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ABSTRACT
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The difficulty of modelling flow through vegetated river floodplains

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ABSTRACT

Vegetation in river floodplains has relevance for ecology but also affects the water level and therefore the flood risk. Models are used to simulate the effects of vegetation on flood water levels and determine dike heights or interventions in the vegetation. There are, however, many uncertainties associated with these models such as the roughness description of the vegetation, complexity of vegetation characteristics, classification uncertainty, uncertainty related to the discretization, application of the model outside the calibrated range, etc. This paper discusses some experiences from past projects with the aim of modelling the hydraulics in vegetated streams or floodplains. To make progress in unraveling the effects of vegetation on water levels, it is suggested to compare various models to each other and to field data and collect extensive measurement data, especially during high water events to capture the flow distribution in the main channel and floodplains.

1. Uncertainties in modelling flow through vegetated floodplains

This paper is inspired by several projects (see for example Fig. 1) that aimed at simulating the effect of vegetation resistance on water levels. In these projects, several modelling choices had to be made that influenced the outcome of the model. This lowered the confidence in the model results that were in some cases meant to support policy decisions. In the sections below some of these choices and uncertainties are discussed.

1.1. Vegetation roughness description

There are many ways to describe vegetation roughness. The most common way is by conventional roughness formulas such as Manning or Chézy. These two formulas describe different relationships between discharge and water level and hence cannot be both right. Moreover, the roughness coefficients are often considered constant while it is known that the flow resistance is dependent on water depth. There are many empirical and semi-theoretical formulas developed that describe the resistance of vegetation to flow as a function of water depth but these are only limitedly applied. Moreover, the performance of these descriptions against a large empirical data set shows a large variation (Augustijn et al. 2008). The choice for a roughness description, therefore, influences the model outcome.

1.2. Complexity of vegetation characteristics

Vegetation is not a static attribute, it is alive and exhibits temporal variations (e.g. growth, dying off, seasonal leaves). Most plants are flexible and have complex geometries. The location and positioning can have a large influence on flow patterns and turbulence generation, affecting the effective resistance. Much research has been devoted to these characteristics at various levels of detail but it remains difficult to translate this to field situations.

1.3. Classification uncertainty

Related to the complexity of vegetation characteristics, the classification of vegetation into roughness classes is subjective. Vegetation maps can be derived from different sources such as field observations, airborne photography or satellite images with varying spatial resolutions. The interpretation of these observations is subject to uncertainties. The number of classes is already a determining choice. Homogeneous vegetation covers are relatively easy to distinguish, but often mixing classes exist. Higher vegetation, like shrubs and trees, may have understories that may not have been detected but has an influence on the flow resistance. Straatsma and Huthoff (2011) found that classification errors can result in significant uncertainty in predicted water levels.

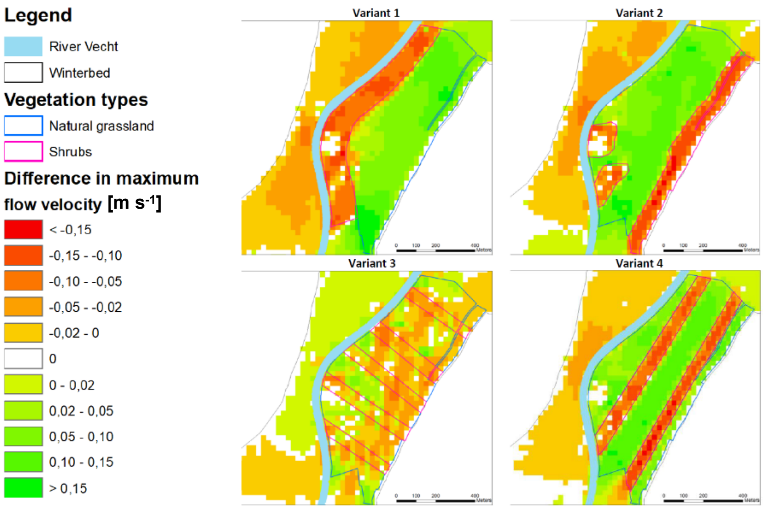

Fig. 1. Results from a 1D/2D model study with Sobek (Deltares, 2019) on the effects of vegetation distribution in the Overijsselse Vecht, The Netherlands. The figure shows differences in maximum flow velocity [m s^{-1}] for different spatial distributions of natural grassland (70%) and shrubs (30%) on a lot compared to a scenario in which the same vegetation distribution is expressed by one roughness value on the same lot. Adopted from Massa (2018).

1.4. Discretization

The discretization of the model has a large influence on the outcome. The choice between 1D or 2D is especially important as the spatial patterns in vegetation can never be captured accurately by a 1D model. But also for a 2D model, the grid resolution strongly determines how well the vegetation cover is represented. Besides the accuracy of the natural variability, numerical anomalies are introduced by the grid resolution and grid shape causing differences in model outcomes (Bomers et al. 2019).

1.5. Application outside calibrated range

Many of the uncertainties discussed above can be corrected for by calibration of the model. This is commonly done by adjusting the roughness of the main channel until simulated water levels are within an acceptable range of measured water levels. This assumes that other parameters (such as the vegetation roughness) are correct. For flood studies, these models are then typically used to simulate extreme conditions for which no measurements are available and that are outside the calibrated water level ranges. It is questionable whether the model results will hold for these conditions.

2. Way forward

Much research has been done on flow through vegetation, empirical studies and model studies, from laboratory scale to field scale. This has generated a lot of knowledge and experience but much of it is not generally known and therefore, but also for other reasons, hardly used in strategic or operational river management. It would be useful to perform more comparison studies between models, model settings and field data to get a better grip on what really matters. In addition, more field data are required to compare our model results to, especially during high water events. It might be difficult and dangerous to take measurements during high water conditions, but with new, innovating monitoring techniques it should be possible to get detailed measurements of flow velocities and water levels that can be used to get a better grip on the impact of vegetation on the hydrodynamics and improve our models.

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