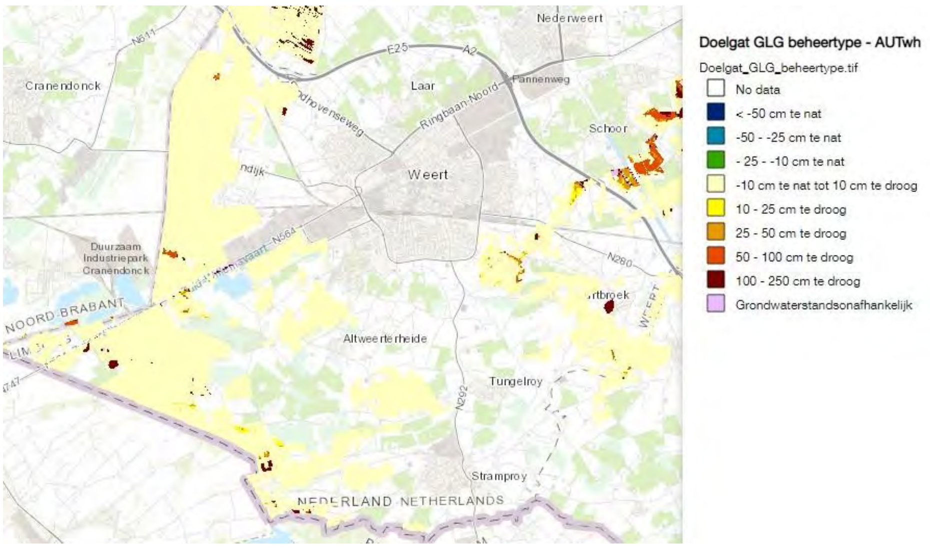

Figure 17: Target GLG for WH2050 scenario assuming current nature target types/management types in N2000 areas and Nature network Netherlands (NNN) (Limburg Water Board, 2022)

Changes in groundwater levels may additionally cause drought or wet damage to agriculture. Figures 18 and 19 show the potential damage to agriculture (Limburg Water Board, 2022).

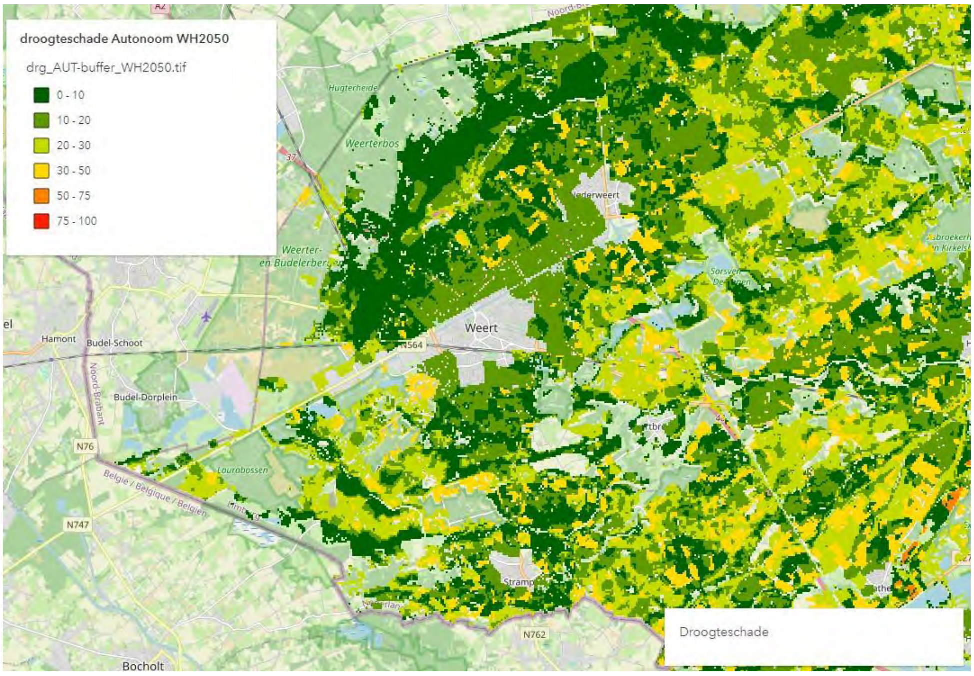

Figure 18: Increase in autonomous drought damage WH2050 (in % compared to current situation) (Limburg Water Board, 2022)

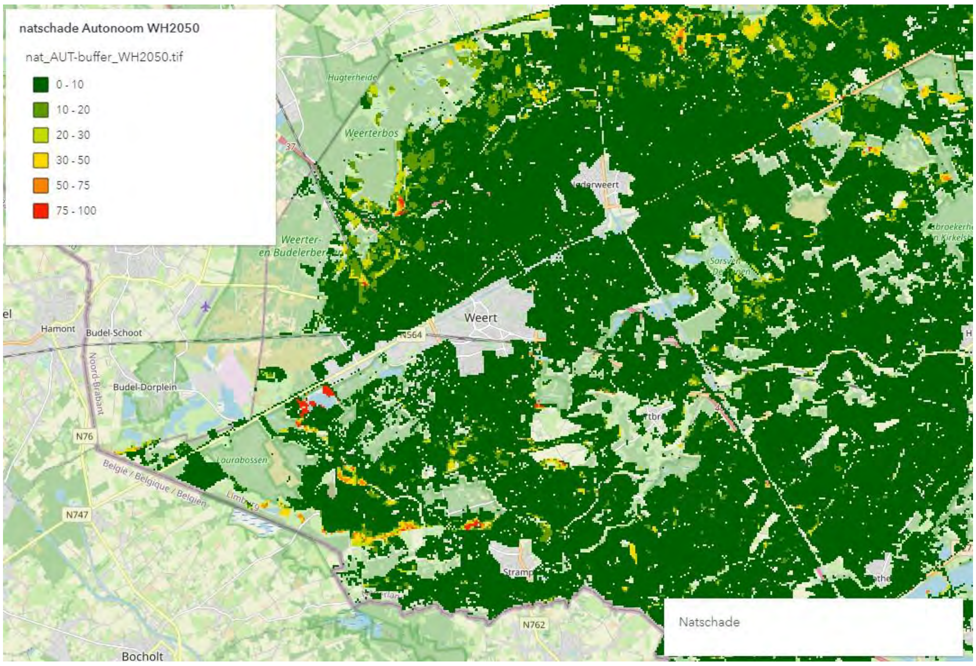

Figure 19: Increase in autonomous wet damage WH2050 (in % compared to current situation) (Waterschap Limburg, 2022)

2.3.2 Flooding

Figure 20 shows flooding after an extreme downpour (140 mm in 2 hours). The combination of increasing precipitation and low water retention capacity of the subsoil may cause more problems in agriculture (wet damage), through erosion of the subsoil or along banks in stream valleys. Figure 2 is indicative and illustrates the effects in the area around Weert. Further elaboration and research is needed to investigate the effectiveness of measures.

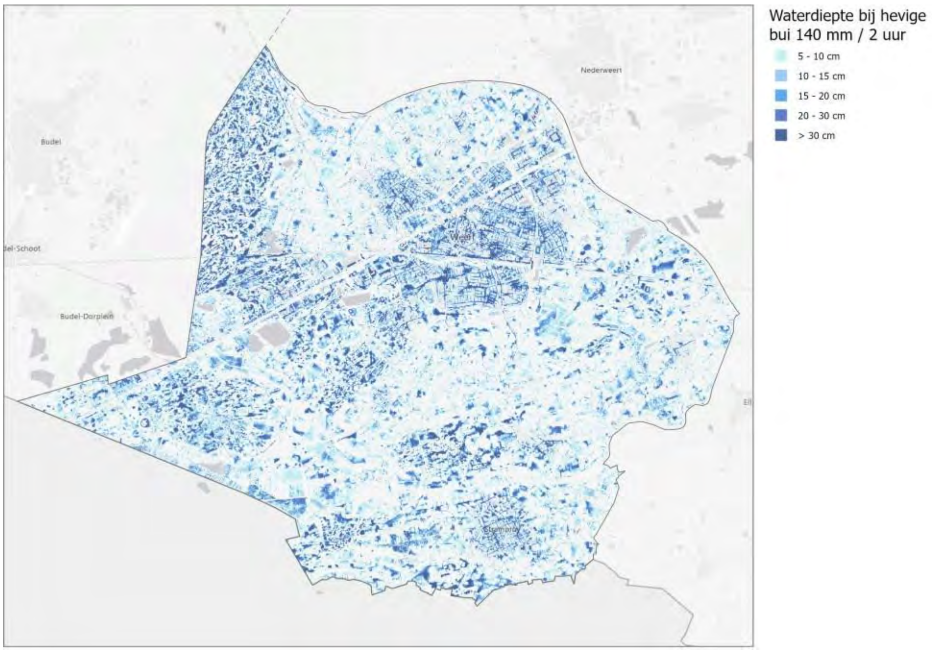

Figure 20: Water inundation for shower 140 mm in 2 hours (source: Climate Impact Atlas CAS, 2019)

3 Bottlenecks in the rural areas of Weert

3.1 Bottlenecks rural areas Weert

Based on literature review, analysis of baseline data and interviews with stakeholders, bottlenecks were collected. In a working session with area experts, bottlenecks were validated and identified. The bottlenecks below serve as the basis for the adaptation pathway map. These bottlenecks occur in the short, medium and long term. There are bottlenecks that occur once and other bottlenecks become more extreme over time and thus recur more often. This section describes the bottlenecks. We distinguish nature-, agriculture-, water- and city-related bottlenecks. We also distinguish integral bottlenecks. These integral bottlenecks arise and affect various sectors.

Table 2: Overview of bottlenecks and sectors

- Nature related bottleneck
- Water related bottleneck
- Agriculture related bottleneck
- Integrated bottleneck
- Urban area related bottleneck

Sector	Corresponding bottlenecks
Nature	3,7,11,14,16,17,18
Water	2,8,9,10
Agriculture	5,12,13,15,19
Integral	1,4
Urban area	6

3.1.1 Short term

1. *Water quality does not meet the established European WFD policy targets for the year 2027;*
   Water quality targets are not met everywhere (despite good examples such as stream restoration and nature-friendly design contributing to the ecological status of streams). Chemical quality is poor and ecological quality is overall moderate (Water Board Limburg, 2022). Besides the design of the system with limited space, this is caused by emissions from agriculture, industry and sewage (including emissions from outside the municipality of Weert).

2. *Limited buffer capacity in system causes more frequent flooding in rural areas;*

Due to limited space in watercourses and streams, heavy precipitation leads to flooding and damage to adjacent land uses, such as erosion damage to agricultural land.

3. *Due to the nitrogen policy implemented, space around N2000 is set aside for buffer areas to protect nature;*

Some of the nature types in the N2000 nature reserve Weerter- and Budelerbergen & Ringselven (Figure 3) are affected by nitrogen deposition, this affects the ecosystems. A possible solution to this is to remove agricultural influence in a zone (buffer) around N2000 areas to reduce nitrogen deposition to these N2000 areas.

4. *Interweaving of functions (urban area, nature and agriculture) creates conflicting conditions (including levels) in ground and surface water (drought and flooding);*

As a result of strong intertwining of different functions, there are conflicting interests, such as conflicting groundwater levels in adjacent nature and agricultural areas, crops in nature areas that pose a threat to livestock farming (Jacob's wort).

5. *Increasing drought and limited water retention capacity of the subsoil create problems for agriculture;*

As a result of lack of precipitation, the soil dries out. If the soil is insufficiently able to retain water in the root zone, damage to crops occurs.

6. *Extreme rainfall causes flooding in and around urban areas, this has an effect on the rural area;*

Due to heavy precipitation and a high degree of paving in urban areas, heavy precipitation will accelerate runoff and create peak loads at overflows and discharge points from urban areas.

7. *Increasing dry periods create drought problems for wildlife, insufficient groundwater and loss of seepage flows in stream systems;*

As a result of drought and declining groundwater levels, problems arise for natural areas, as groundwater levels decline and seepage flows from higher to lower grounds are lost.

8. *Leaching and runoff from agriculture of polluted ground and surface water causes reduced water quality;*

The ecological status of the water bodies is moderate. Chemical status is poor. Meeting the 2027 targets is uncertain. Incidentally, biological status is better than chemical status. Nutrients and metals such as zinc, cobalt, benzo(ghi)perylene, cadmium and selenium in particular are contributors to poor chemical water quality (Limburg Water Board, 2022).

9. *Increasing heat and rise in water temperature causes fluctuations in water quality;*

   As a result of warming of surface water partly due to limited volume and depth of surface water, warming and consequently acceleration of conversion processes of organic matter, aquatic plants etc. that require a lot of oxygen.

10. *Increased dry spells and reduced runoff are reducing the water quality of surface waters;*

   Due to the lack of natural inflow of water and decrease through evaporation, the volume in surface water decreases, increasing the concentrations of undesirable substances.

3.1.2 Medium-term

11. *Ecological water quality and bank quality (Biodiversity) vulnerable to extreme weather (too dry/too wet/too dirty) putting ecosystem under pressure;*

   As a result of extreme weather with highly variable conditions (too dry, too wet, heat) and insufficient size of surface water (depth, width, volume, storage capacity), problems for water quality and loss of biodiversity arise.

12. *Flooding causes damage in agriculture through flooding from stream valleys or waterlogging in fields;*

   Due to limited space in watercourses and streams, heavy precipitation leads to flooding and damage to adjacent land uses

13. *Extreme rainfall causes erosion of agricultural land;*

   Extreme precipitation causes erosion of soil material and washout of crops due to overland flow and inundation from watercourses and limited root capacity of crops.

14. *Interweaving of functions (urban area, nature and agriculture) creates conflicting conditions (including levels) in ground and surface water (drought and flooding);*

   As a result of strong intertwining of different functions, there are conflicting interests, such as conflicting groundwater levels in adjacent nature and agricultural areas, crops in nature areas that have a
   threaten livestock (Jacob's wort).

3.1.3 Long-term

15. *Climate change (increase in humidity and heat) increases disease and pests;*

    Due to increase in weather extremes and further global warming, crops are exposed to more extreme conditions resulting in reduced resistance of crops making them more susceptible to diseases and pests.

16. *Due to weather extremes, there are large fluctuations in water levels, peak loads in surface water and irreversible impacts on water quality and riparian vegetation;*

    As a result of weather extremes such as heavy precipitation and extreme drought and heat, water levels further subside and even lead to drying of water systems, conversely, heavy showers lead to extreme emissions. As a result, there is the loss of riparian vegetation and reduction in water quality.

17. *Due to changing climate and fragmented landscape, ecosystems and habitats are shifting and disappearing;*

    As a result of weather extremes, degraded conditions combined with fragmentation in habitat lead to loss of ecosystems and habitats.

18. *Dry summers and heat increase the risk of forest and wildfires;*

    The combination of heat and drought and deteriorating conditions cause drought damage to crops and, as a result, increased susceptibility of crops to forest and wildfires. Increase in this risk also affects water demand; at vulnerable locations, firewater buffers need to be realised.

19 *Due to changing climate, the current way of farming is not adequate/profitable;*

As a result of more frequent occurrence of weather extremes, damage and loss to agricultural crops occurs more frequently. This is a threat to the profitability of agricultural businesses.

4 Future prospects for Weert's rural area

In this chapter, we describe the measures associated with the bottlenecks in Chapter 3. We organise these into short-term, medium-term and long-term measures. In addition, the adaptation pathway map is described as a result of this process. In the last section, we describe several preferred strategies and a reflection on these pathways by several area experts.

In the steps towards a change of land use, several steps are possible. In doing so, we use the following prong:

1. Optimise operations and land use with current resources.
2. With current function, use differently by other crops, different soil tillage or changed layout of plots by, for example, strip cultivation and more and different vegetation along edges of plots.
3. In case of changed function, change to another use such as change from agriculture to nature or shift from nature to other locations and change of habitats.

Described below are measures that fit into this prong.

4.1 Measures

4.1.1 Optimise

Table 3: Optimisation measures and corresponding bottlenecks

Measure	Corresponding bottlenecks
• **Optimise (above-ground) water storage on agricultural land and in urban areas**; In watercourses and existing disposal sites, regulate levels more intelligently so that collection and buffer capacity are better utilised.	2,5,6,16
• **Improve soil quality, for more water-holding capacity soil (reduce fertilisation, prevent soil compaction);** This means intervening on a plot-by-plot basis, more organic matter application, other forms of fertilisation, less heavy equipment on the plot. This leads to fewer emission and better water retention capacity of the soil.	2,5
• **Adjust management: high water levels, retain water in capillaries e.g. by means of farmer weirs;** Improve water management per plot, apply level-controlled drainage, retain water in capillaries with farmer weirs and prevent unnecessary runoff.	2,5,9,10,12

• **Regulate use of manure and pesticides, and emissions from agriculture, urban and industry;** Reduced use of manure and crop pesticides contributes to emission reduction. In addition, implementing measures to reduce emissions from the sewerage system and reducing emissions from industry by optimising business processes will reduce pollution of surrounding areas and surface water.	1,8
• **Optimise water supply and water level management around natural areas and stream valleys.** Making better use of existing resources, stretching existing supply capacity, arranging smarter seasonally so that existing resources are better utilised.	2,7,10,16

4.1.2 Use differently

Table 4: Alternative use measures and corresponding bottlenecks

Measure	Corresponding bottlenecks
• **Natural design of stream valleys;** Redesign of systems such as stream restoration, zoning around the stream and adjusting vegetation (shading) along streams for more natural situation, reducing runoff by increasing water level management and improved sponge effect. This will, among other things, slow down drainage and create cooling by shaded areas.	2,9,10,11,16
• **Create buffer zones between different land uses;** Transition zones between nature and agriculture, zones around urban centres provide multiple functions and accommodate negative effects of land use of urban versus rural and nature versus agriculture in the form of water level management, emissions, vegetation and management.	4,11,14
• **Adapt agriculture for sustainable soil management (e.g. nature inclusive agriculture);** Nature and agriculture blend together and are present in vegetation on and along plots, along farmyard buildings and in operations in the form of extensive land use with nature-friendly materials, fertilisers (biodynamic, circular). More biodiversity, better soil quality and fewer emissions.	5,8,13,19
• **Change to robust cropping systems, adapting to changing climate;** Other cropping systems may include strip cropping, other crops that are more resistant to changing climate and changing demand, e.g. also from construction.	2,5,12,13,15

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4.1.3 Change use / Designate differently

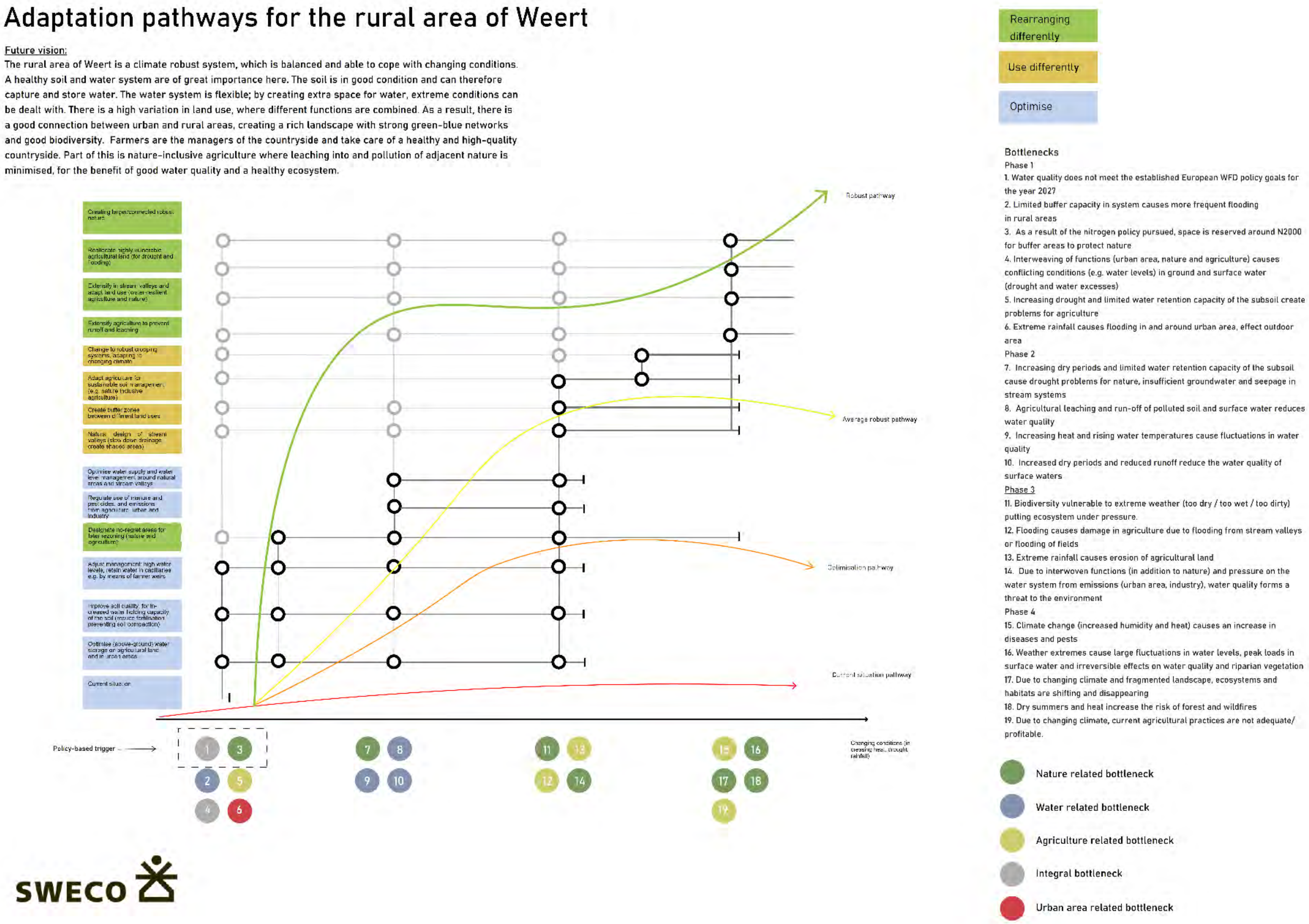
Table 5: Redesigning measures and corresponding bottlenecks

Measure	Corresponding bottlenecks
• **Designate no-regret areas for later rezoning (nature and agriculture);** This is a preparatory measure, which already anticipates rezoning at a later stage. Apply land use in such a way that both nature or changing agriculture can have a place at these locations. This also means rezoning, adapting regulations aimed at climate adaptation.	-
• **Extensify agriculture to prevent runoff and leaching;** Less intensive form of agriculture, less heavy equipment, more space for natural management, e.g. grazing management on grassland plots and fewer cattle per ha. Resulting in fewer emissions (such as nitrogen, fertilisers, pesticides).	1,8,14,17
• **Extensify in stream valleys and adapt land use (water-resilient agriculture and nature);** In the zoning of a stream valley, adjust agricultural use by allowing cattle to graze only periodically close to the stream and in yard and plot vegetation, apply more nature along edges creating more biodiversity in the area.	2,10,16,17,19
• **Reallocate highly vulnerable agricultural land (for drought and flooding);** Search for other use by agriculture to nature and connect with other acreage. No damage to crops, less stringent soil and water system requirements). This simultaneously has positive impacts on nature, creating transitional area and larger/contiguous nature.	2,8,12,13,15,19
• **Creating larger/connected robust nature** Ensure more contiguous nature by creating connections along streams and other corridors in line with Nature Network Netherlands. This includes creating water buffer locations for natural and agricultural purposes and firefighting.	11,16,17,18

4.2 Adaptation pathway map

Below is the adaptation pathways map drawn from this study (Figure 21).

Figure 21: adaptation pathways map



4.2.1 Explanation of adaptation pathways map

Bottlenecks are shown on the horizontal axis and numbered in section 3.1 and to the left of the adaptation pathways map. On the vertical axis are the measures listed in section 4.1. The main components in the adaptation map are:

- *Measures:* the rectangles on the left represent the possible measures in the area.
- *Bottlenecks:* At the bottom of the adaptation map are the bottlenecks. These bottlenecks arise from changing conditions and prompt a decision to switch to other measures.
- *Tipping points* are points where certain measures are no longer sustainable.
- *Decision moments:* are times when different measures can be chosen.

In an adaptation pathway map, the bottlenecks, choices, and tipping points do not depend on a specific time. These points are related to changing conditions. In this study, that is the changing climate (increase in weather extremes, and temperature). Bottlenecks are divided into short-term, medium-term and long-term bottlenecks. Consecutive choices determine the adaptation pathway, which is marked in black. Other preferred pathways are possible. In section 4.3.1 we discuss the established adaptation pathways for the rural area of Weert and in section 4.3.2 we describe the chosen preferred pathway for the rural area of Weert.

This adaptation pathways map was prepared on the basis of interviews, working sessions and a literature review. Climate effects as used in LIWA show an initial look through to 2050. The assumption for this study is that climate effects will increase further with the look ahead to 2100, but these effects have not been quantified.

4.2.2 Adaptation pathways for the rural areas of Weert

In the adaptation pathway map drawn up for the rural area of Weert, we assume that the area will use the tritium: 'optimise, use differently and change use'. In addition, the discussion and analysis showed that the current method of management, is finite due to increased climate effects and intensification of land use. It is already visible that as a result of existing bottlenecks, the current way of working has limitations in solving climate impacts. Below, we describe the progression of the adaptation pathway, highlighting bottlenecks *in italics,* <u>and underlining</u> measures that offer solutions.

The combination of changes in weather extremes (precipitation and dry periods), poor buffering capacity, and pressure on land use is increasing flooding and drought problems. For instance, *increasing drought and limited water retention capacity of the subsoil* create *problems for agriculture* this can be prevented by <u>optimising water storage on agricultural land and adjusting management, to retain water longer</u>.

If in the medium term, the drought problem for agriculture coincides with *flooding of fields by flooding from stream valleys or extreme rainfall, and erosion of farmland by extreme rainfall,* optimisation of the current water system will not be sufficient. Agriculture needs to be adapted for sustainable soil management to improve soil quality. Furthermore, a change to robust cultivation systems is needed to reduce damage to agriculture, and a switch to more suitable forms of agriculture that suit a changing climate.

In the long term, the problems surrounding nature (*ecosystems and habitats are disappearing due to changing climate and fragmented landscapes)* and the vulnerability of agriculture (*climate change is increasing disease and pests)* coincide. *As a result, farming methods are not profitable or sufficient in some places.* Adapting land use around existing natural areas, by reallocating vulnerable farmland offers a solution for nature, and agriculture, and creates a more diverse and robust landscape.

4.3 Preferred pathways rural areas Weert

4.3.1 Description of preferred pathways

The measures can be gone through in different ways over time, by choosing to develop a particular pathway. Figure 22 shows a number of possible preferred pathways for the rural areas of Weert. The text below briefly explains the different pathways.

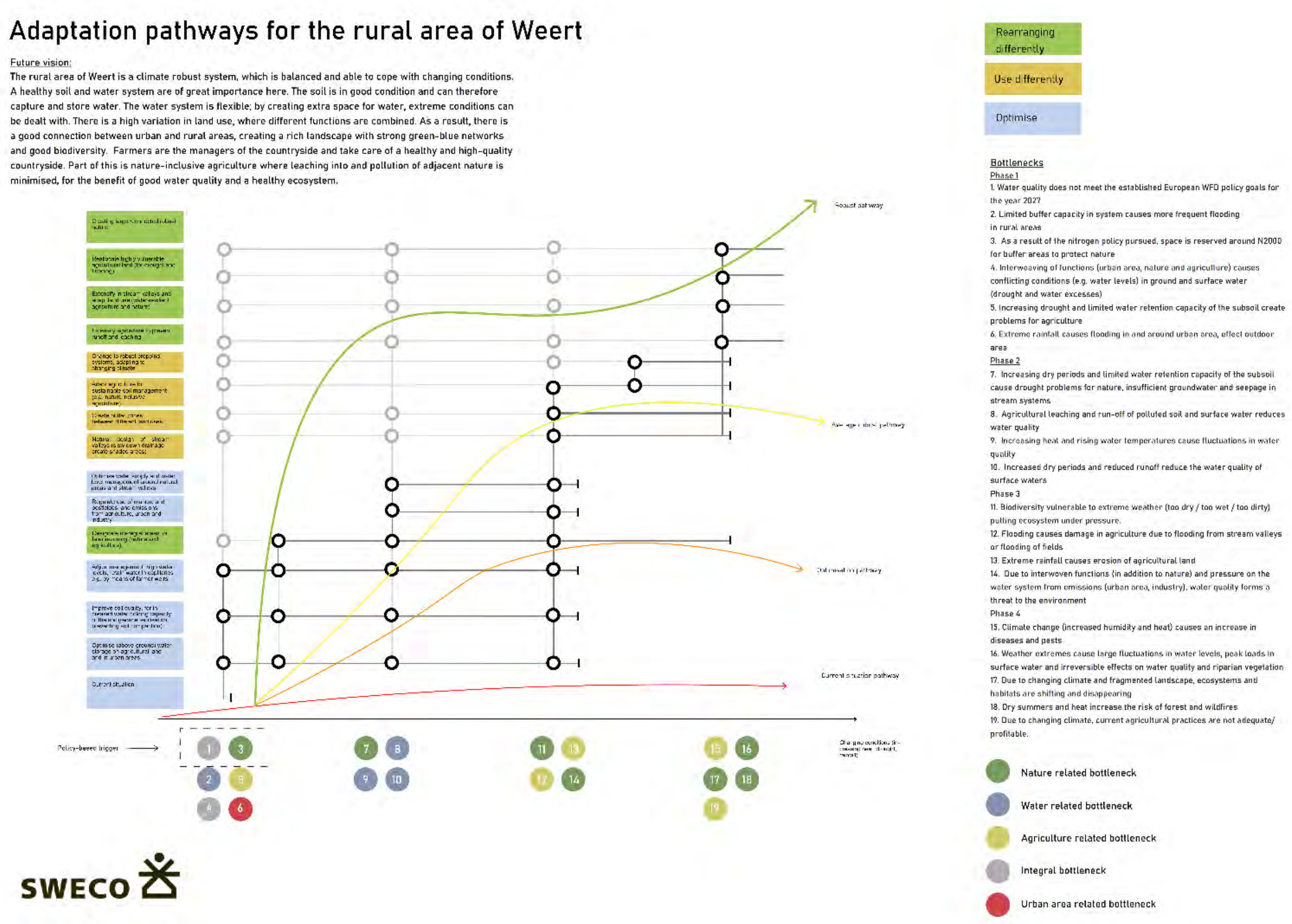


Figure 22 Adaptation pathways map with preferred pathways

Current situation pathway

Chapter 2 describes the existing situation in the rural areas of Weert and where bottlenecks occur.

Optimisation pathway

The pathway of optimisation chooses to optimise the current water and soil system to mitigate the effects of climate change on agriculture and nature. Physical and management measures optimise the system for the benefit of the current land use, in which nature and agriculture are separated. The optimisation pathway has a sectoral approach, the measures affect either nature or agriculture, for example, and do not integrate the different interests.

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medium robust pathway

The medium robust pathway, starts with optimising current soil and water systems. When increasing problems occur in agriculture and nature, an integral area approach is used to take measures aimed at a more natural layout and to adapt land use to changing conditions. For instance, stream valleys are arranged naturally and agriculture adapts through robust cultivation systems and a switch to sustainable soil management. The functions in the area remain the same. The trigger for choosing the medium robust pathway earlier, and switching to measures that encourage different uses, may be policy-related. For instance, failure to meet nitrogen targets may already require measures around N2000 areas and in the stream valley. In addition, linking up with other tasks may be a reason to take this pathway earlier. For instance, creating a transition area between urban and rural areas reduces emissions and creates a buffer zone between functions, which also includes functions such as recreation.

Robust pathway

The robust pathway goes one step further after land use change. Function change takes place because the current land use is not adequate/profitable in a changing climate. In vulnerable locations (such as stream valleys), land use is changed from agriculture to nature, creating a more robust landscape. There may also be a much more interwoven situation of nature, recreation and agriculture around urban areas and more nature-inclusive agriculture and nature around core nature areas. Habitats may also be changed in nature areas and nature may shift. To eventually take the robust pathway, it is necessary to designate so-called *no regret areas* earlier in time (in the short term). In these areas, the function will be changed over time. Designating these no *regret areas* can prevent disinvestment. As with the average robust pathway described above, co-option opportunities or changes in policy can be a trigger to choose the robust pathway earlier.

Adaptivity of preferred pathways

Continuing in the current situation and following the sectoral optimisation pathway risks making investments that will not pay off in the future. Nature that will disappear anyway (habitats that shift or disappear) or forms of agriculture that ultimately have no future are then retained for too long. When the optimisation pathway is followed for too long it reduces adaptability in the future. The longer you continue to optimise, the step towards using and designing differently becomes increasingly difficult as soil and water systems become further depleted and contaminants accumulate.

4.3.2 Preferred pathway chosen from project group

In a working session, together with the project group with area experts, we reflected on the preferred pathways and together determined what the most desirable pathway would be for the rural areas of Weert. The results are described below.

In doing so, it is also clear that this is a snapshot in time and the pathways should be considered with some regularity (depending on changes) once every one or more years. The red pathway of "current situation" does not lead to added value. Existing bottlenecks as also described in the field visit results illustrate this. This also applies to the orange pathway in which solutions are sought sectorally through optimisation per function. This orange pathway is good in itself, but does not lead to maximum added value and robust solutions. Parties are convinced that real added value arises when there is integral cooperation. In this, the yellow "medium robust pathway" and the green "robust pathway" are preferred. In the "robust pathway", the soil and water system is leading and parties work together on the most optimal land use for the area. This is an ambitious step and cannot be done everywhere at present. Good examples of this are needed and the "average robust pathway" with application of zoning around urban areas, vulnerable nature areas and stream valleys can be a prelude to then make the step towards integral and system-driven development of the rural area of Weert.

By working from yellow to green (medium robust, to robust) with an eye on the maximum goal, there is the prospect of maximum added value. Parties realise that the bar is high. Applying the yellow "average robust pathway" is in line with follow-up steps within the framework of the NOVI.

To further engage in dialogue with parties in the area, it is recommended that in the further elaboration, several "cross-sections" from the area are to be made to illustrate these pathways and to show from which preconditions layout and use are possible. In the following chapter, this is worked out for three subareas.

5 Elaboration in 3 subareas

5.1 Introduction

The possible layout of some cutaway plots of land in the rural areas of Weert has been elaborated for two possible choices from the adaptation pathways "**use differently**" and "**change use**". This elaboration is intended to offer insight to stakeholders. But also to clarify the possible choices for area-specific elaboration of the tasks facing farmers, municipalities, water boards, provinces and nature managers. After all, a lot is changing. The climate is changing, biodiversity and nature are under pressure and soil quality must be improved. The picture developed in this chapter for these three subareas provides a possible interpretation of these changes. Its purpose is to offer stakeholders insight into the action perspective and future possibilities for agricultural entrepreneurs taking into account changing circumstances. Everyone is aware that continuing as we are doing now is a dead end. We will have to change together, possibly doing more on the same square meter of land. This requires flexibility from all involved, but in our opinion it is necessary in a country like the Netherlands with space pressures far exceeding the space we have. This also means pushing the boundaries and working together. The depiction of the three subareas as included in this chapter provides possible forms of design and stacking of goals for this purpose. It is an indication based on recent studies such as LIWA and the elaboration of adaptation pathways in the Netherlands. These subareas are representative of other parts in the rural area of Weert. With these examples, a translation can also be made for other parts of the rural area on how the use or design can change. Here, the effects of climate change have been used as a basis and, from the

Water and soil system reasoned what the consequences might be for these scenarios.

The water system is also adapted in the process. In "rearranging", the water and soil system is fully in charge, while in "using differently", we are working towards that situation, but still with an intermediate step from current practice.

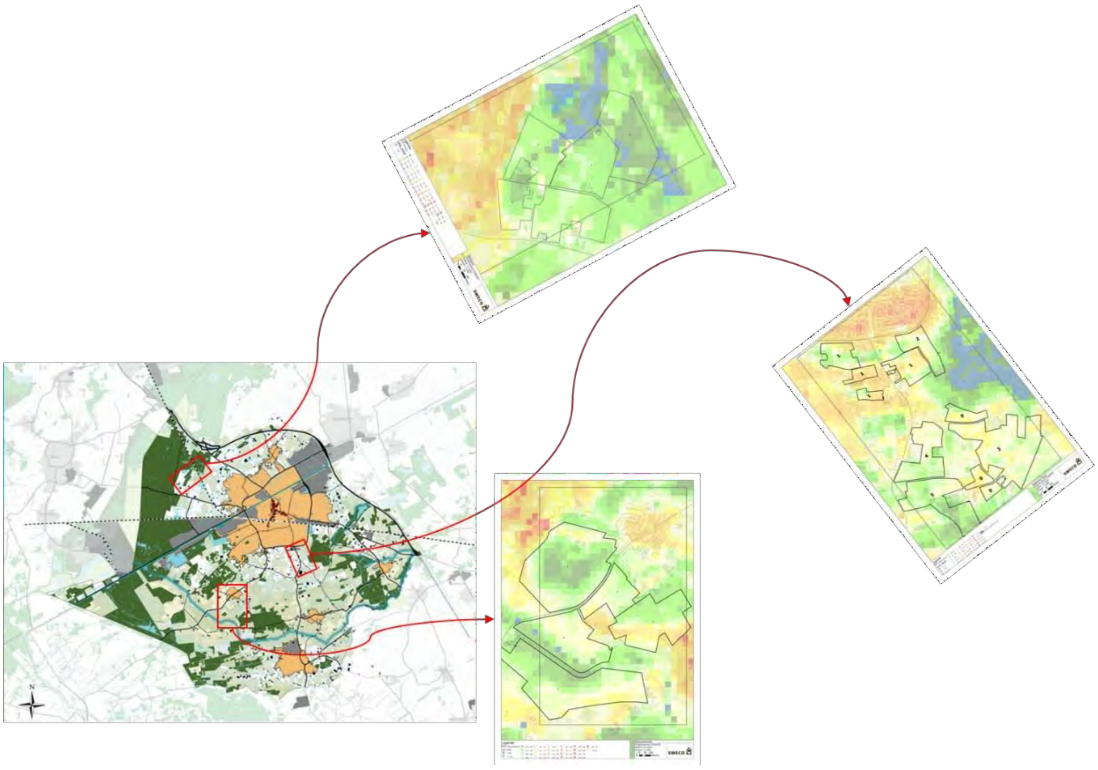


Figure 23: Location of the three subareas

A detailed description of the three subareas and their characteristics is given in Annex 2.

5.1.1 Water and soil adaptations

The rural area of Weert is part of the high sandy soils. The area suffers from droughts, especially of nature areas (N2000), but the sandy soils with agricultural use also face the consequences of droughts. Furter, heavy precipitation also causes flooding. Water quality also suffers from the effects of nutrients[2] and pesticide pollution. The Tungelroyse brook and the Raam cut through the area. These were redesigned in the 1990s and have a nature-friendly design within a limited extent.

The consequences were calculated and analysed on the scale of Limburg as part of the Limburg Integrated Water System Analysis (LIWA) study. The results of this study give an indication of the changes in climate, ground and surface water that will occur. For translation at plot level, the LIWA results give an indication of what will change in the ground and surface water system.

Measures to make the area more climate resilient provide a direction in which water management development will take place. These include interventions such as damming capillaries, increasing the drainage base of stream valley bottoms and improving the

[2] Water quality measurement data - Limburg Water Board

soil fertility and organic matter content. In this translation for three subareas, this has been used and is also based on the structuring choices formulated in the letter "Water and Soil Stewardship" in late 2022[2]. These include the following structuring choices for the high sandy soils:

1. We retain water longer and drain it less quickly. We thus restore the sponge effect of the soil and achieve a robust groundwater system. This is secured in area processes.
2. We raise groundwater levels by possibly 10 cm to 50 cm. This will combat desiccation on the high sandy soils. As this is a tailor-made measure, it will be further elaborated in area processes.
3. In the area processes, we focus on large-scale restoration of brook valleys on sandy soils to improve water quality. In this way, we not only achieve the water quality goals (from the WFD and the Nitrate Directive) but can also realise other objectives (such as nature, green-blue meander and water storage).
4. We limit groundwater withdrawals around Natura 2000 areas. By doing so, we prevent dehydration these areas. This will be worked out in the area processes

In addition to these points, the letter endorses the aim of vital soils, with use consistent with soil quality and restoring natural sponginess as much as possible. One of the interventions in this regard is to increase organic matter content.

The municipality of Weert and the Limburg Water Board and its partners work together within the interreg programme on topics such as water runoff and the measurement, calculation of flow velocities, water volumes, water levels and the like. But also on weather influences and the earlier prediction of expected water flows and water levels in medium to large rivers.
Also in and around Weert, restoring sponge function and increasing water buffering capacity is an important starting point to better cope with the effects of too much and too little water. This methodology focuses on the source. Where the water falls and can be used in that to rearrange areas to reduce water runoff.

Sweco worked out structuring choices for the high sandy soils in a study for the province of Overijssel. Here, the principle of water and soil steering was used as a starting point. The structuring choices are shown in Figure 24.

[2] Brief water en bodem sturend

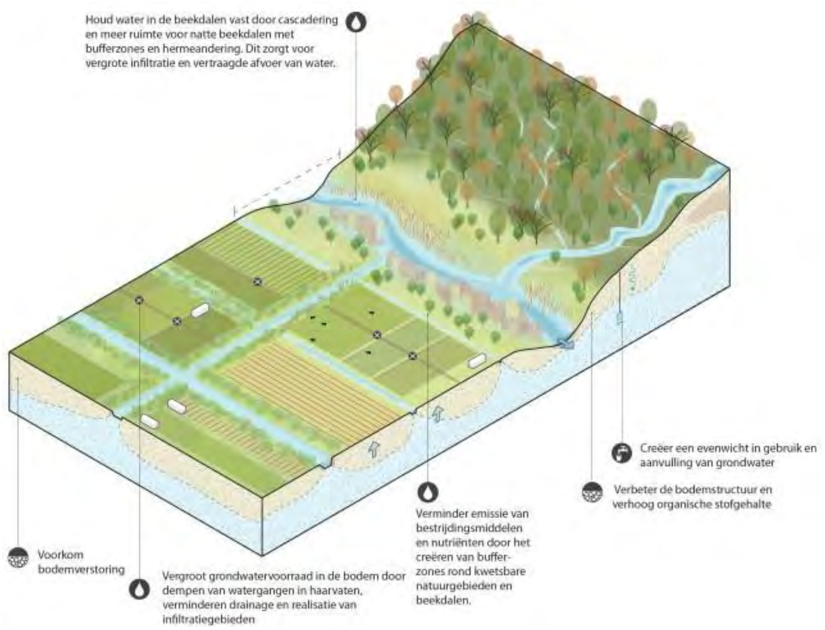


Figure 24: Directional statements for the high sandy soils in eastern Netherlands - water and soil guiding, as an example for the high sandy soils in Limburg

5.1.2 “Change use”

In the adaptation pathways, we have formulated the following principle measures for the long term and medium term. These match these changing conditions and provide opportunities to take them into account in agricultural operations.

Distinction between medium- and long-term measures

<u>Medium-term:</u>

- Moving towards robust cultivation systems, adapting to changing climate.
- Adapt agriculture for sustainable soil management (e.g. nature-inclusive agriculture)
- Creating buffer zones between different land uses.
- Natural design of brook valleys

<u>Long-term:</u>

- Create larger/contiguous robust nature
- Create a different use for highly vulnerable agricultural land (for drought and flooding)
- Extensify in stream valleys and adjust land use (water-resistant agriculture and nature)
- Extensify agriculture to prevent runoff and leaching

Below, this is articulated and depicted for the three subareas.

5.2 Tungelroyse brook subarea - Altweerterheide

The current land use of the agricultural plots varies from grassland along the Altweerterheide forest area to arable farming in most of the area. However, arable farming is in rotation of different crops each year. Effects of drought, reduced soil fertility and periodic waterlogging from the Tungelroyse stream are noticeable. Agricultural use is vulnerable to dry and wet conditions.

Figure 25: Current situation subarea Tungelroyse brook - Altweerterheide

Raising groundwater levels by modifying the Tungelroyse brook and reduced discharge through the capillaries (Altweerterheide discharge) will increase groundwater levels. As a result, water levels in dry periods will not sink as far and there will be humidification. As a result of zoning around Tungelroyse brook, emissions will decrease and water quality will improve. However, this also requires upstream source-oriented measures. The consequences of this for this subarea are:

- More space for the Tungelroyse brook as a marsh zone and humidification of the zone immediately adjacent to the stream (and less space for intensive agricultural use);

- Netting of the plot adjacent to the Altweerterheide forest area.

For the long term, in the final picture "Different design" there is an interlacing network of green and blue concentrated along the brook and along the axes between the forest areas Tungerwallen and Altweerterheide.

5.2.1 'Using differently' Tungelroyse brook - Altweerterheide

Features:

- Zoning along the naturally designed Tungelroyse brook - reduced fertilisation, wetted conditions
- Use adapted to wetland conditions, zone along stream already more extensively used, less emission;
- Arable adapted to conditions, improving soil fertility through less tillage, green manures. Possible adaptation of crops, but arable production remains possible, partly due to less drought sensitivity in crop choice and conditions. This reduces the need for irrigation.
- Grassland less intensive use by zoning adjacent to stream, and humidification plot along Altweerterheide, but still livestock possible.

Figure 26: Medium-term "use differently" picture

5.2.2 “Change use” in the area of the Tungelroyse Brook – Altweerterheide

Features:

- Tungelroyse brook has wider zoning through marsh zone that transitions southeast into steeper profile with cascade or deadwood bridging decline.
- Green-blue veining continued more strongly along the stream and between the Altweerterheide core and the Tungerwallen and Altweerterheide forest areas. Zone along Tungelroyse brook has no fertilisation, wetted conditions, partly extensive grazing management

along south side and north side crop choice arable which can be locally higher if it connects to the green-blue veining of landscape (suitable for wet conditions).

- Area is smaller along the brook, arable farming remains possible but adapted to conditions, improving soil fertility through less tillage, green manures. Possible adaptation of crops, but arable production remains possible, partly due to less drought sensitivity in crop choice and conditions. This reduces the need for irrigation.
- Grassland extensively used e.g. in the form of extensive grazing management.

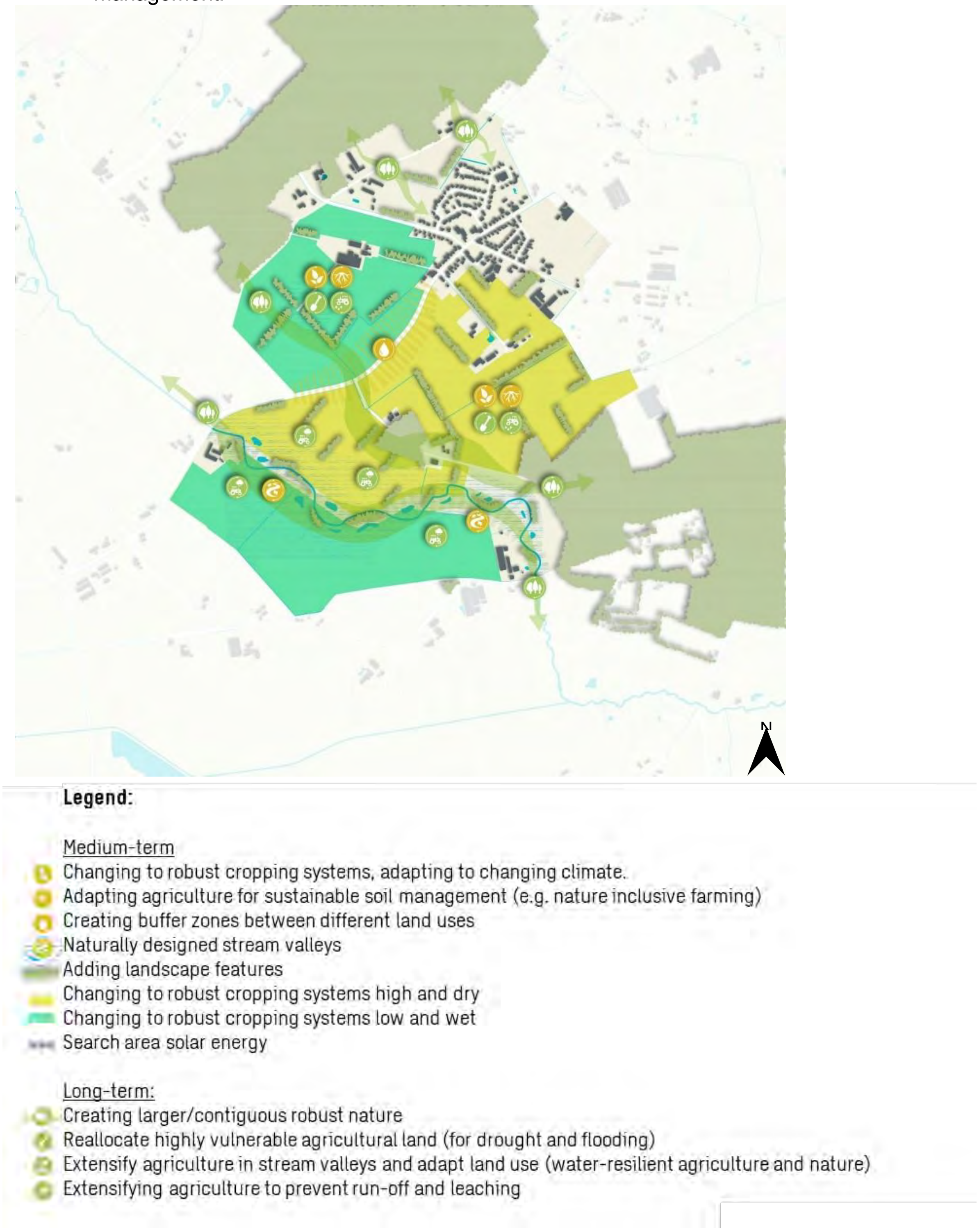
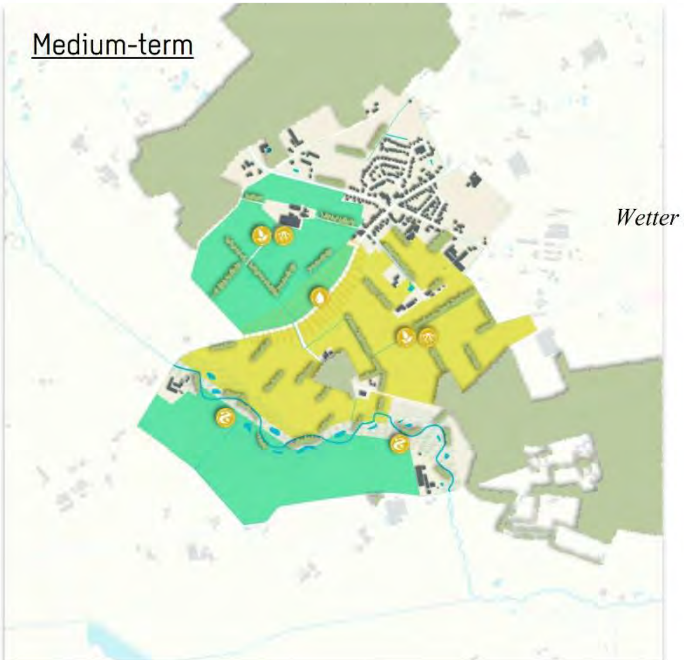
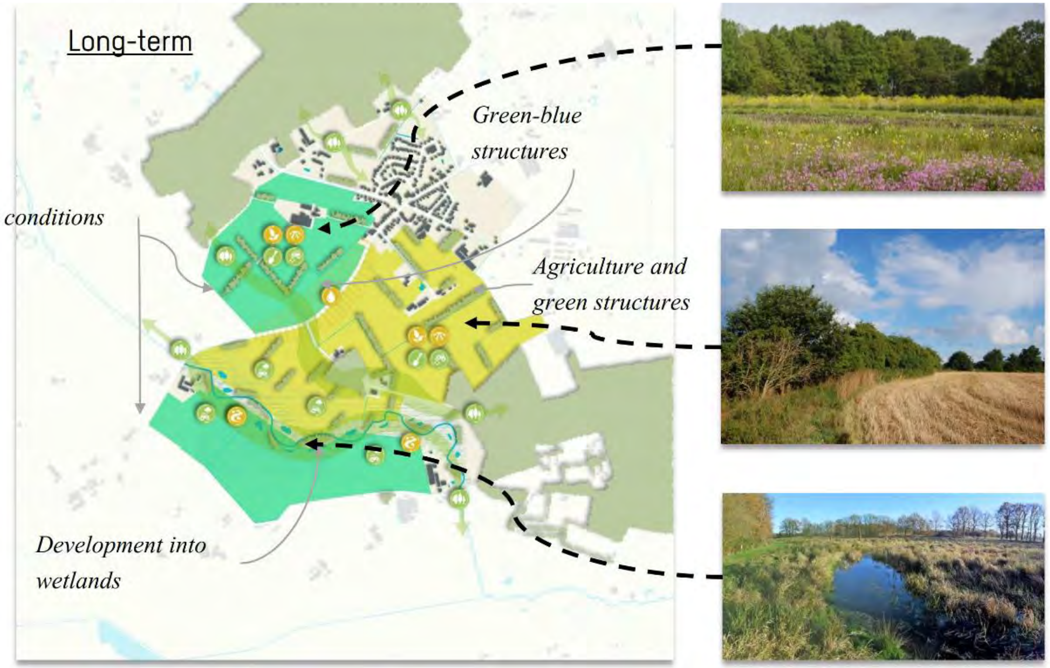


Figure 27: 'Rearrange' image of Tungelroyse brook and Altweerterheide in the long term

Summary sub-area Altweerterheide – Tungelroyse brook





Legend:

Medium-term
- Changing to robust cropping systems, adapting to changing climate.
- Adapting agriculture for sustainable soil management (e.g. nature inclusive farming)
- Creating buffer zones between different land uses
- Naturally designed stream valleys
- Adding landscape features
- Changing to robust cropping systems high and dry
- Changing to robust cropping systems low and wet
- Search area solar energy

Long-term:
- Creating larger/contiguous robust nature
- Reallocate highly vulnerable agricultural land (for drought and flooding)
- Extensify agriculture in stream valleys and adapt land use (water-resilient agriculture and nature)
- Extensifying agriculture to prevent run-off and leaching

5.3 Subarea city urban periphery Weert

Along Weert's urban periphery, there is now a hard division between town and countryside marked by the present peripheral road. This sharp transition is also noticeable between the Natte Natuurparel and agricultural land. Because the area layout is focused on draining water, there are low groundwater levels. The current layout is drought-prone. Much arable farming is present. Infrastructure and buildings are mainly present along the axes from Weert.

There are higher groundwater levels in the vicinity of the Wetland Pearl and to the south.

Figure 28: Current layout city rural areas Weert

Changes to water management around the Leukerbrook wetland area and the reduction of drainage via the capillaries along this area will raise groundwater levels. As a result, water levels in dry periods will decrease and there will be humidification. As a result of zoning around Leukerbrook, emissions will decrease and water quality will improve. However, this also requires upstream & source-oriented measures, such as in the urban area of Weert. Less emission and collection, water buffering in the urban periphery around Weert can take place in a wide area south of the ring road. The implications for this subarea are:

- More space for Leukerbrook and other watercourses.
- Reduced drainage through the capillaries.
- Reduced emissions from urban areas and from agricultural use and improved water quality.
- Netting of plots adjacent to the Wetland Park and along the urban fringe (water buffer).

5.3.1 'Using differently' urban periphery Weert

A characteristic feature is a development of the city edges of Weert, a green-blue veining developed between the Natte Natuurparel and Weert. From the Natte Natuurparel in a southerly direction, this interlacing network can be continued along the axes of infrastructure.

Features:

- Initial development of Weert city rural areas with water storage.
- Raise groundwater levels, especially in capillaries and near Natte Natuurparel.
- Land use then still requires limited adaptation due to relatively large depth of groundwater levels.
- Water quality improves and soil quality improves by adjusting agricultural operations, less emission of nutrients and pesticides.

Figure 29: 'Different use' image of Weert city urban periphery in the medium term

Legend:

Medium-term

- Changing to robust cropping systems, adapting to changing climate.
- Adapting agriculture for sustainable soil management (e.g. nature inclusive farming)
- Creating buffer zones between different land uses
- Naturally designed stream valleys
- Adding landscape features
- Changing to robust cropping systems high and dry
- Changing to robust cropping systems low and wet
- Search area solar energy

5.3.2 “Change use” in the area of the urban periphery Weert differently

In the long-term picture, the green-blue veining is further developed, as is the urban periphery of Weert with water buffering, restored sponginess and delayed discharge to the surrounding area. The Natte Natuurparel around Leukerbrook is robust and wetter in its surroundings and noticeable in the immediate vicinity. On higher grounds, arable farming is still possible, but the choice of crop is tailored to the conditions.

Features:

- Linking Natte Natuurparel and urban fringe Weert.
- Agricultural land use adapted to wet conditions.
- In wet locations and near nature, extensify land use.
- Increase water buffering capacity by restoring sponge effect urban area in urban periphery.

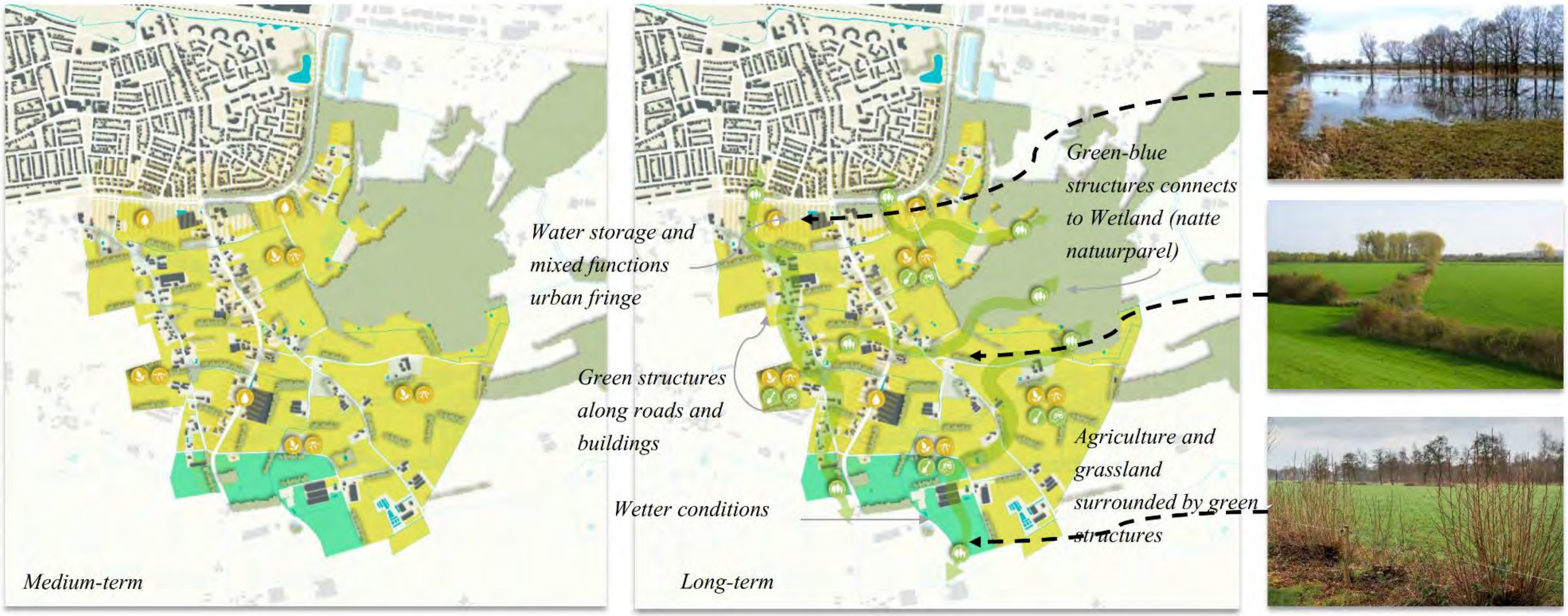
Legend:

Medium-term
- Changing to robust cropping systems, adapting to changing climate.
- Adapting agriculture for sustainable soil management (e.g. nature inclusive farming)
- Creating buffer zones between different land uses
- Naturally designed stream valleys
- Adding landscape features
- Changing to robust cropping systems high and dry
- Changing to robust cropping systems low and wet
- Search area solar energy

Long-term:
- Creating larger/contiguous robust nature
- Reallocate highly vulnerable agricultural land (for drought and flooding)
- Extensify agriculture in stream valleys and adapt land use (water-resilient agriculture and nature)
- Extensifying agriculture to prevent run-off and leaching

Figure 30: 'Rearrange' image of Weert city rural areas in the long term

Summary sub-area city periphery Weert



Legend:

Medium-term
- Changing to robust cropping systems, adapting to changing climate.
- Adapting agriculture for sustainable soil management (e.g. nature inclusive farming)
- Creating buffer zones between different land uses
- Naturally designed stream valleys
- Adding landscape features
- Changing to robust cropping systems high and dry
- Changing to robust cropping systems low and wet
- Search area solar energy

Long-term:
- Creating larger/contiguous robust nature
- Reallocate highly vulnerable agricultural land (for drought and flooding)
- Extensify agriculture in stream valleys and adapt land use (water-resilient agriculture and nature)
- Extensifying agriculture to prevent run-off and leaching

5.4 Boshoven subarea

The Boshoven subarea is located in the upper reaches of the Oude Graaf along the eastern flank of the N2000 area Weerter- and Budelerbergen & Ringselven. In this subarea there is dehydration and in wet periods there is flooding.

Figure 31: Current situation Boshoven

By adjusting discharge along the flanks of the N2000 area Weerter- en Budelerbergen & Ringselven and reduced discharge through the capillaries along the eastern flank of this area, groundwater levels will rise. As a result, water levels in dry periods will not sink as far and there will be humidity. As a result of zoning around the watercourses, emissions will decrease. However, this also requires source-oriented measures upstream. There is an interlacing network of green and blue, connecting to N2000 and Oude Graaf.

The implications of this for this subarea are:

- More space for water and watercourses draining northwards (and less space for intensive agricultural use).
- Naturalising plots adjacent to the N2000 area Weerter- en Budelerbergen & Ringselven and in the source area of the Oude Graaf.
- Increase in biodiversity.
- Improved water quality.

5.4.1 "Using differently" subarea Boshoven

Using it differently in the medium term results in:

- Wet conditions especially along flank of N2000 area
- Weerter- and Budelerbergen & Ringselven
- Green-blue veining along infrastructure
- There is space for energy along the railway infrastructure as well as around built-up areas.
- Landscape elements connecting to the built-up area and green-blue veining.

Figure 32: "Using Boshoven differently" in the medium term

5.4.2 “Change use” in the subarea Boshoven

Designing differently in the Boshoven area further works through the following elements:

- Wetted conditions as source area of the Oude Graaf, draining northwards
- Green-blue veining further developed by humidification in capillaries
- On part of plots adjacent to N2000 area adaptation of functions and land use and also space for energy supply
- Wetter soils also suitable as extensive grazing management

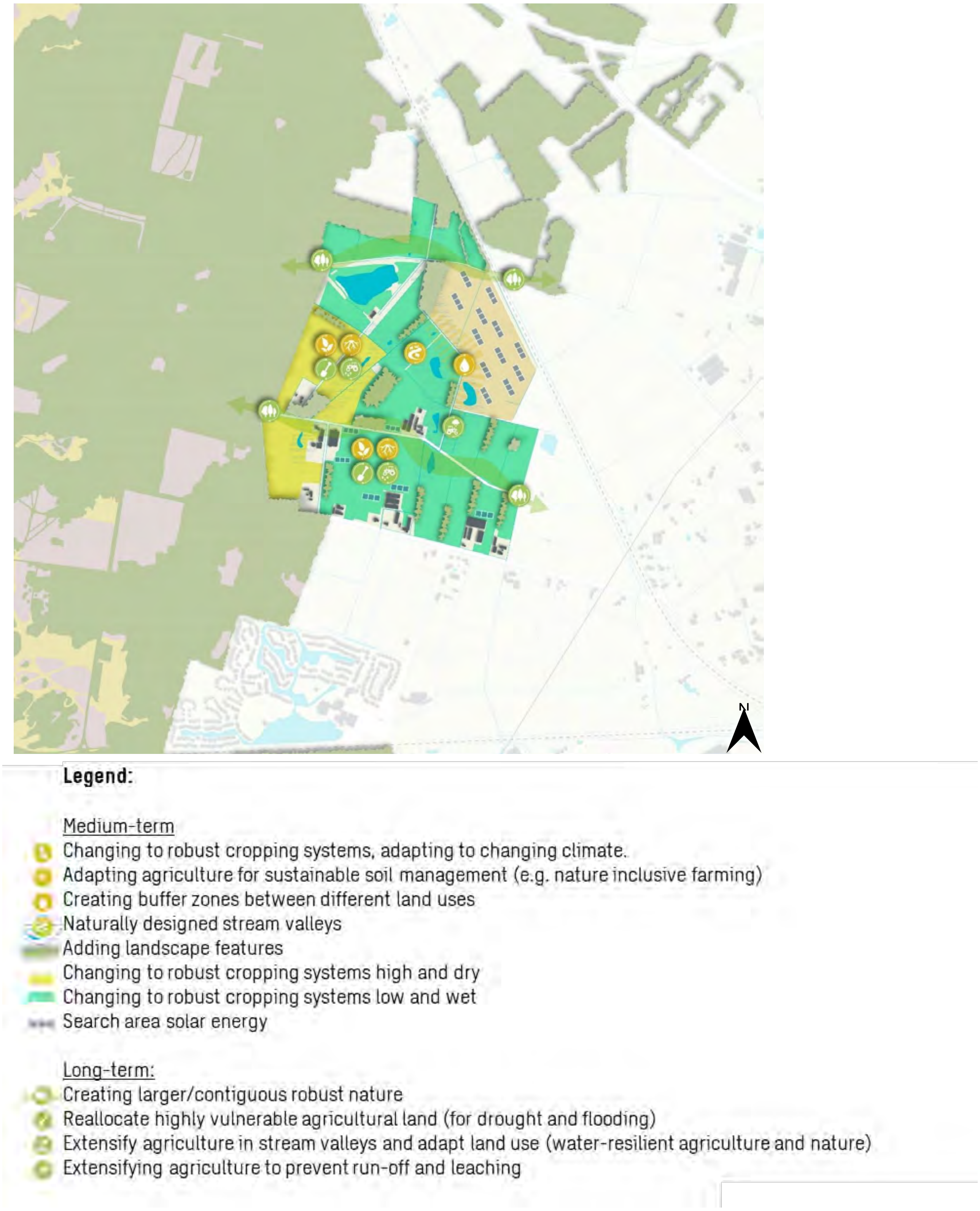
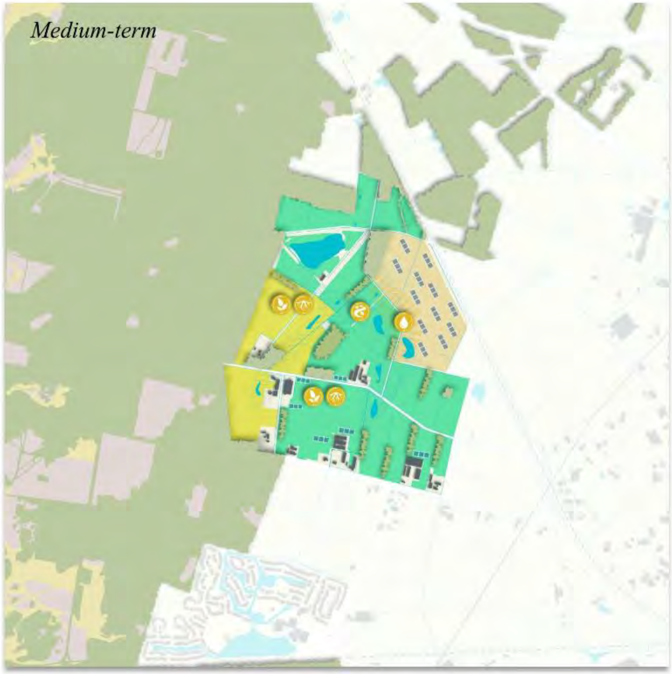
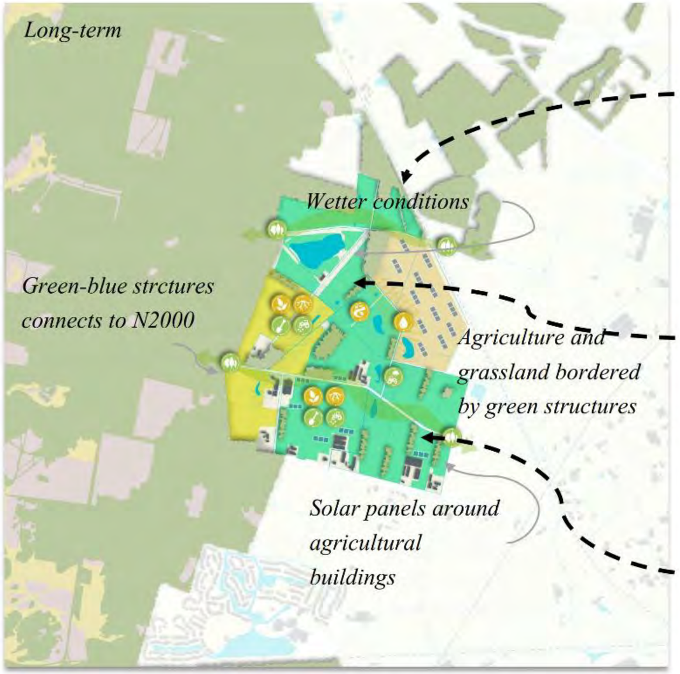


Figure 33: 'Rearranging' Boshoven in the long term

Summary sub-area Boshoven





Legend:

Medium-term
- Changing to robust cropping systems, adapting to changing climate.
- Adapting agriculture for sustainable soil management (e.g. nature inclusive farming)
- Creating buffer zones between different land uses
- Naturally designed stream valleys
- Adding landscape features
- Changing to robust cropping systems high and dry
- Changing to robust cropping systems low and wet
- Search area solar energy

Long-term:
- Creating larger/contiguous robust nature
- Reallocate highly vulnerable agricultural land (for drought and flooding)
- Extensify agriculture in stream valleys and adapt land use (water-resilient agriculture and nature)
- Extensifying agriculture to prevent run-off and leaching

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6 Conclusions and recommendations

6.1 Conclusions

Continuing on the existing pathway (business as usual) and solving bottlenecks by sector is a short-term solution, but it is not sustainable given the long-term effects. Long-term solutions require choices that intervene in land use and functions. Here, two choices are broadly possible.

1. In the first place, applying zoning around the most vulnerable locations such as stream valleys and nature reserves is appropriate as a protective measure. Conversely, zoning can also be used to absorb a negative effect such as peak loads from urban areas and designate an area for this, combined with functions that fit in with it. This corresponds to the average robust pathway in the adaptation pathway map
2. Second, a choice can be made to mix functions, taking a truly integrated look at the system behaviour of water and soil and adjusting functions accordingly. This requires an integrated approach across sectors. Nature-inclusive agriculture is an example of this in the form of extensive livestock farming with grazing management. This corresponds to the robust pathway in the adaptation pathway map.

More specifically for the three subareas, the following can be concluded:

a. Agriculture is possible now and in the future. In many places, agriculture will still be possible even after the water and soil system has become wetter, but especially in zones along stream valleys and transition zones to N2000 areas and Natte Natuurparels, partly wetter conditions must be taken into account. In this elaboration of areas, we have mainly based ourselves on the quantitative preconditions, but water quality also plays an important role and can be a guideline for changes in land use, crops or the design of buffer or transition zones. There are still opportunities for agriculture, but the form (crop) and pressure on the plots must take these conditions into account. Mixing functions with, for example, energy generation as in the Boshoven subarea is a possible form to elaborate further in cooperation with the entrepreneurs concerned.
b. The transition from the rural areas of the city of Weert to the countryside also offers opportunities for infill in which water collection and an infill as Weert's recreational area with an interlacing network of green and blue between the countryside and the city are possible.
c. Medium- and long-term measures form a transition whereby it is possible to grow towards a spatial design that is in line with the future functioning of the water and soil system.

The use of the adaptation pathway map provides insight into what bottlenecks occur, what measures and preferred pathways are possible for the rural area of Weert. At the same time, the adaptation pathway map shows that it is uncertain when these bottlenecks occur in time. Using the adaptation pathway map, spatial choices can be evaluated, and a different pathway can be taken where necessary. Finally, the adaptation pathway map makes it clear that measures needed in the long term sometimes require preparatory actions to be taken now, such as keeping areas free of water in the future or zones around stream valleys and nature areas where space is needed for transition or accommodating increased water levels.

6.2 Recommendations

The described choice to apply an integral approach is ambitious. At the moment, policy on nature areas seems to be approached in such a way that zoning (around N2000 and urban expansion areas) is applied. For this reason, we recommend starting with a zoning of the most important areas and moving from there to a more integral approach and spatial planning.

As part of the LPLG (Limburg Rural Area Programme), an interlacing network of green and blue is proposed outside the N2000 areas and the Nature Network Netherlands (NNN). In cooperation with the province of Limburg, this green-blue meander can be combined with the images outlined for the three sample areas.

6.3 Method discussion

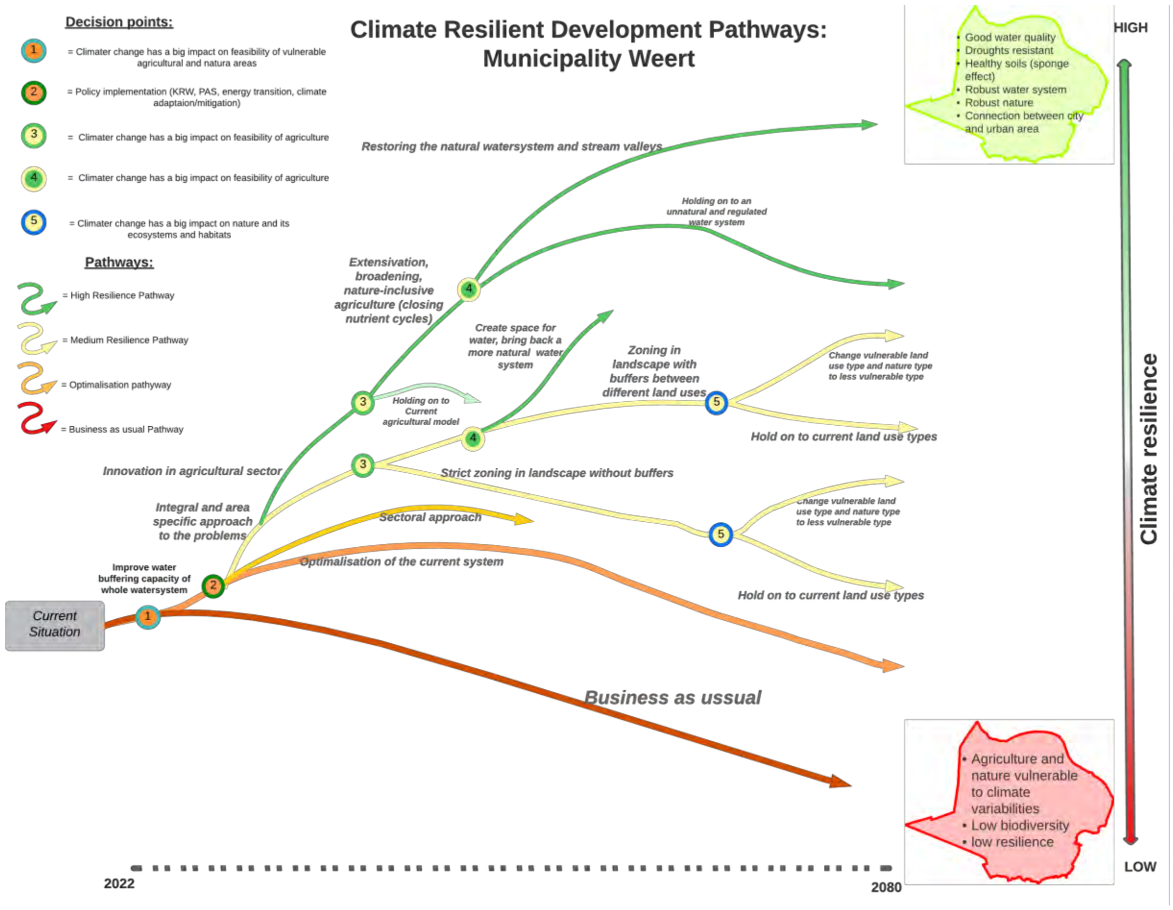
The methodology to develop adaptation pathway is abstract and mainly requires brainpower for a new system, methodology and discussion to go through bottlenecks and kinks with each other. One of the participants expressed this as follows "At first glance, the methodology is fairly abstract, but once you get to the bottom of it, the methodology provides many valuable insights. It is new and requires stepping out of the traditional area development approach".

Being prepared for future choices requires thinking through possible developments and what that means for use of space. Instead of using two working sessions, three working sessions were eventually used and a kick-off meeting in which the approach and ambition were discussed. Especially at the start, taking all stakeholders on board is very important as the methodology is complex. In addition, an extra working session was used to fine-tune bottlenecks and measures, and then arrange them according to the nodal points in time. The final preference can then be derived relatively quickly, as the choices yield more or less.

Arranging bottlenecks and measures is an intensive step. It requires preliminary work with a small team of specialists and a very systematic approach to select measures that match the different pathways.

The method is a first step. The follow-up step to achieve dialogue also requires imagining more than just an abstract timeline. Imagining it in 3D tiles can help in this respect to take those involved into thinking in terms of possibilities.

During this study, a graduation research was carried out in parallel by Joshua van Blaaderen as part of his studies at WUR (Wageningen University & Research). We worked out an alternative pathway in the form of a development pathway. Basically, this uses the same data but assumes that a choice for a desired development and ambition to be achieved is made in advance. The principle of development pathways differs from adaptation pathways in that respect. A development pathway can well be used to illustrate the pathway to a certain ambition and thus the added value to be achieved.
Figure 34 therefore differs slightly from the adaptation pathway, but otherwise shows great similarities in form and structure.



Explanation of development pathway:

The development pathway consists of four main pathways described in section 4.3.1. In red the current situation pathway, in orange the optimisation pathway, in yellow the medium robust pathway, in green the robust pathway. The green pathway leads to the most climate resilient future (High climate resilience). To follow the green pathway, it will be necessary to make the choices at the choice moments (circles with numbers in them) that contribute most to improving the robustness of the system. At choice moment 1 (climate change has a major impact on feasibility of agricultural and nature conservation), the pathway should be followed where more water should be buffered in the area. At Option 2 (Policy implementation of WFD, PAS, energy transition, climate adaptation/mitigation), the pathway should be followed where the various tasks are worked on in an integral way. To get on the green pathway, innovations are needed in the agricultural sector. It is important that extensive agriculture becomes profitable for farmers. At the third decision point (climate change has a major impact on agriculture), a choice has to be made to extensify, broaden and develop nature-inclusive agriculture. At the fourth decision point (climate change has a major impact on agriculture), a choice should be made to design the water system more naturally to achieve the highest level of robustness. The fifth choice moment (climate change has a major impact on nature and its ecosystems and habitats) does not occur on the green pathway. This is because the system is adapted and robust enough that climate change does not have too great an impact on nature. However, the fifth choice moment will be important on other pathways because the system is not robust enough.

Figure 34: Development pathway Municipality of Weert

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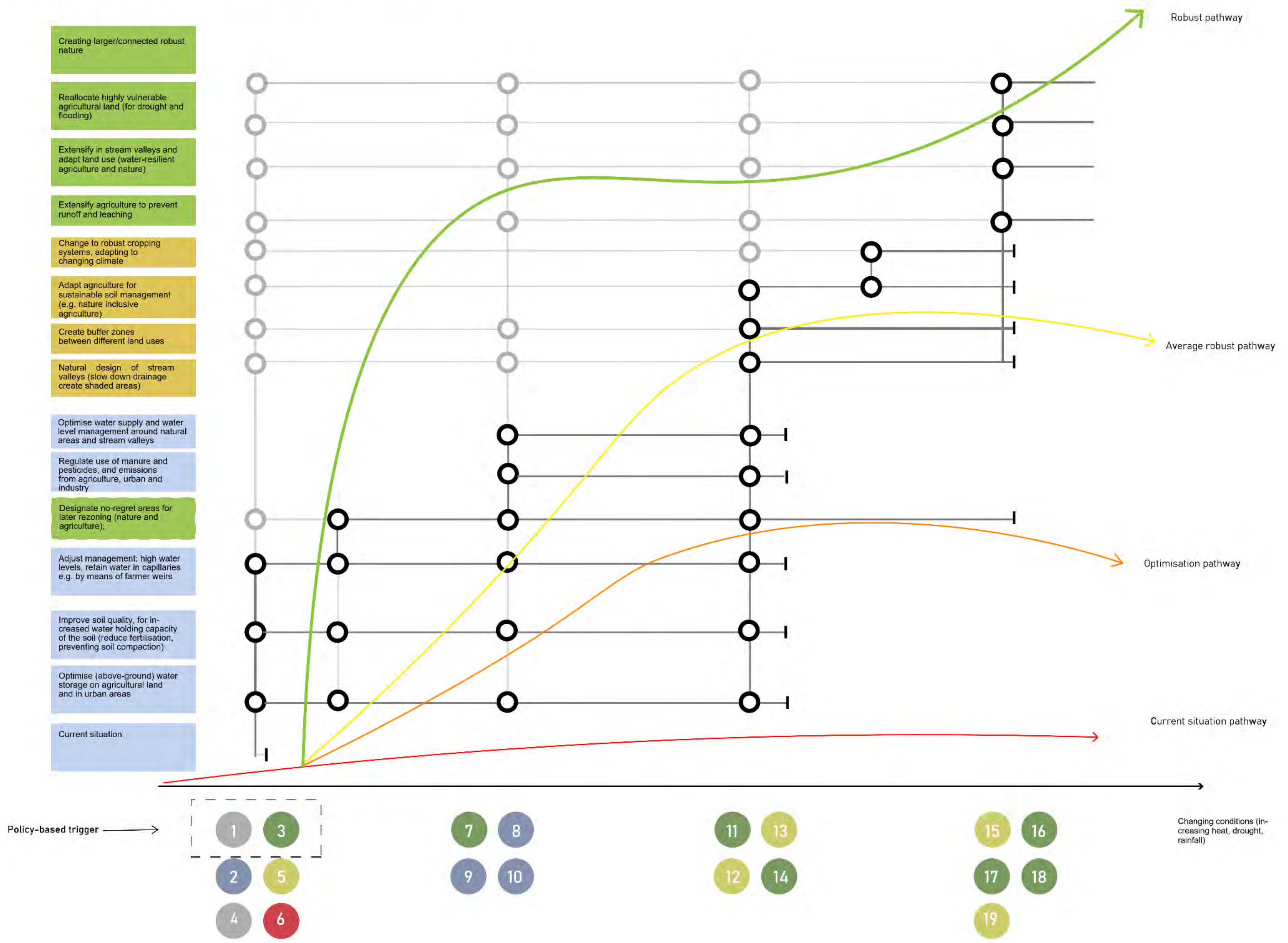
Appendix 1 Pathwaymap

Adaptation pathways for the rural area of Weert

<u>Future vision:</u>

The rural area of Weert is a climate robust system, which is balanced and able to cope with changing conditions. A healthy soil and water system are of great importance here. The soil is in good condition and can therefore capture and store water. The water system is flexible; by creating extra space for water, extreme conditions can be dealt with. There is a high variation in land use, where different functions are combined. As a result, there is a good connection between urban and rural areas, creating a rich landscape with strong green-blue networks and good biodiversity. Farmers are the managers of the countryside and take care of a healthy and high-quality countryside. Part of this is nature-inclusive agriculture where leaching into and pollution of adjacent nature is minimised, for the benefit of good water quality and a healthy ecosystem.



Rearranging differently

Use differently

Optimise

<u>Bottlenecks</u>

<u>Phase 1</u>

1. Water quality does not meet the established European WFD policy goals for the year 2027
2. Limited buffer capacity in system causes more frequent flooding in rural areas
3. As a result of the nitrogen policy pursued, space is reserved around N2000 for buffer areas to protect nature
4. Interweaving of functions (urban area, nature and agriculture) causes conflicting conditions (e.g. water levels) in ground and surface water (drought and water excesses)
5. Increasing drought and limited water retention capacity of the subsoil create problems for agriculture
6. Extreme rainfall causes flooding in and around urban area, effect outdoor area

<u>Phase 2</u>

7. Increasing dry periods and limited water retention capacity of the subsoil cause drought problems for nature, insufficient groundwater and seepage in stream systems
8. Agricultural leaching and run-off of polluted soil and surface water reduces water quality
9. Increasing heat and rising water temperatures cause fluctuations in water quality
10. Increased dry periods and reduced runoff reduce the water quality of surface waters

<u>Phase 3</u>

11. Biodiversity vulnerable to extreme weather (too dry / too wet / too dirty) putting ecosystem under pressure.
12. Flooding causes damage in agriculture due to flooding from stream valleys or flooding of fields
13. Extreme rainfall causes erosion of agricultural land
14. Due to interwoven functions (in addition to nature) and pressure on the water system from emissions (urban area, industry), water quality forms a threat to the environment

Phase 4

15. Climate change (increased humidity and heat) causes an increase in diseases and pests
16. Weather extremes cause large fluctuations in water levels, peak loads in surface water and irreversible effects on water quality and riparian vegetation
17. Due to changing climate and fragmented landscape, ecosystems and habitats are shifting and disappearing
18. Dry summers and heat increase the risk of forest and wildfires
19. Due to changing climate, current agricultural practices are not adequate/ profitable.

Nature related bottleneck

Water related bottleneck

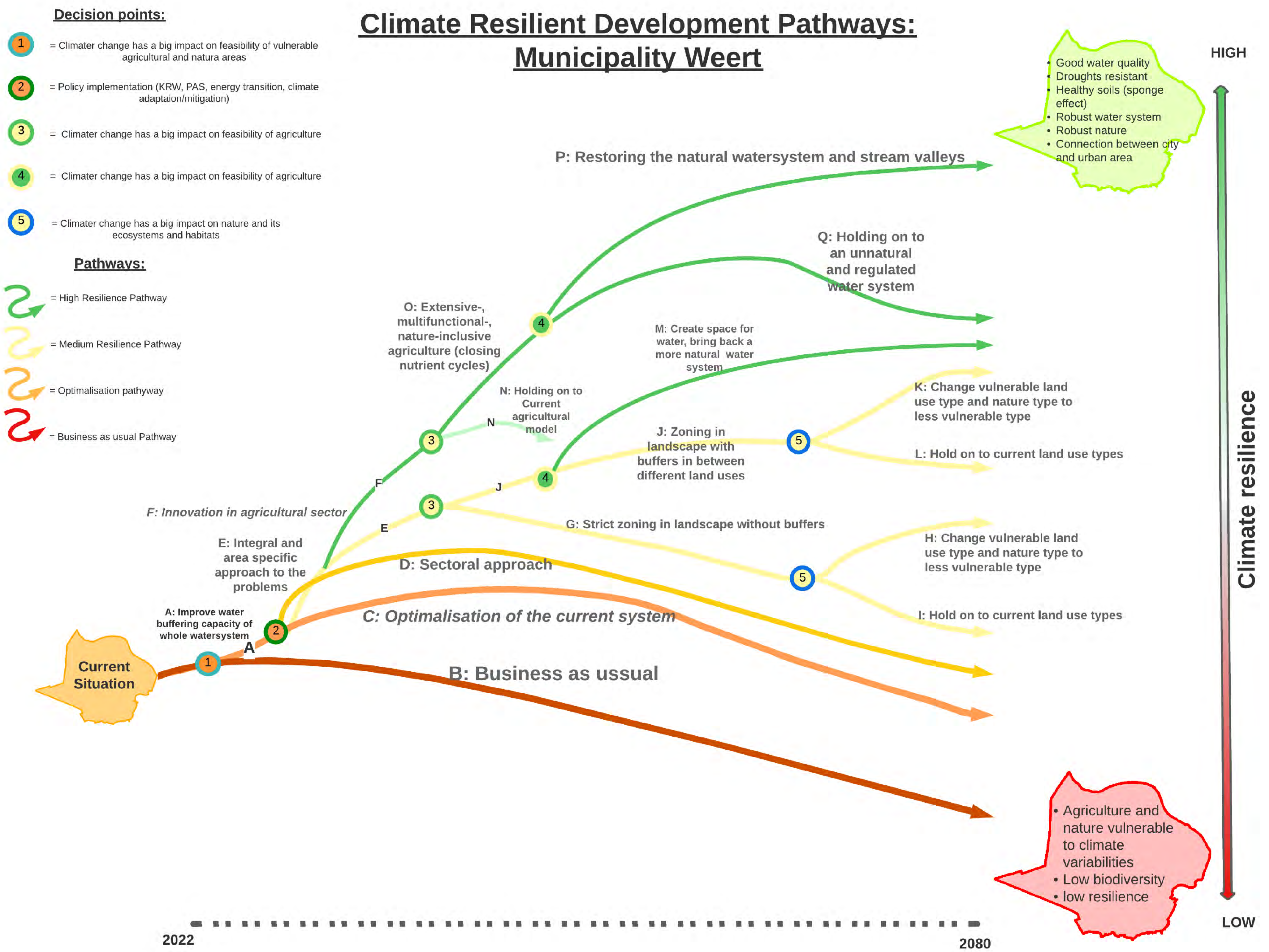
Agriculture related bottleneck

Integral bottleneck

Urban area related bottleneck

SWECO

Climate Resilient Development Pathways: Municipality Weert



Appendix 2 - Elaboration in 3 subareas

Introduction

This appendix contains the three subareas of Weert as a cross-section of the rural area. This appendix contains background information of these three subareas.

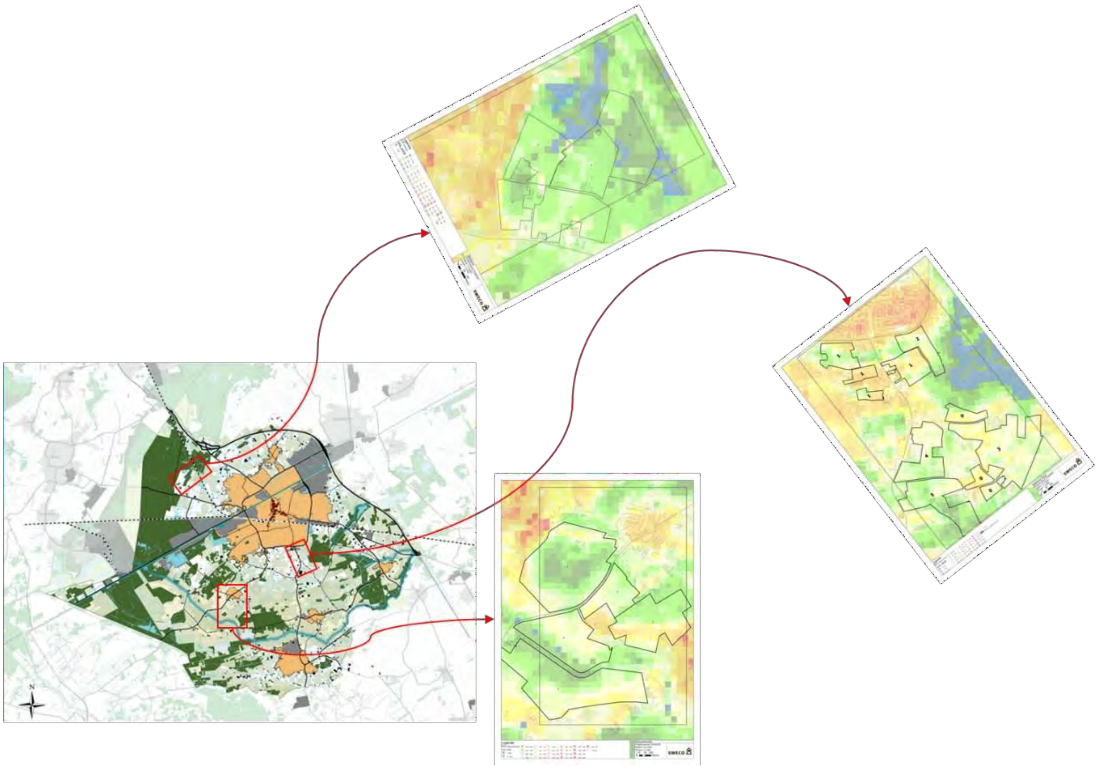
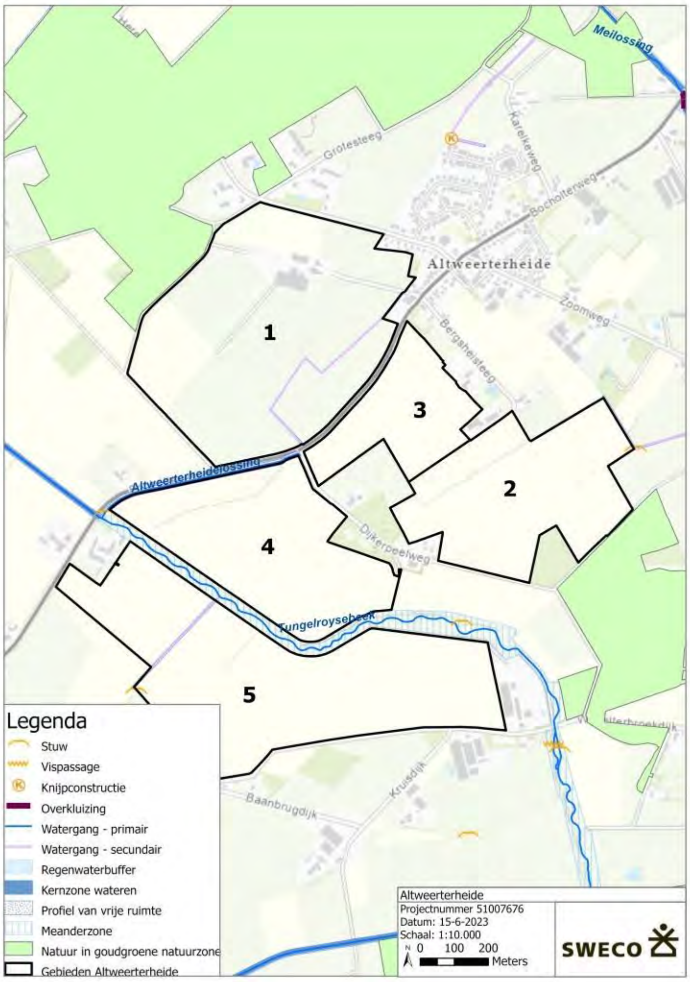
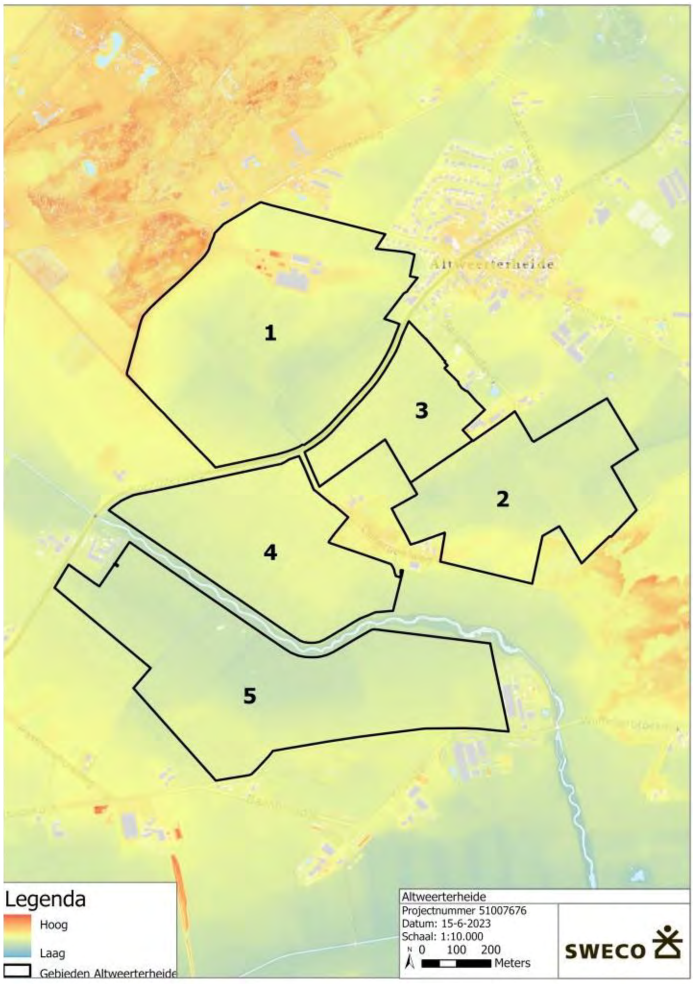


Figure A1: Location of the three subareas

Subarea 1 Altweerterheide and Tungelroyse brook

This subarea is characterised by core areas of agricultural use, also in the future and zoning along the stream that is more oriented towards natural landscaping. The core Altweerterheide on the north side is located at the intersection of the connection between the forest areas Altweerterheide on the northwest side and Tungelerwallen to the southeast and the axis from the stream valley via Bocholterweg to Weert. Land use is now predominantly as arable farming with a small section of grassland along the forest area on the northwest side.





Figures A2 and A3 situation and elevation (AHN4)

The area is characterised by the following types of plots with the numbering as shown in Figure A2:

1. Grassland, with wet spot
2. Arable, with wet spot
3. Arable, with dry spot
4. Arable farming, near Tungelroyse brook
5. Grassland, near Tungelroyse brook

The Altweerterheide core is relatively young, as at the beginning of the last century there was only a single dwelling and farm. Figure 4 shows the picture that was present around 1940 - 1945, with von Frijtag Drabbé[3] mapping all of the Netherlands into dry and wet areas in a shade of red to blue. When the first country-wide groundwater depth map of the Netherlands was produced in the early 1950s, this map was used, which was important for determining the potential for agricultural production. The nuances between red and blue show transitions from wet to dry conditions.

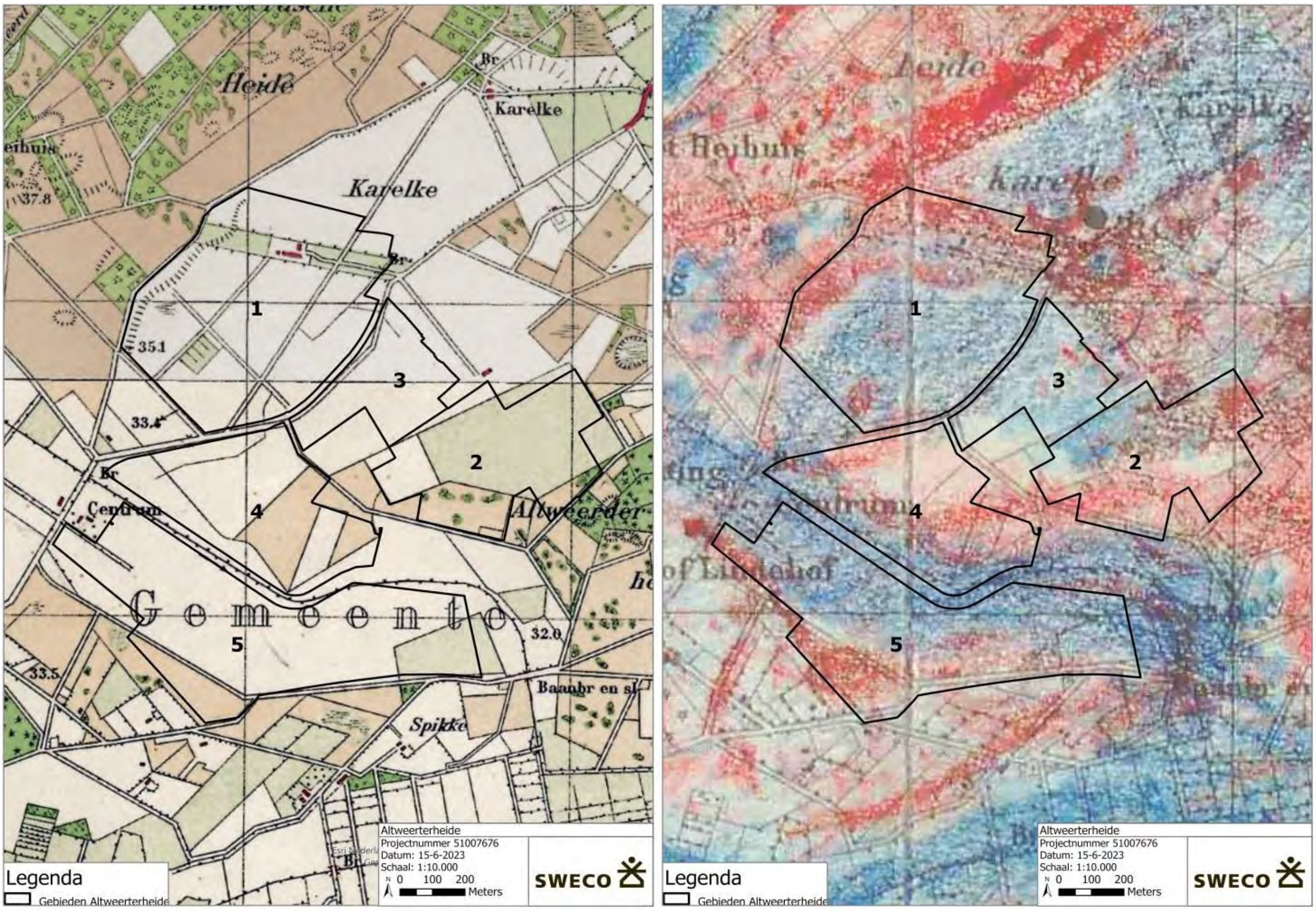


Figure A4 and A5 Historical map and von Frijtag Drabbé's map that formed the basis for the groundwater depth map from the 1950s

3

Water management

The Tungelroyse brook is characterised by remodelling since the 1990s of last century as a stream that meanders in a 10-20 m zone and has a two phase profile, with one bank having a gentle slope (about 1:3 - 1:5) and the other bank having a steeper slope of about 1:1.5. The level in the stream varies based on a threshold with a lower limit of +29.61 m NAP in a range ranging from +29.8 to +30.2 m NAP (range of about 0.4 m). The ground level along the stream is higher than +31.3 m NAP which means there is a drainage of more than 1.1 m here. The bottom of the stream is at about NAP 29.50 m.

The impacts have been calculated and analysed at the scale of Limburg as part of the Limburg Water Management Study (LIWA). The results of this study give an indication of the changes that occur. For translation at plot level, this gives an indication.

Land use and climate change impacts

Agricultural land use is predominantly arable with only along Altweerterheide a section of grassland. This is mainly motivated by the wetter conditions in this plot.

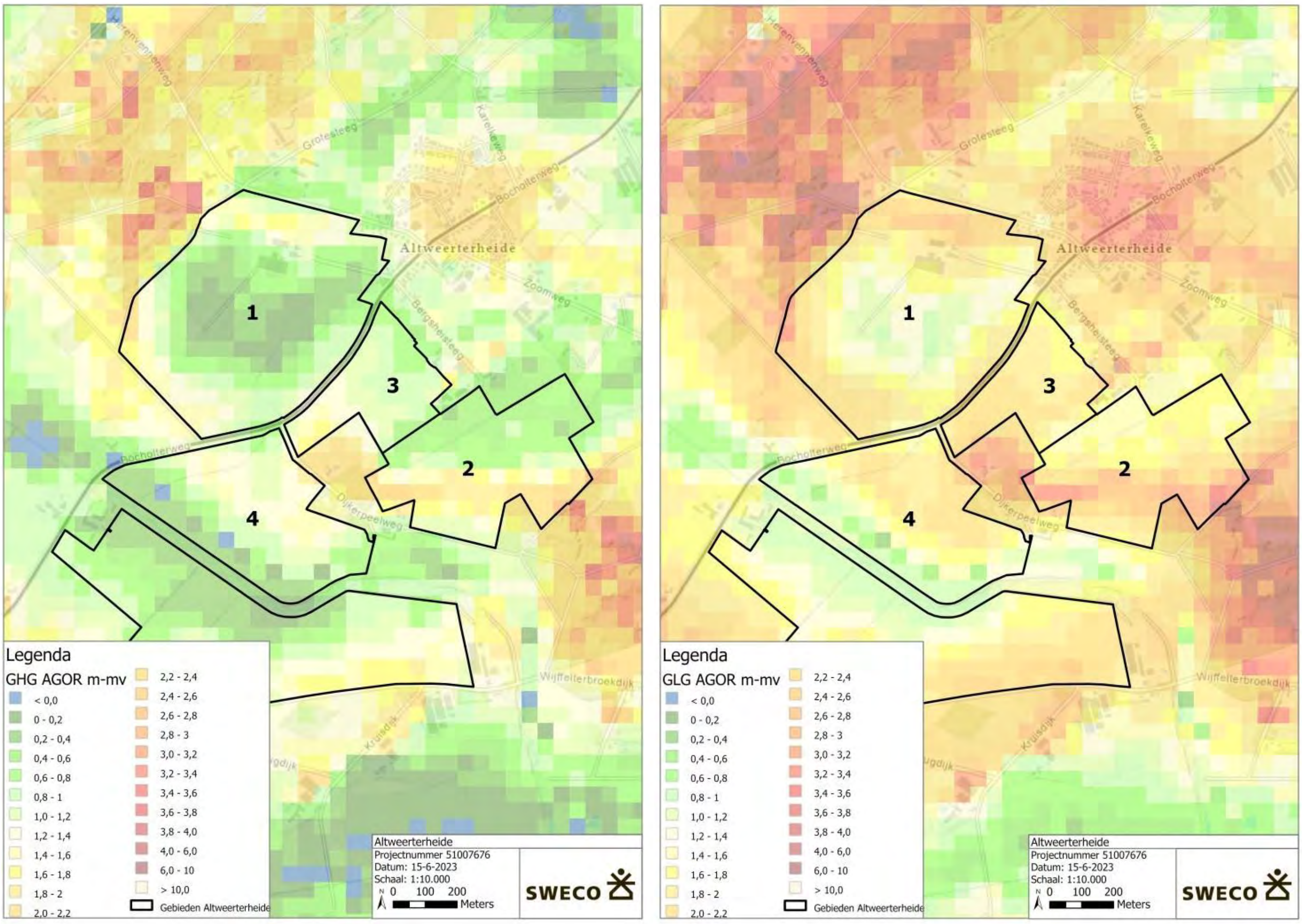


Figure A6 and A7 GHG and GLG

The Mean Highest Groundwater Level (GHG) in plot 1 is at about 0.2 - 0.4 m below ground level (coloured green). This also occurs in a zone along the stream. This zone along the stream has always had much wetter conditions, as evidenced by historical maps in Figure A5: on these, the area is marked as wet.

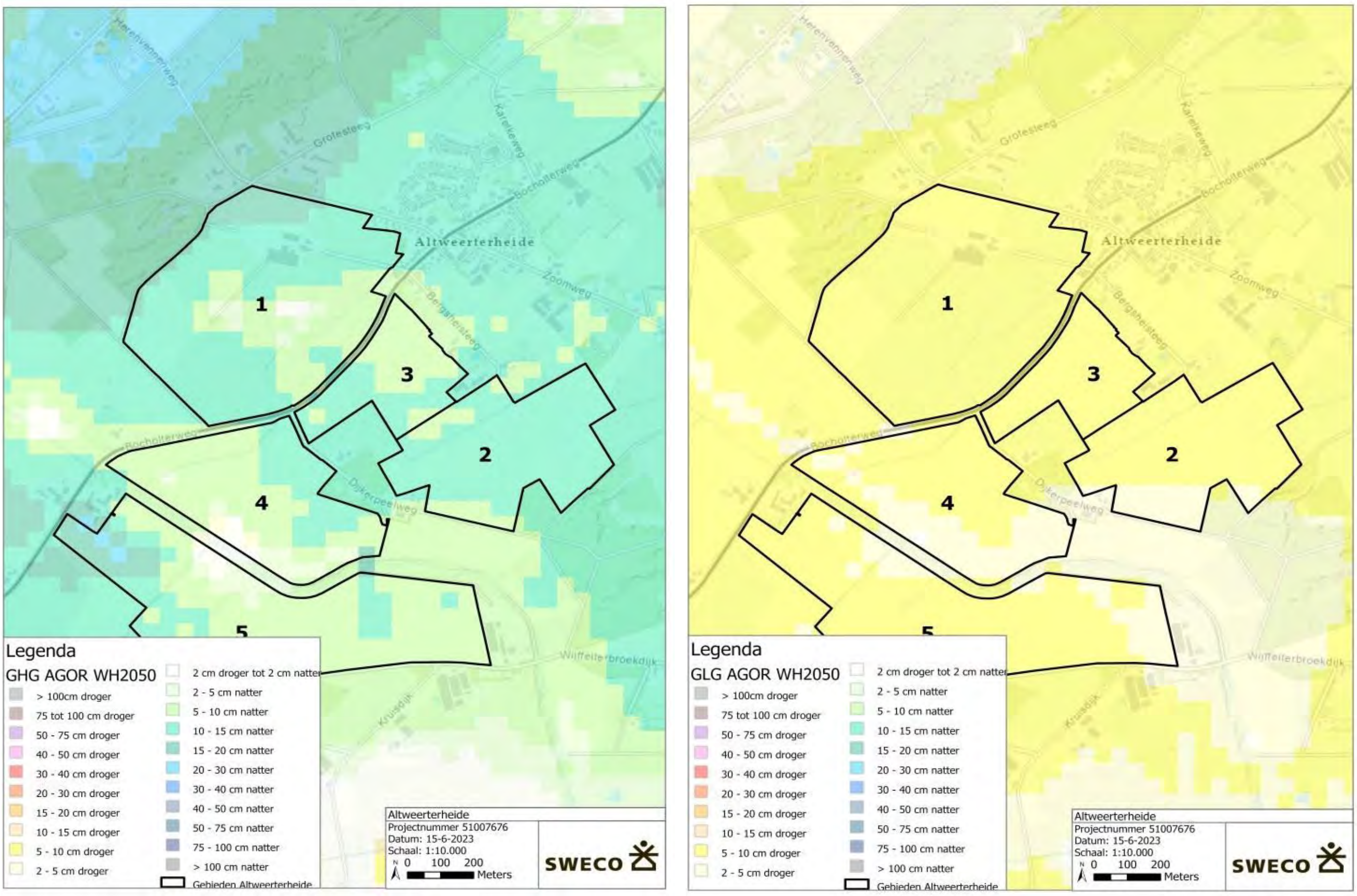


Figure A6 and A7 difference in groundwater levels in 2050 GHG and GLG compared to current situation, droger=dryer & natter=wetter

Effects of climate change

As shown in Figure A6, the GHG changes in 2050 (green-blue areas in Figure A6) and the GLG will continue to drop about 0.10 over much of the area (yellow areas in Figure A7). This mainly means that the extremes increase.

Impact on agricultural yields

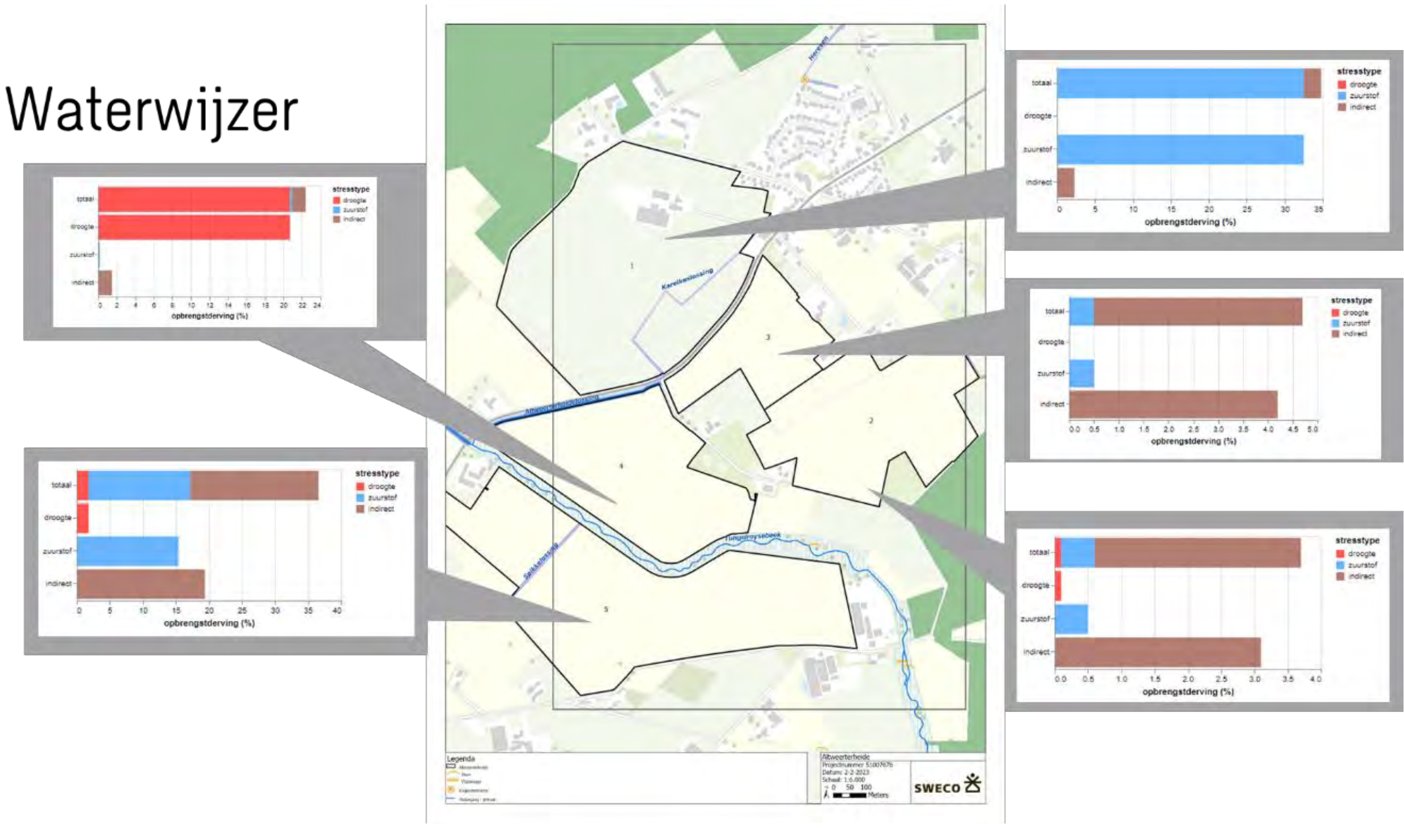


Figure A8 Outcomes “Waterwijzer” showing the yield loss, in **red** caused by drought, in **blue** caused by oxygen deficit, in **brown** by indirect causes

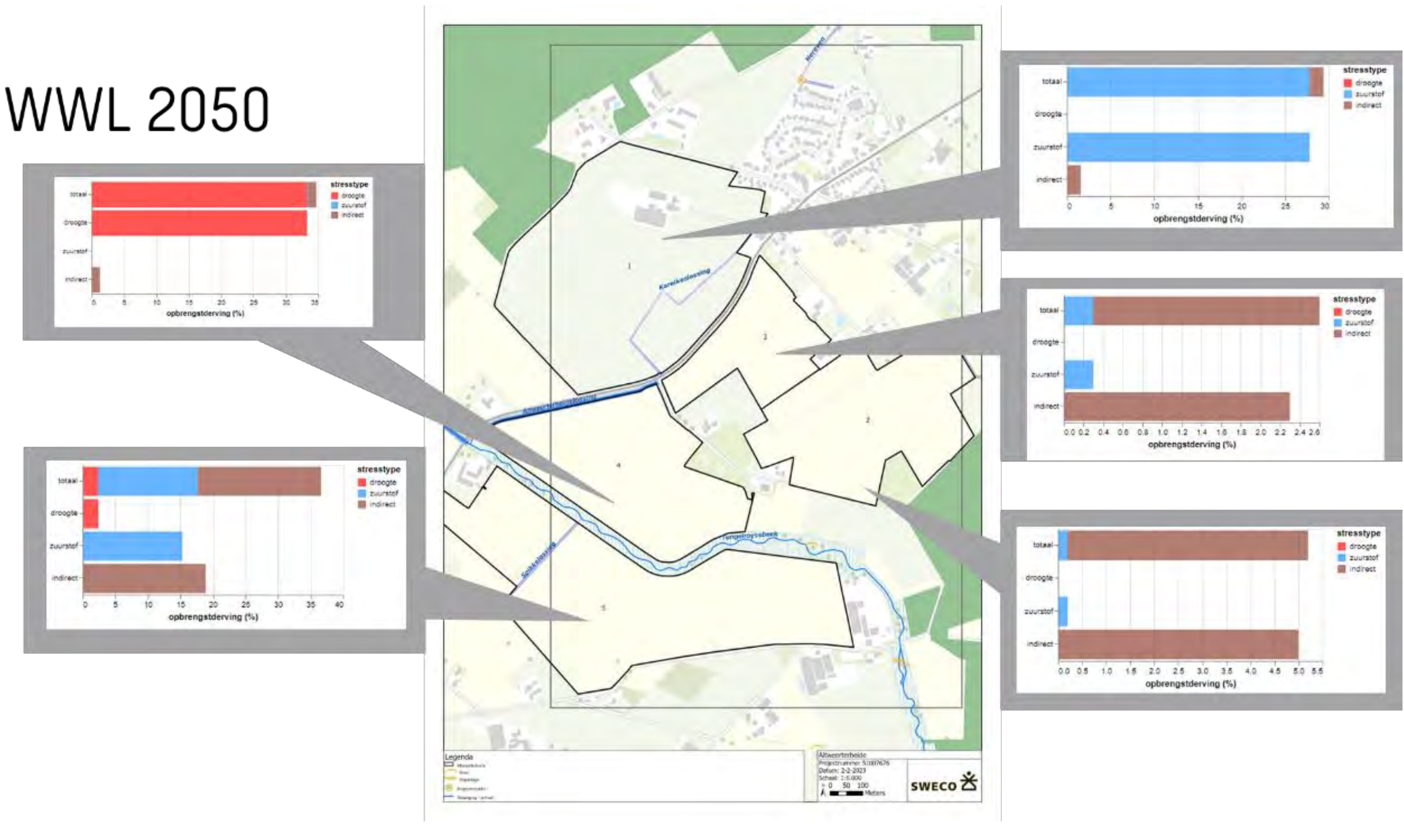


Figure A9 Outcomes “Waterwijzer” 2050, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A9 shows the results of the Waterwijzer for current crops in 2050. The Waterwijzer gives an indication of the relative crop damage caused by water shortage (red, drought), wet damage (blue, displacement of oxygen in the soil by water causes suffocating roots) and indirect damage (e.g. due to shifting seasons, trampling losses and mowing moments). As the GHG will continue to drop in the future, drought-related damage increases. This happens especially on plots where the groundwater level is already dropping far. On the relatively wet plots not much will change.

Building blocks Alweerterheide

Cross-section 1 (medium-term)	1. Dry 'high areas', adjust cropping systems. Nuance: as the stream valley becomes wetter, the low parts become drier -> but stretches the life span of arable plots in the high area
Change to robust crop systems, adapting to changing climate.	1. icons, customise cultivation -> passport
Adapting agriculture for sustainable soil management (e.g. nature-inclusive agriculture).	2. Adapt farm management/agriculture to wetter conditions, accept water for longer time on land. Mowing less.
Create buffer zones between different land uses	3. Restore landscape elements, adapt ditches, green blue network as landscape elements. Linking outdoor area with built-up area via ditches, and green structures.
Natural design of brook valleys.	4. Give stream more space, 100-250m, landscaping.

Cross-section 2 (long-term)	
Create larger/contiguous robust nature.	1. Stream, and stream accompanying forest. Stream as main ecological structure Add landscape elements Use.
Reallocate highly vulnerable agricultural land (for drought and flooding).	2. Only the stretches along the Brook to be zoned differently, the rest being covered by theIntensive zone. The stream zone forms a transition zone between intensive agriculture and nature.
Extensify in stream valleys and adjust land use (water-conserving agriculture and nature).	3. Only the stretches along the Brook to be zoned differently, the rest being covered by theIntensive zone. The stream zone forms a transition zone between intensive agriculture and nature.
Extensive farming to prevent runoff and leaching.	*4 Farm buildings against the stream, create risk of pollution.*

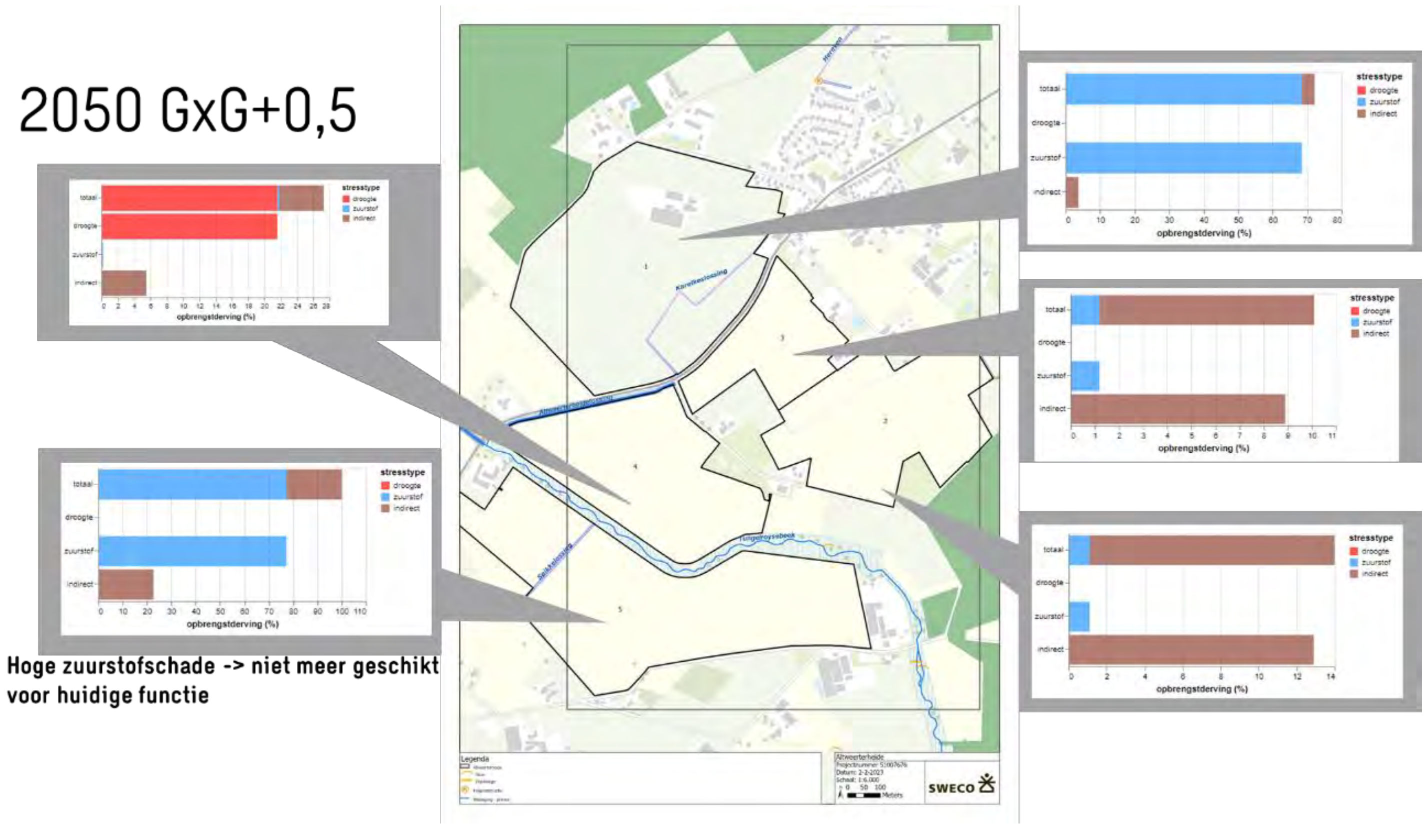


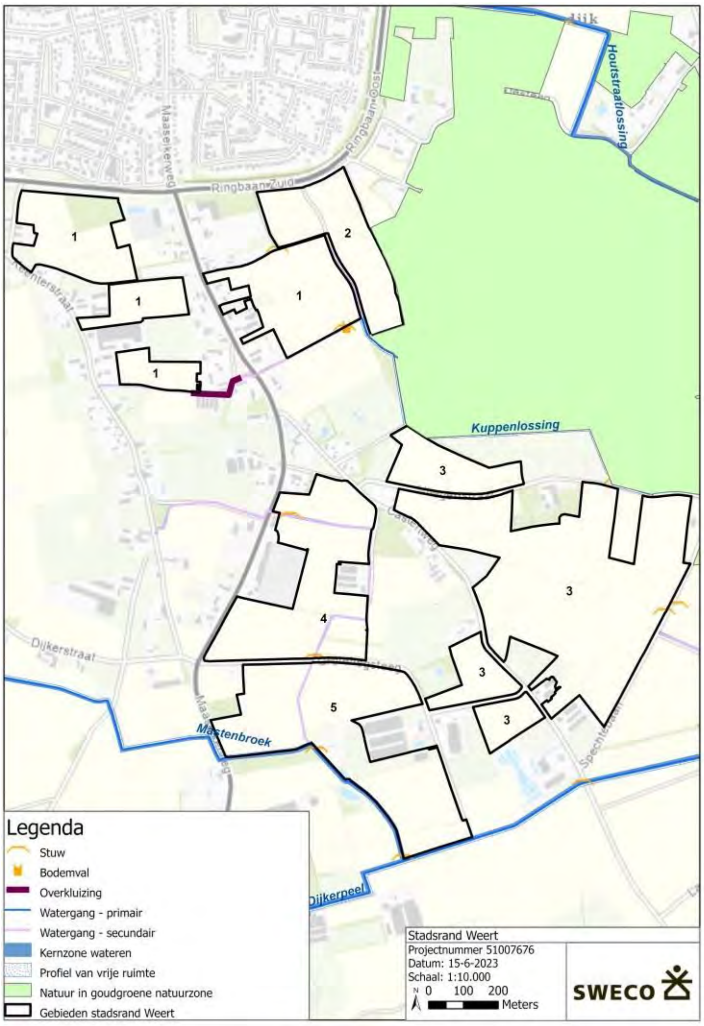
Figure A10: Outcomes water indicator “Waterwijzer”, situation with elevated groundwater levels, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A10 shows the results of the Waterwijzer for current crops in 2050 when groundwater levels are raised 0.5 meters. The Waterwijzer gives an indication of the relative crop damage caused by a water shortage (red, drought), wet damage (blue, displacement of soil oxygen by water causes suffocating roots) and indirect damage (including through shifting seasons, trampling losses and mowing times). As groundwater levels rise, crop losses from drought damage decrease, but crop losses from wet damage increase.

Subarea 2 City rural areas Weert

This subarea is characterised by development along infrastructure to the south of Weert's city rural areas. The following 5 types of areas have been distinguished here:

1. Arable farming, high dry soils
2. Arable, high ground, deep water table
3. Arable farming, high dry soils
4. Orchards
5. Grassland, low grounds



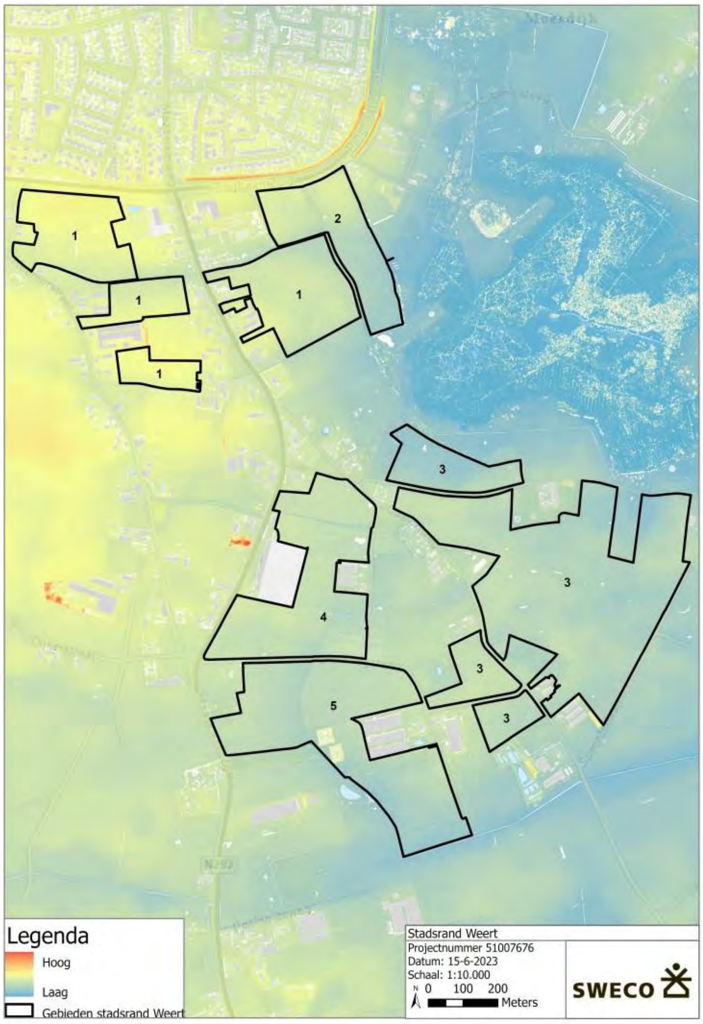


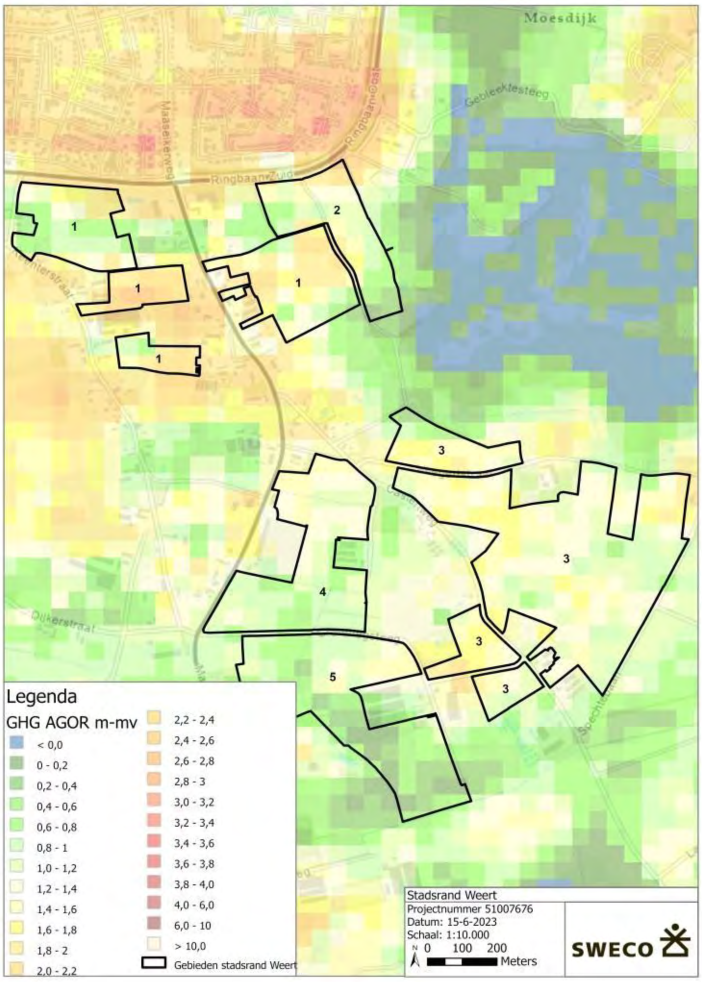
Figure A11 Current situation and Figure A12 Elevation gradient

Figure A12 shows that the natural areas in Figure A11 are lower than the agricultural plots. Between the agricultural plots in the north and south there are relatively large differences in elevation.

Figure A13 Historic land use and Figure A14 wet/dry conditions 1940-1945 von Frijtag Drabbé

Historical maps show that the area where nature now is located was previously a wet (figure A14) marsh (figure A13). Historical irregular block parcels of land on the higher arable plots are still reflected in the current plot division.

Water management



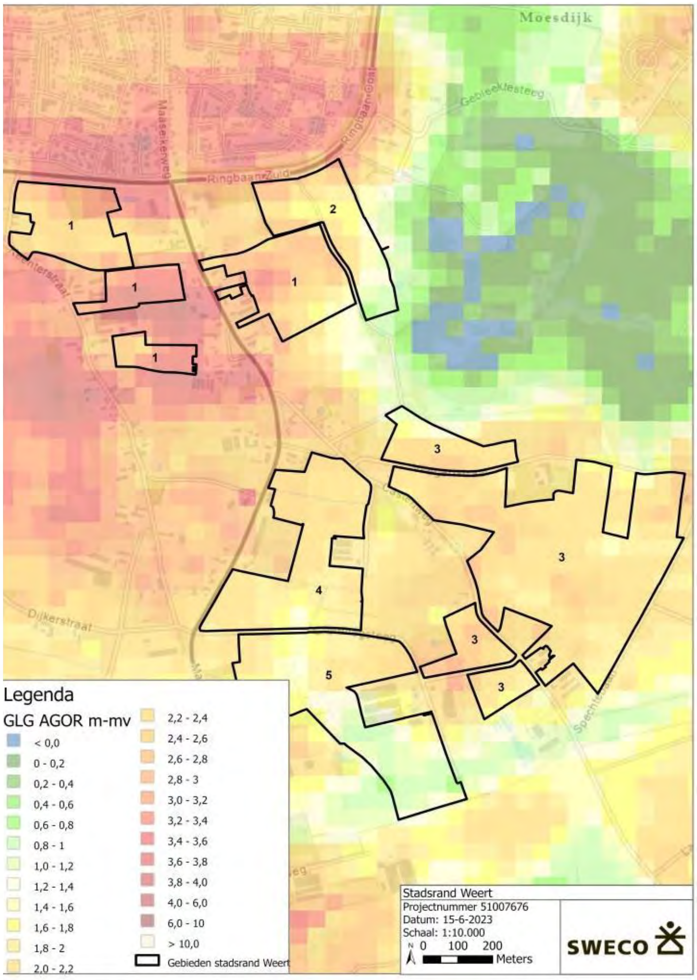
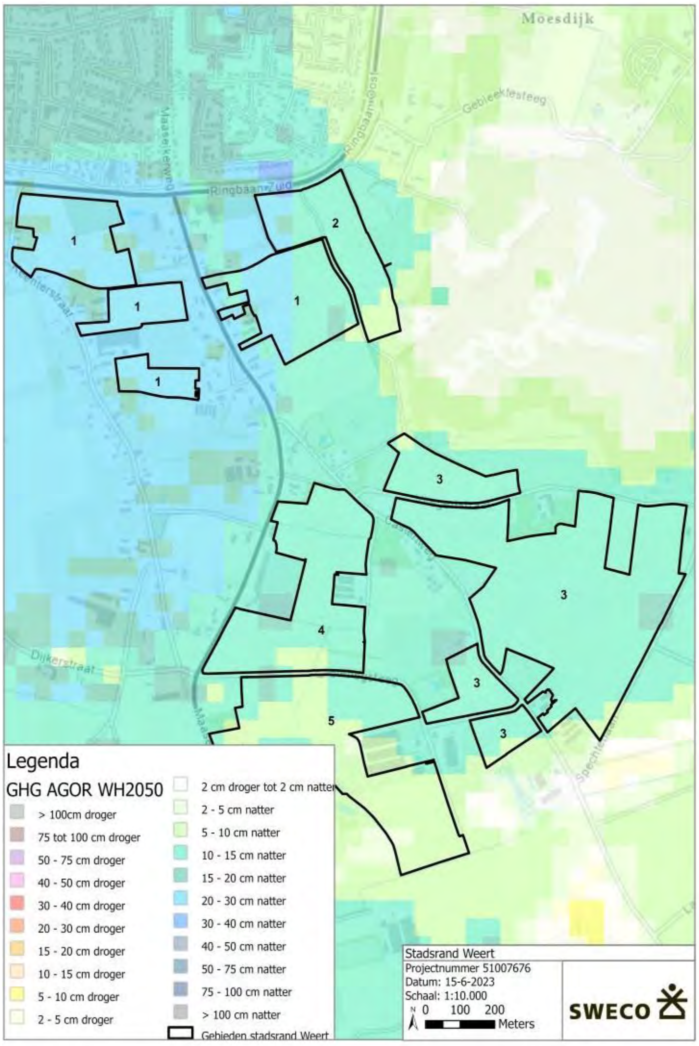


Figure A15 GHG and Figure A16 GLG in the current situation

The Mean Highest Groundwater Level (GHG) is >2 meters below ground level in plot 1. The agricultural areas to the south have shallower groundwater levels. Figures A15 and A16 also clearly show that in wetlands to the east, groundwater levels are much less deep below ground level than in the rest of the area.

Effects of climate change



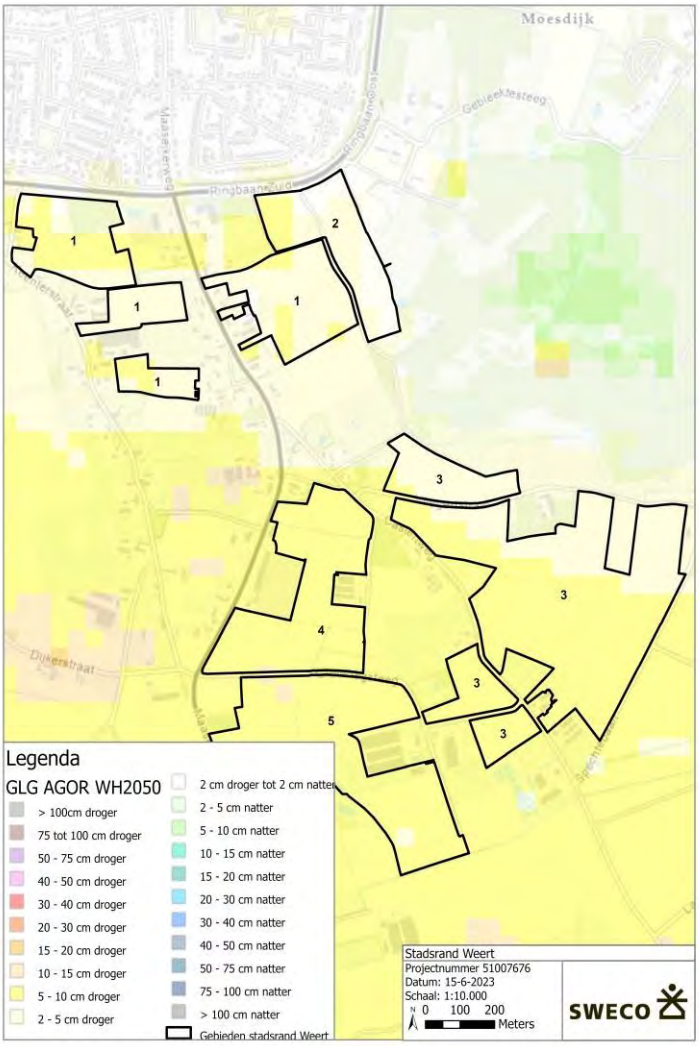


Figure A17 difference GHG 2050 and figure A28 difference 2050 for the GLG compared to the current situation

The GHG will rise slightly in the future (green in figure A17), while the GLG will continue to drop (yellow in figure A28). This means that extremes will increase.

Figure A19 Water indicator “Waterwijzer”, agriculture current situation, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A20 Water guide agriculture 2050, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A20 shows the results of the Waterwijzer for current crops in 2050. The Waterwijzer gives an indication of the relative crop damage caused by water shortage (red, drought), wet damage (blue, displacement of oxygen in the soil by water causes suffocating roots) and indirect damage (e.g. due to shifting seasons, trampling losses and mowing moments). As the GHG will continue to drop in the future, drought-related damage increases. This occurs particularly on plots where the groundwater level is already dropping far. On the relatively wet plots, this may cause a slight decrease in wet damage.

Building blocks urban periphery

Cross-section 1 (medium-term)

Building block	Notes
Change to robust crop systems, adapting to changing climate.	1. Dry parts cultivation systems adapt to future situation, using groundwater passport in intensive parts.
Adapting agriculture for sustainable soil management (e.g. nature-inclusive agriculture).	2. Especially applicable to the parts with land-based agriculture.
Create buffer zones between different land uses	3. Zoning around nature reserve, zone of extensive agriculture around nature reserve, more gradual transition. • Walkout areas from the city 'circle'first example, new cycle bridge for better connection. • Historic structure, as green-blue veining. • Buffer plans water around city on map
Natural design of brook valleys.	4. n.v.t.

Cross-section 2 (long-term)

Building block	Notes
Create larger/contiguous robust nature.	1. Run-off from the city creates structure to the natural areas and villages around it. - Use of historic landscape structures to use as ecological structures.
Reallocate highly vulnerable agricultural land (for drought and flooding).	2. Dry farmland adjacent to urban fringe, to be reallocated for buffer.
Extensify in stream valleys and adjust land use (water-conserving agriculture and nature).	3. n.v.t.
Extensive farming to prevent runoff and leaching.	*4. Intensive (partly) non-land farming in south-east, waters or on tungelroyse brook. Risk of pollution. Extensify in these areas.*

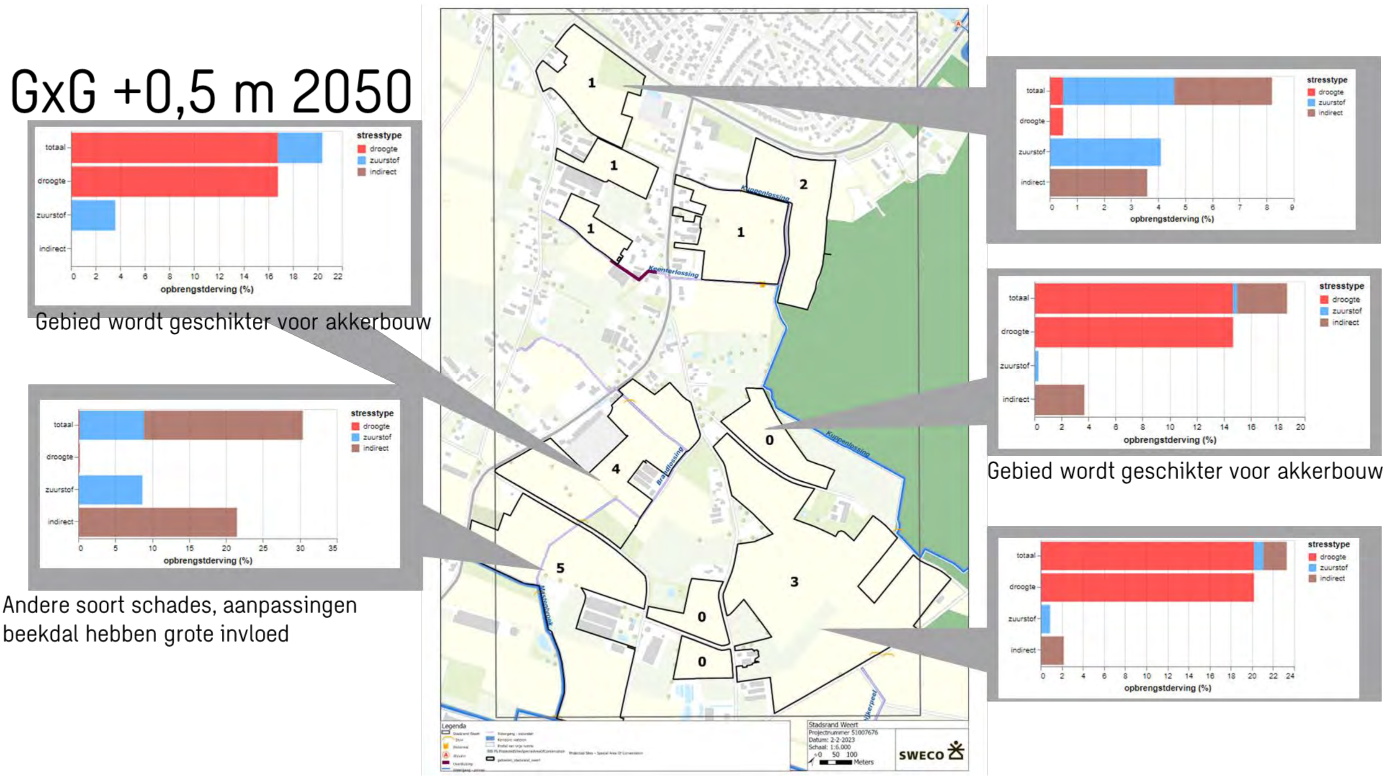


Figure A21 Water indicator “Waterwijzer”, agriculture elevated groundwater levels, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A21 shows the results of the Waterwijzer for current crops in 2050 when groundwater levels are raised 0.5 meters. The Waterwijzer gives an indication of the relative crop damage caused by a drought, wet damage (blue, displacement of soil oxygen by water) and indirect damage (including through shifting seasons, trampling losses and mowing times). With higher groundwater levels, crop losses due to drought damage can be reduced. This increases the likelihood of crop loss due to wet damage for some plots.

Subarea 3 Boshoven

This subarea is located along the eastern flank of N2000 area Weerter- and Budelerbergen & Ringselven and in the upper reaches of the Oude Graaf. This area is now subject to agricultural use, partly by intensive livestock farming.

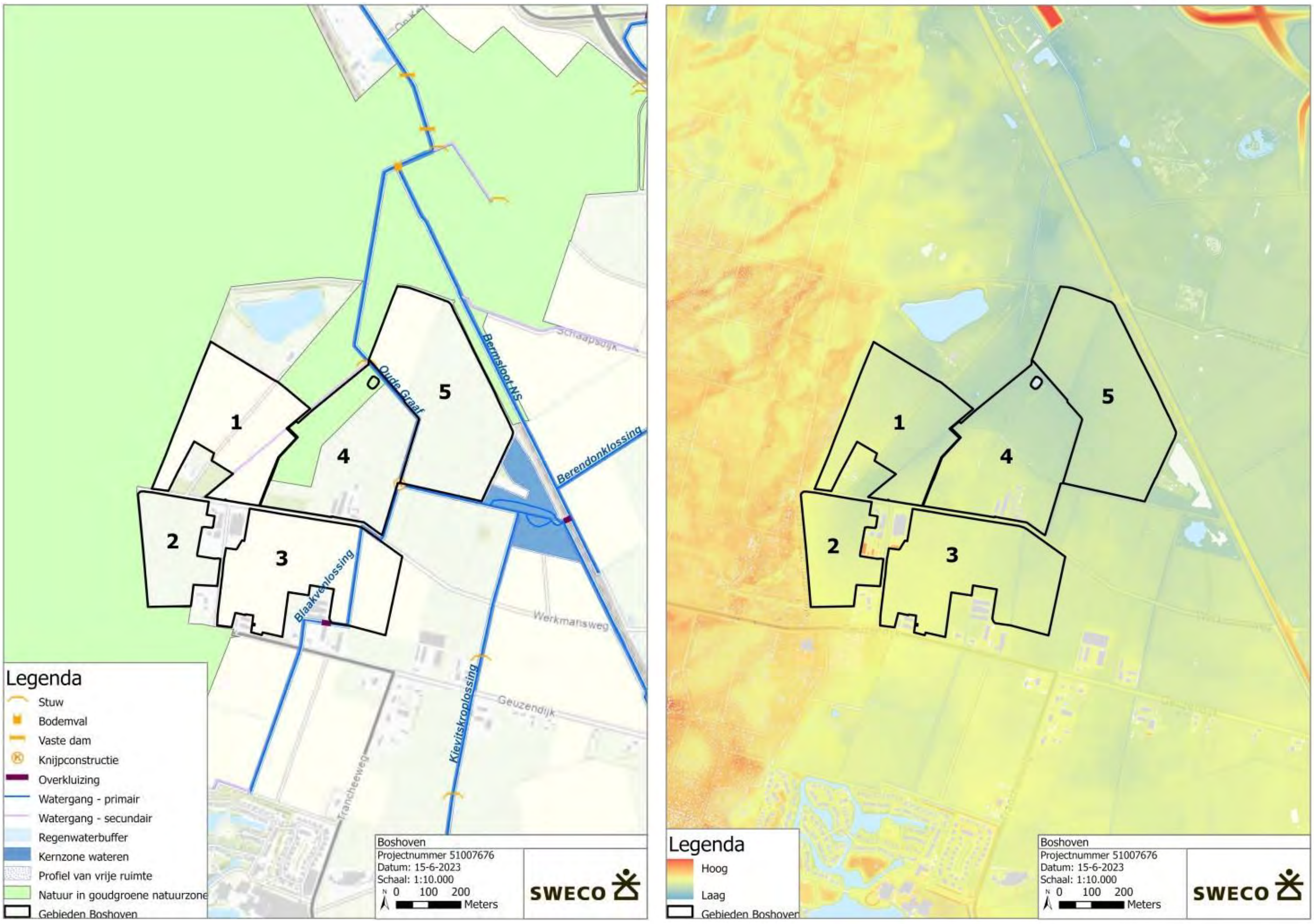


Figure A22 current situation and figure A23 elevation

In the current situation, the following types of plots can be distinguished:

1. Arable, high soil, shallow water table
2. Arable, high ground, deep water table
3. Grassland, high ground
4. Grassland, low soil, shallow water table
5. Grassland, high ground, much desiccation

There is a height difference between the higher (Figure A23, orange-yellow) Natura2000 area Weerter- en Budelerbergen & Ringselven and the lower (green-blue) agricultural plots.

Figure A23 Historic land use and Figure A24 wet/dry conditions 1940-1945 from Frijtag Drabbé

Historical maps of the area show that no stream or other watercourses used to run in the area. Instead, wet parts are inscribed (Figure A23) and toponyms like 'Broek' indicate wet places. Frijtag Drabbé's map of dry and wet conditions also shows a large blue stain near the agricultural plots (Figure A24). This indicates that historically wet conditions are common here, while in on the higher moors dry conditions apply.

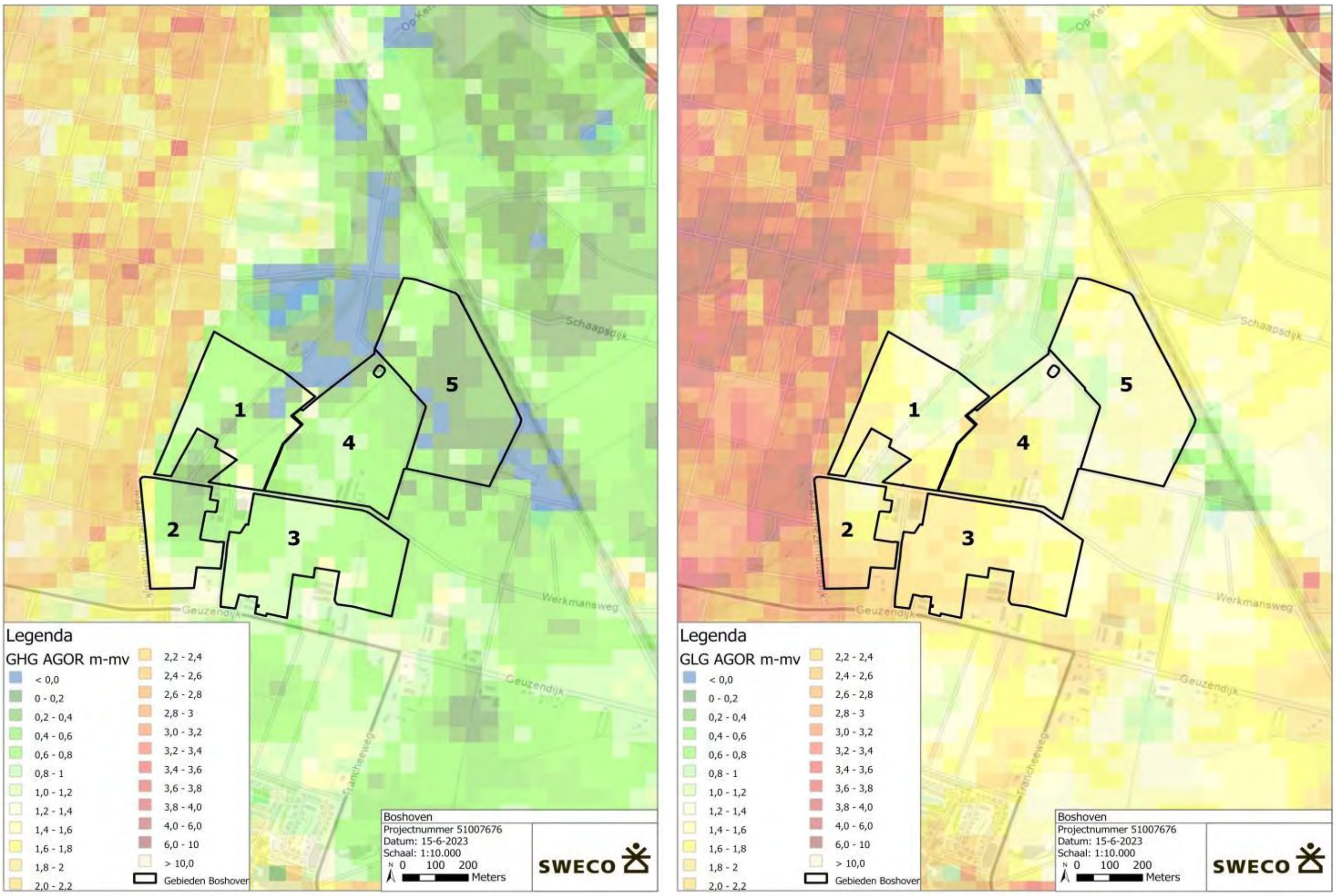
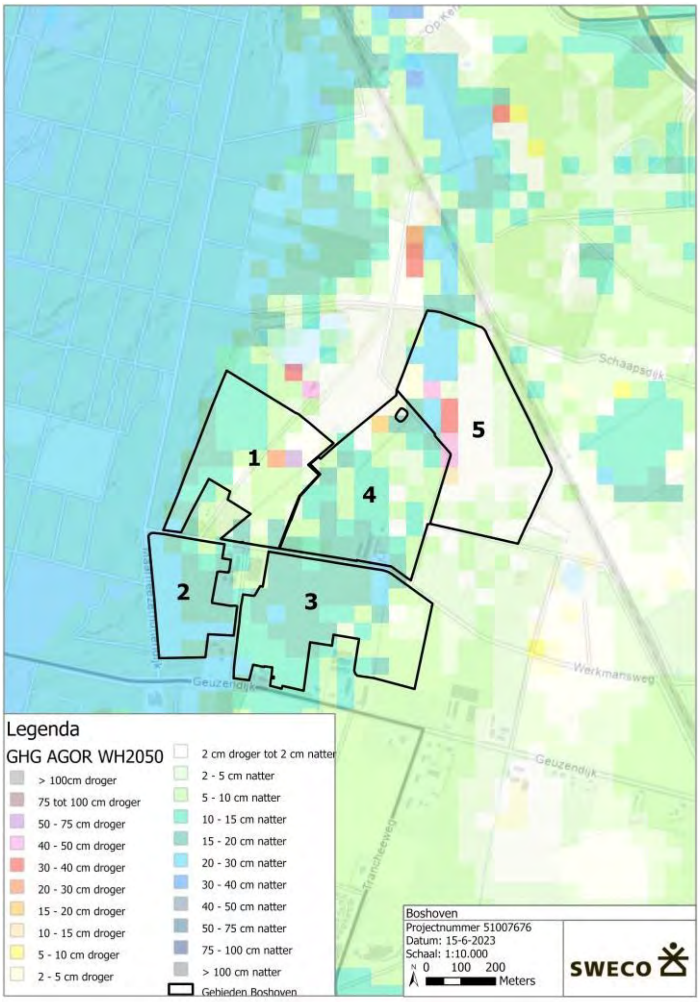


Figure A25 GHG and Figure A26 GLG in the current situation

The Mean Highest Groundwater Level (GHG) is >1 meter below ground level in plot 1. The agricultural areas have shallow groundwater levels. At Area 5, groundwater may rise to ground level (blue areas in Figure A25). Even with the GLG in Figure A26, these areas remain green, meaning that groundwater here does not sink very far either.

Effects of climate change



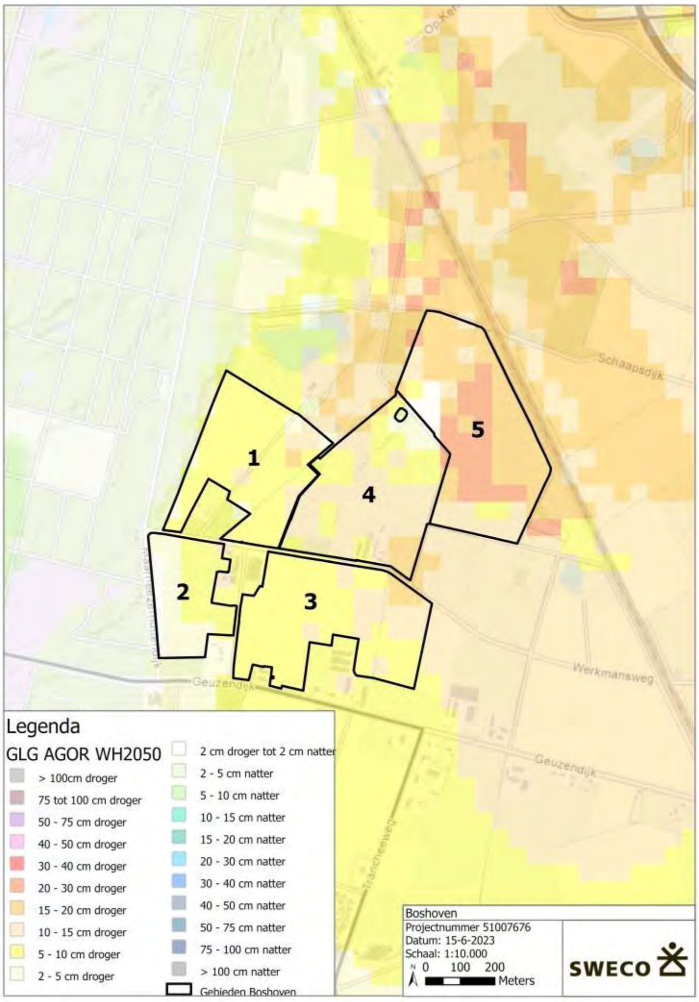


Figure A27 Change GHG in 2050 and Figure A28 change GLG in 2050 compared to the current situation

As shown in Figures A27 and A28, the GHG changes in 2050 due to an increase in the areas that are already wet. On the other hand, the GLG will drop further. This means that extremes increase.

Figure A29 Water Guide Agriculture current situation, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A30 Water guide agriculture in 2050, in red caused by drought, in blue caused by oxygen deficit, in brown by indirect causes

Figure A30 shows the results of the Waterwijzer for current crops in 2050. The Waterwijzer gives an indication of the relative crop damage caused by water shortage (red, drought), wet damage (blue, displacement of oxygen in the soil by water causes suffocating roots) and indirect damage (including from shifting seasons, trampling losses and mowing times). Due to the high groundwater levels in this area, crop losses due to wet damage are especially common. On arable plots (plots 1 and 2), this leads to more damage than on grassland plots.

Building blocks boshoven

Cross-section 1 (medium-term)	
Change to robust crop systems, adapting to changing climate.	1. n.v.t.
Adapting agriculture for sustainable soil management (e.g. nature-inclusive agriculture).	2. n.v.t.
Create buffer zones between different land uses	3. Designate the entire area as a buffer zone between nature and the railway. Vulnerable heathland nature, edge drying out. Already wet by nature, use as buffer area Connect with other ambitions -> such as energy transition. Think solar panels around railway tracks.
Natural design of brook valleys.	4. n.v.t.

Cross-section 2 (long-term)	
Create larger/contiguous robust nature.	1. Through the buffer zone you connect the piece of nature. With the rest of the landscape.
Reallocate highly vulnerable agricultural land (for drought and flooding).	2. Because the area is designated as a buffer zone, it is wetter. This makes farmland less .Suitable for intensive livestock farming. Solution is extensification.
Extensify in stream valleys and adjust land use (water-conserving agriculture and nature).	3. n.v.t.
Extensive farming to prevent runoff and leaching.	4. Extensive livestock farming on the edge of sensitive nature reserve poses risk of pollution. Extensify here, also in the context of nitrogen.

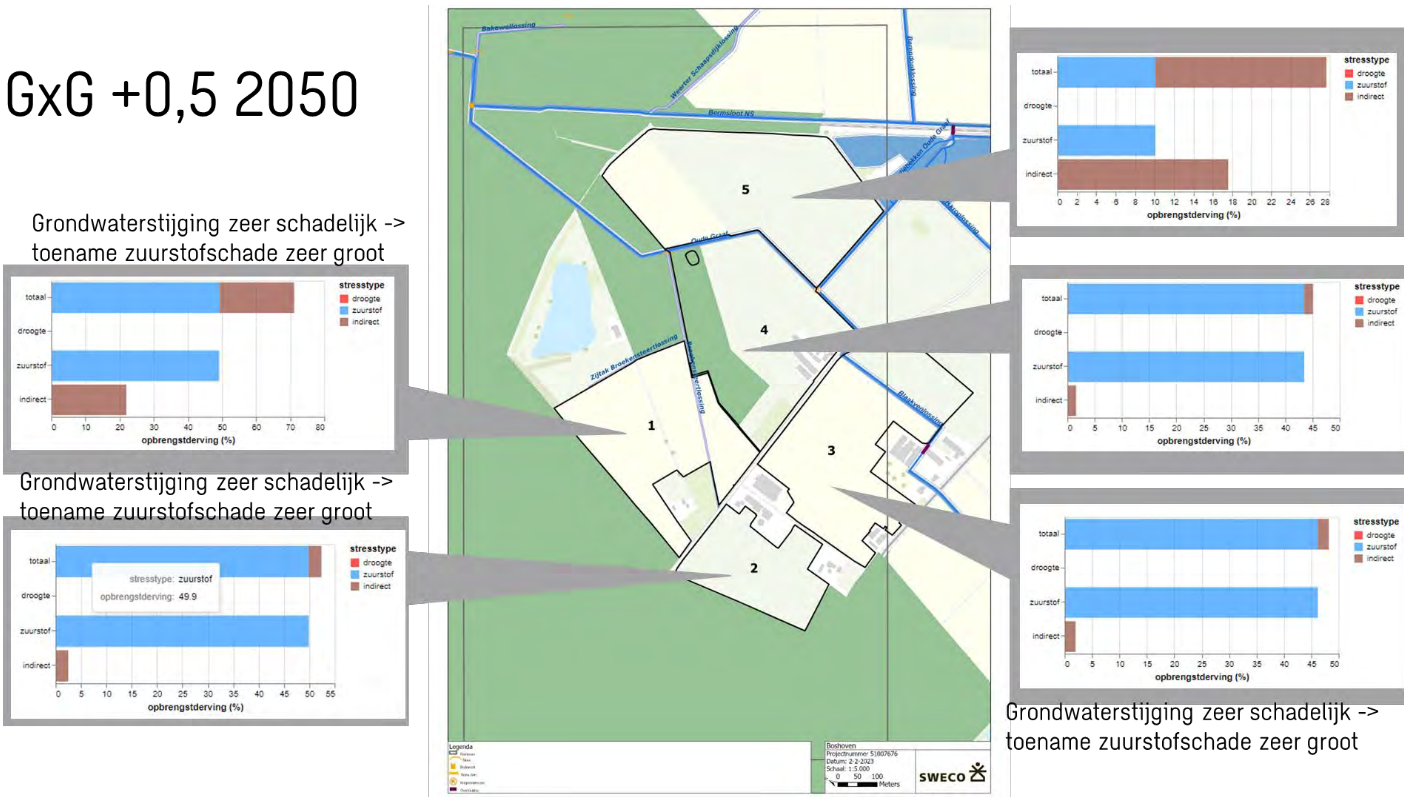


Figure A31 Water indicator “Waterwijzer”, agriculture situation with elevated groundwater levels, in red caused by drought, in blue caused by oxygen deficit,
in brown by indirect causes

If groundwater levels are raised, arable crops in this area will suffer even more crop loss due to wet damage. With a crop loss of almost 50%, crop loss due to soil oxygen deficiency is high. The area will become much wetter, which means that all forms of agriculture will no longer suit these conditions equally well.