The integration of storm water flooding and thermal stress potential in Tainan (Taiwan) and Groningen (Netherlands)

Intégration des inondations et du potentiel des contraintes thermiques à Tainan (Taiwan) et Groningen (Pays-Bas)

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RÉSUMÉ

Les inondations consécutives à des pluies torrentielles, ainsi que le stress thermique dû à des canicules, sont deux phénomènes inquiétants pour la plupart des centres urbains, densément peuplés. Par suite du changement climatique, ces deux phénomènes se produiront à l'avenir plus souvent, et peuvent conduire à de graves problèmes. C'est pourquoi les départements de la santé publique et de la gestion des catastrophes naturelles voudraient être en mesure d'évaluer la vulnérabilité de leurs centres urbains face à des situations d'inondations et de stress thermique. Pour atteindre cet objectif, un projet de recherche a été lancé, en se basant sur deux villes différentes quant à leur région climatique et leur contexte urbain: Tainan à Taïwan et Groningen aux Pays-Bas.
Le projet permettra d'élaborer des cartes indiquant les risques dans les deux cas, afin de permettre des comparaisons ultérieures. Une carte d'altitude indiquera les zones basses, vulnérables à des inondations, et une carte thermique montrera où sont les températures physiologiques équivalentes (valeurs PET) élevées. La carte combinée permettra d'identifier les zones à problèmes d'inondation et de stress thermique, et pourra être utilisées par les urbanistes et les autres parties prenantes pour améliorer notre environnement.

ABSTRACT

Stormwater flooding and thermal stresses of citizens are two important phenomena for most of the dense urban area. Due to the climate change, these two phenomena will occur more frequently and cause serious problems. Therefore, the sectors for public health and disaster management should be able to assess the vulnerability to stormwater flooding and thermal stress. To achieve this goal, two cities in different climate regions and with different urban context have been selected as the pilot areas, i.e., Tainan, Taiwan and Groningen, Netherlands. Stormwater flooding and thermal stress maps will be produced for both cities for further comparison. The flooding map indicates vulnerable low lying areas, where the thermal stress map indicates high Physiological Equivalent Temperature (PET) values (thermal comfort) in open areas without shading. The combined map indicates the problem areas of flooding and thermal stress and can be used by urban planners and other stakeholders to improve the living environment.

KEYWORDS

Stormwater flooding, thermal stress, potential map, vulnerability

1 INTRODUCTION

Storm water floodings and thermal stress are two important issues for most of the developed area in cities. Municipalities and authorities which are in charge of water management, urban planning, and building construction need insight in the effects of the storm water flooding and thermal stress. Therefore, cost effective measures to mitigate these effects, preferably on street or even house level.

Due to the climate change, these two issues may contribute to serious conditions since both are expected to be increase in frequency and impact in the near future, especially for dense urban areas. For example, the dengue fever in some (sub)tropical areas are the results of the retention of surface water and the rising air temperature, while areas with high temperature and frequent flooding will be the disadvantage for local people and tourism potential.

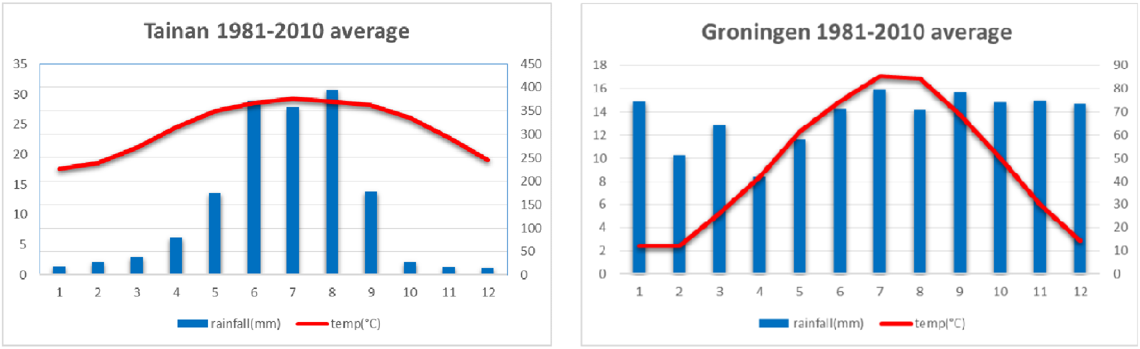
Therefore, the assessments of the vulnerability to storm water flooding and thermal stress are essential for public health and disaster management sector. Furthermore, the interaction of the two issues needs to be further investigated in order to develop the best strategies that abate both flooding and thermal stress.

To achieve this goal, two cities in different climate regions with a different urban context are selected as the pilot areas, i.e., Tainan, Taiwan and Groningen, Netherlands. The potential map of the storm water flooding and thermal stress will be produced in both studies for further comparisons in this study.

2 METHOD

2.1 Study area

Tainan is a highly developed city (22˚59’N, 120˚11’E) in the south of Taiwan in tropical areas. The total area of Tainan is 175.6 km^2, including 6 administrative districts. Groningen (53˚13’N, 6˚34’E) has a population just over of 200.000 (in 2014). It is the largest city in the north of the Netherlands with 83.69 km^2 total area. Figure 1 shows the average rainfall and temperature of both cities. The comparisons indicate that the average temperature of each month are ranged between 18-30 ˚C in Tainan, whereas between 2-16 ˚C in Groningen. Concerning the precipitation, Tainan has the largest rainfall during June to August due to the typhoon seasons. The monthly rainfall in Groningen is lower than the peak in Tainan, and is more constant over the year.


Tainan

Groningen

Fig. 1 Climate data in Tainan and Groningen

2.2 Basic information collection

The basis for the Groningen case is an accurate DEM (Digital Elevation Model) of the urban area with a high resolution (4 points/m^2). For Tainan such a DEM is unfortunately not available so the low resolution of DEM data (30m resolution) validated by mobile field measured elevation data are applied in this study. The basic urban development information for estimate thermal stress potential were collected from the government which including the land use, population density, and total floor area and height of building. The meteorology data in Tainan were derived from the central weather bureau, the data can be used to set up the initial condition for thermal stress calculation, and further make the verification of simulation results.

2.3 Model of the mapping

Models of different levels of spatial resolution and accuracy have been used. In general the larger the area the less accurate models get, due to both physical simplifications and coarser resolutions. Because of the development of the computational capabilities of computers and DEMs with high resolutions it is now possible to make models with high resolutions. To keep computational times limited in a quick scan, it is interesting to simplify the modeling of the physical processes. Comparing the results of quick scan assessments with results of more complete and correct models (for a limited area) shows if the quick scans are valuable or not. This results in a working between coarse and fine modeling.

2.3.1 Flood map

The tool CLOUDS (which is an acronym of Calamity Levels of Urban Drainage Systems – and in Dutch called WOLK) was used as a quick scan method to simulate storm water floodings. CLOUDS is based on a DEM and visualizes the water flow from high to low, while filling up lower areas with water as the final situation. The quick scan is based on only the following readily available data. The Accurate DEM, which is freely available for the whole of the Netherlands. With 4 points per square meter and a vertical accuracy of several centimetres this provides an insight in the surface elevation. GIS-map with houses, streets and waterways. The resulting maps show the expected water depths for cloudbursts of 60 and 100 mm in one hour. The maps also show the main stream lines of the above ground water flow.

2.3.2 Thermal stress map

Two types of models have been used to assess the thermal stress. A quick scan GIS-based thermal stress map for large scale, and a prognostic model EVNI-met for small scale.

The quick scan GIS-based thermal stress maps have been developed in the Netherlands in order to give a quick insight in possible thermal stress locations in a city. It is based on accurate DEM and the assumption that for a quick insight of thermal stress some rough simplifications of the actual physical processes can be made.

ENVI-met model is typically used to simulate the climate conditions in urban and landscaped. The model had been adopted to conduct research in lots of countries. In this study, we use ENVI-met to make thermal stress map. To compare the differences simulation results between different climates zones. In the analysis process, we can not only comprehend the different type of hot spot distribution and thermal stress level between Taiwan and Dutch but also knows the limitation of model in this study.

2.4 Model validations

The thermal stress map made by ENVI-met model has been validated using the measurement survey data with 17 points which were evenly distributed in the research area. In each point, a small weather station is set up to record the meteorological parameters including air temperature, relative humidity, globe temperature in summer daytime to correct and validate the simulation result. The trend of thermal stress between simulation result and measurement survey result is quite corresponding. This validation process confirms that the ENVI-met model can be usefully applied in the urban climate estimation.

3 RESULTS

3.1 Flooding map

The flooding map of Tainan which made by the scenario of three day heavy rain over 1200mm shows that, the place with lower elevation and higher impervious pavement will have higher risk and potential to make flooding occur. However some place with low elevation but high pervious pavement ratio will be safe when facing the storm water e.g. park and school.

The flood map of Groningen shows inundated points in the center that are known to flood during heavy storm water events. Photos and videos are gathered by researchers to verify these points and are mapped on www.climatescan.nl. Measures as sustainable urban drainage systems (SUDS) are planned to minimize these floods. The pathways of the water from the higher centre to the lower parts around will be used as waterways and with reprofiling of some urban spaces these roads will be a cost effective drainage system itself by discharging to the surface water and to stop flooding of houses (Fig.2).

Fig.2 Flooding map in Tainan and Groningen

3.2 Thermal stress map

The thermal stress map was used to identify hot spot locations. The legends were shown in different colors to present different thermal stress levels. The results revealed that, Tainan was generally in high thermal stress, only some spaces with higher greenery and pervious pavement, e.g. park shows lower thermal stress, in some dense areas with high building distributed and large number of impervious pavement, e.g. commercial district are significantly show extreme thermal stress in summer time.

The thermal stress map of Groningen shows hotspots in the center where almost no green or water is available. The Noorderplantsoen, a park on the left top of figure 3, shows lower temperatures in the shades of the trees and near the water that flows through this green area. Measurements in these areas taken while interviews with users of the public space where conducted verified these model results. Inhabitants of Groningen avoid the ‘concrete shopping streets and paved marketplaces’ and recreate in the green park areas.

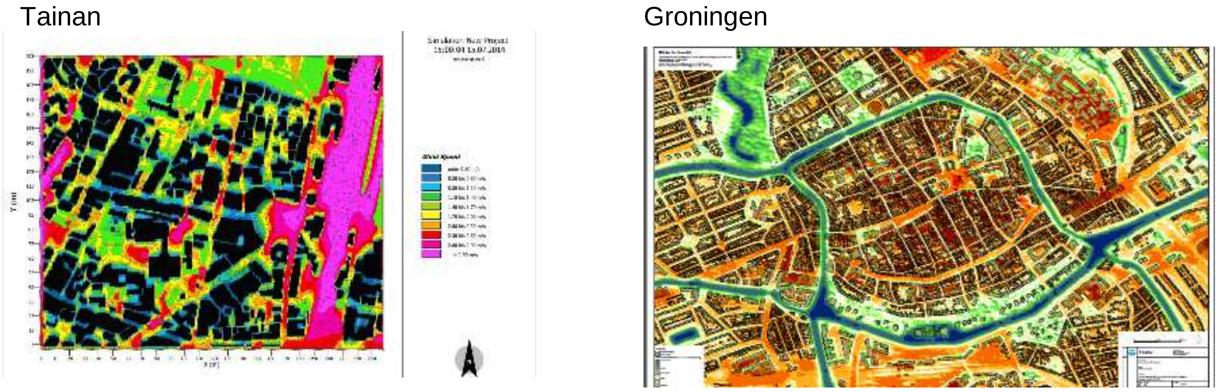


Fig. 3 Thermal thermal map in Tainan and Groningen

3.3 3-D visualization

Combining the elevation model, the dataset with buildings and aerial photographs we can make a 3d model of the city and get a better overview of the outcomes of the model. The model was shown in the 3D virtual reality theater on a cylindrical screen using 6 HD projectors to project an image with a resolution of roughly 5000x1800. To display this model on such a big screen a special 3D viewer, based on the open source OpenSceneGraph 3D toolkit, was used. The software was running simultaneously on 7 PC's, one master PC for the control of the model and 6 slave PC's to drive the projectors (Verlaat et al 2014). https://www.youtube.com/watch?v=mzFahS9RJPA

4. CONCLUSIONS

Challenges and further development: with combining thermal stress and floodings and even more climate issues in dense urban areas the datasets are getting bigger and researchers and customers get more demanding and want fast and good visual results. DEMs (digital elevation maps) are becoming more common and better, improving the accuracy with a higher resolution. The comparison of the results of the models will indicate up to what level quick scan mapping is sufficient and when the more accurate and complete modelling is needed. The choice between coarse and fine modelling will vary within each situation, depending on the needs. The more accurate and complete models lack the ability to perform on a large scale. This will be solved by using our High Performance computing facilities, running the model on the high performance clusters and 3D visualizations.

LIST OF REFERENCES

Kluck J., Boogaard F.C., Goedbloed D., Claassen M. Storm Water Flooding Amsterdam, from a quick Scan analyses to an action plan, International waterweek 2015, Amsterdam.

RUG. (2014). Disaster Risk Management - urban flooding, heatstress & earthquakes [video]. Retrieved from https://www.youtube.com/watch?v=mzFahS9RJPA

Verlaat M., van der Meulen L., Schoof G., Boogaard F., Kluck J., Disaster Risk Management: Urban Flooding and heatstress, Geomatics Workbooks n° 12 – "FOSS4G Europe Como 2015",

Dutemeyer D, Barlag AB, Kuttler W, Axt-Kittner U (2013) Measures against heat stress in the city of Gelsenkirchen, Germany. Erde 144(3-4):181-201

Fröhlich D, Matzarakis A (2013) Modeling of changes in thermal bioclimate: examples based on urban spaces in Freiburg, Germany. Theoretical and Applied Climatology 111(3-4):547-558

Lau KKL, Lindberg F, Rayner D, Thorsson S (2015) The effect of urban geometry on mean radiant temperature under future climate change: a study of three European cities. International Journal of Biometeorology 59(7):799-814