FloodCitiSense: Early Warning Service for Urban Pluvial Floods for and by Citizens and City Authorities

Boud Verbeiren[1,2](✉), Solomon Dagnachew Seyoum[1], Ihab Lubbad[1], Tian Xin[3], Marie-Claire ten Veldhuis[3], Christian Onof[4], Li-Pen Wang[4,5], Susana Ochoa-Rodriguez[6], Carina Veeckman[7], Michelle Boonen[7], Linda See[8], Dominique Nalpas[9], Barry O'Brien[10], Andy Johnston[10], and Patrick Willems[1]

[1] Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel, Brussels, Belgium
Boud.Verbeiren@vub.be
[2] Brussels Company for Water Management (SBGE/BMWB), Direction Exploitation, Brussels, Belgium
[3] CITG, Delft University of Technology, Delft, The Netherlands
[4] Department of Civil and Environmental Engineering, Imperial College London, London, UK
[5] RainPlusPlus Ltd., Derby, UK
[6] RPS Group, Environmental Management, Derby, UK
[7] Vrije Universiteit Brussel, iMEC-SMIT, Brussels, Belgium
[8] Ecosystems Services and Management, International Institute for Applied Systems Analysis, Laxenburg, Austria
[9] Etat Généraux des Eaux à Bruxelles, Brussels, Belgium
[10] Local Government Information Unit, Birmingham, UK

Abstract. FloodCitiSense aims at developing an urban pluvial flood early warning service for, but also by citizens and city authorities, building upon the state-of-the-art knowledge, methodologies and smart technologies provided by research units and private companies. FloodCitiSense targets the co-creation of this innovative public service in an urban living lab context with all local actors. This service will reduce the vulnerability of urban areas and citizens to pluvial floods, which occur when heavy rainfall exceeds the capacity of the urban drainage system. Due to their fast onset and localized nature, they cause significant damage to the urban environment and are challenging to manage. Monitoring and management of peak events in cities is typically in the hands of local governmental agencies. Citizens most often just play a passive role as people negatively affected by the flooding, despite the fact that they are often the 'first responders' and should therefore be actively involved. The FloodCitiSense project aims at integrating crowdsourced hydrological data, collaboratively monitored by local stakeholders, including citizens, making use of low-cost sensors and web-based technologies, into a flood early warning system. This will enable 'citizens and cities' to be better prepared for and better respond to urban pluvial floods. Three European pilot cities are targeted: Brussels – Belgium, Rotterdam – The Netherlands and Birmingham – UK.

G. Mannina (Ed.): UDM 2018, GREEN, pp. 660–664, 2019.
https://doi.org/10.1007/978-3-319-99867-1_114

Keywords: Urban pluvial flooding · Citizen science
Flood early warning system

1 Introduction

The hydrological response in (peri-)urban catchments is dependent on (1) rainfall and (2) the urban landscape. Besides rainfall intensity, rainfall spatial distribution is of great importance as it determines where the rain hits the urban landscape. The rainfall-runoff response at the urban surface is mainly determined by the land cover, with a very distinct behaviour in case of man-made materials (characterised by high sealed surface cover) or urban green. In case of extreme rainfall, fast and abundant runoff from sealed surfaces is the dominating mechanism which can quickly lead to exceedance of the system's drainage capacity, ultimately resulting in urban pluvial flooding. Due to the fast onset and localised nature of this type of flooding, occurring at small temporal and spatial scales, high resolution models and data are needed (Jacobsen 2011; Bruni et al. 2014; Ochoa-Rodriguez et al. 2015b). This also demands a fast simulation of flood forecasts.

Contrary to what would be expected, these specific monitoring and modelling needs for pluvial flood analysis in urban catchments are not translated into a denser monitoring network of rainfall and/or hydrological response. Most urban catchments remain poorly gauged - even ungauged (Rodriguez et al. 2005). The main reason is the relatively high cost for installation and maintenance of dense sensor networks (Lowry and Fienen 2013). In the case of rainfall, recent developments in radar technology have made it possible to obtain spatially-continuous, high resolution rainfall estimates (Bruni et al 2014; Veldhuis ten et al. 2014). However, the accuracy of radar estimates is often insufficient because they only provide an indirect measurement of rainfall. As such, these measurements need to be complemented by direct rainfall measurements on the ground (Wang et al. 2013, 2015).

In recent years, crowdsourcing or citizen science has gained popularity as an alternative data collection technique. Crowdsourcing refers to the involvement of citizen scientists and/or the use of "mass" data to fulfil the need for spatially distributed measurements (Muller et al. 2015). With respect to rainfall, several crowdsourcing initiatives exist, based on voluntary rain gauging and/or smart sensing (CoCoRaHs.org, Rainlog.org, etc.). Though some question the accuracy and usefulness of crowdsourced data (Riesch and Potter 2014), others clearly demonstrate the potential of crowdsourcing (Lowry and Fienen 2013) and smart sensing techniques (Overeem et al. 2013). Very good examples in the field of flood monitoring is the development of Citizen Water Observatories within the framework of the ongoing WeSenseIt.eu project or the citizen-based reporting within the framework of the US FLOCAST project or the P+Taiwan disaster reduction platform. These projects, however, do not focus on urban areas, where the response and lead times are typically much shorter. Smith et al. (2015) demonstrated that crowdsourced information on floods, harvested from social media, could successfully be used for validation of a real-time flood model.

While research seems to have been exploring widely the potential of citizen interaction in the field of flood monitoring (of non-urban areas), efforts have remained relatively limited at the level of public citizen interaction services by governmental agencies. The DIANE-CM project explored the potential of collaborative modelling where different stakeholders (including water managers, local authorities, emergency services and citizens) were involved in order to initiate public dialogue and come to more informed and shared decision-making to support flood risk management (Evers et al. 2012). Ochoa-Rodriguez et al. (2015a) reviewed pluvial flood warning approaches in England. Despite the rapid progress that has been made in recent years in improving forecasting, warning and management of this type of flooding, a number of major drawbacks remain, including insufficient accuracy and resolution of rainfall estimates and forecasts, simulation time still too long in relation to the typical short lead times of pluvial floods, lack of capacity at the local authorities level and low level of (public) awareness on this type of floods. These challenges will be tackled in FloodCitiSense by bringing local stakeholders together and jointly creating flood observatories and flood warning tools.

2 Materials and Methods

The FloodCitiSense project proposes an interactive and cooperative framework (Fig. 1) consisting of citizens, local authorities, research units and industrial partners aiming at improving the monitoring and management of urban pluvial flooding. Citizens are no longer considered as passive, potential "victims" of urban pluvial floods, but are engaged as active contributors in the process of pluvial flood monitoring and mapping, enabling better simulation and forecasting of flood events while enhancing awareness and ultimately resilience. Moreover, the proposed framework aims at establishing strong ties between research and public management, enabling the transfer of the latest state-of-the-art technologies in the monitoring and modelling of pluvial flooding. Both citizen science and smart sensing will play a central role in the envisaged urban pluvial flood early warning service. The service will consist of an intelligent algorithm enabling early detection of threshold levels/volumes triggering potential pluvial flood events and will support better preventive communication to the public.

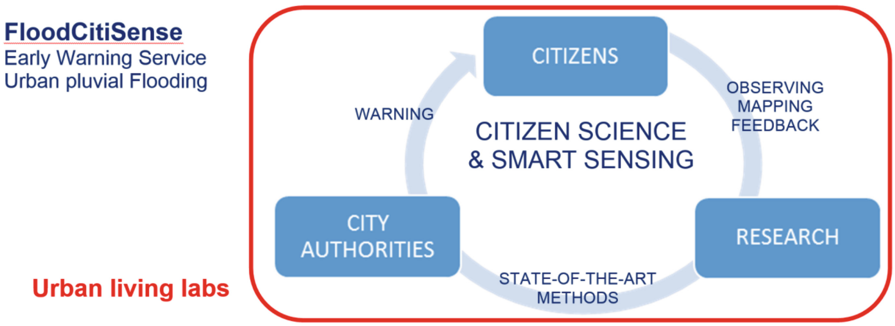

Fig. 1. Concept of FloodCitiSense project

The main outcome will be an urban pluvial flood early warning service for, but also by citizens and city authorities, built upon the state-of-the-art knowledge, methodologies as well as smart technologies provided by research units and private companies. The targeted co-creation of this new, innovative public service is realized by bringing together all actors in urban living labs. The overall design of Living Lab experiments is based on principles of 'transition experiments' (Hoogma et al. 2002). In contrast to traditional innovation experiments aimed at testing and demonstrating, transition experiments focus on broad stakeholder involvement, co-creation, and strategic learning to achieve systemic change (Kemp and van den Bosch 2006).

3 Results and Discussion

In total, nine co-creation workshops with citizens and city stakeholders, were set-up between October 2017 and March 2018 that consisted of multiple creative exercises and group discussions to elicit user and data requirements about the FloodCitiSense solution, i.e. a social sensing application and low-cost rainfall sensor network (Veeckman and Boonen 2018).

Some small differences between the pilots could be noticed. First of all, the city stakeholders in Birmingham are a bit more reluctant towards citizens' contributions, and rely more on the high-density data retrieved from sensors. Brussels and Rotterdam perceived the citizens' contributions as highly valuable, and would like to position this as part of a greater awareness raising campaign around water management and sustainability in the city. Secondly, for the engagement strategy of citizens in Rotterdam and Brussels, some concerns were expressed on how to motivate users in the long-term, as flooding events only happen rarely. As a solution, Rotterdam suggested to integrate FloodCitiSense with the Buitenbeter application, as this system already has a solid basis of frequent users. Brussels suggested to reach out to already existing strong local communities, and to invest in advertising campaigns with support of local media. Since Birmingham already has a large volunteering community through the Flood Action Group, less issues are expected for continued participation of citizens.

4 Conclusions

FloodCitiSense explores the potential of citizen science and low-cost sensing via co-creation of a flood early warning service in a Urban Living Lab context.

References

Bruni, G., Reinoso Rondinel, R.R., van de Giesen, N.C., Clemens, F.H.L.R., ten Veldhuis, J.A. E.: On the sensitivity of urban hydrodynamic modelling to rainfall spatial and temporal resolution. Hydrol. Earth Syst. Sci. Discuss. **11**(6), 5991–6033 (2014)

Evers, M., Jonoski, A., Maksimovič, Č., Lange, L., Ochoa Rodriguez, S., Teklesadik, A., Cortes Arevalo, J., Almoradie, A., Eduardo Simões, N., Wang, L., Makropoulos, C.: Collaborative modelling for active involvement of stakeholders in urban flood risk management. Nat. Hazards Earth Syst. Sci. **12**, 2821–2842 (2012). https://doi.org/10.5194/nhess-12-2821-2012

Goormans, T., Willems, P.: Using local weather radar data for sewer system modelling: case study in Flanders, Belgium. J. Hydrol. Eng. **18**(2), 269–278 (2013)

Hoogma, R., Kemp, R., Schot, J., Truffer, B.: Experimenting for Sustainable Transport: The Approach of Strategic Niche Management. Spon Press, London (2002). ISBN 0-415-27116-9

Jacobson, C.R.: Identification and quantification of the hydrological impacts of imperviousness in urban catchments: a review. J. Environ. Manage. **92**(6), 1438–1448 (2011)

Kemp, R., Van den Bosch, S.: Transitie-experimenten. Praktijkexperimenten met de potentie om bij te dragen aan transities. KCT, Delft, Rotterdam (2006)

Lowry, C.S., Fienen, M.N.: CrowdHydrology: crowdsourcing hydrologic data and engaging citizen scientists. Ground Water **51**, 151–156 (2013)

Muller, C.L., Chapman, L., Johnston, S., Kidd, C., Illingworth, S., et al.: Crowdsourcing for climate and atmospheric sciences: current status and future potential. Int. J. Climatol. **35**, 3185–3203 (2015)

Ochoa-Rodríguez, S., Wang, L.P., Thraves, L., Johnston, A., Onof, C.: Surface water flood warnings in England: overview, assessment and recommendations based on survey responses and workshops. J. Flood Risk Manage. **110**, S211–S221 (2015)

Overeem, A., Leijnse, H., Uijlenhoet, R.: Country-wide rainfall maps from cellular communication networks. Proc. Natl. Acad. Sci. U.S.A. **110**, 2741–2745 (2013)

Ochoa-Rodriguez, S., et al.: Impact of spatial and temporal resolution of rainfall inputs on urban hydrodynamic modelling outputs: a multi-catchment investigation. J. Hydrol. **531**, 389–407 (2015)

Riesch, H., Potter, C.: Citizen science as seen by scientists: methodological, epistemological and ethical dimensions. Public Underst. Sci. **23**, 107–120 (2014)

Rodriguez, F., Cudennec, C., Andrieu, H.: Application of morphological approaches to determine unit hydrographs of urban catchments. Hydrol. Process. **19**(5), 1021–1035 (2005)

Smith, L., Liang, Q., James, P., Lin, W.: Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. J. Flood Risk Manage. (2015). https://doi.org/10.1111/jfr3.12154

Veeckman, C., Boonen M.: Deliverable 1.3 - Scenario specification of FloodCitiSense V2, 48 p. (2018). floodcitisense.eu

ten Veldhuis, J.A.E., et al.: Weather radar for urban hydrological applications: lessons learnt and research needs identified from 4 pilot catchments in North-West Europe. In: Proceedings of the International Symposium Weather Radar and Hydrology, pp. 1–10 (2014)

Wang, L.-P., Ochoa-Rodríguez, S., Simoes, N., Onof, C., Maksimović, Č.: Radar-raingauge data combination techniques: a revision and analysis of their suitability for urban hydrology. Water Sci. Technol. **68**(4), 737–747 (2013)

Wang, L.-P., Ochoa-Rodriguez, S., Van Assel, J., Pina, R.D., Kroll, S., Pessemier, M., Willems, P., Onof, C.: Enhancement of radar rainfall estimates for urban hydrology through optical flow temporal interpolation and Bayesian gauge-based adjustment. J. Hydrol. **531**, 408–426 (2015)