From fields to faucet

Pattern book

Metropolitan Ecologies of Places Series

Master Thesis - Pattern book
MSc Architecture, Urbanism and Building Sciences-Track Urbanism
Faculty of Architecture and the Built Environment
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Title:
From fields to faucet
Sub title: Safeguarding groundwater quality used for drinking water in the rural areas of the province of Utrecht with integrated solutions

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Introduction

This pattern book includes all developed patterns within the research. These patterns together form a pattern language.

The concept of a pattern language is in 1977 developed by architect Alexander Christopher and his colleagues. It helps to tackle the complexity of a variety of systems, under which designing cities and landscapes (Salingaros, 2000). A pattern is a repeatable design principle that provides a solution to recurring problems. The pattern describes the problem and the solution at the same time. Patterns consist of a hypothesis, the theory that supports this hypothesis, and a practical solution or application, often illustrated with a sketch or example (Rooij & van Dorst, 2020).

Patterns together form a pattern language. They work together to design complex systems and are a clear communication tool for presenting solutions. Each pattern is linked to one or more patterns and patterns can be created in different scales (Salingaros, 2000).

Because of the nature of a pattern language to help tackling problems in a complex system, it is also useful for creating integrated solutions. Therefore, this method is used as a design tool in this research.

Organization of the patterns

The pattern language is divided into three categories: technical patterns, organizational patterns, and spatial patterns.

Technical patterns:
These patterns involve the appliction or improvement of existing and emerging technologies within domains of water, agriculture, or urban development. An example is the implementation of new surface water purification techniques. In some cases, technical patterns may overlap with spatial patterns.

Organizational patterns:
These patterns are organizational in nature. While they do not directly result in spatial interventions, they support the realization of such interventions. An example is the provision of subsidies for biological farming.

Spatial patterns:
These patterns focus specifically on the (re)allocation of land and/or the introduction of specific spatial interventions. An example is the implementation of agroforestry.

T Technical

O Organizational

S Spatial

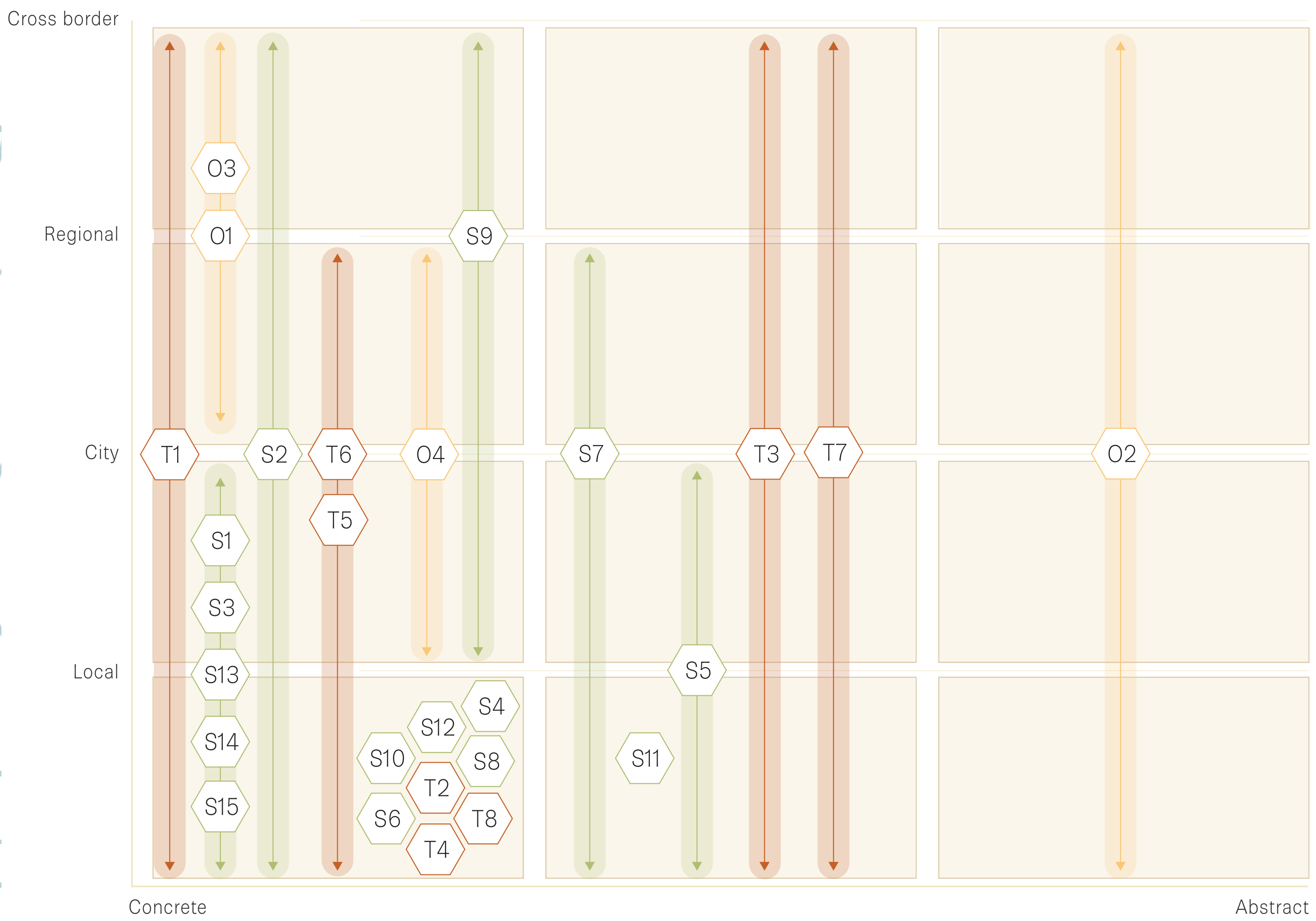
Substantiation of the patterns

The patterns are developed through literature research, interviews, and brainstorming sessions. These interviews and brainstorming sessions were conducted with professionals both within and outside the province of Utrecht. During the sessions, participants were asked to propose solutions for the different bottlenecks that were identified in the research. The solutions were then placed into a conceptual framework to clarify the relevant topics for which the solution applies: agriculture, urbanization, groundwater quality, or a combination of two or more. In this way, the **integrality** of the pattern language is ensured.

Subsequently, these solutions are categorized by scale and level of abstraction (see paragraph: pattern matrix). This approach ensured the **diversity** of the pattern language.

Pattern matrix

In addition to mapping the relationships between the patterns, their diversity is ensured by positioning the patterns along the dimensions of scale and abstraction (see adjacent figure). This visualization shows that several patterns can be applied at multiple scales. Furthermore, the pattern language predominantly contains many concrete patterns. In particular, the technical patterns demonstrate applicability across various scales.



Rules of the language - workshop

In this study, the patterns were applied in a design workshop. During the workshop, various professionals grom within and outside the province of Utrecht collaboratively used the pattern language to develop a design. There was also a test-workshop organized with students from the Urbanism track, who were familiar with the pattern language method. By employing the pattern language, the participants responded to the four scenarios previously developed.

To facilitate the use of the pattern language, a set of rules and a game sequence were created. These elements were intended to make the pattern language accessible to participants from different domains. Additionally, the structured sequence supported the initiation and progression of the discussion. The following page presents the design of the patterns used in the workshop, including the components they comprised. Important note: the patterns for the workshop are made in Dutch, since the participants of the workshop all spoke Dutch.

Workshop rules and sequence:

1. Groups of 4 - 5 participants were formed, each consisting of representatives from different domains (water, agriculture, urban development). At least one participant from each domain needs to be present in every group.

2. All participants read the assigned scenario.

3. The patterns are then distributed by category, with each participant receiving a selection of patterns from various categories. Participants are instructed not to reveal their patterns to others.

4. Participants review their patterns individually and ask the facilitator questions if anything is unclear.

5. One participant (selected freely) begins by placing a pattern on the table that they believe is the most appropriate for the scenario. They briefly explain the pattern and justify its relevance.

6. Proceeding clockwise, each participant places one pattern on the table and gives a brief explanation of its relevance to the scenario.

7. After each participant have placed two patterns, all patterns are turned face down. At this stage, the group engages in a discussion about whether the selected patterns are coherent and aligned with the scenario.

8. Participants then turn the patterns face up again. A group discussion follows regarding whether certain patterns should be replaced to improve the overall design. A maximum of ten patterns can be used in the final design.

9. Once the selection of ten patterns is finalized, participants began the design process using sketch paper, a large overview map of the area, and drawing tools such as markers, pens, and pencils.

Title

Pattern code

R1

ALLEEN BIOLOGISCHE LANDBOUW TOEGESTAAN IN GRONDWATER-BESCHERMINGSGEBIEDEN

Category

Ruimtelijke oplossing

Picture

Bij biologische landbouw worden geen pesticiden gebruikt en dit komt ten goede aan de (grond)waterkwaliteit.

Explanation

Concrete acties

- Regels stellen in de provinciale omgevingsverordening;
- Pachtgronden gebruiken;
- Optioneel: Financiële steun aan agrariërs voor transitie naar biologisch.

Practical implication

Stakeholders

- Provincie Utrecht
- Ministerie van LVVN
- Agrariërs

Most important stakeholders

Scale

Lokaal — Stad — Regionaal — Interregionaal

Term (time)

Kort

L G

Relevance to

Important considerations

Belangrijke afwegingen

- Keuze maken in certificaten and keurmerken;
- Planschadeprocedures;
- Effectiviteit van de maatregel - identificeer effecten buiten grondwaterbeschermingsgebieden

Spatial consequences

Ruimtelijke gevolgen

- Fruitteelt: minder fruitteelt (moelijker om biologisch te telen) of verplaatsen uit grondwaterbeschermingsgebied;
- Akkerbouw: ander soort akkerbouw, mogelijk ook minder

Assessment framework

To evaluate the solutions both individually and in relation to each other, an assessment framework has been developed. This framework clarifies the impact of each solution on the identified challenges, categorizing the effects as positive, neutral, or negative. The impact assessment is based on the current situation and the potential effect of each solution on this context.

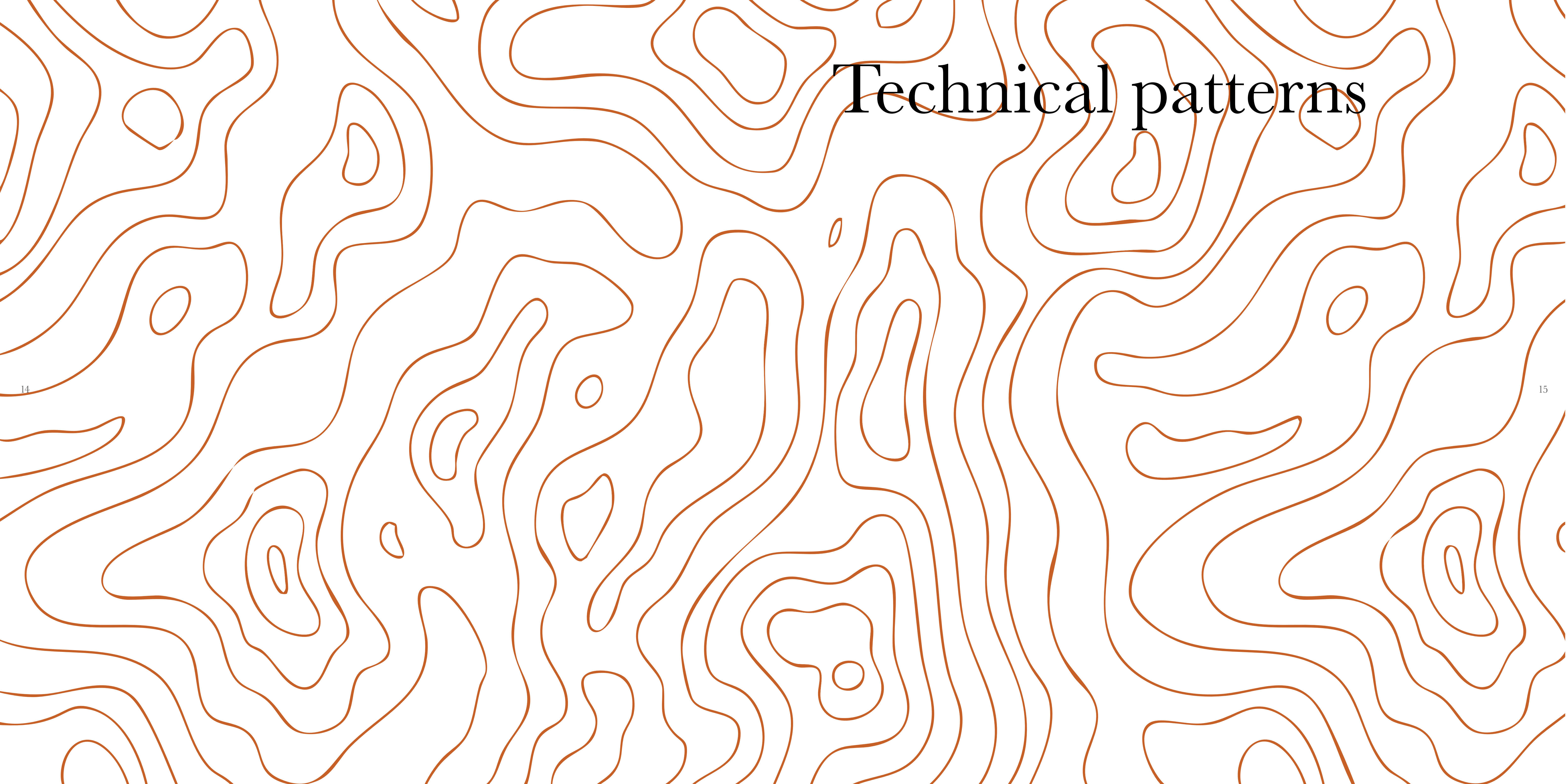
In the development of a strategy, this assessment framework can be utilized to guide decision-making. It provides insight into the collective impact of a set of solutions on the various challenges, facilitating a more informed and balanced approach.

Impact

Positive +
Neutral ●
Negative -

	Vulnerability of drinking water abstractions (to pollution)	Tension between purification effort and costumer costs	Tension between purification effort and (chemical) residual flows	Insufficient control over land-use (transition from grassland to arable farming	Usage of pesticides in conventional agriculture	Surplus of fertilizers in conventional agriculture	Uneven playing field for farmers in groundwater protection zones	(Increase in) emerging substances due to urbanization	Uncertainty of the source of contamination	Increasing subsurface congestion	Increase of (average) drinking water usage	Lack of clear agreements of future water allocation	Influence of drinking water abstraction on surrounding area and vice versa	Reduced (ground)water availability due to drought (climate change)
T1: Develop new drinking water abstractions	+	●	+/●	●	●	●	-	●	●	-	●	●	-	-
T2: Focus on new purification techniques - drinking water	+	+	+	●	●	●	●	●	●	●	●	●	+/●	●
T3: Focus on new purification techniques - surface water	●	+	+	●	●	●	●	+	●	●	●	●	●	●
T4: Precision agriculture	●	●	●	●	+	+	+/●	●	●	●	+	●	●	●
T5: Sustainable abstraction techniques	+/●/-	+/●	+/●	●	●	●	+/●/-	●	●	●	●	●	+/●/-	+/●
T6: Elaborate amount of observation wells groundwater quality	●	●	●	●	●	●	●	●	+	●	●	●	●	●
T7: Water purification before discharge	●	●	●	●	●	●	●	+	●	●	●	●	●	●
T8: Downscaling drinking water abstraction	+/●	●	●	●	●	●	+	●	●	+	-	●	+	+
O1: Stimulation - subsidy scheme for conversion to biological farming	●	●	●	+	+	+	+	●	●	●	●	●	+	●
O2: Collaboration in circular water management	●	+	+	●	●	●	●	●	●	●	+	+	●	+
O3: Stimulation - financial support for innovation in precision agriculture	●	●	●	+	+/●	+/●	+	●	●	●	+	●	●	+
O4: Acquiring land and leasing it to farmers	●	●	●	+	●	●	+/●	●	●	●	●	●	+	●
S1: Only biological agriculture in groundwater protection areas	●	●	●	+	+	+	-	●	●	●	●	●	+	●
S2: Only biological agriculture in infiltration areas	●	●	●	+	+	+	-	●	●	●	●	●	+	●
S3: Sweet water storage in rural land	●	●	●	●	●	●	●	●	●	●	●	●	●	+
S4: Natural water filtering	●	●	+	●	●	●	●	+	●	●	●	●	+	●
S5: Focus on services	●	●	●	●	+	+	+/-	-	●	●/-	+/●/-	●	+/●/-	●
S6: Remediation of soil	●													
S7: Land consolidation	+/●	●	●	+	+/●	+/●	+/●	●	●	+/●	+/●	●	●	●
S8: Expropriation	+/●	●	●	+	+/●	+/●	+/●	●	●	+/●	+/●	●	●	●
S9: Recreational awareness route	●	●	●	●	●	●	●	●	●	●	●	●	●	●
S10: Agroforestry	●	●	●	●	●	+	●	●	●	●	●/-	●	●	+
S11: Groundwater friendly cultivation	●	●	●	●	+	+	●	●	●	●	●	●	●	+/●
S12: No high-category industry allowed	●	●	●	●	●	●	●	+	●	●	●	●	●	●
S13: Bufferzones	●	●	●	●	●	+	●	●	●	●	●	●	●	+
S14: Only abstractions for public drinking water allowed	●	●	●	●	●	●	●	●	●	+	+/●	+	●	+
S15: Expand groundwater protection zone	+	●	●	●	+	+	-	+	●	●	●	●	●/-	●

Technical patterns



T1

DEVELOP NEW DRINKING WATER ABSTRACTION

D

Hypothesis

Developing a new drinking water abstraction in a place that is best suited, could help with lowering the purification effort. It could also conttribute to a higher production rate of drinking water.

Theoretical background

Many drinking water abstractions have developed historically, without always considering the most optimal location within the water system (Jansen, 2024). Establishing a new abstraction site in a more suitable location could reduce the need for extensive purification. A location could be chosen which has less polluting activities at ground level. Furthermore, recent findings indicate that a drinking water shortage is expected by 2030 (RIVM, 2023). By implementing a new drinking water abstraction site, water companies can increase their capacity and address this impending issue.

Involved stakeholders

- Vitens
- Province of Utrecht
- Water boards

Practical implication

- Develop new drinking water searching areas (province of Utrecht)
- Design drinking water abstraction (Vitens)
- Realise new infrastructure (Vitens)

Important considerations

- Environmental impact of drinking water abstraction
- Logical placement in water system
- Quality of groundwater
- Potential protectability of abstraction

Spatial consequences

- Positive or negative impact on water system
- New infrastructure
- Extra rules at groundlevel

Link with other patterns

T5

Local — City — Regional — Cross border

T2

FOCUS ON NEW PURIFICATION TECHNIQUES - DRINKING WATER

D

Hypothesis

Focusing on new purification techniques makes it possible to purify water with declining quality more easily.

Theoretical background

In addition to mitigating the deterioration of water quality, it is essential to invest in innovative purification techniques (H2O/Waternetwerk, 2024). As the quality and availability of raw water decline, it is simultaneously necessary to ensure the production of high-quality drinking water. In response to these rapidly changing conditions, currently applied drinking water treatment technologies must be adapted, replaced, or expanded. Ideally, this should be achieved at an acceptable cost and with minimal energy consumption (KWR Water Research Institute, 2021).

Involved stakeholders

- Vitens
- Central government
- Research institutes (example: KWR)

Practical implication

- Facilitating pilots (central government)
- Experimenting and testing new techniques (Vitens)
- Invest in innovation (central government)

Important considerations

- Finances
- How to deal with residual flows
- Purification efficiency - is it safe and stable?
- Amount of space it takes up

Spatial consequences

- The size of the drinking water abstraction
- Electricity usage (grid congestion)

Link with other patterns

T3

Local (selected) — City — Regional — Cross border

T3

FOCUS ON NEW PURIFICATION TECHNIQUES - SURFACE WATER

G D

Hypothesis

Focusing on new purification techniques makes it possible to purify water with declining quality more easily. Cleaning surface water helps to reduce the amount of low quality water seaping into the ground.

Theoretical background

In addition to mitigating the deterioration of water quality, it is essential to invest in innovative purification techniques (H2O/ Waternetwerk, 2024). Surface water sometimes seaps into the ground and pollutes groundwater. There are also cases of artificial infiltration of surface water into the ground, to reduce periods of drought. The introduction of non-native water into an area may also introduce contaminants, such as pharmaceutical resideurs or other anthropogenic substance (Van Dooren et al., 2022). To minimize these effects, the implementation of advanced purification techniques can be considered, ensuring that cleaner water infiltrates the soil.

Involved stakeholders

- Water boards
- National government
- Research institutes (example: KWR)

Practical implication

- Facilitating pilots (central government)
- Experimenting and testing new techniques (Waterboards)
- Invest in innovation (central government)

Important considerations

- Finances
- How to deal with residual flows

Spatial consequences

- Electricity usage (grid congestion)
- Different residual flows

Link with other patterns

T2 T7

Local — City — Regional — Cross border

T4

PRECISION AGRICULTURE

G

Hypothesis

Precision agriculture improves sustainable food production in intensive agriculture

Theoretical background

The World Food Organization calls for a combination of sustainable agriculture in the EU, maintaining the current agricultural production (FAO et al., 2023). Climate change may cause a shift in crops worldwide and could give extra pressure on the agricultural system in the Netherlands (Provincie Utrecht, 2024b). It is therefore important to transform the current intensive agriculture to a more sustainable variant. This could be partly done by precision agriculture. "In precision agriculture, plants or animals receive highly targeted treatment tailored to their specific needs through the use of advanced technologies" (WUR, 2025b). The province of Utrecht states to focus, among other things, on precision agriculture (Provincie Utrecht, 2024b).

Involved stakeholders

- Farmers
- Province of Utrecht
- Vitens
- Research institutes
- Central government

Practical implication

- Provide education for farmers for the implementation of precision agriculture (province of Utrecht)
- Invest in innovation (central government)
- Facilitate pilots (province of Utrecht)

Important considerations

- Effectiveness of the innovation techniques

Spatial consequences

- Preservation of intensive agriculture in the area

Link with other patterns

03

Local — City — Regional — Cross border

T5

GEOGRAPHICAL DIVERSIFICATION OF DRINKING WATER PRODUCTION LOCATIONS

G

Hypothesis

By distributing groundwater abstractions across a wider area, the pressure on the groundwater system is reduced, which also supports the improvement of groundwater qualiity.

Theoretical background

The horizontal distribution of drinking water production sites is identified by Deltares as one of the potential solutions to enable increased water abstraction while minimizing negative environmental impacts. By spatially dispersing groundwater abstractions, the pressure on the groundwater system is reduced, which can also contribute to improved groundwater quality (Jansen et al., 2024).

Involved stakeholders

- Vitens
- Province of Utrecht
- Waterboards
- Municipalities

Practical implication

- Allocate new locations for groundwater abstraction sites (Province of Utrecht)
- Design new groundwater abstraction location (Vitens)

Important considerations

- The impacts on other functions in the surrounding area

Spatial consequences

- Positive and/or negative impact on groundwater flows
- Extra rules for specific functions in potential newly created groundwater protection zones

Link with other patterns

T1 T8

Local ● — City ● — Regional ● — Cross border ○

T6

ELABORATE AMOUNT OF OBSERVATION WELLS GROUNDWATER QUALITY

G

Hypothesis

Installing additional observation wells in the surrounding area enhances insight into the origin and pathways of contaminants.

Theoretical background

Groundwater quality in the province is monitored through the Provinciaal Meetnet Grondwaterkwaliteit (PMG) (Vissers, 2024). By adding new monitoring wells, it becomes clearer where specific contaminent originate (Gathered during internship, March 5, 2025).

Involved stakeholders

- Province of Utrecht
- Waterboards

Practical implication

- Invest in more observation wells (Province of Utrecht)

Important considerations

- Location of new observation wells
- Costs and benefits - the potential likelihood of identifying a clear source of contamination

Spatial consequences

- More observation wells in area

Link with other patterns

T7

WATER PURIFICATION BEFORE DISCHARGE

G

Hypothesis

Mandating (new) industrial companies to achieve near-complete wastewater treatment prior to discharge into surface water bodies enhances the quality of (ground)water.

Theoretical background

Research is being conducted, including under the KWR Research Water Institute, into new techniques for wastewater treatment, with the aim of producing cleaner water. In this context, wastewater is increasingly regarded as a source of sustainable energy and raw materials (KWR Water Research Institute, 2023a). By making companies responsible for (near) complete purification of their wastewater, the risk of contamination of groundwater from industrial sources is significantly reduced.

Involved stakeholders

- Industrial companies
- Province of Utrecht
- Central government
- Waterboards

Practical implication

- Changing legislation and regulations – revoking and/or tightening permits

Important considerations

- Corporate responsibility for (ground)water quality
- Optional: providing financial support to companies for the implementation of water treatment facilities
- Liability for damages

Spatial consequences

- Little to no direct discharge of (chemical) industrial wastewater.
- Potential increase in spatial demand by businesses due to the installation of treatment facilities.

Link with other patterns

O2 T3 S12

Local — City — Regional — Cross border

T8

DOWNSCALING DRINKING WATER ABSTRACTION

G

Hypothesis

Reducing groundwater abstraction maintains sufficient groun-water quality and thereby also contributing to improved ground-water quality.

Theoretical background

Water quality and water quantity are inseparable. Groundwater abstraction has a signifcant impact on the entire groundwater system, thereby affecting groundwater quality as well. For example, soil contaminants can be mobilized through abstraction (Informatiepunt Leefomgeving, 2025a). By reducing the volume of groundwater abstraction, these effects can be minimized.

Involved stakeholders

- Vitens
- Province of Utrecht

Practical implication

- Achieving reduced groundwater abstraction at abstraction site (Vitens)
- Optional: Reducing permitted abstraction capacity

Important considerations

- Potential positive and/or negative effects on groundwater-system
- Increasing drinking water production at an alternative location?

Spatial consequences

- A potential change in the scale of drinking water abstraction.
- Potential change in groundwater flows
- Potential change in groundwater quantity

Link with other patterns

T5 S14

Local — City — Regional — Cross border

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Organizational patterns

01

STIMULATION: SUBSIDY SCHEME FOR CONVERSION TO BIOLOGICAL FARMING

A G

Hypothesis

Stimulating farmers financially ensures a shift to biological agriculture, which has no chemically negative impact on groundwater quality.

Theoretical background

The World Food Organization calls for a combination of sustainable agriculture in the EU, maintaining the current agricultural production (FAO et al., 2023). Climate change may cause a shift in crops worldwide and in the EU. and can give extra pressure on the agricultural system in the Netherlands (Provincie Utrecht, 2024). It is therefore important to transform the current intensive agriculture to a more sustainable variant. This can be partly done by using biological agriculture. In biological agriculture, no pesticides are used in the activities, which is positive for the groundwater quality (F. A. Swartjes & Van Der Aa, 2019)

Involved stakeholders

- Province of Utrecht
- European Union
- National government
- Vitens

Practical implication

- Drafting regulations and making finances available
- Province promotes to the EU and the central government that the scheme is made available

Important considerations

- Ensure sufficient participation
- The duration of the arrangement (structural costs - term)

Spatial consequences

- Shift to biological agriculture in area
- Extensification of a number of companies

Link with other patterns

S1 S2 S15

Local — City — Regional — Cross border

02

COLLABORATION IN CIRCULAR WATER MANAGEMENT

A U G D

Hypothesis

A collaboration of different stakeholders improves the development of circular water management. Circular water management could ensure enough high-quality drinking water and simultaneously has no negative impact on the groundwater quantity.

Theoretical background

Stakeholders are able to help each other in creating a circular water cycle. Setting up a collaboration makes it possible to share innovations and experiences and can connect businesses to each other to close the watercycle. For example, effluent from sewage treatment plants can be made suitable as a source for irrigation, according to the research EffluentFit4Food (Elsevier B.V., 2024). Groundwater quantity is strongly linked to groundwater quality and this solution ensures that the use of groundwater is reduced.

Involved stakeholders

- Province of Utrecht
- National government
- Municipalities
- Waterboards
- Drinking water companies

Practical implication

- Set up a partnership between stakeholders. A good example of a collaboration in circular water management is Zoetwaterboeren (Zoetwaterboeren, 2024), which commits to research, development and demonstration of a sustainable watersystem for farmers.
- Organise meeting points, like a congres, where stakeholders can meet and learn from each other and/or choose to collaborate.
- Changing legislation: Changes in legislation are necessary to be able to allow certain aspects of circular water management, like using effluent for agriculture.

Important considerations

- Ensure sufficient participation
- The duration of the collaboration

Spatial consequences

- -

Link with other patterns

T7 S12

Local — City — Regional — Cross border

03

STIMULATION: FINANCIAL SUPPORT FOR INNOVATION IN PRECISION AGRICULTURE

A G

Hypothesis

Precision agriculture improves efficiency in intensive farming and has less negative impact on groundwater quality.

Theoretical background

The World Food Organization calls for a combination of sustainable agriculture in the EU, maintaining the current agricultural production (FAO, IFAD, UNICEF, WFP and WHO, 2023). Climate change may cause a shift in crops worldwide and in the EU. and can give extra pressure on the agricultural system in the Netherlands (Provincie Utrecht, 2024). It is therefore important to transform the current intensive agriculture to a more sustainable variant. This can be partly done by using precision agriculture. Precision farming enables the precise application of fertilizers, crop protection agents, and veterinary medicines in the optimal dosage, at the right time, and in the most suitable location. This can enhance agricultural yields while significantly reducing the negative impact on water quality (KWR, 2018)

Involved stakeholders

- Province of Utrecht
- European Union
- National government
- Vitens

Practical implication

- Invest in research: financial support for research in the Netherlands to apply this form of agriculture. Pilotprojects can be done to investigate the applicability of this form of agriculture.
- Educate farmers to work with this new form of agriculture.
- Enhance and change (spatial) policy and legislation about innovative technology, to make it possible to work with these new technology.

Important considerations

- Financial resources
- Ensure sufficient participation
- The duration of the arrangement (structural costs - term)

Spatial consequences

- Potential more precision agriculture in the area

Link with other patterns

T4

Local — City — Regional — Cross border

04

ACQUIRING LAND AND LEASING IT TO FARMERS

A G

Hypothesis

Governments could influence the type of agriculture by purchasing land and leasing it to farmers, in order to improve groundwater quality.

Theoretical background

Agricultural enterprises have the option to sell their land to the National Land Bank, after which the government incorporates this land into regional planning processes managed by the provinces. The province determines the type of land use and the conditions under which the land may be sold. This grants provinces the authority to alter the designated function of the land. They may impose conditions, such as permitting only agricultural activities that do not negatively impact groundwater quality.

In recent years, the average price of agricultural land has increased, placing financial pressure on farming operations (Kadaster, 2025). Through this approach, the government van support farmers who whish to remain in the area and assist them in transitioning to more extensive farming practices.

Involved stakeholders

- National government
- National Land Bank
- Province of Utrecht
- Municipalities
- Agricultural collectives
- Other stakeholders in entire chain of the farmer

Practical implication

- Create long term goals
- Identifying strategic areasfor acquiring land
- Incorporating groundwater protection zones into subsidy programs to support agricultural transition

Important considerations

- Financial resources
- Possibility to change the landscape - in relation to cultural-historical and natural values (farmland birds)
- Possibility to depreciate the land

Spatial consequences

- Following Utrecht's policy; more extensive and nature-inclusive farming;
- Zoning with extra rules for specific functions

Link with other patterns

S7 S8

Local City Regional Cross border

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Spatial patterns

S1

ONLY BIOLOGICAL AGRICULTURE IN GROUNDWATER PROTECTION AREAS

A G

Hypothesis

Biological agriculture does not chemically pollute groundwater.

Theoretical background

Biological agriculture is, according to a study from Swartjes and van der Aa (2019), the most effective measure to reduce pesticides that are leaching into groundwater-based drinking water resources. In sustainable agriculture, synthetic fertilizers and chemical pesticides are not utilized during production. Also, the province of Utrecht focuses in their agricultural vision on the implementation of biological agriculture (Provincie Utrecht, 2024). To allow only biological farming in groundwater protection zones, the negative effects of pesticides leaking into the ground will be diminished/removed.

Involved stakeholders

- Province of Utrecht
- Ministry of agriculture
- Farmers

Practical implication

- Setting rules in the provincial environmental regulation
- Use leased land to create conditions
- Optional: Financial support for switching to organic farming

Important considerations

- Indicate what is meant by the term biological - make a choice in certificates and quality marks;
- Plan damage procedures;
- Effectiveness of the measure - Indentify effects outside groundwater protection area.

Spatial consequences

- Decline of fruit cultivation or displacement from groundwater protection area
- Decline of arable farming or shift to other forms of cultivation

Link with other patterns

O1 S2 S11

Local — City — Regional — Cross border

S2

ONLY BIOLOGICAL AGRICULTURE IN INFILTRATION AREAS

A G

Hypothesis

Biological agriculture does not chemically pollute groundwater.

Theoretical background

Biological agriculture is, according to a study from Swartjes and van der Aa (2019), the most effective measure to reduce pesticides that are leaching into groundwater-based drinking water resources. In sustainable agriculture, synthetic fertilizers and chemical pesticides are not utilized during production. Also, the province of Utrecht focuses in their agricultural vision on the implementation of biological agriculture (Provincie Utrecht, 2024). To allow only biological farming in infiltration zones, the negative effects of pesticides leaking into the ground will be diminished/removed, also in the long term.

Involved stakeholders

- Province of Utrecht
- Ministry of agriculture
- Farmers

Practical implication

- Setting rules in the provincial environmental regulation
- Use leased land to create conditions
- Optional: Financial support for switching to organic farming

Important considerations

- Indicate what is meant by the term biological - make a choice in certificates and quality marks;
- Plan damage procedures;
- Effectiveness of the measure - Indentify effects outside groundwater protection area.

Spatial consequences

- Decline of fruit cultivation or displacement from infiltration area;
- Decline of arable farming or shift to other forms of cultivation

Link with other patterns

O1 S1 S11

Local — City — Regional — Cross border

S3

SWEET WATER STORAGE IN RURAL LAND

A

G

Hypothesis

Water storage in farm land assures water availability without damaging groundwater levels.

Theoretical background

In summer, there is a precipitation deficit, while in winter there is a precipitation surplus (Verstand et al., 2024). To prevent drought in spring and summer it is necessary to store the surplus in the winter, because the waterquantity has effects on the waterquality. A lower water quantity means relatively more nutrients and other harmful substances in the groundwater (Khatri & Tyagi, 2014). Water storage improves soil infiltration. Furthermore, by storing the sweet water in the farm land, it is possible to use this water for food production.

Involved stakeholders

- Province of Utrecht
- Water boards
- Agricultural collectives
- Farmers

Practical implication

- Develop water storage policy for the entire region. This measure is only effective if there are taken measures in the whole area regarding water storage (Verstand et al., 2024).
- Connect Water boards and other important stakeholders with farmers for innovative solutions, like an 'agriculture water storage': a rural water storage combined with food production (Roelsma et al., 2015).
- Give financial support to farmers to realise water storage practices.

Important considerations

- Effectiveness - effects on the groundwater quality
- Storage capacity (spatial claim)
- Prioritization in relation to other (important) functions)

Spatial consequences

- Change of function to sweet water storage - less space for other functions
- Positieve and/or negative impact on groundwater system

Link with other patterns

S4 S10 S11 S13

Local — City — Regional — Cross border

S4

NATURAL WATER FILTERING

G

Hypothesis

Natural water filtering improves (ground)water quality

Theoretical background

Natural water filtering can be used to filter pollutants out of effluent, before it flows back to the surface water and infiltrates into the ground. In addition to using technical water purification installations, flora, fauna and the soil can help with water filtering and/or improving the water quality (Verstand et al., 2024).

Involved stakeholders

- Province of Utrecht
- Water boards
- Nature organizations
- Agricultural collectives
- Farmers

Practical implication

- Implementing specific water filtering techniques in rural area. Examples of water filtering techniques are using reed and floating waterplants to absorp nutrients or the removal of virusses and bacteria by sand filtration in the dunes (Verstand et al., 2024).
- Give financial support to farmers to realise natural water filtering practices.

Important considerations

- Effectiveness of the natural filter

Spatial consequences

- Alteration of the appearance of banks and ditches

Link with other patterns

S3 S6 S10 S13

Local — City — Regional — Cross border

S5

FOCUS ON SERVICES

A U G

Hypothesis

Mixed functions on an agricultural company means that multiple activities take place in addition to traditional agriculture, such as nature management, recreation or water storage. This could improve the groundwater quality.

Theoretical background

The intensive agriculture in the Province of Utrecht is currently based on a massive export industry, with many negative effects on the soil and groundwater (Arcadis Nederland B.V., 2023). The Province of Utrecht aims to a more extensive form of agriculture, mixed with services, instead of products. This includes a focus on tourism, recreation and water- and soil management (Provincie Utrecht, 2024). These services can generate income to compensate the switch from intensive to extensive farming. Extensive farming has a less negative effect on groundwater quality.

Involved stakeholders

- Province of Utrecht
- Farmers
- Waterboards
- Municipalities
- Nature organisations
- Agricultural collectives

Practical implication

- Change legislation and allow a diverser amount of functions in the rural area.
- Optional: Create new bussinesmodels: - help farmers with creating new business-models with the newly set up services. Embed ecosystem services in the financial organisation of the government(s).

Important considerations

- Impact of the new function on the groundwater quality
- Business model of the farmer

Spatial consequences

- A change of land use in the area

Link with other patterns

S9

Local — City — Regional — Cross border

S6

REMEDIATION OF GROUNDWATER

G

Hypothesis

The remediation of soil ensures that contaminants are removed , preventing them from entering the groundwater.

Theoretical background

In groundwater remediation contamination is managed, limited, or removed from the groundwater. In this way, groundwater quality is improved (Informatiepunt Leefomgeving, 2025)

Involved stakeholders

- Province of Utrecht
- Gemeenten
- Private eigenaren van percelen
- Exploitanten van kabels en leidingen
- Rijkswaterstaat
- Waterschappen

Practical implication

- Remediation study (costs-benefit analysis)
- Selecting optimal variant and prepare a budget - apply for funding
- Develop remediation plan (preffered variant)
- Select a contractor to carry out the work

Important considerations

- Clarity on the exact location of contamination
- Clarity regarding the type(s) of substance(s)
- Costs and benefits
- Future land use

Spatial consequences

- The soil becomes cleaner

Link with other patterns

S4 S13

Local ● — City ○ — Regional ○ — Cross border ○

S7

LAND CONSOLIDATION

A | G

Hypothesis

Land consolidation to relocate undesirable land use from recharge areas or groundwater protection zones.

Theoretical background

Land consolidation allows for the exchange of land uses that are better suited to the surroundings of a groundwater abstraction site in place of the current land use. In this way, the risks of deteriorating groundwater quality are minimized while ensuring that the farmer's activities are not disrupted (Vitens, 2025).

Involved stakeholders

- National Land bank
- Province of Utrecht
- Farmers
- Municipalities

Practical implication

- Discussing the needs and requirements of (future) landowners
- Drafting a land consolidation agreement
- Land-use change in environmental zoning plan
- Optional: Providing subsidies to facilitate the land exchange

Important considerations

- Land value ratio
- Future land use of the land

Spatial consequences

- A change of land use in the area

Link with other patterns

O4 S8

Local — City — Regional — Cross border

S8

EXPROPRIATION

G

Hypothesis

Expropriation to alter undesirable land use within recharge areas or groundwater protection zones.

Theoretical background

Exrorpiation allows to sell land with land uses that are not suited within the existing area. With this solution, the farmer can be fully compensated for their property. In this way, the risks of deteriorating groundwater quality are minimized (Vitens, 2025).

Involved stakeholders

- Province of Utrecht
- Municipalities
- Waterboards
- Private landowners
- Legal authorities

Practical implication

- Engaging in discussions with landowners
- Appraise the real estate
- Allocate financial resources

Important considerations

- Future land use
- Necessity of expropriation other options considered, such as land consolidation
- Financial resources for compensation

Spatial consequences

- A change in land use

Link with other patterns

O4 S7

Local City Regional Cross border

S9

RECREATIONAL AWARENESS ROUTE

U G

Hypothesis

Creating a recreational route raises awareness of water abstraction and groundwater protection areas.

Theoretical background

Research by the Randstedelijke Rekenkamer has shown that parties are often unaware of the additional regulations in groundwater protection zones (Randstedelijke Rekenkamer, 2021). The awareness of these parties, including residents, can be increased by creating a pathway that provides more information about groundwater protection zones.

Involved stakeholders

- Province of Utrecht
- Municipalities
- Private landowners
- Touristic organisations

Practical implication

- Developing a possible route (concept and design)
- Arranging facilities (benches, route maps, informational signage, wayfinding indicators

Important considerations

- Purpose of and interest in the route
- Target audience
- Which attractions should be integrated?

Spatial consequences

- Informational signage, wayfinding indicators and similar in the area
- Area is likely to be visited more frequently by tourists and day-trippers

Link with other patterns

S5

Local City Regional Cross border

S10

AGROFORESTRY

A G

Hypothesis

The application of agroforestry reduces nutrient leaching and increases the soil's capacity to absorb nutrients.

Theoretical background

Agroforestry can buffer extreme wather conditions such as droughts and heavy rainfall, and can reduce nutrient leaching into surface and groundwater (Fuchs et al., 2022). The application of agroforestry thus contributes to the improvement of groundwater quality.

Involved stakeholders

- Province of Utrecht
- Farmers
- Municipalities
- Nature organisations

Practical implication

- Change environmental zoning plan to make agroforestry possible
- Optional: financial support to make transition possible

Important considerations

- Financial feasibility of (new) operations
- Type of agroforestry and effects on groundwater quality

Spatial consequences

- Change of land use
- Change in the landscape character

Link with other patterns

S3 S4 S13

Local (selected) — City — Regional — Cross border

S11

GROUNDWATER FRIENDLY CULTIVATION

A G

Hypothesis

The implementation of cropping systems that minimize nutrient surplus and the use of pesticides contributes to improved groundwater quality.

Theoretical background

As part of Deltaplan Agrarisch Waterbeheer (Deltaplan Agricultural Water Management), experiments have been conducted with alternative crops that place les pressure on groundwater quality. Examples include chemical-free fodder beets and the cultivation of Sorghum. These types of crops have a lower negative impact on groundwater quality in terms of nutrient surplus and/or the use of pesticides. As such, they are considered promising options for implementation in groundwater protection areas (Deltaplan Agrarisch Waterbeheer, 2022)

Involved stakeholders

- Province of Utrecht
- Municipalities
- Farmers
- Agricultural collectives
- Research institutes

Practical implication

- Providing education to farmers for the implementation of alternative crops (Province of Utrecht
- Invest in innovation (National government)
- Facilitate pilots (Province of utrecht)

Important considerations

- Financial feasibility of (new) business models
- Possibility of integration into current business operation
- Suitability of the soil for alternative crops

Spatial consequences

- Alternative crops in the relevant area
- Potential alternative landscape structure

Link with other patterns

S1 S2

Local — City — Regional — Cross border

S12

NO HIGH-CATEGORY INDUSTRY ALLOWED

U G

Hypothesis

Prohibiting high-category industries in order to reduce their negative impact on groundwater quality.

Theoretical background

Industrial activities place significant pressure on groundwater quality due to the emission of industrial substances and heavy metals. In regional case files, high-category industries are identified as posing greater risks to drinking water abstraction (Engel et al., 2023). By restricting industrial development in designated areas, these negative impacts on groundwater quality can be mitigated.

Involved stakeholders

- Province of Utrecht
- Municipalities
- Industrial companies

Practical implication

- Changing laws and regulations - revoking and/or tightening permits
- Changing laws and regulations - adjusting environmental plan

Important considerations

- Consideration of measures to reduce output
- Damage claims
- Offering a new location

Spatial consequences

- No heavy industry in the relevant area
- Reduction of industrial discharges in the area

Link with other patterns

T7 S15

Local — City — Regional — Cross border

S13

BUFFERZONES

G

Hypothesis

Buffer zones can filter water that infiltrates the soil, thereby contributing to improved groundwater quality.

Theoretical background

According to research by Wageningen University Research, bufferzones can retain diffuse nutrient flows and/or remove substances (Bakker et al., 2023). This contributes, among other things, to improved (ground)water quality.

Involved stakeholders

- Province of Utrecht
- Municipalities
- Farmers
- Nature organisations

Practical implication

- Allocate financial resources
- Change environmental zoning plan

Important considerations

- The need to realise a bufferzone
- The size of the bufferzone

Spatial consequences

- Change in the landscape character

Link with other patterns

S3 S4 S6 S10

Local — City — Regional — Cross border

S14

ONLY ABSTRACTIONS FOR DRINKING WATER ALLOWED

G D

Hypothesis

By allowing groundwater abstractions only for public drinking water supply, it is prevented that excessive pressure is exerted on the groundwater system.

Theoretical background

Groundwater quantity is closely linked to groundwater quality, and excessive groundwater abstraction can negatively impact water quality. Especially in the context of increasing drought, it becomes essential to make choices between essential and less essential functions (Gathered during internship, March 5, 2025). By allowing only certain groundwater abstractions within a given area, groundwater quantity can be safeguarded, which in turn helps protect groundwater quality.

Involved stakeholders

- Province of Utrecht
- Municipalities
- Vitens
- Potential users private groundwater abstraction

Practical implication

- Changing laws and regulations - revoking and/or tightening permits
- Changing laws and regulations - adjusting environmental plan

Important considerations

- Presence of other functions that abstract groundwater
- Damage claims

Spatial consequences

- Change in groundwater flows
- Disappearance of other functions that abstract groundwater

Link with other patterns

T8

S15

EXPAND GROUNDWATER PROTECTION ZONE

G D

Hypothesis

Increasing the groundwater protection area leads to improved groundwater quality.

Theoretical background

The province protects groundwater through a number of protection zones, including the groundwater protection zone. Within these zones, additional regulations apply to the use of certain pollutants (Provincie Utrecht, 2024). By expanding this zone, a larger area will fall under these regulations and fewer pollutants will infiltrate into the groundwater.

Involved stakeholders

- Province of Utrecht
- Water boards
- Municipalities
- Inhabitants
- Vitens
- Farmers
- (Industrial) companies

Practical implication

- Conducting hydrological research
- Changing laws and regulations - adjusting environmental plan
- Providing financial resources for the compensation of current functions.

Important considerations

- Negative impact on current functions and activities
- Other preventive measures considered
- Compensatory arrangements
- Damage claims

Spatial consequences

- Certain activities and functions are no longer possible - disappearance and/or reduction of these functions
- Limitation on the use of fertilizers and pesticides

Link with other patterns

O1 S12

Local — City — Regional — Cross border

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