Multi-Level Climate Effect Modeling, best management practices From private property to national level

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abstract

The changing climate has an effect on the quality of life in our cities: heavier rainfall (resulting in floodings), longer periods of drought, reduced air and water quality and increasing temperatures in cities (heat stress). Awareness about these changes among various stakeholders is of great importance. Every Dutch region is required to perform a stresstest indicating the effects of climate change (o.a. flooding and heatstress) before 2020. The level of execution, area size and level of participation of stakeholders, has intentionally been made flexible.

To provide more insight into the approaches and best management practices to climate resilience, this article provides 3 examples of stresstests performed on several levels: single object real estate level, city level and national district level. The method 'stresstestíng', involves flood and heatstress modeling, defines the current status of climate adaptation characteristics of an object, city or district. The stresstest form the base line and starting point for the national 3 step approach adaptation strategy 'analyse, ambition and action'.

The 3 pilots have been evaluated as 'successful' by stakeholders and yielded a significant amount of valuable information, further improvement is recommended as increasing the participation of the private sector, in a 'quadruple helix approach'. The learning points from these 3 examples of stresstests will subsequently be implemented in the form of improved stresstesting in the near future in (inter)national cities around the world.

Introduction

The changing climate has an effect on the quality of life in our cities, so it affects us all. Rainfall with a high intensity and a short duration, resulting in flooding, is a well-known event. An example is the cloudburst event in Copenhagen in 2011 (150 mm rain within 3 hours), discussed later in this paper. Extreme intense storms are becoming more frequent across the world due to climate change.

Less known is the effect of increasing temperature on the built environment (heat stress) and the effect of this higher temperature on air and water quality. Awareness among various stakeholders about these changes is of great importance. In the Netherlands, the 3-step adaptation strategy comprised of 'analyze, ambition, act' is often applied. All municipalities in the Netherlands must conduct a stress test before 2020 in order to identify bottlenecks related to challenges such as flooding and heat stress. This is stated in the 'Delta Plan for Spatial Adaptation', which was presented in The Hague at the end of 2017 [Dutch Ministry Infrastructure and Environment, 2017]. When specific priority problem locations are located using flood and heat stress maps, quick win measures can be selected. A climate adaptation strategy / vision needs to be translated into spatial plans and policy domains, so that 'No Regret' measures can be taken to create a more resilient situation in the future. The long-term measures for climate proofing an area can be realized together with other projects, and thereby restrict the costs and nuisance. While stakeholders predominantly from governmental organizations are involved in these stress tests, 'quadruple helix involvement' is needed with the help private sector and residents. Governmental organizations have the opportunity and the control to select and apply climate adaptation measures in the public area, but what about the private area, what about the contribution of inhabitants to climate adaptation measures, what about our shared responsibility to a resilient built environment regarding the effects of climate change?

Method

Three pilots are reviewed where an assessment of the effects of intensive rainfall is taken place on an object, city and or district using the Calamity Levels of Urban Drainage Systems (CLOUDS) tool [Kluck et al., 2010]. This is a high level decision support tool to simulate storm water flooding. CLOUDS is based on the assumption that for a cloud burst (> 60 mm/h) most of the storm water will flow and stay above ground. CLOUDS visualizes the flow and the depth of storm water in depressions where water will accumulate. The quick-scan is only based on readily available data. The most important factor is an accurate DEM, which is freely available for the whole of the Netherlands (AHN3). With 9 points per square meter and a vertical accuracy of several centimetres this provides an insight in the surface elevation [Boogaard et al, 2017].

The quick-scan GIS-based thermal stress maps have been developed in The Netherlands in order to give quick insight into possible thermal stress locations in a city. It is based on an accurate DEM and the assumption that for quick insight into thermal stress some rough simplifications of the actual physical processes can be made. The maps give an estimate of the maximum PET (physiological equivalent temperature) during a heat wave. Such maps have also been made for other cities in European, Africa (Johannesburg) and Asia (Thailand and Taiwan) [Boogaard et al, 2016].

Table 1 3 pilots on different level of size and stakeholder involvement

pilot	level	Location	modelling	Stakeholders involved	background
1	Object level	Moerdijk, The Netherlands	Floodmodel	Real estate, water authority	(environmental) impact assessment extreme stormwater events and disasters (after a fire at Chemie-Pack in 2011).
2	City level	Copenhagen, Denmark	Floodmodel	Municipality, water authority	Climate effect stresstest as part of Cloudburst Mitigation Plan (after cloudburst in 2011).
3	National District level	Friesland, The Netherlands	Flood- and heatstress modelling	Municipality, water authority Province, national level	Stresstest flood and heatstress maps (preparing and prevention of damage for extreme climate events)

Example 1 Object level: Moerdijk

Moerdijk is a municipality and a town in the South of the Netherlands, in the province of North Brabant. Moerdijk is a well-known name in the Netherlands, because of the large Moerdijk industrial area. In 2011 research started in that area on the effects of climatechange when a disaster happened in that area. On January 5 in 2011 a devastating fire started on the Chemie-Pack site, located on a large industrial park in Moerdijk, 35 kilometers south of Rotterdam. The company (activities: packing, filling and labelling of hazardous chemicals, including pesticides) was completely destroyed. Two neighboring companies were also destroyed and several others incurred severe damage. The fire went as high as 40 meters and could be seen for some 40 kilometers around; motorways and railroads were blocked off and it took the firefighters more than 30 hours to control the fire. No people were injured[1].

Chemie-Pack, a family business for more than 60 years, had permission to store 4,000 tons of hazardous chemicals, including pesticides. The fire fighters decided to allow the fire to burn out on its own under controlled conditions before starting to extinguish the fire with foam. The area surrounding the fire zone was subjected to severe pollution, raising a lot of consternation. The

[1] https://www.internationallawoffice.com/Newsletters/Environment-Climate-Change/Netherlands/NautaDutilh/Government-takes-Chemie-Pack-to-court-over-remediation-following-fire

disaster resulted in 35,000 square meters of contaminated water and 1,800 tons of contaminated soil. It must be assumed, therefore, that all 4,000 tons of chemicals were released into the environment [De Munnik , 2011].
In order to prevent accidents and provide more info to prevent or act, CLOUDS was used after the event to give insight into water management during regular situations and extreme events (fire brigade during fire, intensive rainfall) as indicated in figure 1. The fire was allowed to burn under controlled conditions and the area surrounding the fire zone was subjected to severe pollution, raising a lot of consternation.

Figure 1a (left) Fire in chemical firm, Moederijk 5 january 2011 (source: KLPD DLV[2]). (1b, Right) modelling of water with CLOUDS.

Under the final conclusions and recommendations of The Dutch Safety Board [The Dutch Safety Board, 2012] it is noted that by addressing the lack of knowledge, action before and after a disaster could be improved. More insight and open control over data should be stimulated. The results of quick-scan tools such as CLOUDS could help provide insight into the effects of climate change and disasters. Figure 1b gives a visual presentation of the floodmodel that was used to calculate the streamtracks (flow of water) at the company and enviroment. Figure 2 show the locations where contaminated water reaches the surrounding waterways. These calculations were initiated by private company and waterauthority as an enviromental impact assesment.

[2] https://www.onderzoeksraad.nl/en/beeldbank/910/fire-in-chemical-firm-moerdijk-5-january-2011?s=0124D454CC0641CA8169BCF127D36E205596AF33

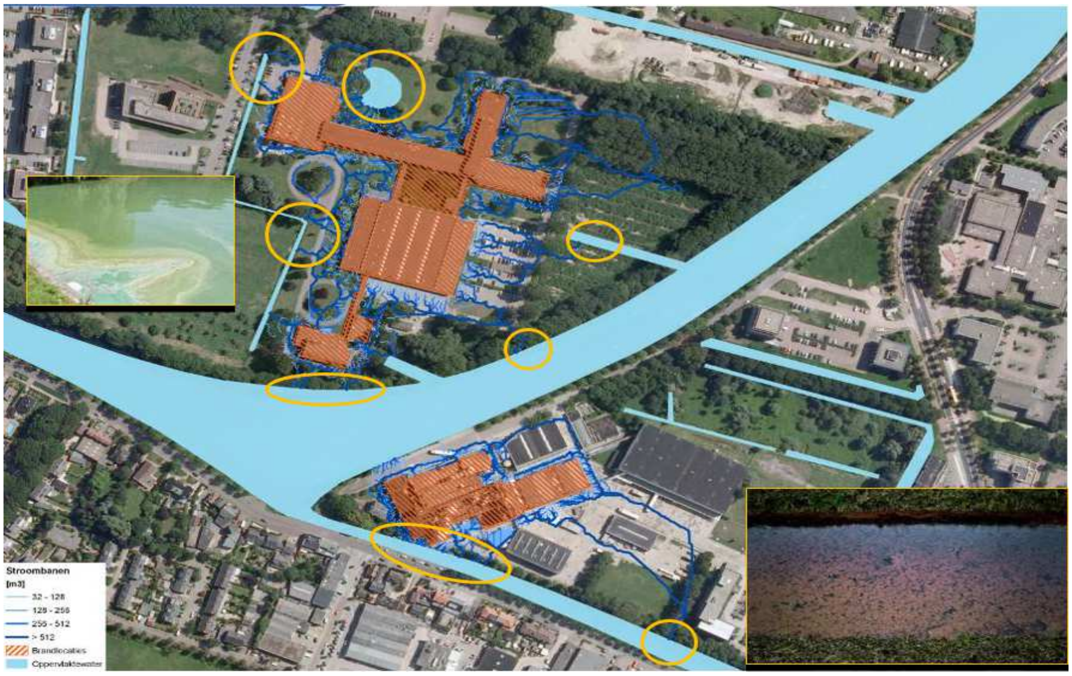

Figure 2 modelling of water with CLOUDS to prevent pollution of water and soil (The disaster resulted in 35,000 square metres of contaminated water and 1,800 tons of contaminated soil).

Example 2 City Level: Copenhagen
150 mm of rain fell on the city of Copenhagen in less than 3 hours on July 2nd, 2011, flooding parts of the city with up to a metre of water. This "cloudburst" event (from the Old Danish word Skybrud), caused damage in excess of 6 billion Danish kroner (US$863 million), not including direct costs such as repairing municipal infrastructure or indirect costs such as loss of earnings (IWA, 2016). The total socio-economic loss has been estimated to be double this amount. In recognition of the significant impact on society and the economy, the city produced a Cloudburst Mitigation Plan. This plan, and the subsequent catchment level plans (example figure 3a), identifies the parts of the city most at risk from future cloudburst events, and proposes a toolkit of solutions to increase the city's resilience to flooding.

The overall principles of the strategy are: to retain rainwater in the upper catchment; to provide robust and adaptable drainage of lower lying areas; and to focus on implementing green and blue solutions in existing projects (example figure 3b).

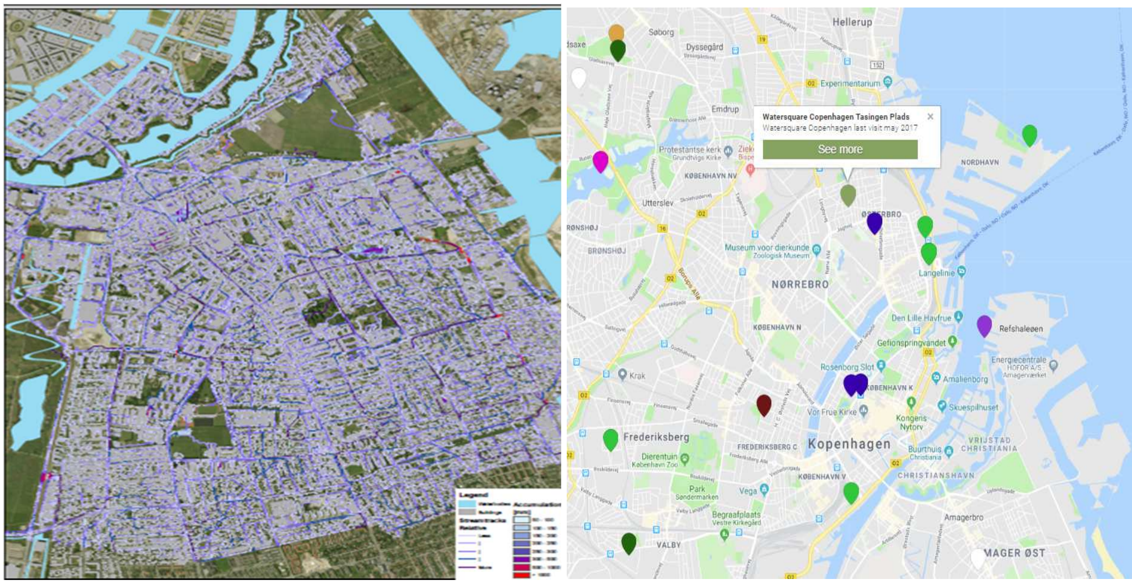

Figure 3 CLOUDS model Copenhagen by EnviDan and Tauw (left). 3b Mapping Sustainable Urban Drainage Systems for international knowledge exchange on www.climatescan.nl

To combat the impacts of cloudbursts, the City of Copenhagen developed a Cloudburst Management Plan in 2012 (City of Copenhagen, 2012). The Plan outlines the priorities and measures recommended for climate adaptation including extreme rainfall. The City carried out an overall assessment of the costs of different measures (traditional vs. different options including adaptation measures), the cost of the damages despite the measures and resulting financial impact.
It was showed that continuing to focus on traditional sewage systems would result in a negative societal gain: despite capital investments, financial damages from flooding would remain high and not justify the high investment in measure implementation. On the other hand, the combined solution (including adaptation) would result in a net saving.
The chosen measures for climate adaptation consist of expanding the sewer network and around 300 surface projects focusing on water retention and drainage [City of Copenhagen, 2011]. Some of these surface projects can be found on the open source web-based page www.climatescan.nl[3] (figure 3b)

Example 3 National District level Stess test province of Fryslân

Recently a stress test for the whole province of Fryslân has been conducted using flood maps and heat stress maps (Boogaard et al, 2018). The flood maps indicate vulnerable low-lying areas, whereas heat map indicate open, unshaded areas where severe thermal discomfort can be expected. In a triple helix composition (governments, companies and knowledge and educational institutions) experts of 20 municipalities divided over 7 masterclasses have compared the flood and heat stress maps with the real situation and with their own experiences. After comparison and addressing priority problem locations, concrete climate adaptation measures were suggested for these locations. In these masterclasses the steps from the adaptation strategy were taken from 'analyse' to 'act'.
In addition to area specific measures the masterclasses gave the participants more insight into potential risk areas. The municipalities acknowledged the mutual problems they have regarding climate adaptation. Shared learning as done in the masterclasses was experienced as positive and supportive. The municipalities often miss a kind of review framework to determine water and heat nuisance and to decide when to take action. Sometimes this depends on the amount of complaints of the residents. A vision or Climate Adaptation Plan could, in such situations, offer a solution and be consulted or incorporated in new spatial plans to restrict problem areas in the future.

Figure 4 heatstressmap Leeuwarden (left), workshop with stakeholders (right)

Thermal comfort (heat stress) is quite a different kind of nuisance compared to flooding. Although the effects of heat stress in a delta area such as the province of Fryslân is not yet clear, the participants admitted specific attention should be paid to vulnerable areas such as homes for the elderly and hospitals.
While it is difficult to support heat stress restricting measures in this stage, during realisation of spatial plans scheduled in the near future, green and other shadow stimulating measures could also be applied. Green measures decrease temperature through evapotranspiration and often provide shadow, water with enough depth or streaming water reduces the temperature in the direct vicinity and well-oriented buildings can provide shadow during the hottest moments of the day.
Moreover, green measures not only provide a cooling effect, they also have an added value for biodiversity and health and are able to retain water.

Discussion Stresstesting and participation on several levels

The realisation of floodmaps in the 3 examples showed that the level of participation of several stakeholders is different, and regarded as important for the acceptance of the end result and for the next steps (implementation of measures to mitigate the effects of climate change). At 'object level' in example 1, the water authority was mostly involved, whereas in contrast, at 'city level' in example 2, both the residents of Copenhagen and the public sector were involved in the implementation of climate adaptation measures. The first 2 examples where disaster driven, which helps in the recruitment of participation and budget at an early stage, example: the city of Copenhagen has also called the cloudburst a 'fundraising event'. The third example - 'Fryslan' - is not disaster driven but learnt from disasters such as the disaster in Copenhagen. A large area and all stakeholders were involved in the masterclasses, but it could be improved by getting the private sector involved.

Conclusions

In conclusion, the outcomes of the 3 pilots show that aside from the size of area (object, city or national district) and level of participation of stakeholders, there is a clear demand for quickscan models 'stresstest' and a collaborative knowledge sharing tools where first impressions of different urban resilience projects can be quickly gained. It is advised to run a stresstest as precaution measure instead of acting after a disaster as in pilot 1 and 2, and involve multiple stakeholders as in pilot 3. Quickscan models can give a fast interpretation of areas being flooded during extreme rainfall or areas with high temperatures during heatwaves.

Improvements of the stresstest procedure derived from these 3 pilots are:

- While stakeholders predominantly from governmental organizations are involved in these stress tests, ‘quadruple helix involvement’ is needed
- More involvement of the private sector and especially real estate owners (from inhabitants owning a house to large area real estate owners) since their assets are effected with the effects of climate change
- Shared learning and cooperation between stakeholders is necessary to develop a climate adaption plan
- Not only floodmaps should be created. Masterclasses and workshops (exmpale stresstest Fyslan and Copenhagen) create awareness about climate adaptation among stakeholders.
- The flood- and heatstress maps could be further improved and used by urban planners and other stakeholders to assess the resilience and well-being of cities and individual properties. The work presented shows that the floodmodelling is the main interest but combined analysis of heatstress and floodmaps in example 3 also has a strong potential. Its recommended to use combined maps for the analysis of other challenges in urban dense areas such as air and water pollution, immobility and noise disturbance.
- Further involvement and awareness of stakeholders can be created by means as a planned City Climatescan which is a methodology to measure, map, scan and assess different parameters that provide insight into the vulnerability of urban areas and neighborhoods

The 3 pilots show that the level of participation of several stakeholders varies with size and approach of the area. Higher participation of stakeholders, especially the private sector, is regarded as important for the next step in the national climate adaptation approach from ‘ambition to action’ to implement measures to mitigate the effects of climate change.

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