River flows and riparian vegetation dynamics

1. Introduction

Natural streamflow variability is currently recognised as a major driver for most processes occurring in fluvial landscapes. Riparian zones play an important role in soil conservation, biodiversity, and water quality in the surrounding environments as well as the upland. Therefore, the study of riparian vegetation dynamics at the reach scale in fluvial environments is important.

Flooding and groundwater availability are key controls in the dynamics of riparian plant communities and the associated ecological processes (Auble et al., 1994; Lite et al., 2005; Nilsson and Svedmark, 2002; Tockner et al., 2000). In order to evaluate the species-specific behaviour of riparian vegetation under different flow regimes, a process-based understanding of the role played by the hydrological variability as the driver for vegetation growth and decay along a river transect, is necessary. In this study we analyse the signature of catchment-scale hydro-climatic processes and river flow regimes in the patterns of vegetation biomass.

2. Background to the Research

In this study (explained in full in Doulatyari et al., 2014) we provide an analytical stochastic description of the impact of the flow regime on vegetation dynamics in the aquatic-terrestrial transition zone. The modelling framework incorporates two recently proposed models of flow regimes characterisation (Botter et al., 2007) and riparian vegetation dynamics at the river transect driven by flooding and groundwater access (Camporeale et al., 2006). The modelling framework is applied to two case study watersheds, characterised by contrasting flow regimes.

The flow regime, which defines the variability of flows and can be captured in the stream flow probability density function (pdf), is characterised through an analytical mechanistic model (Botter et al., 2007) based on a catchment-scale soil water balance forced by stochastic Poisson rainfall (modelled at daily timescales) and exponentially distributed precipitation depths (Rodriguez-Iturbe et al., 1999; Porporato et al., 2004). Two distinct flow regimes can be identified based on the coefficient of variation of observed streamflows, (i) persistent regimes, marked by reduced flow variability and (ii) erratic regimes with enhanced flow variability (Figure 1) (Botter et al., 2013). Camporeale and Ridolfi (2006) developed a comprehensive process-based and stochastic model of the riparian vegetation dynamics driven by varying water table and river stages, where the role of flow variability on vegetation distribution along a riparian transect was investigated by modelling the hydrological noise as a dichotomous noise.

3. Sites Used in the Study

This study is the first attempt at bridging the two above mentioned models, by means of explicitly incorporating climatic and hydrological parameters in the estimation of vegetation biomass, in order to provide a better process-based understanding of riparian vegetation dynamics in unpredictable flow regimes. Vegetation biomass, at a given point along the river transect, alternates between growth (when the site is exposed) and decay (when the site is inundated). The extent of growth and decay for this point is determined by the length of time spent in the exposure and inundation states, as well vegetation-specific properties such as root depth. River stage fluctuations determine the pattern of exposure/inundation for a given point. These fluctuations are stochastic in nature since they are a mirror of stochastic fluctuation of the stream flows, driven by climatic and landscape features of the contributing watershed (expressed by the pdf of streamflows). Moreover, the morphological features of the river transect modulate these pulses at each transect. Therefore the growth and decay of vegetation along a river transect can be estimated by coupling of catchment-scale hydroclimatic processes, morphologic attributes of the river transect and vegetation-specific biological features. The change of climatic features and its impact on mean vegetation biomass along the transect were explored by means of studying the inter-annual variability of rainfall.
the Dolomites region in north eastern Italy. It drains a catchment of 313 km² at Cancia with an average discharge of 12.7 m³/s. Rainfall, streamflow and stage data from the summer months (June-August) of the period 1986-2008 were used. The Youghiogheny River, a tributary of the Monongahela River, is located near Oakland (MD), in the United States. It drains an area of 347 km² and has an average discharge of 3.6 m³/s. Rainfall, streamflow and stage data from the summer months of the period 1993-2012 were used.

4. Outcomes of the Research

In this study we set up a stochastic analytical framework to describe streamflows, stages and riparian vegetation dynamics. The model was applied to the terminal reach of two different catchments characterised by persistent and erratic flow regimes. It was shown that riparian vegetation patterns behave differently in erratic vs. persistent regimes. Figure 2 shows the probability distribution of streamflows (a&d), river stages (b&e) and riparian vegetation represented as the unitless parameter mean biomass (c&f) (for details see Doulatyari et al., 2014). In persistent regimes vegetation growth is primarily limited by groundwater access, while in erratic regimes the zone impacted by flooding is larger and vegetation patterns of different species are quite heterogeneous. The different behaviours observed in erratic and persistent flow regimes allow the use of this hydrological distinction as a framework to understand the patterns of riparian vegetation and in particular the role of flooding as a limiting factor for vegetation growth.

5. Acknowledgements

The research leading to these results has received funding from the European Community’s Seventh Framework Programme (FP7/2007-2013 under grant agreement n°265063). The US Geological Survey, the National Climatic Data Center, and the Italian Regional Agency for Environmental Protection of the Veneto Region are acknowledged for providing hydrological and hydro-meteorological data. We would like to particularly thank the USGS staff at Oakland (MD) for their exceptional support. Additional assistance was provided by Eawag, the Competence Center Environment and Sustainability (CCES) of the ETH domain in the framework of the RECORD (Restored Corridor Dynamics) and RECORD Catchment projects.

6. References


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