Journal of Environmental Management 161 (2015) 38–50

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research paper

A cloud based tool for knowledge exchange on local scale flood risk

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A R T I C L E I N F O

Article history:
Received 5 December 2014
Received in revised form
13 May 2015
Accepted 5 June 2015
Available online 3 July 2015

Keywords:
Cloud computing
Flooding
Stakeholder engagement
Rural land management
Local EVOp Flooding Tool (LEFT)

A B S T R A C T

There is an emerging and urgent need for new approaches for the management of environmental challenges such as flood hazard in the broad context of sustainability. This requires a new way of working which bridges disciplines and organisations, and that breaks down science-culture boundaries. With this, there is growing recognition that the appropriate involvement of local communities in catchment management decisions can result in multiple benefits. However, new tools are required to connect organisations and communities. The growth of cloud based technologies offers a novel way to facilitate this process of exchange of information in environmental science and management; however, stakeholders need to be engaged with as part of the development process from the beginning rather than being presented with a final product at the end.

Here we present the development of a pilot Local Environmental Virtual Observatory Flooding Tool. The aim was to develop a cloud based learning platform for stakeholders, bringing together fragmented data, models and visualisation tools that will enable these stakeholders to make scientifically informed environmental management decisions at the local scale. It has been developed by engaging with different stakeholder groups in three catchment case studies in the UK and a panel of national experts in relevant topic areas. However, these case study catchments are typical of many northern latitude catchments. The tool was designed to communicate flood risk in locally impacted communities whilst engaging with landowners/farmers about the risk of runoff from the farmed landscape. It has been developed iteratively to reflect the needs, interests and capabilities of a wide range of stakeholders. The pilot tool combines cloud based services, local catchment datasets, a hydrological model and bespoke visualisation tools to explore real time hydrometric data and the impact of flood risk caused by future land use changes. The novel aspects of the pilot tool are; the co-evolution of tools on a cloud based platform with stakeholders, policy and scientists; encouraging different science disciplines to work together; a wealth of information that is accessible and understandable to a range of stakeholders; and provides a framework for how to approach the development of such a cloud based tool in the future. Above all, stakeholders saw the tool and the potential of cloud technologies as an effective means to taking a whole systems approach to solving environmental issues. This sense of community ownership is essential in order to facilitate future appropriate and acceptable land use management decisions to be co-developed by local catchment communities. The development processes and the resulting pilot tool could be applied to local catchments globally to facilitate bottom up catchment management approaches.

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http://dx.doi.org/10.1016/j.jenvman.2015.06.009

1. Introduction

Europe is currently experiencing a relatively flood-rich period with a spate of major floods across the continent over the last decade (Macklin and Rumsby, 2007; Wilby and Keenan, 2012). UK agriculture has experienced significant intensification over the past 70 years as a direct result of national government and European incentives to increase productivity (O'Connell et al. 2007; Marshall et al. 2014). Agricultural land use management is known to have an influence on downstream flood risk in the UK (Burton et al. 2003; O'Connell et al. 2007; Wilby et al. 2008; Hess et al. 2010; McIntyre and Marshall, 2010; Wilkinson et al. 2013b). Instead of fighting and controlling flood hazards with only traditional engineered solutions (e.g. higher dikes, flood walls), new management styles focus on "understanding and managing the flood risk" (Samuels et al. 2006; de Groot, 2014). Farmers and land managers are increasingly targeted by scientists to help inform research and policy tools (Nettle et al. 2010; Vignola et al. 2010; Winsten et al. 2010; Oliver et al. 2012). There is growing recognition that the appropriate involvement of local communities in land and water management decisions can result in multiple environmental, economic and social benefits. Therefore, local stakeholder groups are increasingly being asked to participate in decision making alongside policy makers, government agencies and scientists (see Lane et al., 2011 which illustrate a way of working with experts, both certified [academic natural and social scientists] and non-certified [local people affected by flooding], for whom flooding is a matter of concern). As such, addressing issues such as flooding requires new ways of learning about the catchment, by engaging with local communities for better mutual understanding. There is a need for a catchment based, community led initiative to understand and respond to flood hazards, using a bottom up approach. Tools are required which are developed through a behaviour driven design process. The communities at risk of flooding, the landowners who manage the land which generate the runoff and the organisations who manage catchments need to be part of the development process from the beginning rather than being presented with a final product at the end.

Recent advances in the area of computing and cyber infrastructure have provided computing platforms to enhance the management of data resources, using services which bring together people and tools, facilitating information sharing for science or other data rich applications (Yang et al. 2010; Fox and Hendler, 2011; Huang et al. 2013). In short this means that we can now compute, model, share information and therefore, potentially, achieve higher levels of insight, and make better decisions than before. A problem today is not so much that we can visualise a virtual reality that has the appearance of being more and more realistic; it is much more the evaluation of the models on which that representation of reality is based. Models can be misleading in the detail, even if they provide some broad resemblance to observations of real variables. An important concept in this respect is treating models as tools for learning about places (the "models of everywhere" concept of Beven (2007) and Beven and Alcock (2012)), whereby models become repositories of knowledge that can assimilate data, integrate information about places from local stakeholders, and be interrogated to guide management and policy decisions, or to inform the requirements for new data to constrain uncertainties.

This type of learning process about places will be similar regardless of discipline, process, users and uses. Detailed visualisation changes the focus from the concepts and issues about how to represent the system to the idiosyncrasies of places; to learn in depth about a particular reach of river, a soil profile or a field. This will require making all the data available about that place on a shared platform; being able to access a collection of models and choose those that are appropriate to understand the complexities that exist; and, allowing that the information collected by communities of volunteers (such as farmers, catchment managers or members of the public) might be valuable in constraining the virtual view of a place. This sense of place can be particularly useful in engaging local communities with processes in familiar contexts to them (Lane et al. 2011). If all of these opportunities can be truly managed and brought together, this is the vision and the possibility of what we see as a great new way of doing hydrology and earth science and is what we describe the start of here – an environmental virtual observatory.

New and specific computational opportunities that can contribute to this vision include: (i) the use of cloud computing techniques to allow disparate databases to be readily available to inform the representation of a complex sequence of processes and forcing boundary conditions for a particular application and scale, (ii) the choice and the linking-in of the relevant process representations in a complex system in a way that allows those representations to be easily modified in an open source, user-driven, future-proofed way, (iii) the means of evaluating and managing uncertainty by conditioning against past and new future observations at different scales in space and time, and (iv) ways of presenting complex interpretative and predictive model results to different groups of users using effective visualisation methods. A particularly difficult issue is how to convey the assumptions on which such results are based, and record the audit trail of the decisions that lead to them, in a way that is accessible to users if required (e.g. Kloprogge et al. 2011; Beven and Alcock, 2012). Accountability should be an important part of the process (e.g. Stirling, 2010).

The Environmental Virtual Observatory Pilot project (EVOp) was a proof of concept project to develop new cloud based applications for accessing, interrogating, modelling and visualising environmental data by developing a series of exemplars at the local, national and international scale (in this paper we focus on the local scale exemplar). The long term vision of the Environmental Virtual Observatory concept is to (http://www.evo-uk.org):

1. Make environmental data more visible and accessible to a wide range of potential users including public good applications;
2. Provide tools to facilitate the integrated analysis of data, greater access to added knowledge and expert analysis and visualisation of the results;
3. Develop new, added-value knowledge from public and private sector data assets to help tackle environmental challenges.

The aim of this work was to develop a cloud based learning platform for stakeholders, bringing together fragmented data, models and visualisation tools that will enable these stakeholders to make scientifically informed environmental management decisions at the local scale. This novel cloud based tool was developed through an evolutionary iterative development process involving active local stakeholder engagement. In particular we focussed on communicating the management implications related to flooding, which was identified as a key environmental issue with stakeholders in three focus areas across the UK. More specifically, the objectives were to (1) Develop a framework for creating the cloud based learning platform using stakeholder engagement to identify the crucial components for the end-users, (2) Based on outcomes from (1), build and evaluate the cloud based tool utilising further stakeholder feedback, and (3) Explore how complex hydrological processes (e.g. concepts of hydrological modelling) can be effectively communicated to all stakeholders using cloud based tools to increase understanding of environmental management decisions.