CL:AIRE

AB 4
(November 2014)

ADVOCATE bulletin

CL:AIRE's ADVOCATE bulletins describe practical aspects of research which have direct application to the characterisation, monitoring or remediation of contaminated soil or groundwater. This bulletin describes modelling studies to understand river flow regimes and vegetation dynamics in riparian zones.

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 dichotomic noise.

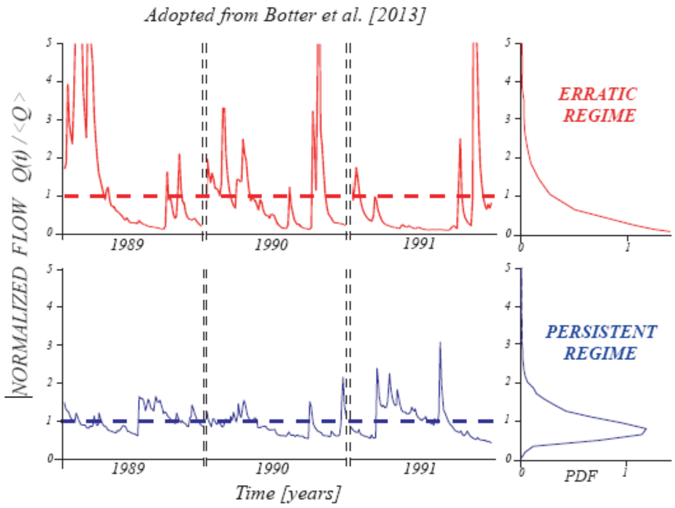

Figure 1: Persistent and erratic flow regimes.

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 streamflows, 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.

3. Sites Used in the Study

The model developed in this study was applied to the terminal reach of two different catchments characterised by contrasting flow regimes: the Boite (persistent flow) and Youghiogheny (erratic flow) river basins. The Boite river is a tributary of the Piave river located in

This bulletin was written by Behnam Doulatyari, Swiss Federal Institute of Aquatic Science & Technology (EAWAG), Department of Water Resources and Drinking Water, Überlandstrasse 133, P.O.Box 611, 8600 Dübendorf, Switzerland. For further information please email: behnam.doulatyari@eawag.ch

the Dolomites region in north eastern Italy. It drains a catchment of 313 km^2 at Cancia with an average discharge of 12.7 m^3/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 km^2 and has an average discharge of 3.6 m^3/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.

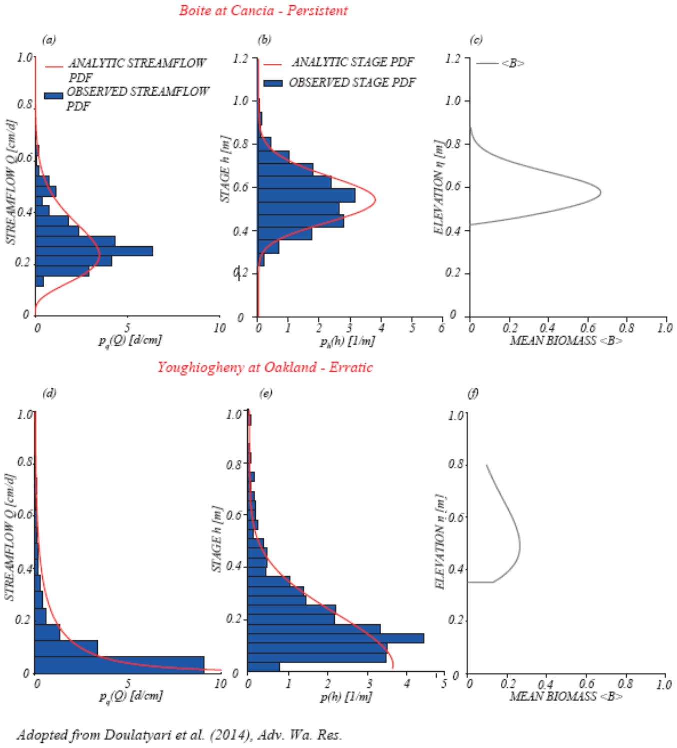

Figure 2: Probability distribution of streamflows (a&d), river stages (b&e) and riparian vegetation (c&f).

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

- Auble, G. T., J. M. Friedman, and M. L. Scott. 1994. Relating riparian vegetation to present and future streamflows, Ecol. Appl., 4(3), 544-554.
- Botter, G., A. Porporato, I. Rodriguez-Iturbe, and A. Rinaldo. 2007. Basin-scale soil moisture dynamics and the probabilistic characterization of carrier hydrologic flows: Slow, leaching-prone components of the hydro- logic response, Water Resour. Res., 43 (2).
- Botter, G., S. Basso, I. Rodriguez-Iturbe, and A. Rinaldo. 2013. Resilience of river flow regimes, P Natl Acad Sci USA, 110(32), 12925-12930.
- Camporeale, C., and L. Ridolfi. 2006. Riparian vegetation distribution induced by river flow variability: A stochastic approach, Water Resour. Res., 42(10).
- Doulatyari, B., S. Basso, M. Schirmer, G. Botter. 2014. River flow regimes and vegetation dynamics along a river transect. Adv. Wa. Res., DOI: 10.1016/j.advwatres.2014.06.015.
- Lite, S. J., K. J. Bagstad, and J. C. Stromberg. 2005. Riparian plant species richness along lateral and longitudinal gradients of water stress and flood disturbance, San Pedro River, Arizona, USA, J. Arid. Environ., 63(4), 785-813.
- Nilsson, C., and M. Svedmark. 2002. Basic principles and ecological consequences of changing water regimes: Riparian plant communities, Environ. Manage., 30(4), 468-480.
- Porporato, A., E. Daly, and I. Rodriguez-Iturbe. 2004. Soil water balance and ecosystem response to climate change, Am. Nat., 164(5), 625-632.
- Rodriguez-Iturbe, I., A. Porporato, L. Ridolfi, V. Isham, and D. R. Cox. 1999. Probabilistic modelling of water balance at a point: the role of climate, soil and vegetation, Proc. R. Soc. A-Math. Phys. Eng. Sci., 455(1990), 3789-3805.
- Tockner, K., F. Malard, and J. V. Ward. 2000. An extension of the flood pulse concept, Hydrol. Process., 14(16-17), 2861-2883.