BUILDING RESILIENCE FOR SUSTAINABLE FRESH WATER USE IN THE NETHERLANDS

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-FIRST DRAFT-

Abstract

This paper makes a series of suggestions for strengthening our understanding of dealing, through spatial planning, with increasingly challenging fresh water capacities. Based on a literature review and a detailed case study on the Netherlands, the paper explores current capacities and the resilience of the users of fresh water resources at a national level.

More theoretical issues of adaptive capacity and resilience are central to framing the case. Accordingly, the paper offers a framework for planning practice featuring these issues as evaluative indicators. The suggestions are intended to reveal the resilience among fresh water users like industry, energy producers, drinking water suppliers, nature and agriculture, and contribute to the quality of spatial planning work in this field.

The paper reveals that, currently, these users suffer in varying degrees from lacking capacities for efficiency, productivity and substitution. There is also a need for a longer term commitment to innovation. Important emerging practices include efforts to strengthen accessibility and reliance at specific places, efforts to establish water as a factor of choice and certainty of location, and institution building for policy integration between water, urban and economic development.

It is suggested that vulnerability strategies express themselves through interventions at two notions of place. *On-site* vulnerability implies levels of capacity at current locations and contexts, typically featuring strategies like productivity innovation, efficiency and thrift. *Beyond-site* vulnerability implies the potential capacity for locational change and adjustment, typically involving integration and substitution.

1. Introduction

This paper discusses current issues on adaptive capacity among large users of fresh water in the Netherlands. The notion of 'large users' refers more specifically to

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activities and choices in five prevailing sectors: industry, energy, water supply, agriculture and nature. These activities typically require relatively large amounts of fresh water for their existence and continuation. A leading question for the paper is to identify the major vulnerabilities these water users may face, given water availability issues from climate change, and to identify what capacities may be associated with these vulnerabilities.

Fresh water is an indispensable resource for many human activities. At the same time, it is distributed unevenly over space. It also suffers from inconsistent availability and variable accessibility. This is true on a global scale. Asia, for example, represents 60% of the world's population, but about 36% of global fresh water resources. Overall only 15% of the world's population lives in areas with abundant fresh water resources (United Nations, 2003, Revenga et al, 2000). But a similar uneven distribution occurs within continents, within individual countries, and at regional and local scale. One third of European citizens reside in countries with water stress, in particular around the vulnerable Mediterranean Sea (EEA, 2007). But also countries like Germany and Belgium deal with water stress.

For the Netherlands, vulnerabilities to water in general (like flooding), and fresh water shortages in particular, are on the increase. The European Water Exploitation Index (WEI) has been shown growing vulnerability (EEA, 2008). The Netherlands is also vulnerable due to its down-stream location for large European rivers like the Rhine, Meuse, Scheldt and Ems. Specifically, the country is vulnerable because of its high urban densities and the vast associated values on land, especially at places with serious potentials for water shortages and nuisance.

Overall, the problem here is one of changes in fresh water availability, specifically episodes of drought and intruding saline water from sea, due to climate change. The general situation is perceived as a situation with enough fresh water over the whole year, but, at the same time, increasing occurrences of insufficient quantities at the right place, insufficient quantities at the right time, and insufficient quantities of the right quality (Klijn et al, 2011; RWS, 2010).

Consequently, during the last decade there is growing uncertainty about locally continuous availability, and hence concerns about practices of securing adequate fresh water (e.g., RWS 2011). Climate changes in the Netherlands are producing higher sea levels, irregularities in rainfall intensity, limiting groundwater replenishment and unstable river flows, leading to land-use changes like 'space for water' and 'water sensitive' spatial planning in the Netherlands (e.g., Woltjer and Al, 2007). Climate change and resulting impact on water quality and availability have had important implications for the activities of water users. The vulnerability of their life and production is at stake (Nicholls et al, 2007). Vulnerability here refers to the degree to which an activity is sensitive to, and is able to anticipate the adverse effects of climate change, including variability and extremes in freshwater availability. The vulnerability of water users to climate change may be alleviated if their efforts and the efforts of planners and policy makers seek resourceful ways to deal with water or establish substitution possibilities like alternative sources.

Clearly, therefore, the issue of fresh water usage is not only related to the availability of water itself, but specifically also the capacities among users to handle issues like water shortage and improve efficiency and substitution.

2. Analysis

The analysis here assumes the hydrological system of fresh water in the Netherlands and its related institutional arrangements to represent an adaptive system with abilities to change or adapt in response to stresses and strains. We see resilience as a dynamic attribute, as it changes over time (e.g., Holling, 1994; Pendall et. al (2010). We follow a definition on adaptive capacity from the IPCC: “the ability or potential of a system to respond successfully to climate variability and change, and includes adjustments in both behaviour and in resources and technologies” (IPCC, 2007). The paper focuses, therefore, on current capacities and strategies of dealing with fresh water and the changes in its availability in terms of location. Obviously, notions of adaptive water management are related to our thinking (e.g., Pahl-Wostl, 2007; Gleick, 2003), as are notions of water-sensitive spatial planning (e.g., White, 2010).

Location is a key aspect for water use. The international literature on freshwater consumption points to two types of location considerations (e.g., Gleick, 2003; Mitchell, 2005). First the analysis considers the potential capacity to anticipate a changing freshwater availability *on-site*, at current locations and contexts. Secondly, there is the potential capacity in the corresponding sector *beyond-site*, or for altered vulnerability, in other words, involving locational change and adjustment. The paper, therefore, considers a variety of contextual factors affecting potentially the adaptive capacities of a sector (such as transportation, proximity, quality and location). It will be clear, incidentally, that both types of location considerations are closely linked to planning and policy making.

Another key aspect from the literature is the policy or management strategy used for fresh water management. These strategies, as explained earlier, may involve a focus on:
- Efficiency (using as little water as possible for the same production) or
- Productivity (higher returns from the same amount of water);
- Thrift (to use less water per se);
- Substitution (the use of alternative sources or other qualities of fresh water).

The extent to which users are able to influence these aspects is reflected by their capacity to innovate, invest and adapt. An investment to adjust production processes for drinking water to switch from local ground water sources to local surface water sources, for example, would suggest adaptive capacities *on-site* related to a substitution strategy. A widespread emphasis in the international literature, but also in national policies is on an efficient and sustainable use of land and resources. A central idea is that users are located at collectively the most effective place allowing for sustainable production. Within river basins, for instance, intensive users of water would be located downstream rather than upstream, thereby generating fewer effects on other users.

The paper will now focus on the capacities per sector for both possibilities at current places and opportunities elsewhere. Efficiency, productivity, economy, substitution and, overall, resilience are our central concepts. The paper attempts, theoretically, to refine the idea of resilience specifically to questions of place and strategy, and, empirically, to understand the capacities of fresh water users in the Netherlands.

3. Results

Dutch fresh water use involves both ground water extraction practices and surface water intake. Groundwater extraction is an activity common to the paper sector, the food and beverage industry, the chemical industry, and in agriculture and livestock, but above all in the drinking water sector (more than three quarters of the total). The general trend is that the extraction of groundwater by industry and water companies has decreased slightly in recent decades (PBL, 2011; Vewin, 2002, CBS, 2010).

Figure 1 shows that both industry and the drinking water sector nowadays obtain less groundwater than in the seventies, both in absolute terms and in terms of substitution with surface water. Considerations about drought and low groundwater levels are partly behind this (limited) shift. Extractions by water companies primarily involve tap water for households and industry (see Table 1). In the industrial sector, groundwater is used both as a raw material in manufacturing and as process water for cooling. For industry and energy companies, however, surface waters are an important source. It is striking that by far most surface water consumption (90%) involves use as a coolant (CBS, 2010). In particular, electricity companies are a bulk user (approximately 70% of the total), and represent risks in terms of quality of their effluent waters (e.g., oxygen balance). The largest plants are located around major rivers and the immediate coastal zone. There has been a slight downward trend in cooling water use.

Finally, it is striking that the total consumption has been relatively stable in recent decades (PBL, 2011): every year about 1 billion cubic meters of groundwater (found mainly in higher eastern and southern regions of the Netherlands) and around 13 billion cubic meters of surface water. In the same period, consumption and economic growth have been considerable.

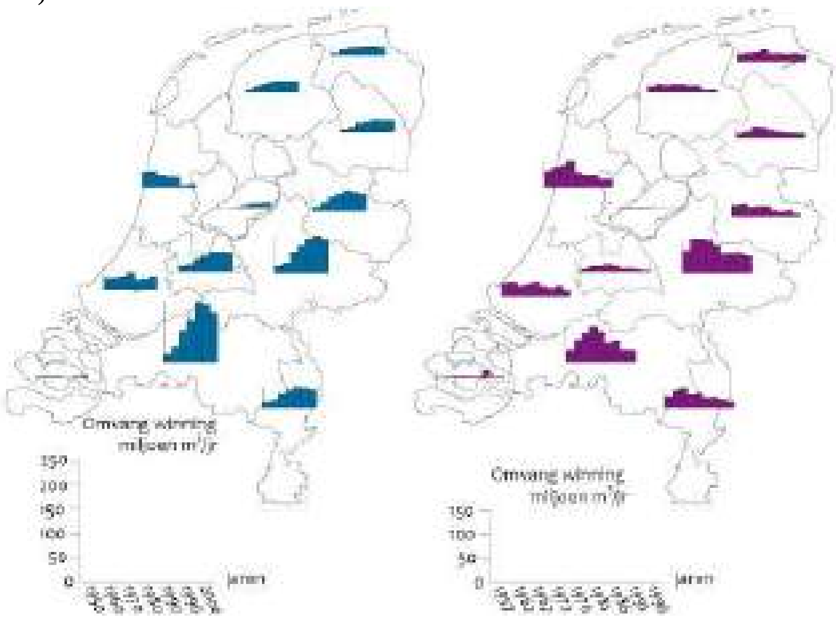
Table 1. Water extraction and use in the Netherlands per sector (2008, mln m^3/year)

	Total	Ground water	Surface water	Piped water
Extraction water supply agencies	1 252	762	490	-
Usage agriculture	119	47	24	47

Usage industry	3 643	155	3 308	181
Usage electricity plants	9 050	2	9 044	3
Usage other companies and households	1 329	1	431	905

Source: CBS, 2010.

Figure 1. Ground water extraction (in mln m^3/year) for water supply (left) and industry (right) (PBL, 2011)



3.1 Water use per sector

This section discusses consecutively possible capacities for 'water problems' in the sectors central to the paper: industry, energy companies, water companies, agriculture, industry and nature. The review here is based on recent (2000-2012) policy and strategy documents utilized by stakeholders from these sectors. In addition, the authors have held interviews with senior officials from organizations representing them, including the Association for Energy, Environment and Water (VEMW), Netherlands Energy Organisation (EN), the Netherlands Waterworks Association (Vewin), the Dutch Agricultural and Horticultural Organisation (LTO) and the Nature Society (VN).

Industry

Industrial products like steel, petroleum, chemicals and paper involve a number of heat-intensive processes. Typically, excess heat is transferred into cooling water, sometimes through large cooling towers. The industrial use of fresh water may also include the production of food or the generation of steam for temperature control or sterilization. Until recently, these industries have regarded fresh water as a relatively ubiquitous and rather cheap good. This perception of abundance, however, is gradually changing. There is a trend to invest more in capacities aimed at:

- efficiency and reducing freshwater use;
- measuring and monitoring water consumption (in view of the cost);
- the deployment of technologies for further efficiency and adaptive capacity.

A strong point for the industrial sector involves the relatively large adaptability of some larger users. A more economical and efficient use of groundwater is apparent, although the use of sustainable technology and also possible substitutions with surface water have experienced a slow start. An emerging practice involves alternative management arrangements, featuring area-oriented options for clustering of industry and water companies. Shared infrastructure (e.g., pipelines) and the collaborative management of freshwater reservoirs are among recent initiatives. Companies have also advocated for improved, public-private management of water purification plants.

Overall, our findings for industrial water users suggest that they adjust gradually, for example through more sustainable production processes (efficiency). There are limited short-term vulnerabilities. The sector already anticipates towards more restricted future water availability. At the same time, the pace of anticipation is somewhat slow. There is some considerable attention to new regulatory arrangements for area-management and innovation.

Energy plants

Electricity plants generally use water in two ways. The first way entails cooling water, which is obtained from the sea, rivers, lakes or canals. This water can both be saline and fresh, depending on the installation. The second way involves internal water, or process water, which flows through closed circuits. Cooling water in particular is typically used in large quantities and is therefore of key interest. The amount of cooling water used has been fairly stable in recent years. Cooling capacity is one of the factors taken into account to find a suitable location for any energy plant. The current vulnerability of the sector is significant. These plants can usually absorb a few days of interruption in the availability of cooling water, but repeated interruption is clearly problematic.

Energy companies, therefore, experience significant vulnerabilities to freshwater availability (cooling water for large plants). On the other hand, adaptivity and substitution are also significant: energy companies now select profitable locations at sea, using salt water as a coolant. There is also a clear intention to invest in renewable energy, thereby reducing dependence on cooling conceivably further.

Overall, our findings indicate that the energy production sector is vulnerable but no major problems will be found, at this time and in the near future. The greater part of Dutch power in the future will increasingly be produced at the coast, where enough (saline) cooling water is available. Shares of renewable energy are growing, but lagging behind internationally. A final aspect is that energy producers tend to release heat more efficiently at their plants, thereby increasing productivity.

Figure 2. Large-scale energy production units in 2011 (Energie-Nederland, 2011)

Water supply

Water supply agencies must ensure that they have sufficient supplies available to meet current and future demand. A resilient provision requires companies to develop the following capabilities (e.g., Wuijts et al, 2011; Gleick, 2003):

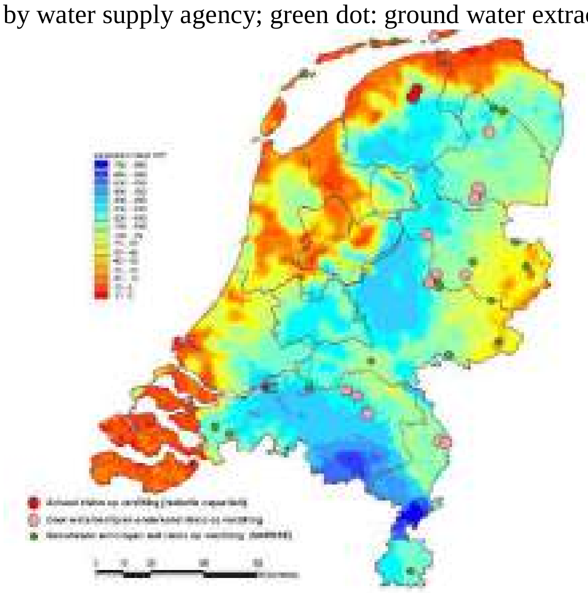
- Monitoring of local changes in rainfall and water supply and groundwater stocks, both short and long term;
- Possibility to store water or retain water volumes within their own areas;
- Programs aimed at reducing water consumption by large users (e.g., through price incentives, regulatory support and market mechanisms);
- Attention to diversify from different sources (surface and ground water, or from adjacent basins), and from available infrastructure;
- Promote water conservation through technological innovation and logistics.

Water companies get their water mainly from groundwater sources (approximately 55%) and surface waters (45% including 5% through dune infiltration). The extraction of groundwater occurs through some 220 extraction points, out of which 33 are vulnerable to salinization (Klijn et al 2011). There is a slight increase in the utilization of surface water (Geudens, 2010), which is consistent with policies to reduce groundwater depletion and diminish desiccation for agriculture and nature. Since groundwater in the western Netherlands is generally too brackish, these regions principally use surface water as a source for drinking water.

The dependency among water supply agencies from ground water represents an important bottleneck. Ground water volumes are gradually compromised by intruding brackish water. Salinity occurs along the coast or by ascending deep groundwater (Figure 3). This dependence is waning, however: the sector is seeking to build resilient through establishing a diversification of sources, particularly through substitution with surface water. On the other hand, this attention to alternative sources is also sparse. A similar finding applies to the utilisation of new techniques and innovations aimed at water conservation and efficiency. The sector, therefore, displays some considerable vulnerability to climate-induced changes in freshwater availability. Capacity-building may be required for safeguarding groundwater supplies, building surface water reservoirs and seeking possibilities for substitution.

A promising initiative among some water supply agencies has been to work together more strongly with industry, to produce industrial water. The focus is on establishing sustainable, integrated areas with coordinated infrastructure (i.e. water pipes), re-use of effluent waters, water reservoirs and differentiation for water quality demand.

Figure 3. Salinization risks for drinking water supply in the Netherlands (Klijn et al., 2011).
(red dot: current risk for salinization, reduction of capacity; pink dot: salinization risk acknowledged by water supply agency; green dot: ground water extraction with salinization risk)



Agriculture
The dependence of agricultural activities from fresh water is land-based. These activities depend on the existence of sufficient soil water, controlled ground water levels, and irrigation (LTO, 2010). The agricultural sector is prominent to the Netherlands as they are by far the largest land user in the Netherlands (about 60% of all available land). Irrigation is the main form of water use. The capacities needed to alleviate water dependency for agriculture focus, among other things, on:

- Efficient irrigation systems;

- Shift to crops that require less water in areas where groundwater levels fall, as precipitation decreases (higher sandy regions);
- Efforts to gradually concentrate, cluster or move (further) sensitive agriculture such as fruit and flower bulbs;
- Attention to potential economies of scale and technological innovation;
- Establishing robust management approaches to surface and ground water, focusing more on either extremely wet or dry episodes.

Our findings for agriculture reveal a diverse picture showing a varied dependency on groundwater and surface water, but also strong contextual dependencies related to socio-economic conditions. The vulnerability of the sector represents itself in two ways. First, there are quantitative difficulties, in terms of irregular water supply and episodes of drought. A second category of vulnerability is more qualitative: soil salinization. Both categories represent serious vulnerabilities. At the same time, however, we see substantial capacity-building efforts, particularly with regard to knowledge development on strengthening crop tolerance (against drought, salt), establishing new techniques, and increase productivity (Stuyt, 2006).

The Dutch agricultural sector is clearly not shying away from implications from climate change and hence water availability. The sector invests considerably in innovations (including pilot projects), thereby pursuing more efficient uses of water. There also is a focus on strengthening redundancies in terms of water sources and its infrastructure, and create the conditions for internationally high level of water certainty with the aim to improve European competitiveness to agricultural production.

Nature

For nature and ecological land uses, capacities to protect and regulate hydrological systems and understand consequences from climate change is essential. These capacity express themselves, for example, in:

- Attention both temperatures, the timing and volume of water flows in relation to ecosystem aspects like habitat, migration, survival, and food;
- Estimates of the adaptation of species to hydrological variability;
- The construction of water reservoirs and areas for buffers and natural variability;
- Anticipating natural, ecological and biodiversity change.

Nature protection and management is a sector working on complex interrelations between nature and the qualitative and quantitative characteristics of surface water and groundwater (Paulissen et. al, 2011). Issues such as habitat, reproduction, migration, survival, and food potentially pose high levels of vulnerability. Adaptation possibilities for animals and plant species to hydrological variability are essentially challenging. Our findings suggest ample adaptive capacity, however. At the regional level buffer zones offer good opportunities to battle drought and create more self-sufficient nature. There is also capacity to actively develop nature in a different, adaptive direction, through adjustment of types of nature (more brackish habitats, with fresh-salt gradients).

3.2 Capacities per sector

Table 2 provides a general overview of all location factors, current capabilities and policy options broken down by sector. The overview shows relatively high capacities to deal with climate change impacts on fresh water at existing locations and places. Nevertheless, for three sectors a lack of situational capacities may require changes in location. At the short term relocation plays a role for energy production plants, who are increasingly taking coastal locations, near the sea, and thus would use less cooling water along major rivers and canals. In the longer term, locational change manifests itself as a reality to those water companies facing salinization, and for whom substitution possibilities with surface waters are limited. The proximity of infrastructure (pipelines) will be highly important to create redundancies towards water sources. It may also be possible that a gradual replacement of highly water-sensitive types of agriculture such as fruit and flower bulbs will be emerging. But these users also have many capacities on-site, including rich local regulatory arrangements and water management options like water buffers and reservoirs.

Table 2. Overview of place, capacity and strategies per sector

Sector	***Place***	***Capacity***	***Further strategies***
Industry	- proximity to surface waters key - specific activities rely on ground water - limited amount of large users do most consumption - smaller industries rely on drinking water	- substantial adaptive capacity, particularly for cooling water - recent efficient use of ground water - gradual application of sustainable technology (production, re-use) - limitations to innovation due to regulations and tax arrangements - capacities from attention to new 'water economy'	- technologies for efficiency, restraints and adaptive capacity - clustering of industry and water companies (e.g. separate water supply infra) - private of (semi-)public water management (e.g., for purification) - new fresh water reservoirs
Water supply	- proximity of clients and infrastructure essential - varying types and qualities of sources - by far largest user of ground water	- resilience through decreasing dependence on ground water (substitution with surface waters) - vulnerable due to uncertainties in demand, limited anticipation on increasing water demand - necessities and capacities for change of location (e.g., due to brackish water) - some, yet limited attention to alternative sources and technology	- attention to ground water supply and reservoirs - attention to curbing use through price incentives and innovation - attention to diversification towards sources (surface, ground, adjacent water sheds)
Energy pro-	- strongly linked to proximity of surface	- vulnerable due to need for consistent availability of cooling	- attention to risk management for

duction	waters - large users - mostly electricity companies (cooling water for large plants)	water - strongly decreasing vulnerability given viable locations at sea (saline cooling water) - growing (but varying) investment capacity in sustainable energy, decreasing dependence from cooling water	diminished water supply for plants - verification of optimism about sustainable energy, and the volumes of water use with new energy technologies
Agri-culture	- multiple dependence from ground- and surface waters - strong interrelation with socio-economic conditions - largest water user, heterogeneous composition	- vulnerable both in a quantitative (supply, drought) and qualitative sense (salinity) - changing fresh water patterns potentially cause serious changes in soil conditions - substantial attention to knowledge development and policy proposals - strong attention to adaptation strategies (e.g., tolerance of crops, new techniques, productivity enhancement)	- attention to efficient systems for irrigation - consequences of shift towards water-efficient crops - (further) concentrate, cluster of relocate highly water-sensitive agriculture like fruit and flower bulbs - more vigorous water management aimed at excessive wetness and drought
Nature	- complex coherencies between temperature, timing and volumes of water, and ecosystem characteristics like reproduction, migration, survival, and food	- focus on desiccation and 'natural' water level management - attention to buffer zones, self-sufficiency and nature as 'water supplier' - vulnerable from decreasing public funds - adaptive capacity from adjustment to 'target nature' (more brackish, saline-fresh)	- assessment of hydrological adaptability among species and plants - attention to anticipating ecological change

4. Conclusions

This paper has explored major capacity bottlenecks among major water users. The focus has been on location considerations, and also the capabilities and potential adjustments for five sectors, namely industrial companies, energy companies, water companies, agriculture and nature. Based on this study, a series of three general empirical conclusions may be drawn:

- The situation in which sectors, parts of sectors or individual companies are dependent singularly on locally available reserves or supply to such an extent that they will need to terminate production or relocate in the short term (next decade), is unlikely;
- There are no activities for which improvements in efficiency, economy, productivity, or substitution are all greatly reduced at the same time. Overall, there is sufficient capacity in all sectors *on-site*, to establish situationally specific adjustments and redundancies to commit to climate change.

- There is a varying awareness or recognition in the sectors of changes in future fresh water availability, and their own vulnerabilities. Further investment in innovation and capacity building in the longer term (more than ten years) will be necessary.

For spatial planning, the implications are to strengthen practices of building resilience at existing sites (including the establishment of integrations between water sources and infrastructure for water accessibility and delivery) and to strengthen efficiency through further integration of functions and more area-specific (water) management. But there are also other requirements for achieving more water-sensitive spatial planning. Various institutional designs should be examined, including those oriented towards accessibility and availability due to rules and regulations regarding ownership, rights, transport and access. It is also important to estimate the role of spatial planning in the short term (through the strengthening of site conditions) and to place and location in the long term (through other land use arrangements and geographies).

Industrial companies are mainly focused on spatial planning arrangements for renewal, and clustering, privatized water purification, and new freshwater reservoirs. Spatial planning for energy companies implies a focus on the use and conditions for sustainable technology. Spatial planning practices for water supply would concentrate on the protection of groundwater sources, preserving less salinity-sensitive ground water extraction sites, and making available more accessible alternative sources (through institutional arrangements and infrastructure). Area-oriented policies may be required to include buffers and reservoirs for nature and water sensitive agriculture like fruit and flower bulbs. For agriculture, and industries based on agricultural products, there is also the opportunity to play out, through spatial planning, the issue of internationally relatively secure fresh-water availability as an element of attractive economic location.

Overall, the paper has shown a need for further development of capacities against diminishing fresh water. Capacity represents an ability to adapt and innovate in the face of changing climate. Current initiatives in the Dutch case on fresh water have shown a prevailing practice in particular on vulnerabilities among large water users to on-site strategies. Important emerging practices include efforts to strengthen accessibility and reliance at specific places, efforts to establish water as a factor of choice and certainty of location, and institution building for policy integration between water, urban and economic development. The findings also suggest the need to further understand the resilience per sector, in particular related to episodes of reduced freshwater availability.

The notion of vulnerability for this case has also suggested a distinction between two notions of place. On-site vulnerability implies levels of capacity at current locations and contexts, typically featuring strategies like productivity innovation, efficiency and thrift. On-site planning practices seem to be particularly well-developed and rich, particularly for private actors and their activities (the focus is on establishing redundancies and efficiency). Public agencies tend to take a more facilitating role (the focus is on area-oriented management and integration). Practices beyond-site are also emerging, but are considerably longer-term. Beyond-site (focusing on altered vulnerability) interventions imply capacities for locational change and adjustment, typically involving substitution between sources, and imply substantial public intervention.

For both levels of intervention (on-site or beyond) and in particular for the substitution strategy, establishing resilience turns out to be an issue of setting up alternative options of choice. Choosing between varying sources of water, between a variety of water networks, or between varying levels of production: more generic notions of vulnerability involve issues of available choice. Opportunity and capability theory, therefore, could potentially help to strengthen our theoretical understanding of these kinds of cases, and their overwhelming focus on on-site strategies, even further.

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