# Without History no Climate Adaptation. The Importance of Historical-System Analyses in Changing Environments. A Case Study from the Netherlands

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Over the last few decades the impact of climate change and coinciding weather extremes in the Netherlands increasingly has become evident. In order to better protect the country against these extremes the Dutch government has initiated an intergovernmental ‘Delta’ program. Through this initiative cities are obliged to develop planning policies that cope with weather extremes such as extreme rainfall or droughts. Besides traditional flooding, heat has become an increasing problem for cities in the Netherlands. Not only damaging buildings, but also risking the health of especially the sick and the elderly. In order to help cities develop (spatial) adaptation policies coping with these extremes, the ‘stress test climate adaption’ was developed. Built-up out of several GIS-based models, this test depicts possible bottlenecks for flooding or inner-city heat. Despite being multidisciplinary, these models are solely based on contemporary variables and contain almost no historical data on geophysical setting or town development and morphology. Consequently, the current models ignore crucial spatiotemporal variables essential for accurate climate stress-test calculations.

In order to increase the chronological resolution of these climate adaptation stress-test models a number of municipalities, reflecting a large part of the old historical towns in the Netherlands, have asked the Cultural Heritage Agency of the Netherlands (RCE) for additional historical (spatial) data. This way the GIS-based models will not only be more accurate but also better equipped for incorporating town-specific heritage situations.

In this contribution we will present several examples of expanded stress test climate adaptation models incorporating historical water systems, natural-landscape dynamics, climate change and urban morphology. The resulting models show the essentiality of integrating (1) cultural and natural data, and (2) modern and historical data. Additionally, these models underline the importance of cultural-heritage research for modern policy and planning purposes.

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Key words:
Water management, historical water systems, urban climate adaptation strategies, historic GIS, GIScience, climate policies in the Netherlands.

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## INTRODUCTION

Situated in the northwest-European delta, the Netherlands is generally low lying and characterized by the presence of some of the largest European rivers (e.g. Rhine, Meuse). On the one hand these rivers always have provided good transportation and communication routes between coastal regions and the hinterland, providing flourishing trade and the rise of merchant cities (Fig. 1).

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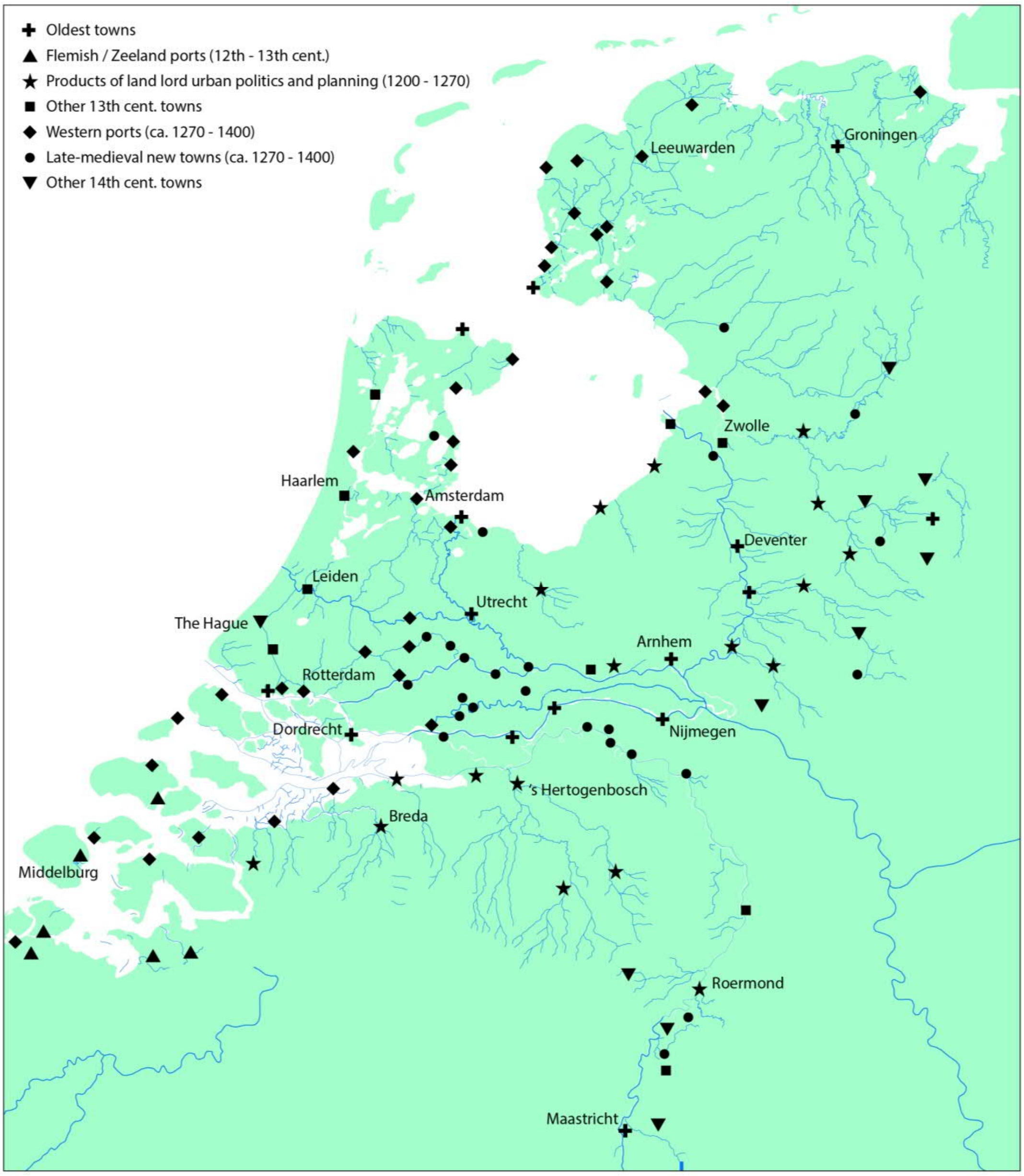


*Fig.1. Dutch medieval cities and their relation to water*

On the other hand, this landscape setting made these newly developed cities prone to flooding and required continuous adaptation on their part.

Even to the present day, these cities are confronted with these kinds of threats. For example, due to climate change the Dutch cities have to adapt not only to rising water levels from sea and rivers, but also to extreme weather conditions, like long periods of heavy rain or heat and drought. Since these adaptations vary through time and place, they have greatly influenced the development of individual cities. Consequently, the layout and appearance, and therefore their character, of the Dutch cities were in large part defined by their adaptation strategies.

Modern climate adaptation strategies, however, often only rely on modern technical engineering solutions, without taking into account specific local historical characterizations. These kind of technocratic solutions often don't find a support with the local population, lacking character. Besides, proven historical solutions that have worked for that specific city or area are not incorporated. This potentially makes these modern solutions ill-fitted, unnecessary complex and often too expensive.

This paper will show how integrating knowledge of historical water engineering works into present-day engineering models provide better-suited solutions for adapting to environmental changes in urbanized areas.

## SOCIO-POLITICAL FRAMEWORK

Fuelled by climate change, we are increasingly confronted with weather extremes, rising sea levels and notable temperature excesses. Adaptation to these changes is vital for a low-lying country such as the Netherlands. Therefore the national government has defined an overall strategy in order to develop adaptations to these changes, namely the Deltaprogram Spatial Adaptation. [Deltaprogramma Ruimtelijke Adaptatie 2018] One of the main goals of this program is to assess the risks concerning themes like water safety, water quality, heat stress in cities and drought. Based on these risk assessments several implementing plans can be executed. For climate adaptation, these plans are coordinated within the National Adaptation Strategy. [NAS 2018]

This national policy calls for all cities to perform several so-called stress tests. These are not physical tests on several aspects of climate change, but models to assess which areas in a city have higher risks of flooding or heat stress. Based on these assessments the local politics can then address the risks with specific adaptation policies.

However, these stress test-models often only take present-day surface aspects into account and neglect historical information. For instance, a model on flood risks by heavy rain only calculates the maximum water levels based on the amount of rain and the altitude variations within the city’s streets. Sewer systems, (historical) watercourses and other urban morphological features are not taken into account. (Fig. 2)

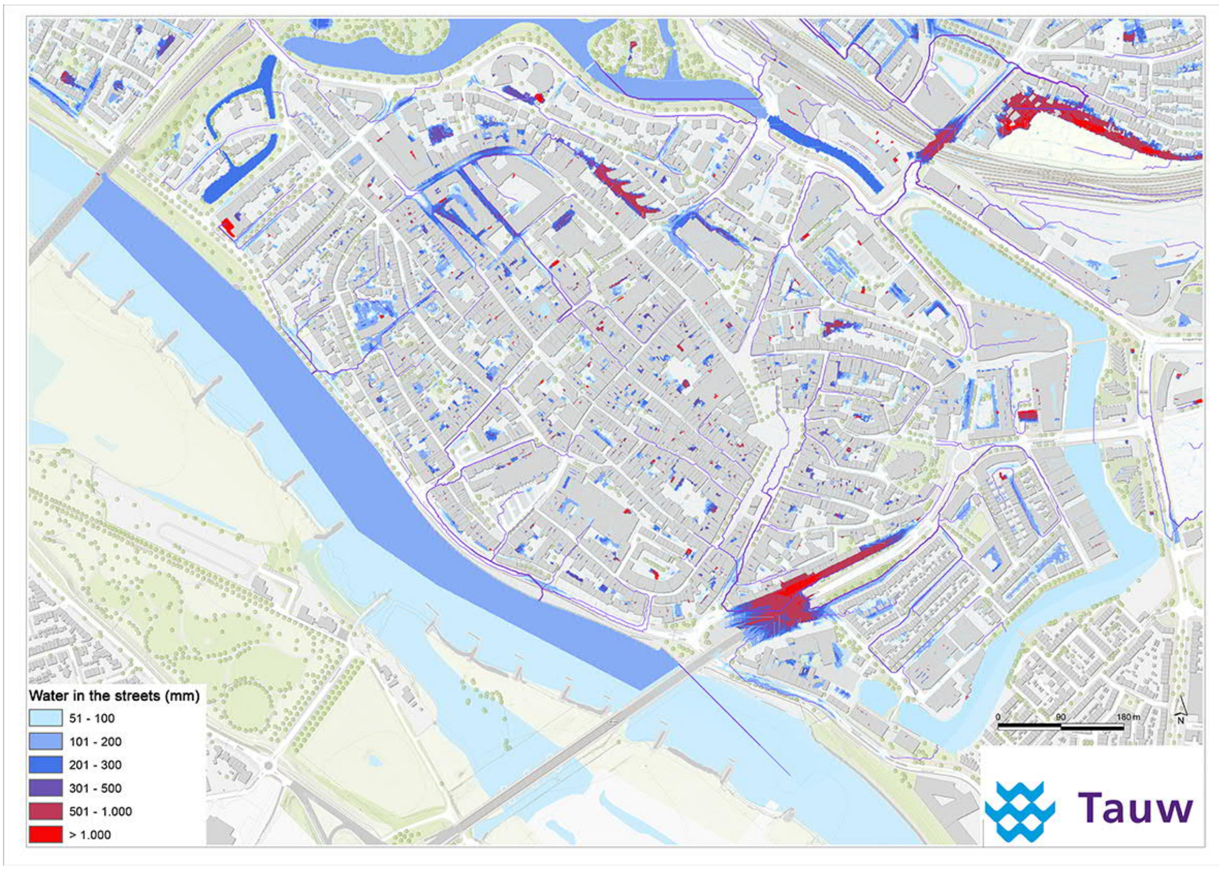


*Fig.2. Flood risk-model of the city of Deventer depicting areas in severe risk (dark blue to red). Sewer systems and natural drainage are not taken into account*

Even cities equipped with archaeological and historical departments often miss integrality and historical context.

The Cultural Heritage Agency of the Netherlands aims to help these parties integrating historical knowledge into both these stress tests as well as the resulting policies. These ambitions are formulized in the national line of policy “Kiezen voor Karakter” (Choosing for Character) [Ministerie Onderwijs, Cultuur en Wetenschap 2011] part of the larger program “Visie Erfgoed en Ruimte” (Vision on Heritage and Environment). [ Rijksdienst voor het Cultureel Erfgoed 2017]

## METHODS & MATERIALS

Because of its geographical positioning, inhabitants of the Netherlands traditionally have a strong relation with water. Consequently, almost all of the historical Dutch cities arose near to, and because of, streams and rivers. These waterways gave the emerging cities vital means of transport and communication and made them, already from their earliest beginning, what we nowadays call ‘water adaptive’. In the Netherlands, we are in a very fortunate position that we have accurate maps of almost all of our cities as they were at the end of the Middle Ages. In the sixteen hundreds, the surveyor and mapmaker Jacob van Deventer (ca. 1500-1575) started to map the cities of the Netherlands (Fig. 3).


*Fig.3. The city of Deventer ar the IJssel river by Jacob van Deventer mapped between 1557 and 1559 [Rutte and Vannieuwenhuyze 2018]*

Initially probably self-employed, he soon was granted a formal commission by King Philip II of Spain, the then ruler of the Netherlands. This commission gave him access to all the cities under Spanish rule and a travelling pass through the troublesome areas of the country (during the beginning of the Dutch revolt against Philip, 1568-1648). [Rutte and Vannieuwenhuyze 2018]

The revolt against Spain resulted in the emergence of the new Dutch Republic in 1609. This young country needed accurate descriptions and maps and because of the economic boom, known as the Dutch Golden Age, had the financial means to commission these. Combining these maps with the earlier Van Deventer-maps allows us to accurately model the growth of the cities during the 17th century. At the end of the Dutch Golden Age most of the cities reached their peak and had grown to the size which they kept until the end of the 19th century. These areas are what we now refer to as the historical city centres. [Abrahamse and Rutte 2016]

Next to these urban-development models, the Dutch also have a long history of soil and landscape research resulting in not only high-resolution soil maps, but also providing enough geological data to create detailed paleo geographical maps. Through these maps, we can assess the landscape conditions and much of the water risks the early cities in the past must have faced. Landscape features like amongst other river dunes and levees proved to have been important location factors. Cities in the lower western areas are mostly situated in or nearby marshy peat lands, with rivers and canals as main location factor for trade. In these areas huge water engineering projects were undertaken to drain the land and make it suitable for habitation and agriculture (mostly cattle). [Vos et al. 2018]

In order to able to maintain these elaborate engineering systems a separate political layer was installed from the Middle Ages onwards, the water boards. As maintenance organisations they, too, developed high-resolution maps. Today these water boards still function and all their engineering and policy information are preserved in their archives.

The Cultural Heritage Agency of the Netherlands is in a continuing process of disclosing this kind of historical-environmental data. In 2016 the digital dataset Nederland in 1575 (the Netherlands in 1575) was presented. [Kosian, Van Lanen and Weerts 2016] This dataset provided georeferenced and vectorised city maps of Jacob van Deventer, combined with the contemporary landscape and soil type, main waterways and a first reconstruction of the main land routes and roads. [Kosian and van Lanen 2017] At present, a similar project is being carried out for the western part of the Netherlands, mapping the water system, dikes, cities and economic landscape over four periods; late Middle Ages (around 1600), the end of the Dutch Golden Age (around 1730), the end of the Industrial Revolution (around 1900) and the present day. [Kosian and van Lanen submitted]

Important and handy as this information might be, it still is mainly the work area of historians. Merely disclosing these datasets does not automatically mean they are going to be used and certainly not by civil servants and municipal engineers dealing with climate assessments and stress tests for their city. These are often rather small task forces with limited means and limited historical knowledge.

The main challenge is to have municipalities adopt heritage information as an integral part of their climate-adaptation policies. Not as something to care for and deal with, but as a valuable source of information, an inspiration and sometimes as (part of the) solution. This means that disclosure of historical information should also give means to include this information in other then academic studies. In order to do so we have not only vectorised and combined historical maps, reconstructed soil conditions and historical water engineering information, but also devised several ways to integrate these, mostly qualitative data, with quantitative models.

As a pilot we took on to build a GIS model for the city of Deventer. This GIS should provide insight in the actual development of the urban area through time, but also to the changes in land use of the modern area of city centre and direct surroundings, as well as water management and heat management through green spaces.

First four period maps were selected for digitalisation. The first was the map by Jacob van Deventer from ca. 1557-1559. This is not only the oldest map of the city, but it is also highly reliable as the research of Rutte and Vannieuwenhuyze and Kosian et al. Showed. [Kosian et al. 2016, Rutte and Vannieuwenhuyze 2018] This medieval map not only gives a good representation of the city, but also rather detailed information on land use and soil conditions during this period. Comparing the several Van Deventer maps give insight in the humidity of the soil since Van Deventer had made a uniform colour legend on land use and aridity. [Kosian et al. 2016, Rutte and Vannieuwenhuyze 2018] This map was georeferenced by matching the centre lines of the roads as drawn by Van Deventer to those of the still existing roads in the old centre of the town. This line model of the road network served later also as a basis for georeferencing other, less exact, historical maps. [Abrahamse and Kosian 2014]

The second map was the map by Joan Blaeu from 1652, the map of the city of Deventer at its maximum size during the Dutch Golden Age in the mid-17th century. Although the Blaeu map is less geometrically exact [Rutte and Vannieuwenhuyze 2018], the digital road network map digitized from the Van Deventer map could be used to georeference the map and correct the geometrical oddities. The last historical map used was the, again highly exact, Dutch land registry map from 1832. This map is not only geometrically exact, but has already been digitized in the

HISGIS project, a nationwide project aiming to digitize into GIS the whole of the 1832 land registry maps and information in the Netherlands. [HISGIS]

The last map in the series was the topographical map from the Dutch Topographic Register, the for the Netherlands standard 1:10,000 digital topographical map.

After this digitalization process we placed a 10 by 10 meter grid over these maps in order to be able to quantify land use and the capability of water absorption or drainage of the top soil. Land use was classified into 11 classes that could be compared through time. (Fig. 4)

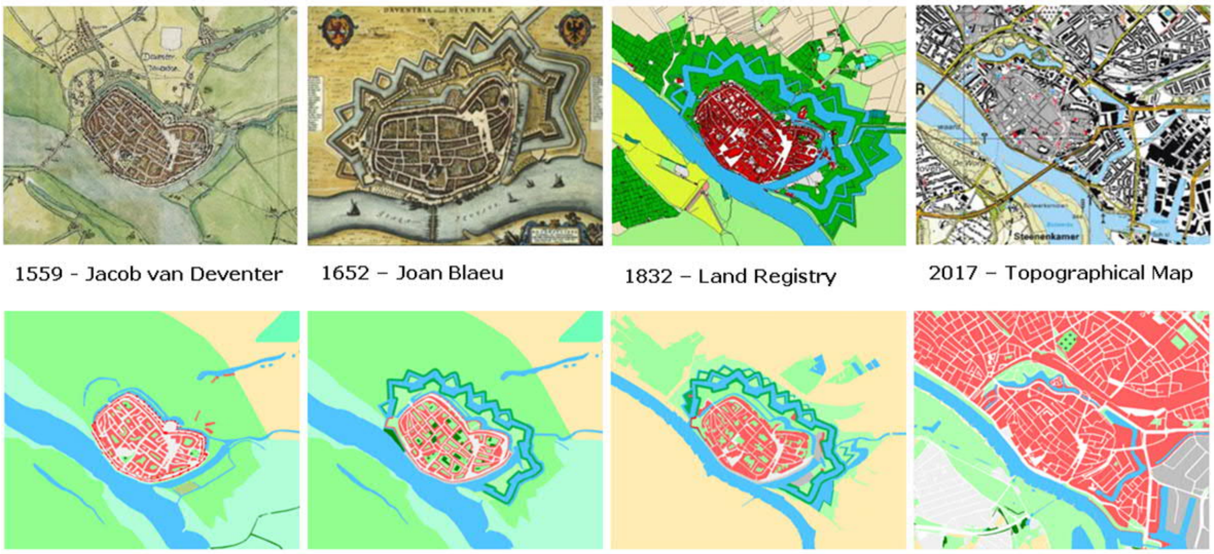


*Fig.4. Historical maps of the city of Deventer put into a GIS as an uniform land-use model. The water absorptive qualities of the several areas are not shown in this figure*

Based on soil map and paleo geographical data we also had information on the water storage capacity of the several classes. For instance, modern infrastructure are mainly hardened surfaces with engineered water drainage, while the medieval and even 17th century streets mostly were paved with loose stones, if paved at all. This gave water the opportunity to seep into the ground. Of course, in gardens and fields this absorptive quality was higher than in the streets, but modern infrastructure has no absorptive qualities at all. (Table 1)

*Table 1. Classification of land use and water absorptive qualities as used in the historical quantitative GIS model of the city of Deventer*

| **Land use class** | **Water absorption class** | | | | | |
|---|---|---|---|---|---|---|
| | **1559** | **1652** | **1832** | **2010** | **Absorption class legend** | |
| Built-up area | -2 | -2 | -2 | -2 | No or indirect drainage | -2 |
| Industrial area | -1 | -1 | -2 | -2 | Mainly indirect drainage | -1 |
| Infrastructure | 1 | 0 | -1 | -2 | Moderate absorption | 0 |
| Park or garden | 1 | 1 | 1 | 1 | Absorption | 1 |
| City wall | -2 | -2 | | | Direct drainage | 2 |
| Ramparts | | 0 | 0 | 0 | Non-existent | |
| Agriculture | 1 | 1 | 1 | 1 | | |
| Grass and meadows | 1 | 1 | 1 | 1 | | |
| Peat area | 2 | 2 | 2 | | | |
| Dry nature area | 1 | 1 | 1 | 1 | | |
| Water | 2 | 2 | 2 | 2 | | |

This way we could not only classify land use, but also enrich the attribute table with a basic water absorptive classification. This gave a comparable GIS model of the city over four different time periods. And since the attribute table was uniformly classified, we could also give insight into the deterioration or, in some cases, amelioration of the water absorptive qualities over time. Fig. 5a shows the land use in 1559 and Fig. 5b the land use in 2010. It immediately is clear that the built-up area is dramatically increased, but when we compare that to the water absorption index, we could see that has become even worse, since not only green areas have diminished, infrastructure has no longer a absorptive quality (Fig. 5c and 5d) Subtracting 2010 from 1559 we can map those areas that have deteriorated the most (Fig. 5 c-d)

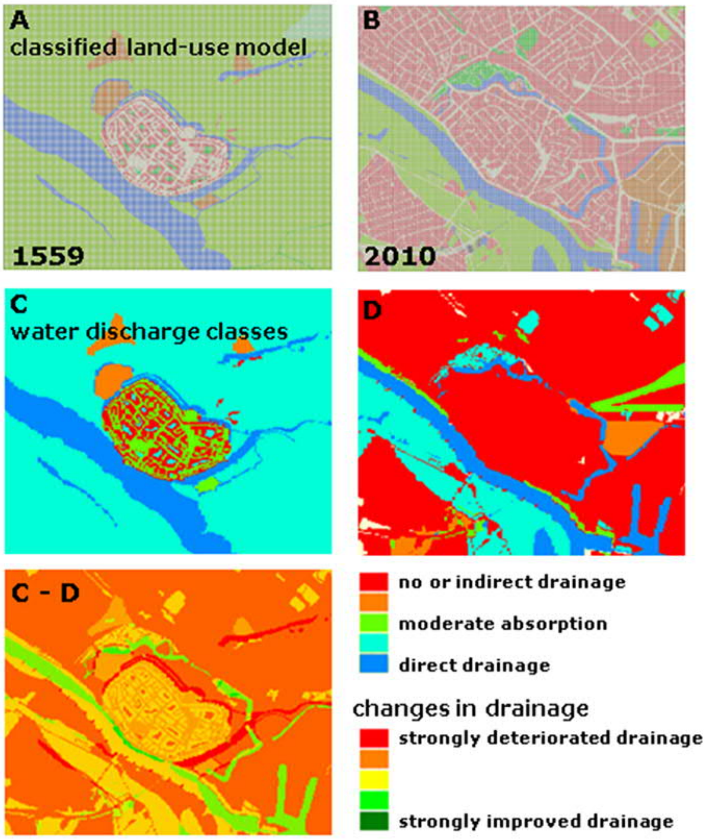


*Fig. 5. Classified drainage and absorption model devised from the historical model and enriched with soil information. The top line represents land use in two periods, 1559 and 2010, the middle line represents the absorptive qualities of the areas and the lower map gives the deterioration of absorptive qualities by subtracting 2010 index from 1559 index*

The model could not only give insight into the water absorption of several urban areas, but can also provide an inspiration for heat-stress solutions. Were we see the modern, ancient, inner cities as completely built-up, densely populated areas this was not always the case. In fact, a lot of the medieval town consisted of open areas: squares and gardens were everywhere, and a lot of cities even had urban farms within their walls. Since the GIS has an uniform legend for land use over time, it could show the changes in inner city green and open areas. (Table 2) Trying to re-match the old percentages of green spaces in the city could help to adapt the urban area to the heat effects of climate change. One could think, for instance, on grass-filled open concrete as surface parking spaces, or green roofs on inner city apartment stores that are often build on former “useless” squares or inner-city greens.

*Table. 2. Red-green-blue ratio during several periods for inner city Deventer (see aereal photo above). A lot of the innercity green areas or squares have been filled in with closed building blocks. A lot of the gardens within the medieval and 17th century buildings are used as building plots as well, making the city centre far more dense than it has been originally*

| Land use | 1559 | 1652 | 1832 | 2010 |
|---|---|---|---|---|
| Built-up areas | 27,23% | 15,40% | 22,40% | 46,76% |
| Green areas | 21,67% | 28,79% | 40,98% | 15,98% |
| Infrastructure | 17,80% | 12,60% | 8,77% | 17,56% |
| Water | 33,31% | 43,21% | 27,85% | 19,69% |

Adding geomorphological data to the GIS enriches the data even more. Deventer, for instance, was originally built on a river dune along the IJssel river. Only a small brook, the Schipbeek had broken through the dune to discharge into the IJssel, just south of the medieval city. Water northeast of the city had to be diverted, either via the Schipbeek, or via canals leading to the north to discharge further downstream into the IJssel. Until the 19th century there was a harbour where the Schipbeek flowed into the IJssel. Today, both the harbour as well as the Schipbeek have been moved further south, and the old harbour area has been filled-in and become the access to the bridge over the river. This modern road, however, has good sewer systems in place, reducing the risk of flooding in this former harbour area. However, it blocks off the area just north of it, today the train station, where there is a risk of flooding. Combining this historical GIS with the risk-assessment models give policy makers a far more detailed view on the areas at risk. The risk-assessment model alone indicates for Deventer two major (red coloured) areas of risk, while the combined model shows that one of these areas is the, low lying, former harbour. This area lights up in the risk-assessment, only because of its low-lying position. This area has actually no water problem. (Fig. 6)

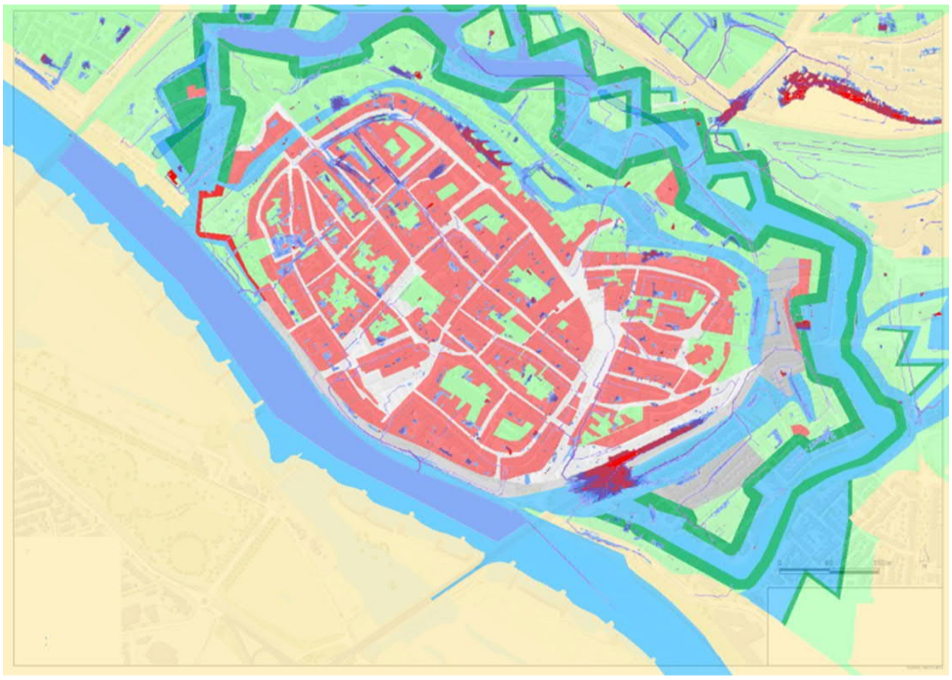

*Fig. 6. Integrated map of the standard risk-assessment water-shed model with the historical GIS. The red-blue areas show areas at risk of flooding according to the risk-assessment water shed map. The southern of these areas clearly is situated in the old harbour, the location of the modern IJssel-bridge ramp and the N344 carriageway. The northern risk area, however, is cut of from draining into the IJssel river by the natural river dune on which the city sits, and the before mentioned N344*

The most important part is to get everybody in the city administration involved. For example, a potentially high-risk flooding area recently also could have been supplied with large capacity sewers. Therefore it is important to involve all departments and agencies and integrate knowledge both historical and modern as well as political and technical. This new interdisciplinary and interdepartmental approach is the main focus point of the "Cultural Heritage Agency Method", an integrated method published as a manual on climate adaptation. [Rijksdienst voor het Cultureel Erfgoed 2018]

## RESULTS

Most of the work of including heritage information into urban politics is not just the disclosure, but mainly creating awareness of heritage as a mean, rather than a hindrance. In order to do this we have published several manuals and guidelines. Within the program "*Visie Erfgoed en Ruimte*"[1] we have developed several guidelines: *Nederland kavelland* (the Netherlands; Fields Country) on heritage and agricultural changes, *Nederland energieland* (the Netherlands: Energy Country) on heritage and energy transitions, *Nederland waterland* (the Netherlands: Water Country) on heritage and adaptive water management and *Nederland stedenland* (the Netherlands: City Country) on heritage and climate adaptation in cities.

Next to these guidelines we also gave courses and lectures at municipalities, to show, hands on, the advantage of multidisciplinary and multi-departmental approaches and of course we still offer the historical datasets as service or downloadable GIS data.[2].

[1] More on the program can be found on the site of Erfgoed en Ruimte https://erfgoedenruimte.nl. The several guidelines and folders are published on https://www.cultureelerfgoed.nl/publicaties/publicaties/2017/01/01/nederlands-cultuurlandschap-in-vier-tijdlijnen. The Manual Water, Heritage and Environment is published on https://www.cultureelerfgoed.nl/publicaties/publicaties/2018/01/01/manual-water-heritage-and-environment (all consulted Feb. 11, 2019)

[2] https://www.landschapinnederland.nl (consulted Feb. 11, 2019)

## DISCUSSION

As discussed before, since all cities have their own character and specific history, a general template for adaptation and change policies is impossible and undesirable. This is not only true for modern engineering solutions, but equally for the implementation of historical data. The method presented in this paper is not a strict rule, but much more a guideline and a source of inspiration. The maps of Van Deventer and Blaeu[3] can provide insight into the urban development of many cities, but they are not the only maps to be taken into account. For example, several of the cities in the province of Holland grew more rapidly than other cities and therefore more high-resolution maps exist depicting their development. For these specific cities, these maps should also be included. Additionally, if cities have been profoundly altered in recent times, it is essential to incorporate younger maps. This is the case for example in the cities of Rotterdam and Nijmegen, where, although still having their original layout recognisable in their modern city plan, the bombings of the Second World War completely changed the cities appearance and (underground) infrastructure. In these cases the post-war damage assessment maps and restructuring plans should be taken into account as a major source.

Besides urban-development models incorporating overarching data on water systems are also essential. The intricate system the water boards developed over the years extended far beyond the city limits. Research currently being executed at the Cultural Heritage Agency on water discharge systems in the west of the Netherlands shows the importance of system thinking when dealing with local problems. This system thinking however necessitates the consultation of local water boards and accesses their data when performing stress tests.

The historical map analysis also gives an insight on the amount of open, green spaces within the cities. Insight in where these spaces were located in the city centre can be an inspiration for modern planners to open these spaces up again, helping against heat stress in cities. The datasets provided by the Cultural Heritage Agency might not be sufficient for all towns and cities, but will give at least an insight into what kind of data, and what kind of data sources can, and should be used.

## CONCLUSIONS

In order to develop customized local policies for climate adaptation cities in the Netherlands should assess the risks of these changes to their specific situation. When only done in a technical engineering way, policy makers might lack information needed to sufficiently prepare their city for these future threats. Heritage in this respect can be applied both as inspiration and as a mean towards the solution. After all, we have dealt with water related problems for ages. Many of the newly-designed solutions have been tried and tested before. Taking this information into account not only ameliorates the technical solution, but also respects the character and history of the city. Helping to preserve heritage and create support with local inhabitants. The here presented method is a base for such a history integrated solution. However it is not a strict rulebook. It wants to be a guideline that gives insight into how historical data can be useful, how it can be integrated into modern designs and political processes. Next to these guidelines, the method also generates practical data which is publicly shared. Although these datasets are far from complete, they are at least a good starting point to carry out city-specific heritage and history integrated multi-disciplinary risk assessments for future politics.

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