An Agent Based Modelling tool exploring decision-making processes for flood risk management

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Abstract
Cities at risk of extreme hydro-meteorological events need to be prepared to decrease the extent of the impacts. However, the majority usually reacts to the catastrophe, having failed to proactively prepare against extremes. This can be a result of both absent structural protection measures and problematic governance. While for the first, models exist that can simulate the effect, the effect of the latter is difficult to quantify. This work aims to explore how the different decisions authorities make, regarding for example: whether or not to cooperate with someone; build something; assign funding to something else etc., affect the flood risk management of an area. For that matter, the Institutional Analysis Framework was used to conceptualise the decision-making processes of authorities responsible for flood risk management. Based on this, an Agent Based Modelling tool has been created, enabling the exploration of the system's behaviour under different decisions and risk scenarios. The tool has used as a case study the responsible authorities for flood protection in the city of Rethymno, Greece. The tool has a user-friendly interface enabling the end-user to explore the drivers of decision-making processes under different conditions.
Keywords: decision-making, flood risk management, agent based modelling

1. Introduction

An "experimental" approach, gives the opportunity to decision makers to better understand the way the system may react to changes (structural or operational). In hydro-informatics, Agent Based Modelling (ABM) is gaining ground as means to experiment with the behaviour of the social component of the water cycle (Koutiva & Makropoulos, 2011). The main reason for the prevalence of ABM is its ability to address problems that concern emergence arising from interactions between a system's individual components and their environment (Grimm & Railsback, 2013). This method is ideal for simulating the dynamic interaction between different components of the same complex system i.e. the social component and the water system component (Koutiva & Makropoulos, 2016).

This work presents a tool developed to enable the experimentation with the decision-making process of authorities responsible for a city's flood risk management. This research was included within the activities of the EU funded PEARL project (www.pearl-fp7.eu), which was completed at the end of 2017. The produced ABM was part of an overall Toolbox that was created to support decision-makers regarding flood risk management (Lykou et al., 2017).

2. Methodology

In this research, the Institutional Analysis and Development framework (IAD) developed by Ostrom (Ostrom, Gardner, & Walker, 1994) was used as a roadmap in order to conceptualise the decision making processes of authorities responsible for flood risk management. Based on Ostrom's theory, in order to analyse institutions, we need to identify the external variables that comprise the biophysical conditions, the attributes of the community, the previously implemented actions and the rules of the system identifying who may implement actions and whom and how these actions affect.

Figure 1 presents an implementation of the IAD to the flood protection decision making. The relevant biophysical conditions have been identified as the specific characteristics of the river basin, the climatic characteristics and the existing flood protection measures. The attributes of community include among others the historical flooding events and their effects to the area, including the decision makers' actions. In terms of the outcomes, these can be measured based on the performance of the area to protect, prevent and prepare against floods. Finally, the rules-in-use are something explicit in each case and need to be defined on a case by case basis. This representation was used to identify the main components of the decision making process of flood risk management which was used in turn to design the developed ABM tool.

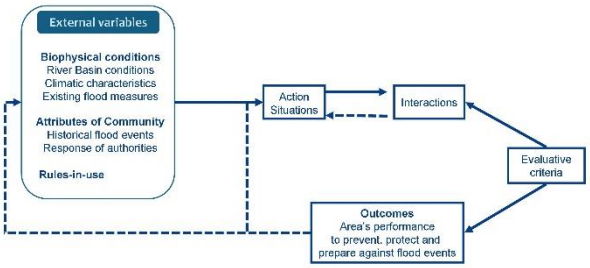

Figure 1. IAD of flood risk management decision making

3. PEARL ABM SAS

The developed ABM, called PEARL ABM SAS was based on the PEARL project's case study of the city of Rethymno in the island of Crete in Greece (Lykou et al., 2017). Rethymno is a city vulnerable to both rainfall and coastal floods. The PEARL ABM SAS simulates the authorities' decision-making process for the selection of resilience strategies and assesses the performance of the case area under different socio-economic and flood events scenarios (Figure 2).

Figure 2. PEARL ABM SAS conceptual framework

The agents follow specific rules that allow them to get information regarding the available funding and the characteristics of the resilience strategies, interact with the stakeholders to prepare the city for flooding events and implement actions, decide to implement new flood resilience measures, inspect existing flood resilience measures and maintain them.

Additionally, and most importantly, PEARL ABM SAS provides a useful and a tangible way for authorities to examine and explore all decisive factors which affect the actual implementation of a measure. Such factors are related to the available funding, the level of authorities' collaboration, etc. The outcome of the PEARL ABM SAS is a qualitative measurement of the performance of the area in respect to the flood events that occurred during the simulation year.

4. Conclusions

The validation of the PEARL ABM SAS was performed by the stakeholders of flood risk management in Rethymno. Additionally, the participants of a stakeholder workshop in Rethymno were able to use the PEARL ABM SAS through an online user interface (Figure 3), and explore different socio-economic and flood scenarios on their own, without any further assistance. The stakeholders identified a leverage point in the decision-making process which controls the implementation of actions and is responsible for the performance of the city against flooding incidences, that of the cooperation between the local authorities and the stakeholders. While this was already identified as a focal point towards the implementation of the decided actions, the stakeholders were able to see and discuss between them its effects on the protection of the city. The produced computational experiments were therefore able to inform authorities about the effects of their decisions.

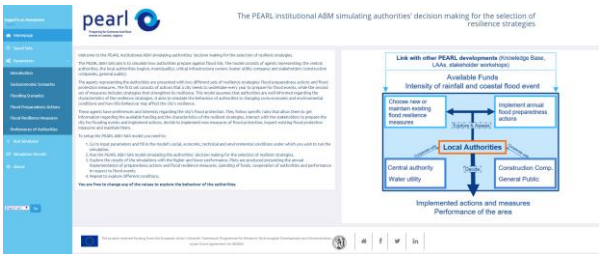

Figure 3. User interface

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References

Grimm, V., & Railsback, S. (2013). *Individual-based modeling and ecology*. Princeton university press.

Koutiva, I., & Makropoulos, C. (2011). Towards adaptive water resources management: Simulating the complete socio-technical system through computational intelligence. *Proceedings of the 12th International Conference on Environmental Science and Technology (CEST 2011).*

Koutiva, I., & Makropoulos, C. (2016). Modelling domestic water demand: an agent based approach. *Environmental Modelling & Software, 79*, 35-54.

Lykou A., Koutiva I., Karavokiros G., Tsoukalas I., Pantazis C., and Makropoulos C. (2017), The PEARL-toolbox: supporting the decision making process in selecting flood resilience strategies, *Proceedings of the 15th International Conference on Environmental Science and Technology (CEST 2017).*

Ostrom, E., Gardner, R., & Walker, J. (1994). *Rules, Games, and Common Pool Resources.*