

Nature-based Solutions for water resilience in Flevoland

Pattern Book

Metropolitan Ecology of Places Series



Introduction

This pattern book is part of the master's research of nature-based solutions (NbS) for different water problems in Flevoland. Each nature-based solution could be used in and/or outside Flevoland. The NbS are solutions for flooding, water nuisance, drought, salinisation, and soil subsidence. The last patterns are policies connected to the nature-based solutions. These patterns are used as a base for the maximisation strategy and are used for the governance and vision of this research. The complete pattern book answers the sub-question: 'Which nature-based solutions could be used for which specific water problem?'

Master Thesis- Pattern book

MSc Architecture, Urbanism and Building Sciences-Track Urbanism

Faculty of Architecture and the Built Environment

Delft University of Technology

Title:

Designing a water-resilient landscape

Sub title:

Integrating nature-based solutions for a sustainable water system in Flevoland

Graduation Lab: Metropolitan Ecology of Places

Author: Maaïke Marry Dijkstra

Student number: 5951461

Supervisors

First Mentor:

Kristel Aalbers - Environmental Technology & Design

Second Mentor:

Remon Rooij - Spatial Planning & Strategy

Explanation of patterns

Scale

The scale of the patterns is visible through the circles. The scale goes from neighbourhood scale towards national scale. If a pattern is possible on multiple scales, there will be multiple circles coloured.



Related to

Sometimes the patterns are related to different subjects. The colour of the main subject shows which topics the patterns are connected to. For instance, the circle on the right shows that it is connected with salinisation.



Specific location

The specific location is used to see instantly if a pattern in a certain area is possible. The practical implementation will explain more in-depth about the requirements.

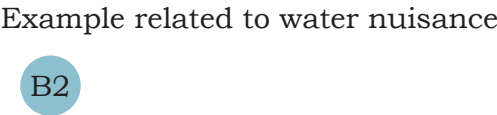
Related to patterns

Some patterns are related to other patterns. The letter and colour show the subject related to the pattern, and the number shows which specific pattern it is related to.



Number of pattern

Each pattern has a specific number and colour/letter. The letter and colour show the main subject of the pattern, for instance, water nuisance. The number is used as a reference to the specific pattern. This is helpful to see the relations of patterns.



Hypothesis

The hypothesis explains in one sentence the goal of the pattern.

Theoretical background

The theoretical background explains why a pattern is needed and what the background is for the pattern.

Practical implementation

The practical implementation explains how a pattern fits in the environment. Some interventions/patterns can be implemented in many different locations, like blue-green networks. Others are more specific and cannot be implemented everywhere.

List of patterns

- A1 Living shorelines
- A2 Restoration and improvement dynamic nature of the dunes
- A3 Restoration salt marshes
- A4 Dike restoration (HWBP)

- B1Blue-green network
- B2 Water storage for heavy rainfall
- B3 Water retention basin
- B4 Crops for wet conditions
- B5 Stormwater parks
- B6 The sponge city concept
- B7 Room for the river

- C1 Circular and nature-friendly agriculture
- C2 Rewetting the clay-peat lands
- C3 Subsidence-proof urban design

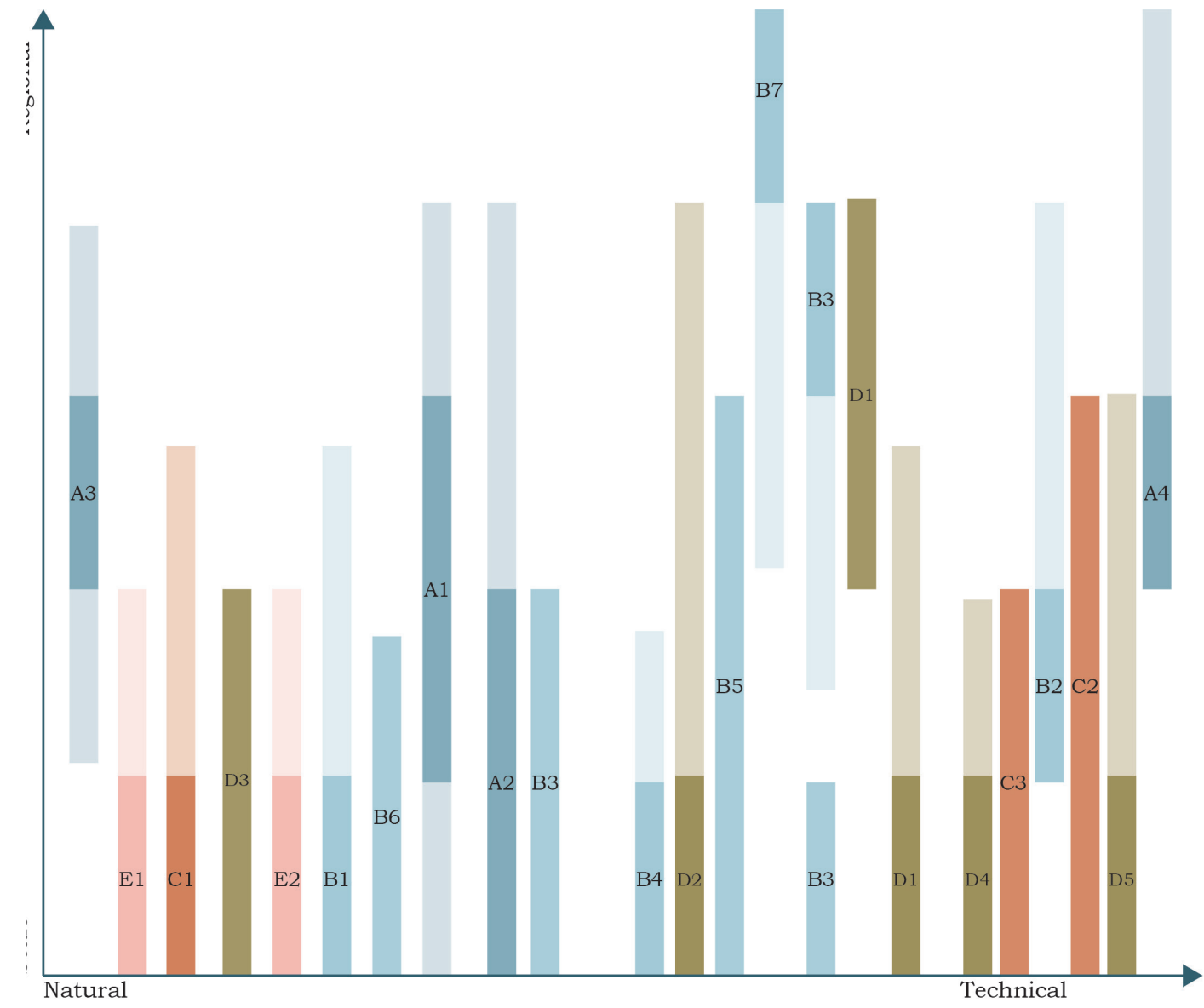
- D1 Creating more freshwater storage
- D2 Wetland restoration and creation
- D3 Crops for dry conditions
- D4 Rainwater harvesting system
- D5 Aquifer storage and recovery

- E1Riparian buffer
- E2 Salt tolerant crops

- P1 Water level fluctuations IJsselmeer
- P2 Multilayer safety
- P3 Reduction of soil sealing
- P4 Transition fund for rural areas and nature
- P5 Smart water management system

Pattern field

The pattern field shows at what scales the patterns are applicable and how natural each solution is. It shows that most patterns are applicable at multiple scales. However, due to certain types of interventions, most patterns fit the small scale the best. For instance, numerous solutions focus on the design of water storage, are on the smaller scale, and are related to each other. The most technical patterns are dike restoration and aquifer storage.



Scale



Related to



Specific location

Coastal areas

Related to patterns

A2

Positive effect on



Negative effect on



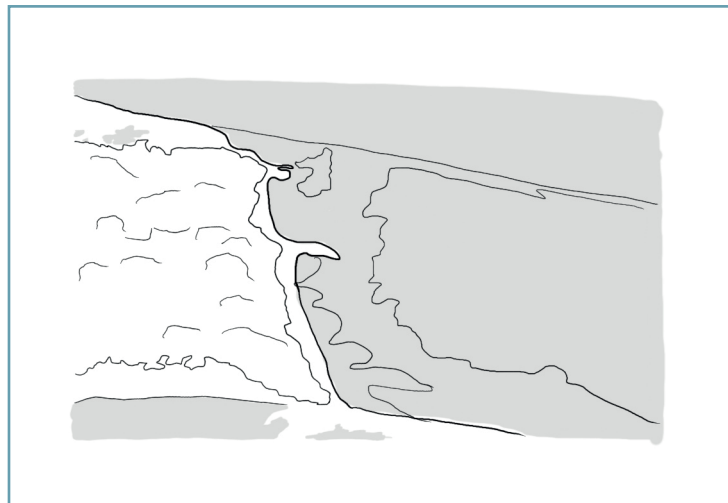
Stakeholders

- Rijkswaterstaat
- Waterboard Zuiderzeeland
- Province of Flevoland
- Staatsbosbeheer

Waterboard Zuiderzeeland, Staatsbosbeheer and Rijkswaterstaat have the most interest in living shorelines. Staatsbosbeheer could identify the natural qualities, while the two other parties focus on the strength of the dikes.

Effects explanation

Living shorelines have a positive effect on biodiversity and ecology because of the development of new habitats.



A1

Living shorelines

Hypothesis

Living shorelines provide wildlife habitat and are a cost-effective solution for coastal management.

Theoretical background

A living shoreline is a stabilised coastal border made of natural materials such as plants, rock or sand. These shorelines can grow and change over time and are low-maintenance. Furthermore, they purify water, buffer floods and reduce erosion (NOAA Fisheries, n.d.).

Practical implication

To introduce living shorelines, the determination of whether a living shoreline stabilisation fits in a certain area is needed first. An evaluation of the bank erosion, elevation, wave energy and wind is necessary as well. If the shoreline fits a certain area, the site needs to be cleared of debris and unstable seawalls. Lastly, the shorelines must be monitored after the construction phase (NOAA Fisheries, n.d.).

Living shorelines could be implemented on the local scale to improve the ecology/biodiversity of a place, but they can also be implemented on the regional scale. In that case, it could work as dynamic coastal defence.

References

NOAA Fisheries. (n.d.). Understanding living shorelines. Retrieved March 18, 2025, from <https://www.fisheries.noaa.gov/insight/understanding-living-shorelines#what-is-a-living-shoreline?>

Scale



Related to



Specific location

Coastal areas,
Dunes

Related to patterns



Positive effect on



Negative effect on



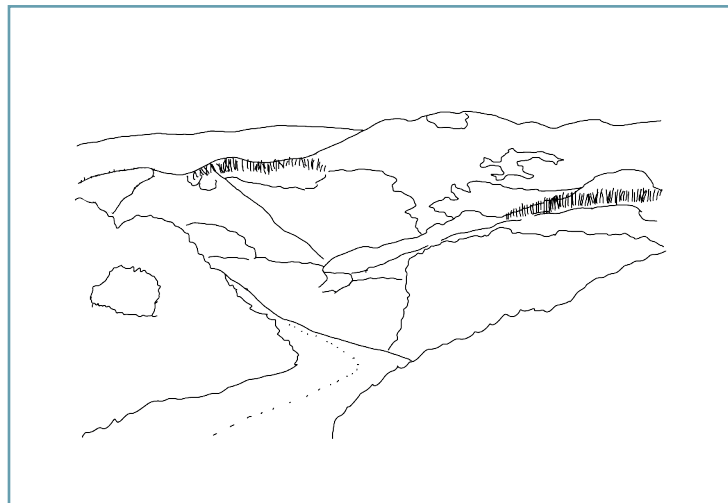
Stakeholders

- Rijkswaterstaat
- Waterboards
- Provinces
- Staatsbosbeheer

Staatsbosbeheer will mostly focus on the improvement of ecology, while the waterboards and Rijkswaterstaat focus on the improvement of the strength of the dunes against flooding.

Effects explanation

Restoration of the dunes has a positive effect on biodiversity and ecology because of the development of new habitats.



A2

Restoration and improvement dynamic nature of the dunes

Hypothesis

Restoration and dynamic nature management improve the dune's capability to protect the land against flooding and improve biodiversity.

Theoretical background

The dune landscape has a variety of landscape types. For instance, there are lakes in dunes, forests and dry dune valleys. These different typologies create a biodiverse landscape (Duinen, 2019). Restoring the dunes will protect these different landscapes in the dunes and will help with the conservation of biodiversity. Furthermore, it ensures that the dunes will be more resilient against threats from climate change and restoring the dunes improves water retention (Verstand et al., 2024).

Practical implication

Dunes are sandhills created by wind and are held in place by plants. Because of the sea and wind, they change a lot, and they are a natural solution for coastal defence. The dunes start with a small sandy hill, and this will grow further because of the growth of plants that catch more sand. On this sand, new plants will settle, creating a higher hill (Duinen, 2019). The dunes can be restored on a landscape scale, but it is also possible to intervene on a smaller scale to improve natural processes. For instance, letting animals graze to remove exotic plants from the dunes (Verstand et al., 2024).

References

- Duinen. (2019, 30 september). Ecomare. <https://www.ecomare.nl/verdiep/leesvoer/landschappen/duinen/#:~:text=Als%20het%20duintje%20een%20meter,nieuwe%20duinvallei%20komen%20te%20liggen.>
- Duinen Schoorl. (z.d.). Frankwandelt. <https://www.frankwandelt.nl/noord-holland/duintoppentocht-in-de-schoorlse-duinen-van-uitzicht-naar-uitzicht>
- Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.

Scale



Related to



Specific location

Land directly connected to the sea
Waddensea

Related to patterns

Positive effect on



Negative effect on



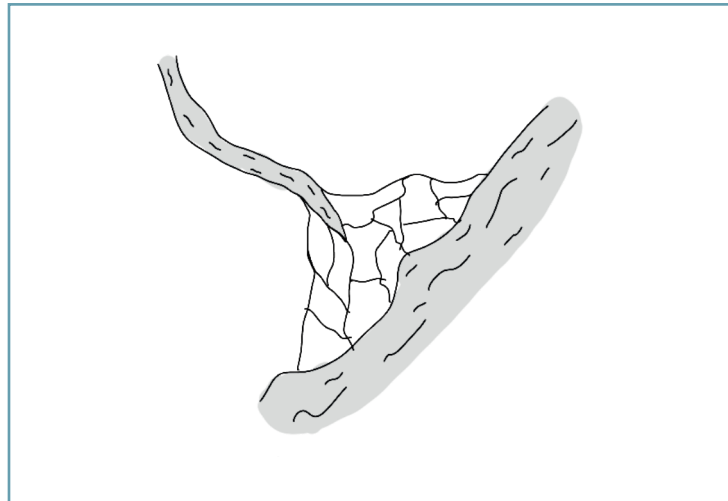
Stakeholders

- Nature reserves
- Staatsbosbeheer
- Municipalities along the coast
- Provinces along the coast
- Waterboards along the coast

Staatsbosbeheer will mainly focus on the improvement of ecology, while the waterboards and especially Rijkswaterstaat focus on the restoration for the improvement of the resilience of the salt marshes.

Effects explanation

Salt marshes have a positive effect on biodiversity and ecology because of the development of new habitats.



A3

Restoration salt marshes

Hypothesis

Salt marshes protect the land against high water and create a unique biodiversity.

Theoretical background

Salt marshes are located on spots where freshwater and saltwater come together. For instance, in the Waddensea (NIOZ, 2020). Salt marshes in coastal areas are often located next to dunes. Because of the specific location, the flora and fauna are unique and protected (Natuurkennis, z.d.). Therefore, these lands are monitored. Furthermore, they can reduce the wave load on dikes. Salt marshes are under pressure because of climate change, and therefore, they ask for restoration.

Practical implication

Salt marshes are created by the supply of sand and sludge from the waves. This builds up and creates a higher ground where plants can grow. During low tide, the salt marsh will be dry and during high tide, the marshes can be flooded. It is possible to make new salt marshes by stimulating siltation, but it is an investment with high costs. In the end, the restoration will create a stronger, more robust protection zone (Verstand et al., 2024).

References

Kwelders en duinen. (z.d.). Waterinfo Extra. <https://waterinfo-extra.rws.nl/monitoring/biologie/vegetatie/kwelders/>
Natuurkennis. (z.d.). N09 Schorren of kwelders - Het Kennisnetwerk Ontwikkeling en Beheer Natuurkwaliteit (OBN). <https://www.natuurkennis.nl/natuurtypen/n09-schorren-of-kwelders/>
NIOZ. (2020, 7 mei). Rattekaai vanuit drone. <https://www.nioz.nl/en/news/koolstofopslag-langs-de-nederlandse-kust-niet-alleen-bos-ook-schorren-en-kwelders-remmen-klimaatverandering>
van der Brugge, R., & de Winter, R. C. (2024). deltares deltasenarios 2024

Scale



Related to



Specific location

Dikes

Related to patterns

Positive effect on



Negative effect on



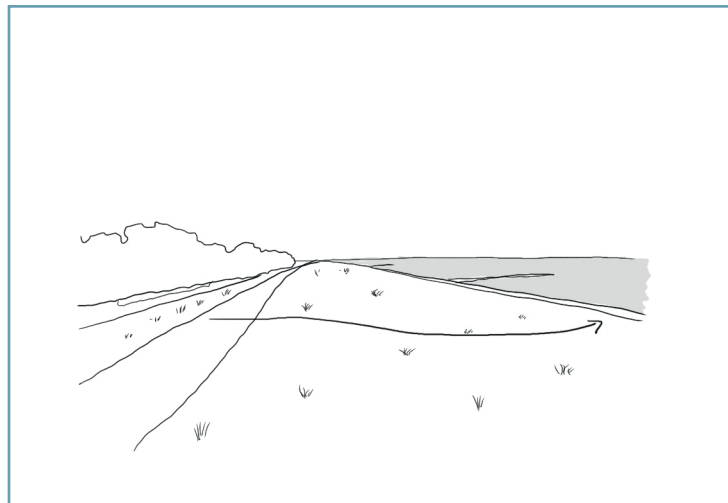
Stakeholders

- Rijkswaterstaat
- Waterboard Zuiderzeeland
- Province of Flevoland
- Staatsbosbeheer

Waterboard Zuiderzeeland and Rijkswaterstaat have the most interest in dike restoration. These parties also have the highest power in the development of the dike system.

Effects explanation

Dike restoration could harm ecology because of the limitations of vegetation on the dikes.



A4

Dike restoration (HWBP)

Hypothesis

Dike restoration improves the dike system and therefore keeps the land safe from flooding.

Theoretical background

Without dunes and dikes, 60% of the Netherlands would often be under water. Therefore, protection against high water is essential. The primary water systems are often tested against high safety norms. The dikes that do not reach the norm will be improved in the HWBP (High Water Protection Program). The most urgent ones will be done first, and the focus is on a total of 1400 km of dikes. The goal is to finish this project in 2050.

Dike restoration could also improve the biodiversity around the dike. This depends on the location and the different possibilities of dike restoration.

Practical implication

For the improvement of the dike system, it is possible to intervene with a more natural solution for the dikes. The possibilities depend on the location and there are many possibilities, such as the double dike system, the creation of vegetated foreshores, broader dikes and the construction of different grasses on the dike.

The improvement of the dike system in the Netherlands now depends on the High Water Protection Program, which is a program that helps with the payment of the dike improvements in a certain area. This could go more hand in hand with nature development, creating more nature-based dikes.

References

Ministerie van Infrastructuur en Waterstaat & Rijkswaterstaat. (n.d.).

Hoogwaterbeschermingsprogramma (HWBP). Rijkswaterstaat. Retrieved January 21, 2025, from <https://www.rijkswaterstaat.nl/water/waterbeheer/bescherming-tegen-het-water/maatregelen-om-overstromingen-te-voorkomen/hoogwaterbeschermingsprogramma>

Scale



Related to



Specific location

Rural and urban areas

Related to patterns



Positive effect on



Negative effect on



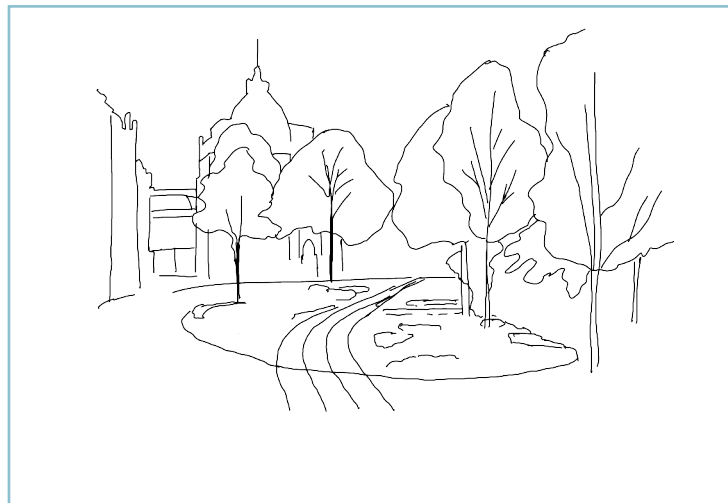
Stakeholders

- Municipalities
- Provinces
- Waterboard Zuiderzeeland
- Staatsbosbeheer
- Farmers

Staatsbosbeheer and other nature organisations will focus on an improved ecological network, while the Waterboard Zuiderzeeland will focus more on the water quality and quantity of the network.

Effects explanation

The blue-green network could help hold water in the soil, but could also create cracks in the soil, causing both positive and negative effects for soil subsidence. Furthermore, the hold of water by plants could help with drought and salinisation.



B1

Blue-green network

Hypothesis

Improving the blue-green network will mitigate water nuisance, create more biodiversity and be good for the health of people.

Theoretical background

The blue-green network is an urban development concept that uses a network of existing/restored rivers and their surrounding green areas as a basis for sustainable development and adaptation to climate change. These networks need to preserve biodiversity, to give free movement through ecological corridors and to mitigate the effects of climate change, such as water nuisance and water regulation (European Commission, z.d.). Furthermore, it adds to storing CO2 in the soil.

Practical implication

Blue-green networks can be implemented from small-scale projects to city plans and in rural areas. However, for this implementation, there is a minimum surface of 10% of the landscape needed. This means that the blue-green network can be implemented in all landscape typologies, but it requires a certain space. The important factor for this solution is connectivity. So it should be a link between different landscapes (Verstand et al., 2024).

In the rural areas, the network will use agricultural land, and therefore, there is sometimes a need for subsidies. In cities, the focus is more on removing pavement in the public and private domains (Verstand et al., 2024). An example of creating more nature in cities is the project 'a tile for a plant', where people can remove a tile and get a plant in return. This creates more greenery in the streets and gardens.

References

European Commission. (z.d.). Creating blue-green networks. Green Best Practice Community. <https://greenbestpractice.jrc.ec.europa.eu/node/399>
Green cities europe. (2018, 23 oktober). Rotterdam, stad van innovatie. Green Cities Europe. <https://nl.thegreencities.eu/rotterdam-stad-van-innovatie/>
Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.

Scale



Related to



Specific location

Almost in all landscape typologies in the Netherlands

Related to patterns



Positive effect on



Negative effect on



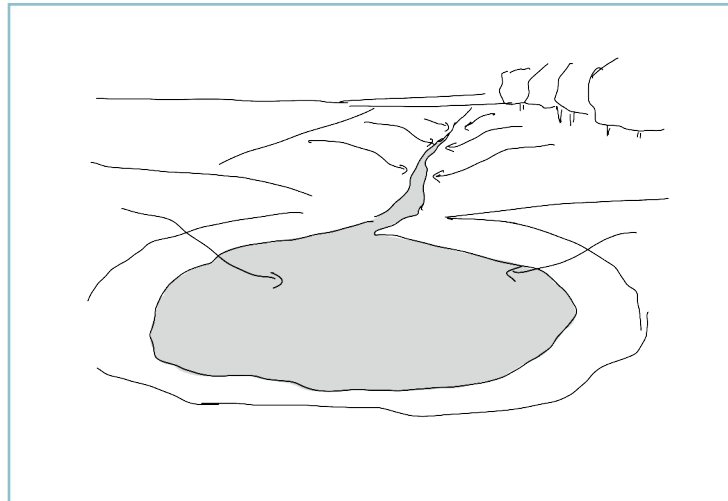
Stakeholders

- Waterboard
- Farmers
- Municipality of the specific location
- Province

The waterboard has an important role in the design of the water storage because it makes the calculations for the water nuisance. Furthermore, the farmer is an important stakeholder because water nuisance is mostly located on agricultural land, and the consequences are the largest for the farmers.

Effects explanation

Water storage could help in dry periods because the water collected in wet periods could be used.



B2

Water storage for heavy rainfall

Hypothesis

Excess water on farms could be collected in spaces for water storage during and after heavy rainfall.

Theoretical background

In the Netherlands, there is a growing pressure on freshwater, and the country faces more extreme weather. This leads to water nuisance in the wetter months and water shortage in the dry months. To prevent water nuisance in the wet months/winter, the water could be collected (Verstand et al., 2024).

Practical implication

It is possible to implement water storage in almost all landscape typologies in the Netherlands. Especially the low-lying areas are suitable for storage, while higher areas should work as infiltration zones.

Based on the nature-based solutions catalogue (Verstand et al., 2024)

References

Van Vliet, J. (2023, 19 december). De Houtrakpolder, het groen net over de gemeentegrens bij het Westelijk havengebied, is nu nog aangewezen als strategische reserve voor de haven. Het Parool. <https://www.parool.nl/amsterdam/houtrakpolder-in-beeld-voor-waterberging-minder-kans-op-uitbreiding-haven~bba6fee1/?referrer=https://www.google.com/>
Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.

Scale



Related to



Specific location

Related to patterns



Positive effect on



Negative effect on



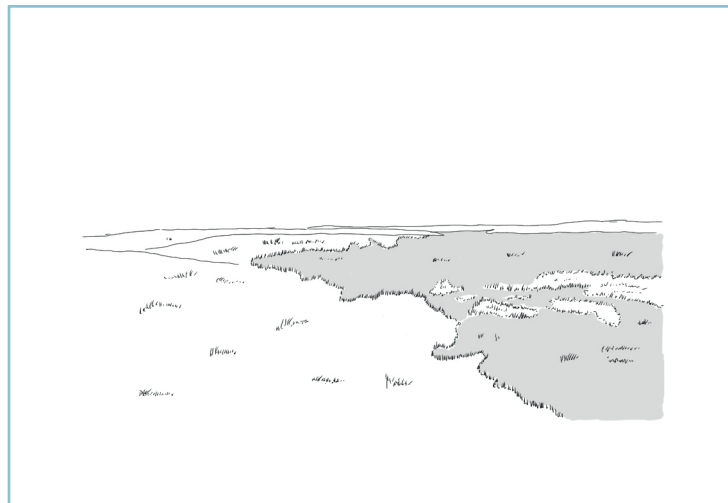
Stakeholders

- Province of Flevoland
- Municipalities
- Waterboard of Zuiderzeeland
- Staatsbosbeheer

A water retention basin could be beneficial for water storage inside cities and parks. Therefore, both the municipalities and Staatsbosbeheer are important stakeholders in the design and management.

Effects explanation

A water retention basin could store water for the longer term and keep the soil wetter. Therefore, it will help with drought and soil subsidence.



B3

Water retention basin

Hypothesis

A water retention basin stores and slows stormwater runoff from nearby areas, while providing water quality benefits.

Theoretical background

Retention ponds are ponds that store stormwater and improve the stormwater quality with the use of natural vegetation around the pond. The vegetation provides bank stability and aesthetic benefits as well (Leber, 2015).

Practical implication

A retention pond should contain four different zones: An upstream pre-treatment system, a permanent pond that stays wet throughout the year, a space for temporary storage and a shallow zone to support wetland plants (NWRM, n.d.).

References

Leber, B. (2015, April 30). Stormwater Basins: How detention and retention ponds work. Wessler Engineering. Retrieved February 20, 2025, from <https://info.wesslerengineering.com/blog/stormwater-basins-detention-retention-ponds>
NWRM. (n.d.). Retention ponds | Natural water retention measures. Retrieved April 30, 2025, from <https://www.nwrm.eu/measure/retention-ponds>

Scale



Related to



Specific location

Related to patterns

C1

Positive effect on



Negative effect on



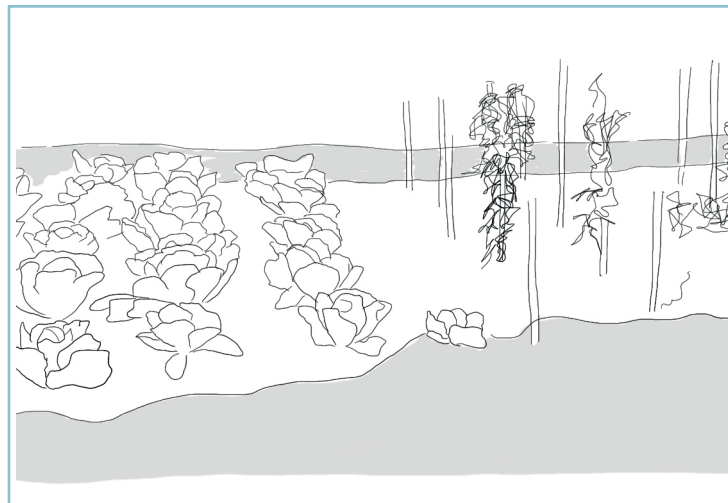
Stakeholders

- Farmers
- Aeres Hogeschool
- Wageningen University and Research (WUR)

Aeres Hogeschool and the WUR could help with the research needed for new or changed crops. This could help farmers in transforming their farms and how to deal with water nuisance.

Effects explanation

It could harm farmers who also deal with drought, because not every crop can deal with both drought and water nuisance.



B4

Crops for wet conditions

Hypothesis

Crops that are more resistant to water nuisance create a higher success rate for crop yields.

Theoretical background

Water nuisance can cause depletion of oxygen, leading to reduced root respiration and other plant processes. The tolerance to oxygen depletion depends on the species. Prolonged exposure to water nuisance could result in the same problems as when a plant is exposed to drought (Province of Manitoba, n.d.).

Practical implication

Plants that could better deal with too much water are oats, fababeans and grasses (Province of Manitoba, n.d.). If farmers want to keep their farm in an area with a lot of water nuisance, then they could look into new crops and use them.

References

Province of Manitoba. (n.d.). Managing Crops For Excess Water Stress. Province of Manitoba - Agriculture. Retrieved May 5, 2025, from <https://www.gov.mb.ca/agriculture/crops/crop-management/managing-crops-for-excess-water-stress.html>

Scale



Related to



Specific location

Related to patterns



Positive effect on



Negative effect on



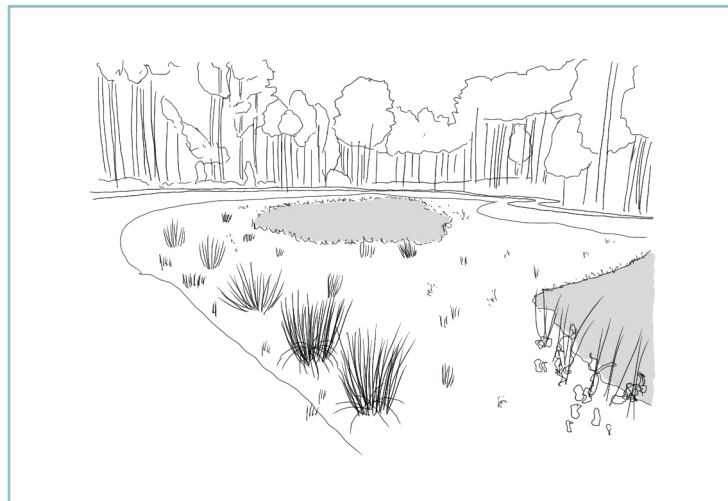
Stakeholders

- Staatsbosbeheer
- Municipality of Zeewolde/Almere
- Province of Flevoland
- Farmers if the location is in agricultural areas
- Waterboard of Zuiderzeeland

The water board has a controlling role in maintaining stormwater parks. The Forestry Commission has a managing role when it comes to sites in nature reserves.

Effects explanation

Stormwater parks retain rainwater, this water could be used in dry seasons.



B5

Stormwater parks

Hypothesis

Stormwater parks manage stormwater from a larger area and provide recreational opportunities for the community.

Theoretical background

Stormwater parks use stormwater infrastructure to reduce flooding and its financial impact. Additionally, it enhances biodiversity and mitigates extreme heat. Along with these benefits, there is also a social aspect to the parks. The parks create work (maintenance), places to come together as a community and are used as recreation (City Parks Alliance, n.d.).

Practical implication

To design a stormwater park, it is important to create a win-win situation to make it more interesting for investors or policymakers to invest in the project. Because of the different stakeholders, it is important to show the different perspectives and to prevent potential conflicts.

Green stormwater parks focus on the use of native vegetation, porous pavement or other materials instead of concrete and asphalt (City Parks Alliance, n.d.).

References

City Parks Alliance. (n.d.). NATURE-BASED SOLUTIONS FOR MANAGING STORMWATER IN PARKS. Retrieved April 30, 2025, from <https://cityparksalliance.org/wp-content/uploads/2023/05/Parks-and-Green-Stormwater-PolicyBrief-12-10-2024.pdf>

Scale



Related to



Specific location

Urban areas

Related to patterns



Positive effect on



Negative effect on



Stakeholders

- Municipality
- Residents
- Engineers/architects/urban planners
- Waterboards
- Aeres Hogeschool

The municipalities decide which regulates which neighbourhoods should use the sponge city concept, and this concept must be implemented in new urban development. The urban planners should use the sponge city as a tool to design a resilient neighbourhood.

Effects explanation

The sponge city concept helps with the catchment of water and improves the soil. Therefore, it will help with salinisation, drought and soil subsidence.



B6

The sponge city concept

Hypothesis

The sponge city concept provides sustainable solutions for water management and replicates natural water cycles within urban settings.

Theoretical background

The sponge city is based on the idea of evaporation. By improving greenery and replacing grey infrastructure with green infrastructure, there will be more evaporation during hot weather and rainfall, the water will be absorbed by the green surfaces (Hawken et al., 2021).

Practical implication

The sponge city is a toolbox of 'low tech' solutions and could be applied in different ways, depending on the circumstances of the environment (Hudson & Hudson, 2023). Sponge city solutions are green roofs, facades and bioswales. It is intended to integrate with the natural city environment, and the interventions are multi-functional.

References

- Hawken, S., Sepasgozar, S., Prodanovic, V., Jing, J., Bakelmun, A., Avazpour, B., Che, S., & Zhang, K. (2021). What makes a successful Sponge City project? Expert perceptions of critical factors in integrated urban water management in the Asia-Pacific. *Sustainable Cities and Society*, 75, 103317. <https://doi.org/10.1016/j.scs.2021.103317>
- Hudson, L., & Hudson, L. (2023, February 8). Urbanism 101: What is a Sponge City? - The Urbanist. *The Urbanist - Examining urban policy to improve cities and quality of life*. <https://www.theurbanist.org/2023/02/08/urbanism-101-what-is-a-sponge-city/#:~:text=A%20Sponge%20City%20is%20one,and%20cools%20the%20city%20down.>

Scale



Related to



Specific location

Along rivers

Related to patterns

Positive effect on



Negative effect on



Stakeholders

- Ministry of Infrastructure and Water
- Rijkswaterstaat
- Province of Gelderland and Overijssel
- Local municipalities
- Waterboard Rivierenland, Vallei en Veluwe
- Farmers
- Knowledge institutions

The design is a large project with a lot of different stakeholders. The farmers could have a negative attitude towards the project because they could lose their farms to this project.

Effects explanation

The 'room for the river' project creates new space for biodiversity because there is more space for nature development and floodable terrain.



B7

Room for the river

Hypothesis

By giving the river more space (room), there is a reduction of flood risks.

Theoretical background

When the water level rises in the river, water can flow to the bypass. The bypass will fill with water and therefore keep the river from flooding. During lower water levels, the bypass could be used for recreation, nature and aesthetic values (Holmes, 2017).

Practical implication

For the room for the river, a bypass is needed, and between the river and the bypass, an island is necessary. Bridges can connect the island to both sides of the river. The design is based on river dynamics, erosion and sedimentation processes and the tides (Holmes, 2017).

References

Holmes, D. (2017, June 22). Room for the River | Nijmegen, The Netherlands | H+N+S Landscape Architects. WLA. Retrieved January 20, 2025, from <https://worldlandscapearchitect.com/room-for-the-river-nijmegen-the-netherlands-hns-landscape-architects/?v=1a13105b7e4e>

Scale



Related to



Specific location

Can be implemented in already existing farms and could work with new farms.

Related to patterns



Positive effect on



Negative effect on



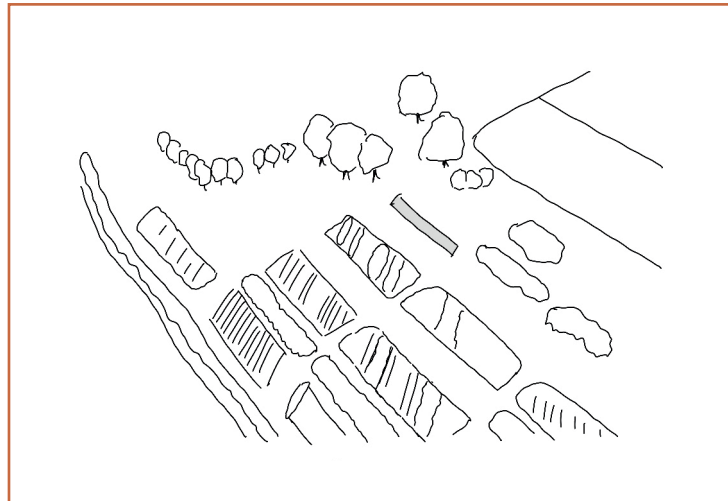
Stakeholders

- Waterboard of Zuiderzeeland
- Province of Flevoland
- Farmers

Circular agriculture could improve the land of the farmer. Therefore, the farmers must be involved in the implementation of this type of agriculture. If the implementation is difficult to realise, it could lead to a new policy and transition for farmers.

Effects explanation

Circular and nature-friendly agriculture leads to an improved soil system. An improved soil could better withstand climate change. Therefore, drought will cause less damage to the soil.



C1

Circular and nature-friendly agriculture

Hypothesis

Circular and nature-friendly agriculture improves the soil. Therefore, the soil absorbs more water, and the soil is more resistant to drought.

Theoretical background

Circular agriculture is a way of agriculture where arable land, livestock and horticulture are using each other's materials and residual flows (Ministerie van landbouw, natuur en voedselkwaliteit, 2018). The goal is to keep these chains as short as possible. Nature-friendly agriculture is agriculture that uses and improves nature. Both types of agriculture improve the soil because agriculture uses fewer artificial fertilisers and pesticides. By improving the soil, the soil will be able to store more water and will become more resilient to climate change (Verstand et al., 2024).

Practical implication

Nature-friendly and circular agriculture is possible on multiple scale levels. For instance, it can work on one parcel where there are multiple types of agriculture (horticulture, arable, and livestock) or on a larger scale where multiple farmers work together. If you want the same intensity of farming, then you need more space, because nature-friendly agriculture asks for more space for nature. Therefore, the farmer has less space on a farm for crops.

Also, the change towards circular and nature-friendly agriculture asks for a large investment. This investment will pay for itself in the long term through the services of nature. (Verstand et al., 2024)

References

Agroforestry. (z.d.). GoodFoodClub. <https://www.goodfoodclub.nu/voedselbossen/>
Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.
Ministerie van landbouw, natuur en voedselkwaliteit. (2018). Landbouw, natuur en voedsel: waardevol en verbonden.

Scale



Related to



Specific location

Low lying polders with a topsoil of clay and peat

Related to patterns

P5

Positive effect on



Negative effect on



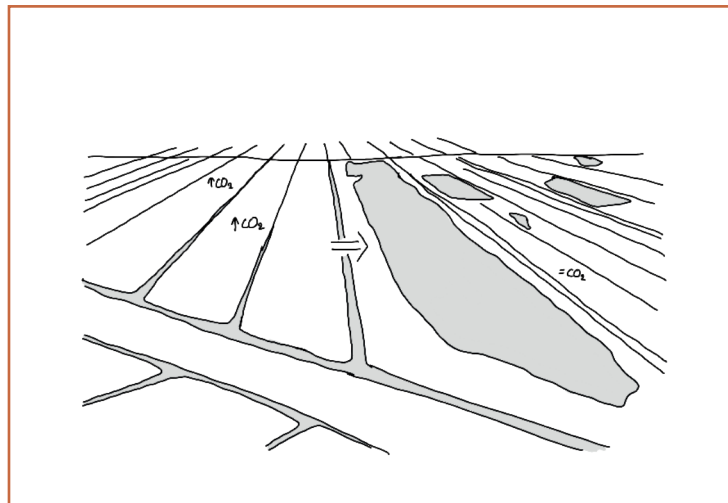
Stakeholders

- Farmers
- Waterboard Zuiderzeeland
- Province of Flevoland
- Municipalities

Rewetting the clay-peat lands causes problems for agricultural practices. Therefore, farmers may have a negative attitude towards this nature-based solution.

Effects explanation

Rewetting the land could cause problems for drought and water nuisance, but it could also help solve drought. There is more water needed for a higher groundwater level, and therefore could cause more drought.



C2

Rewetting the clay-peat lands

Hypothesis

Rewetting the landscape will create a more biodiverse and healthy (soil) environment.

Theoretical background

Right now, the groundwater height is kept low for agriculture. This means that the clay and peat areas are drying and therefore shrinking. By rewetting the clay-peatlands, the soil will no longer subside, and it will create natural pressure against salinisation, and reduce soil subsidence. Therefore, it is an important solution for climate change. The improvement of biodiversity depends on the location and on how nutrient-rich the environment is (Verstand et al., 2024).

Practical implication

Wetting the area can be done in multiple ways. For instance, it can be done with passive humidification or a change in land use.

It can be implemented in low-lying peat areas. The implementation works on a parcel scale, but it is better to implement it on a higher scale, and it could work together with freshwater storage. The implementation will be done on a parcel scale, but it is better to manage it on a higher scale, because some solutions may be connected with rewetting the peatlands, and this is visible on a higher scale.

Based on the nature-based solutions catalogue (Verstand et al., 2024).

References

Veen: ons meest unieke ecosysteem! (z.d.). Natuurpunt. <https://www.natuurpunt.be/projecten/veen-ons-meest-unieke-ecosysteem>

Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.

Scale



Related to



Specific location

Related to patterns

B6

Positive effect on



Negative effect on



Stakeholders

- Municipality of Zeewolde and Almere
- Citizens
- Urban planners

The design of subsidence-proof urban areas should be regulated by the municipalities that want to develop new housing. If it is a transition of the urban design towards a subsidence-proof urban design, citizens should be able to participate or at least be informed about the changes.

Effects explanation

Subsidence-proof urban design could help with the already existing urban environment as well, especially when streets need a transformation.



C3

Subsidence-proof urban design

Hypothesis

Subsidence-proof urban design is a resilient way of design, already acknowledging soil subsidence as a future problem.

Theoretical background

Subsidence-proof construction is a resilient way to accept soil subsidence. The buildings will not be damaged by the sinking of soil. The urban environment could also be designed in such a way that the soil will no longer cause damage to the urban areas. The urban area will use the natural height difference and the water system as the basis for the design. The design should focus on a high-quality environment without damage from the soil subsidence (SWEKO, 2024).

Practical implication

There are multiple ways to design subsidence-proof constructions. For instance, you could build with amphibious houses, marsh neighbourhoods and without a crawlspace (SWEKO, 2024).

References

SWEKO. (2024). STRATEGISCHE UITGANGSPUNTEN BODEMDALINGBESTENDIGE NIEUWBOUW.

Scale



Related to



Specific location

Almost in all landscape typologies in the Netherlands

Related to patterns



Positive effect on



Negative effect on



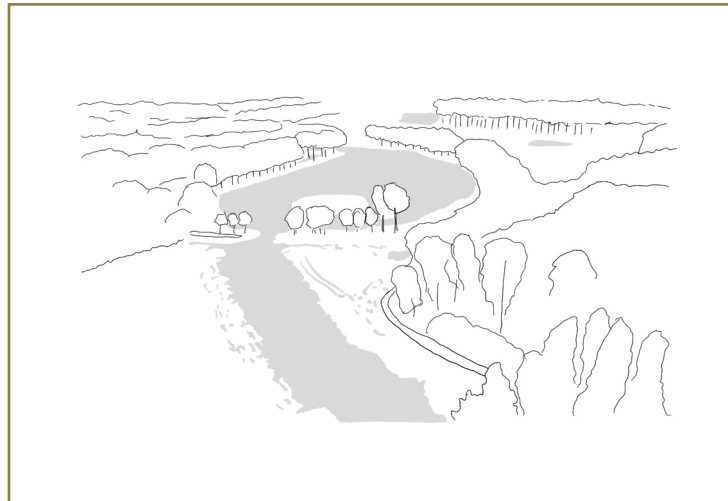
Stakeholders

- Waterboard
- Farmers
- Municipality of specific location
- Province

The waterboard has an important role in the design of the water storage because it makes the calculations for drought and takes measures. Furthermore, the farmer is an important stakeholder because drought mostly affects agricultural land, and the consequences are the largest for the farmers.

Effects explanation

Freshwater storage could collect rainwater in wet periods. Because the water is collected in a certain area, the water will cause less damage in other parts of the region.



D1

Creating more freshwater storage

Hypothesis

Freshwater storage will help prevent water shortage in dry periods.

Theoretical background

In the Netherlands, there is a growing pressure on fresh water, and we face more extreme weather. This leads to water nuisance in the winter and water shortage in the summer. To prevent water shortage in summer, the water needs to be collected in the winter. This could be done by natural processes like soil infiltration, sponge effects and meandering. In peat areas, it will also help with storing CO2 in the soil. Furthermore, freshwater storage helps with strengthening biodiversity (Verstand et al., 2024).

Practical implication

One of the main solutions is to improve the organic material in the ground. This will improve the water capacity of the soil.

It is possible to implement freshwater storage in almost all landscape typologies in the Netherlands. For instance, the low-lying areas are suitable for water storage, and higher areas should work as infiltration zones.

Fresh water storage is only effective on a large scale because different solutions should work together. With this solution, the focus is on creating a natural dynamic of land and water, so maintenance is not needed. (Verstand et al., 2024)

Based on the nature-based solutions catalogue (Verstand et al., 2024)

References

Van Vliet, J. (2023, 19 december). De Houtrakpolder, het groen net over de gemeentegrens bij het Westelijk havengebied, is nu nog aangewezen als strategische reserve voor de haven. Het Parool. <https://www.parool.nl/amsterdam/houtrakpolder-in-beeld-voor-waterberging-minder-kans-op-uitbreiding-haven~bba6fee1/?referrer=https://www.google.com/>
Verstand, D., Berkhof, M., De Haas, M., Pellens, N., Voskamp, I., & Diersmann, M. (2024). Nature-based Solutions Catalogus.

Scale



Related to



Specific location

Related to patterns



Positive effect on



Negative effect on



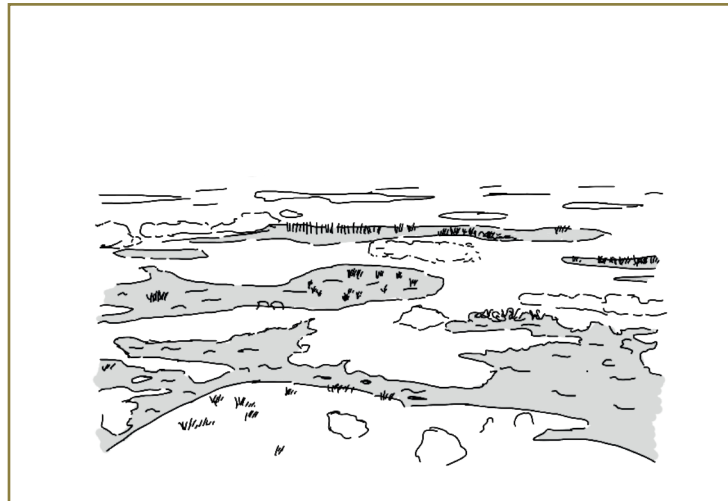
Stakeholders

- Staatsbosbeheer
- Waterboard Zuiderzeeland
- Province of Flevoland
- Municipalities
- Recreants

Wetland restoration could be combined with recreation to create a new nature area. Therefore, this project benefits both recreationists and biodiversity.

Effects explanation

Wetland restoration and creation could be combined with recreation to create a new nature area. Therefore, this project benefits both recreationists and biodiversity.



D2

Wetland restoration and creation

Hypothesis

Restoring wetlands allows wetlands to improve the natural water circulation.

Theoretical background

Wetlands function like sponges and can retain large amounts of water. During drought, this water will be released. They also hold large amounts of CO2. They are under pressure due to agriculture, forestry and urbanisation. The Netherlands has more than one million hectares of wetlands, for example, the Wadden Sea, the IJsselmeer region and the Friesian lakes. The wetlands are natural water filters and keep the Netherlands safe against flooding, store water and reduce heat stress in urban areas. Furthermore, they provide recreation and improve biodiversity (City Parks Alliance, n.d.).

Practical implication

Wetlands can be improved and designed in peatlands, marshes and floodplains. Protecting the wetlands is already a step towards improving wetlands.

References

City Parks Alliance. (n.d.). NATURE-BASED SOLUTIONS FOR MANAGING STORMWATER IN PARKS. Retrieved April 30, 2025, from <https://cityparksalliance.org/wp-content/uploads/2023/05/Parks-and-Green-Stormwater-PolicyBrief-12-10-2024.pdf>

Scale



Related to



Specific location

Farms

Related to patterns

C1

Positive effect on



Negative effect on



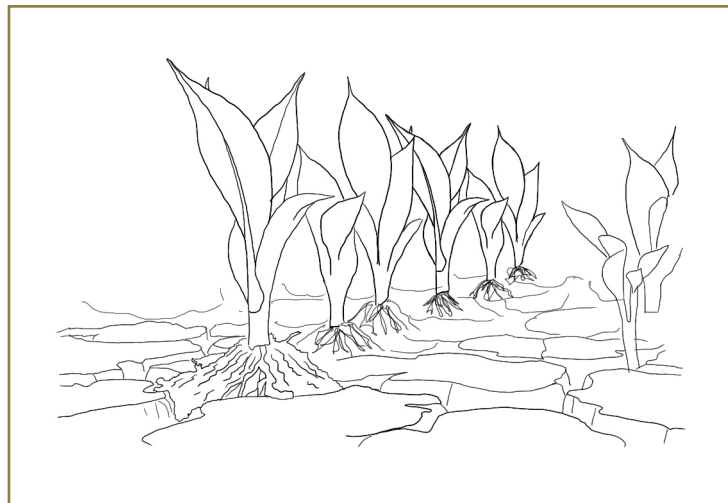
Stakeholders

- Farmers
- Aeres Hogeschool
- Wageningen University and Research (WUR)

Aeres Hogeschool and the WUR could help with the research needed for new or changed crops. This could help farmers in transforming their farms and how to deal with drought.

Effects explanation

It could harm farms that also deal with water nuisance, because not every crop can deal with both drought and water nuisance.



D3

Crops for dry conditions

Hypothesis

Crops that could deal with drought are better suited for warmer summer months.

Theoretical background

To reduce drought stress, it is important to focus on early planting and optimised fertilisation. Furthermore, it is important to focus on weed control and to reduce evaporation from the soil surface (NDSU, n.d.).

Practical implication

Corn is a crop that could better deal with siltage. Furthermore, alfalfa and soybeans could deal with drought as well, just like peas and small grains (NDSU, n.d.). By using these plants in summer, the farmers increase the chance of crop yields in dry periods.

References

NDSU. (n.d.). Alternative Crops During a Drought. Retrieved May 5, 2025, from <https://www.ndsu.edu/agriculture/ag-hub/ag-topics/natural-resources-and-facilities/grazing-management/alternative-crops-during#:~:text=Alfalfa%2C%20red%20clover%2C%20trefoil,Small%20grains>

Scale



Related to



Specific location

Related to patterns

B6

Positive effect on



Negative effect on



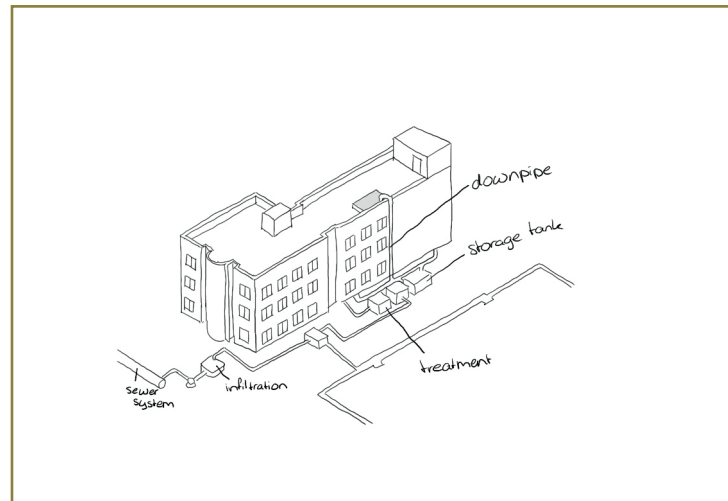
Stakeholders

- Municipalities
- Province of Flevoland
- Residents
- Urban planners/engineers

Rainwater harvesting methods could be applied in new urban areas, therefore, municipalities must focus on the implementation of these systems in the region.

Effects explanation

Rainwater harvesting could help with water nuisance, because the rainwater will be collected before the water from roofs and buildings falls on the street and in the sewage system. Therefore, there will be less water nuisance.



D4

Rainwater harvesting system

Hypothesis

Rainwater harvesting systems provide a sustainable method for water conservation, mitigation of drought impacts and water nuisance.

Theoretical background

Rainwater harvesting focuses on the storage and collection of rainwater. This water could be used as grey water (for flushing the toilet) or for watering the garden. Furthermore, the collection of rainwater could reduce erosion in dry areas and reduce flooding (Vartan, 2024).

Practical implication

Rainwater harvesting could be done with multiple systems. It is possible to install basic roof systems where water will be collected and led through a downspout towards a barrel or tank. This could be used for watering plants (Vartan, 2024).

It is also possible to install surface runoff harvesting, where rainwater is collected in a series of aquifers. This water could be used for showering, washing machines and toilets.

References

Vartan, S. (2024, May 30). A Beginner's guide to rainwater harvesting. Treehugger. <https://www.treehugger.com/beginners-guide-to-rainwater-harvesting-5089884>

Scale



Related to



Specific location

Drinking water locations

Related to patterns



Positive effect on



Negative effect on



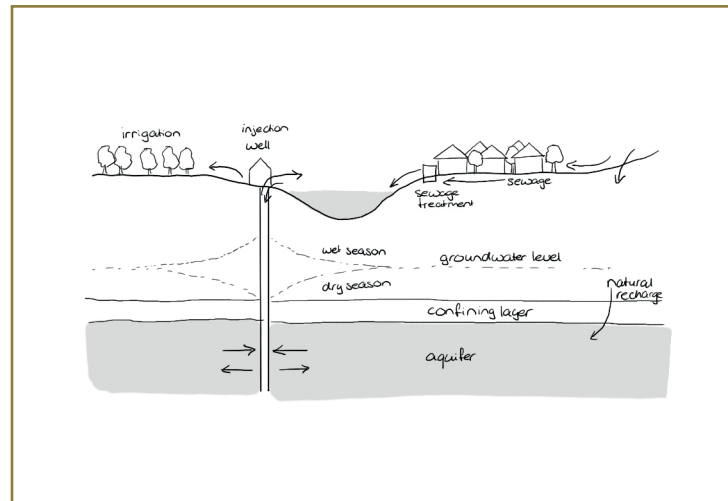
Stakeholders

- Waterboard Zuiderzeeland
- Province of Flevoland
- Municipalities

Aquifer storage and recovery is a technical solution that could be managed by the waterboard. For farmers, the solution could be beneficial because it could lead to less water shortage in dry periods.

Effects explanation

Aquifer management has a positive effect on water nuisance because it captures the excess water.



D5

Aquifer storage and recovery

Hypothesis

Aquifer storage and recovery uses the aquifer layers for water storage and the recovery of water, leading to less water shortage in summer.

Theoretical background

The technology could be used in areas with poor groundwater quality, due to salinisation or on locations where net extraction could cause damage because of dehydration. In the Netherlands, this system is mostly used for drinking water companies and in the greenhouse sector with rainwater capture on greenhouse roofs (STOWA, n.d.). Furthermore, it contributes to the reduction of water nuisance.

Practical implication

Excess water is infiltrated and stored in aquifers with the use of wells and infiltration ponds. The wells will be used again when the water is needed in the summer, because then the water will be pumped out. It is a technological solution (STOWA, n.d.).

References

STOWA. (n.d.). Aquifer storage and recovery. Retrieved April 30, 2025, from <https://www.stowa.nl/deltafacts/zoetwatervoorziening/delta-facts-english-versions/aquifer-storage-and-recovery>

Scale



Related to



Specific location

Along waterways

Related to patterns

B1

Positive effect on



Negative effect on



Stakeholders

- Staatsbosbeheer
- Waterboard Zuiderzeeland
- Province of Flevoland

Staatsbosbeheer is important for the riparian zone because they could maintain the riparian buffer and improve the biodiversity.

The waterboard could look at the effects of this nature-based solution on the water quality.

Effects explanation

A freshwater buffer zone creates more space for water storage. Furthermore, the plants will improve the soil and therefore might reduce soil subsidence.



E1

Riparian buffer

Hypothesis

Riparian buffer zones provide ecosystem services and play a critical role in climate regulation and salinisation.

Theoretical background

The riparian buffer zone is the zone between land and waterways. They are characterised by their combination of aquatic and terrestrial habitats (European Environment Agency & European Commission, n.d.). This cross-over of habitats is important for wildlife habitat, air and water quality and carbon sequestration. The buffer zone has a mixture of trees, shrubs and plants and extends back from the bank for at least 10 metres. For agricultural fields, the buffer zone is the area between the crops and the riverbank.

Practical implication

Riparian buffers could be implemented on the landscape-scale green infrastructure to provide a variety of functions (USDA, n.d.). It is important to consider the landscape context when designing buffers, design each buffer for multiple objectives, and be aware of potential unintended effects.

References

European Environment Agency & European Commission. (n.d.). Riparian zones. Copernicus. Retrieved May 1, 2025, from <https://land.copernicus.eu/en/products/riparian-zones>
USDA. (n.d.). Riparian forest buffers. USDA Forest Service. Retrieved May 1, 2025, from <https://www.fs.usda.gov/nac/practices/riparian-forest-buffers.php>
<https://www.fs.usda.gov/nac/buffers/index.html>

Scale



Related to



Specific location

On farms that deal with salinisation

Related to patterns

C1

Positive effect on



Negative effect on



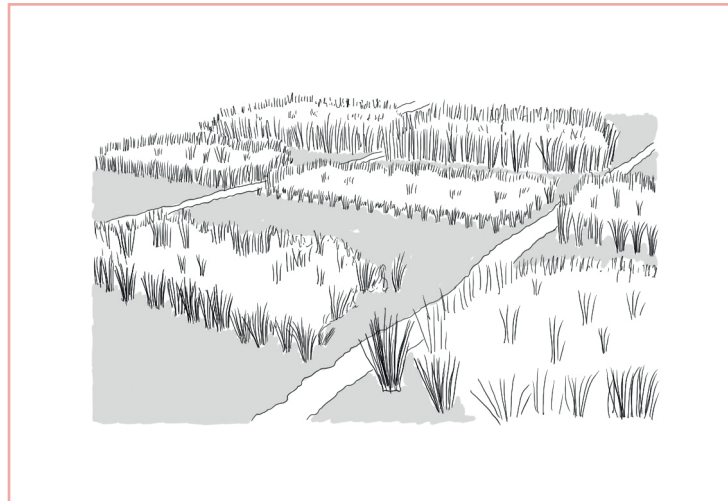
Stakeholders

- Farmers
- Province of Flevoland

Salt-tolerant crops are important for the farmers because they give a solution for salinisation. Wageningen University and Research could give advise on the type of plants that could be used and the consequences of the use of these plants.

Effects explanation

The salt-tolerant crops could also have a positive effect for farmers who deal with drought, because the farmers could use salt water from the ditches to water their plants instead of using drinking water.



E2

Salt tolerant crops

Hypothesis

Salt-tolerant crops improve food security with less impact on freshwater supplies.

Theoretical background

Saline agriculture provides a solution to farming on salt-affected soils by selecting salt-tolerant crops and employing irrigation, fertilisation and soil management techniques. The use of salt-tolerant crops reduces the dependency on freshwater (STOWA, n.d.-b).

Practical implication

Plants such as onions, beets, cabbage and potatoes could be used for saline agriculture. Onions require a loose, sandy or loamy soil that is high in nutrients. They have a shallow root system and do not require a lot of water. They are a little bit more sensitive to salt than carrots and potatoes (Saline Agriculture Worldwide, n.d.) There are multiple species of cabbages, and each species differs in salt tolerance. Generally speaking, kale has a better salt tolerance than cauliflower. Lastly, potatoes are relatively salt sensitive, but a few varieties could deal with a higher salt level.

References

STOWA. (n.d.-b). Salt-tolerant crops. Retrieved May 4, 2025, from <https://www.stowa.nl/deltafacts/zoetwatervoorziening/delta-facts-english-versions/salt-tolerant-crops>
Saline Agriculture Worldwide. (n.d.). Saline agriculture. Retrieved May 4, 2025, from <https://www.salineagricultureworldwide.com/saline-agriculture>

Scale



Related to



Specific location

IJsselmeer and Markermeer

Related to patterns

Positive effect on



Negative effect on



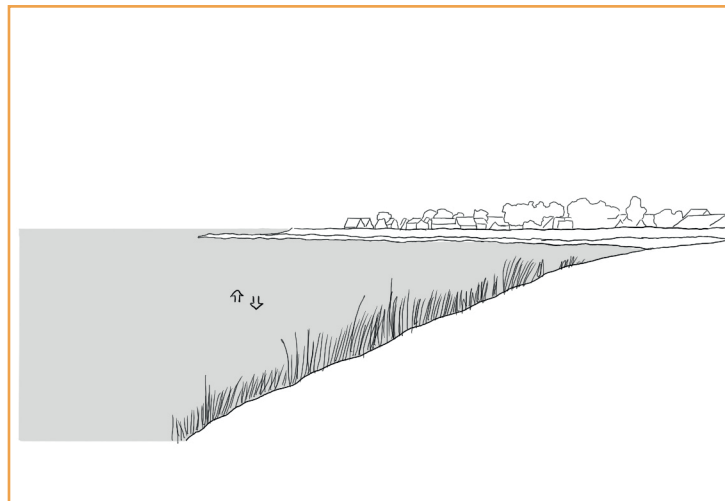
Stakeholders

- Rijkswater
- Deltacommission
- Ministry of Infrastructure and Water
- Flevoland

The water level fluctuations could be important for the water quantity of the IJsselmeer region. The decision is made by the Deltacommission and could have consequences for the province of Flevoland.

Effects explanation

Water fluctuations could have a negative impact on the dikes because there will be more water pressure if the water level goes up. But it could have a positive effect on drought, because it creates more drinking water in summer.



P1

Water level fluctuations IJsselmeer

Hypothesis

A higher water level in the summer reduces water shortage during drought, and a lower water level in the winter reduces water nuisance during the wet season.

Theoretical background

The IJsselmeer region is used for drinking water, recreation, ships, agriculture and the flushing of the polders. With high temperatures, it is possible that there will not be enough water supply from the rivers to the IJsselmeer. By approving water level fluctuations, it is possible to store more water in the summer, and therefore have more water when there is a drought (Rijkswaterstaat, n.d.).

Practical implication

In summer, the water level is allowed to change between -0,10 m NAP and -0,30 m NAP. If the NAP height is 0 m, it will be almost even with the North Sea. In winter, there is a chance that there is too much water. Therefore, the water level will be lowered to -0,40 m NAP at the end of the summer (Ministerie van Infrastructuur en Waterstaat & Rijkswaterstaat, n.d.-b).

References

Rijkswaterstaat. (n.d.). Het IJsselmeer en Markermeer als regenton. Retrieved May 4, 2025, from <https://www.rijkswaterstaat.nl/water/projectenoverzicht/ijsselmeer-zoetwatervoorraad-op-peil/doelen-en-resultaten>

Ministerie van Infrastructuur en Waterstaat & Rijkswaterstaat. (n.d.-b). IJsselmeergebied: zoetwatervoorraad op peil. Rijkswaterstaat. Retrieved May 4, 2025, from <https://www.rijkswaterstaat.nl/water/projectenoverzicht/ijsselmeer-zoetwatervoorraad-op-peil>

Scale



Related to



Specific location

Related to patterns

Positive effect on



Negative effect on



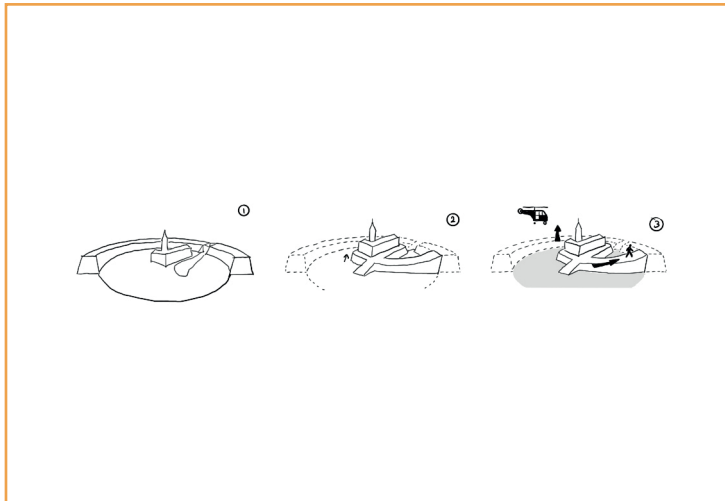
Stakeholders

- Ministry of Infrastructure of Water
- Province of Flevoland
- Waterboard Zuiderzeeland
- Municipalities

Multilayer safety is a way of risk management that is important on multiple scale-levels. Therefore, it becomes important that the municipalities, province and waterboard work well together.

Effects explanation

Multilayer safety is risk management and therefore deals with flooding through policies.



P2

Multilayer safety

Hypothesis

Multilayer safety is an important policy that focuses on risk management of flooding and consequence mitigation.

Theoretical background

Multilayer safety works in three ways: the first layer is prevention. The second is focusing on the realisation of a sustainable spatial environment. Lastly, the third layer focuses on better preparation for flooding. Multi-layer safety is a combination of probabilities and the consequences of flooding (STOWA, n.d.-b).

Practical implication

Multilayer safety could result in dike improvements or could be combined with building with nature. For the second layer, it could result in new types of buildings. Furthermore, it could result in not building in risky areas (STOWA, n.d.-b).

References

STOWA. (n.d.-b). Meerlaagsveiligheid in de praktijk. Retrieved May 4, 2025, from <https://www.stowa.nl/deltafacts/waterveiligheid/innovatieve-dijkconcepten/meerlaagsveiligheid-de-praktijk>

Scale



Related to



Specific location

Related to patterns

Positive effect on



Negative effect on



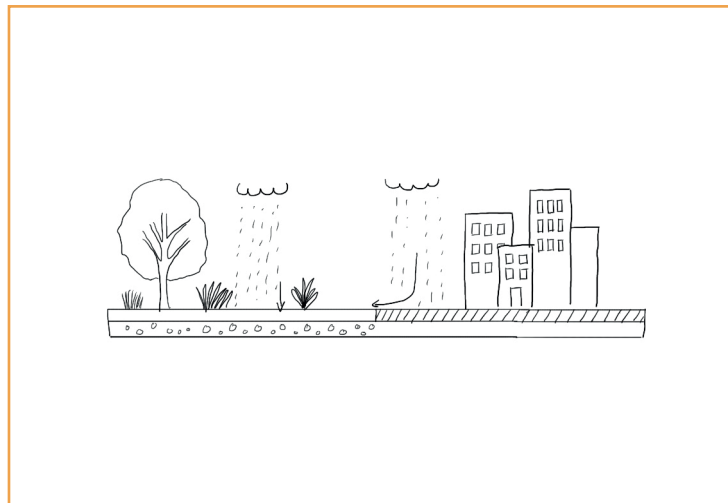
Stakeholders

- Municipalities
- Residents
- Waterboard Zuiderzeeland

The reduction of soil sealing is a policy that should be managed by municipalities. This policy mainly works on a small scale. It is possible to let residents participate in the design of their street with less pavement.

Effects explanation

The reduction of paved materials creates more space for open soil and therefore more space for water storage in the soil.



P3

Reduction of soil sealing

Hypothesis

The reduction of soil sealing is better for the catchment of water, and it reduces the impact of climate change.

Theoretical background

Soil sealing has multiple negative impacts, such as the reduction of possible infiltration, the amount of water storage that the soil could take, and it reduces the root system of plants (Informatiepunt Leefomgeving, n.d.).

Practical implication

In new developments, designers should already focus on minimising soil sealing. This could reduce the impact of soil sealing and climate change. Another way of reducing soil sealing is green roofs, blue-green networks and permeable pavement (Informatiepunt Leefomgeving, n.d.).

References

Informatiepunt Leefomgeving. (n.d.). Bodemambities voor bodemafdekking. Retrieved May 5, 2025, from <https://iplo.nl/thema/bodem/bodembeleid/bodemambities/bodemafdekking/>

Scale



Related to



Specific location

Related to patterns

C1

Positive effect on



Negative effect on



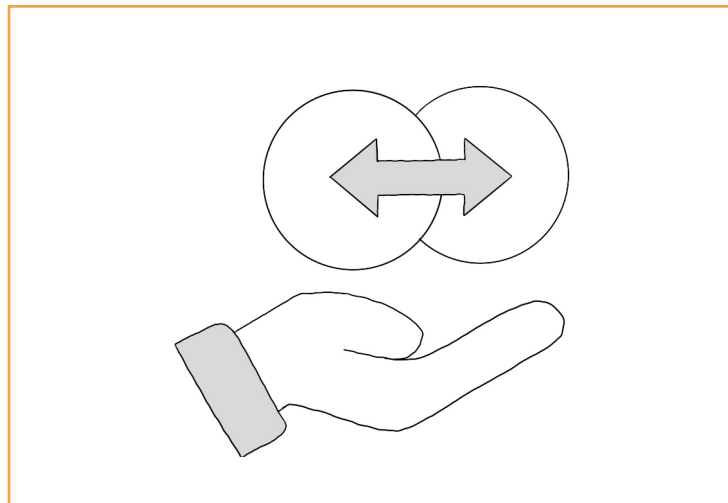
Stakeholders

- Ministry of Infrastructure and Water
- Province Flevoland
- Farmers

The transition fund could motivate farmers to transform their farms into more nature-friendly agriculture.

Effects explanation

A transition fund does not directly impact the water problems.



P4

Transition fund rural areas and nature

Hypothesis

The fund finances the measures that reduce the nitrogen load for nature and reduce CO2 emissions from agriculture.

Theoretical background

The government facilitates this fund to restore nature.

Practical implication

The Minister of Nature and Nitrogen is the administrator of the fund and assesses the applications for expenditure from the fund. Governments such as provinces, municipalities and water boards could submit proposals, as can the national government. The proposals must be based on the area programs for the following years (Rijksoverheid, 2022).

References

Rijksoverheid. (2022, December 15). tijdelijke wet transitiefonds landelijk gebied en natuur. <https://www.rijksoverheid.nl/actueel/nieuws/2022/12/15/tijdelijke-wet-transitiefonds-landelijk-gebied-en-natuur>

Scale



Related to



Specific location

Related to patterns

C2

Positive effect on



Negative effect on



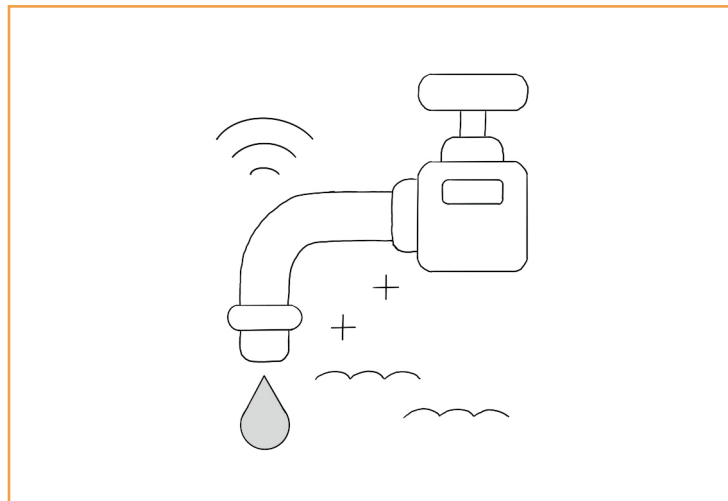
Stakeholders

- Waterboard Zuiderzeeland
- Province of Flevoland

The water levels are managed by the waterboard Zuiderzeeland. They could also advise the province on the height of the water levels.

Effects explanation

Smart water management could improve the soil quality because of a change in water level. This could lead to the reduction of soil subsidence and drought.



P5

Smart water management system

Hypothesis

Smart water management systems focus on efficient, sufficient and sustainable water utilisation by the integration of innovative technologies.

Theoretical background

The expectation is that there will be more water shortages in the future due to climate change. This means that there is a need for innovative ways to achieve water security. It improves water allocation, efficient water usage and water security while reducing operation costs, improving energy usage efficiency, and promoting sustainable behaviour.

Practical implication

Smart water management systems use the application of technology. The systems collect and process data to optimise decision-making processes. The collected data sets are used for the development, testing and evaluation of possible interventions relating to water management (BABLE - Solution: Smart Water Management, n.d.).

References

BABLE - Solution: Smart Water Management. (n.d.). BABLE Smart Cities. <https://www.bable-smartcities.eu/explore/solutions/solution/smart-water-management.html>