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Interactions between flow and vegetation: Translating knowledge from academic research to daily water management

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Abstract. Rivers and streams cannot be viewed without the vegetation growing in and alongside it. The riverine ecosystem is strongly organized by the presence of plants in interaction with flow and morphological processes. This creates challenges for water management, as a profound knowledge of these interactions is needed when management decisions must be made. At the same time other aspects of water management, such as societal-economic demands, might compromise the depth at which these processes can be studied and incorporated in the daily management of these systems.

1. Translating academic research to river management

Over thousands of years people have tried to manage rivers and streams to make most benefit out of their functions. A lot of this was initially based on trial and error, and long time experience, but over time the built up of expertise, and the development of organized research on hydrodynamics, morphodynamics and vegetation development became a strong fundament for the current understanding of rivers and their behaviour, which allows us to better manage our river systems. Nowadays, highly detailed indoor flume studies on the 3D hydrodynamic processes in vegetated flows are being carried out [e.g. 1,2] and used for validating detailed analytical and numerical models of these intricate processes [3]. Most indoor flume studies still use artificial representatives of plants [4], making the comparison with a real field situation challenging [5]. Also, the highly computational intensive numerical models tend to be time consuming, making them less suitable for day to day management. Still, the value of these experiments and models in management is strong, as based on these detailed measurements and calculations simplified models have been made that are more adept to daily river management [6,7].

During this key-note lecture I will address the potential impact of academic research on water management and how such impact can be made to last. It requires a multidisciplinary dialog to come to integrated water management plans that take into account the requirements of both flood risk management and ecological restoration for example. In this, the recent developments of Nature Based Solutions, also known as Building with Nature

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solutions, have helped strengthening this dialog, as natural processes are taken into account to come up with new strategies for river management.

At the same time there are still many challenges in implementing nature based solutions, especially since many of these new approaches have not yet been put to the extreme tests that are needed to fully understand their functioning under such rare, yet crucial conditions. Also, the natural dynamics of vegetation over time can be deemed unpredictable, or undesirable, especially in the longer term, making a good life cycle costing or long term prediction adherently complicated. It is especially in these uncertainties where academic research is needed to help overcome these obstacles in the implementation of nature based solutions for river management, as they might give solutions on how to take into account these dynamics of the system over time.

2. Daily practise - quantifying the impact of vegetation on flood risk

Vegetation is a dynamic aspect of rivers, streams and channels that must be accounted for in the management of these water systems. Both riverine floodplain development and instream vegetation in waterways can cause obstruction during high discharges to the level it can cause risk of flooding. At the same time vegetation in front of dikes may reduce wave impact on the dikes providing a natural barrier against flooding [8]. Water management must therefore manage vegetation seasonally or annually (e.g. mowing or grazing).

Also today, decisions on how best to manage this vegetation is often done based on expert judgement or in data-poor situations by the people working directly in the field, despite strong detailed academic knowledge on vegetated flows is existing. Applying this knowledge can help water managers to make more cost-effective choices in their management. However, it takes effort to translate this knowledge in meaningful manner for daily practise, taking into account some specific requirements to make the knowledge last. Information on the vegetation and its impact on hydrodynamic processes must be:
1. *quickly and easily obtainable and accessible* in case immediate action is required;
2. *reliable and undebatable* in case legal requirements need to be checked;
3. *trustworthy* in case a new solution is presented.

During this keynote, I will discuss how these three requirements were dealt with in three different examples where vegetation-flow interactions were an aspect of the management challenge and how innovative monitoring techniques and new quantifying tools can help address the challenge.

Example one deals with the challenges of mowing instream vegetation in smaller channels during the growing season. In these channels little information is available on the exact location of vegetation blocking the channels and often too much vegetation is mown, harming the ecological values within the channel. Using hyperspectral camera's on drones and real time water level recordings at gauging stations provide a better spatial and temporal view on the development of the vegetation, making it easier to define where and when to mow [9]. These technological advances are new and challenge the traditional ways of working, making a strong dialog with the end-users necessary from the very start of the development.

Example two focusses on assessing floodplain vegetation development in line with the legal requirements coming from flood risk management within the full area of the river branches of the Netherlands. For the full floodplain area a legal map with allowable vegetation types per cadastral plot is available (with over 12.000 land owners that need to comply with this legal map) [10]. Before each winter period the current vegetation status in this area must be checked against this legal map. Using the latest Sentinel2 satellite images, processed in Google Earth Engine and combined within the legal map in a web-viewer allows to get a first estimate of the areas that have undergone change compared to the legal map and focus the efforts of maintenance in these areas in direct discussions with the relevant land owner. In this discussion the accuracy of the classification system used to make the comparison with the legal map is still an important point for discussion.

Example three focusses on the potential role of vegetation in dike safety under extreme storm conditions. Despite it is well known [e.g 11] that vegetation on foreshores will reduce wave height and thereby wave run-up and overtopping over dikes, this is not yet quantified for dike safety in a standard manner [12]. Especially woody vegetation and shrubs can have significant wave reducing capacity [13]. One of the main arguments for not yet including vegetation in dike safety solutions is the fact that numerical models that can include vegetation in the hydrodynamic calculations have not yet been validated for these extreme conditions. With vegetation being dynamic and potentially prone to quick damage during such an event or unforeseen failure during a normal year (e.g. due to disease) there is a general reluctance against including vegetation in dike safety calculations. Both dialog with stakeholders to find solutions for such problems [14] and the use of large scale physical flume facilities is helping bridging this gap by putting real vegetation to the test under extreme conditions in real time, real scale experiments.

3. Summarizing remarks

Fundamental academic research has strengthened the basic understanding of vegetated flows, although we are still lacking a proper understanding of the behaviour of this vegetation under extreme field conditions based on validation data. Fortunately there are more and more examples in which the biomechanical properties of vegetation are taken into account, by either making realistic (scaled) surrogates, or simply by carrying out unscaled tests with real vegetation [e.g. 15,16, 17, 18].

One important part of bridging the gap between these scientific efforts and daily water management is a strong dialog between the two worlds, to ensure that the research carried out is meaningful, and to ensure that water managers take on board as much of the new insights as possible in their management. These new insights are not only the academic advances on vegetated flows, but perhaps more importantly also the latest innovative monitoring tools to obtain data in a different way than the traditional manual way of measuring. By now, the use of portable tablets allows for quick processing and visualisation of information directly in the field. Online, real time and remote sensing tools have opened up a world of information that was not so easily available even ten years ago. In this perspective making a lasting impact of scientific advances lies also in how these new data streams and technologies can be best used to translate scientific knowledge for the management challenges ahead.

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