Conceptualising Hydrogeomorphology – Vegetation Interactions along River Corridors

Conceptualisation des interactions entre la végétation et l'hydrogéomorphologie dans les corridors fluviaux

A.M. Gurnell[1], M.T. O'Hare[2], D. Corenblit[3], D. García de Jalón[4], M. González del Tánago[4], R.C. Grabowski[5], T. Buijse[6]

[1] School of Geography, Queen Mary University of London, Mile End Road, London, E1 4NS, UK. a.m.gurnell@qmul.ac.uk
[2] Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian, EH26 0QB, UK. moha@ceh.ac.uk
[3] Geolab – UMR 6042, Université Blaise Pascal, Clermont-Ferrand 2, France. dov.corenblit@univ-bpclermont.fr
[4] E.T.S. Ingeniería de Montes, Forestal y del Medio Natural, Universidad Politécnica de Madrid, ES-28040, Madrid, Spain. diego.gjalon@upm.es marta.gtanago@upm.es
[5] School of Energy, Environment and Agrifood, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK. r.c.grabowski@cranfield.ac.uk
[6] Deltares, Boussinesqweg 1, 2629 HV Delft, the Netherlands. Tom.Buijse@deltares.nl

RÉSUMÉ

Les interactions entre la végétation et les processus hydrogéomorphologiques (écoulement et dynamique sédimentaire) affectent les formes fluviales, leur complexité et leur dynamique. Cet article propose un cadre conceptuel dans lequel les interactions entre les processus hydrogéomorphologiques et les plantes aquatiques et riveraines peuvent être expliquées selon un modèle unique dans différents contextes fluviaux.

Les interactions sont considérées ici de l'échelle de la plante à l'échelle du corridor fluvial en insistant sur la complexité des interactions abiotiques-biotiques qui caractérisent les cours d'eau.

ABSTRACT

Vegetation combines with hydrogeomorphological (hydrological and fluvial) processes of water flow and sediment mobilisation-transport-deposition to drive channel and floodplain form, complexity and dynamics. This paper proposes a framework within which interactions among hydrogeomorphological and fluvial processes and aquatic and riparian vegetation can be conceptualised within a single model in different river corridor settings.

Interactions are considered from the individual plant to river corridor scale, emphasising the complex biotic-abiotic interactions that occur in unmanaged systems that are frequently restricted, modified or completely destroyed by human actions

KEYWORDS

Aquatic vegetation, Biogeomorphology, Hydrogeomorphology, Riparian vegetation

1 INTRODUCTION

Within Europe, rivers and their floodplains are subject to increasing human pressures and few naturally-functioning river systems remain. Restoration efforts are being increasingly applied, and the European Union funded FP7 project, REFORM (REstoring rivers FOR effective catchment Management) aims to contribute to this endeavour.

In naturally-functioning situations, vegetation combines with hydrogeomorphological processes to drive channel and floodplain morphological complexity and dynamics (Corenblit et al., 2009 ; Gurnell, 2014). It is important to comprehend interactions among vegetation and hydrogeomorphological processes and how these may contribute to river resistance, change and recovery from human interventions. Such understanding is essential to ensuring that river management and restoration measures work with these interactions providing the best opportunity for being both sustainable and cost-effective.

This paper reports on research conducted within the REFORM project and proposes a multi-scale conceptual framework within which vegetation-hydromorphology interactions can be identified and can contribute to the design of management prescriptions. The conceptual framework recognises that plants both respond to and influence hydrogeomorphological processes, with certain species operating as physical river ecosystem engineers (*sensu* Jones et al., 2010), creating new hydrogeomorphological conditions that increase the chances of the species' survival while also supporting colonisation by other plant species. These engineering plant species are :

- constrained by local hydromorphological conditions of climate, moisture availability and fluvial disturbance,
- interact with different hydrogeomorphological processes depending upon their location in one of five river corridor zones,
- display non-linear interactions with hydrogeomorphological processes in each zone, often resulting in complex dynamic habitat mosaics as a result of self-organisation,
- play a fundamental role at the leading edge of vegetation – hydrogeomorphology interactions within zones 1 (permanently inundated) and 2 (subject to frequent inundation and erosion and deposition of sediment, organic matter and plant propagules). This 'critical zone' displays pioneer landforms that drive the advance of vegetated patches and the creation of a naturally-functioning river margin.

2 HYDROGEOMORPHOLOGICAL CONTROLS ON VEGETATION

The plant species that are found within river corridors are governed by a range of hydrogeomorphological controls that operate from biogeographical region to reach scales. These controls fall into three groups: climate, moisture availability, and fluvial disturbance. From recruitment to establishment, they constrain the 'potential' plant species that may be found and, therefore, the potential interactions that may occur among vegetation and hydrogeomorphological processes. Climate (precipitation) is the most fundamental control, influencing both moisture availability and fluvial disturbances within river corridors. Moisture availability is additionally a function of the permeability of the river and floodplain sediments; flow within and depth to the saturated zone within the alluvial aquifer; the river's flow regime; and lateral water inputs from surrounding hillslopes. Fluvial disturbances involve the magnitude, frequency and timing of extreme river flow events and associated sediment transport, including the ability of such events to inundate, impose drag, damage, erode or bury plants.

3 PLANTS AS RIVER ECOSYSTEM ENGINEERS

The riparian and aquatic plant species that can cope with the constraints imposed by the broad climatic / biogeographical setting, display a range of traits that allow them to tolerate or avoid the pressures imposed by local hydrogeomorphological processes. Typical traits include an ability to reproduce freely asexually as well as sexually; to germinate or sprout and grow rapidly, developing underground organs that anchor plants to unstable substrates and canopies that are either flexible or sufficiently robust to cope with imposed drag; and when the canopies retain sediment, an ability to cope with burial, often sending out new shoots and adventitious roots that stabilize the newly-deposited sediment and increase resistance and growth performance. Where sediment is retained and stabilized, the plants aggrade new, elevated landforms and habitats. Plant species that interact

strongly with hydrogeomorphological processes, retain and stabilize sediment, organic matter and propagules of other plant species, to build pioneer landforms. In this way, these plant species act as physical ecosystem engineers (Gurnell, 2014).

4 DYNAMIC ZONES OF PLANT–HYDROGEOMORPHOLOGY INTERACTIONS

The hydrogeomorphological processes with which plants interact depend on their location within the river corridor. Five spatially and temporally dynamic zones can be identified. Zone 1 is present in moist environments as a zone of perennially-flowing water. Zone 2 is subject to frequent inundation and high flow velocities which erode, transport and deposit sediment. Zones 3 and 4 are also subject to inundation, but decreased flow velocities lead to sediment deposition dominating in zone 3 and negligible sediment dynamics in zone 4. Zone 5 is rarely flooded and so soil moisture and groundwater dominate.

The five zones display different surface water, soil water and groundwater dynamics; fluvial disturbance intensity; and vegetation cover and biomass. Their character and extent also varies with climate (biogeographical setting), river confinement and river planform type, but all zones may display complex interactions among vegetation and hydrogeomorphological processes, including periods of zonal expansion and contraction. These interactions remain roughly the same in the different river settings.

5 CRITICAL ZONE OF PLANT–HYDROGEOMORPHOLOGY INTERACTIONS

The leading edge of the riparian or aquatic vegetation lies somewhere within zones 1 and 2, within a buffer zone between the physical process-dominated river channel environment and the vegetation-dominated floodplain. Between large destructive floods, engineering plant species drive the development of pioneer land forms that can aggrade, expand, coalesce and advance the vegetation-dominated landform or habitat mosaic within this complex and dynamic critical zone, at the interface between the river and its floodplain.

Within this critical zone, characteristic landforms develop and show self-organising behaviour, according to the response and effect traits of the engineering plant species or in some cases the dead plant material, particularly wood, that the species produce.

6 CONCLUSIONS

The concepts presented here provide a way of viewing river corridors subject to different climatic, hydrological and fluvial processes within a single framework. Even in heavily degraded systems, incipient pioneer landforms associated with engineering plant species are often identifiable, providing an indication of their potential behaviour within zones 1 and 2. They may also be identifiable in isolated patches on the floodplain in zones 3 to 5, giving an indication of natural floodplain vegetation-hydromorphology behaviour. Coupling this evidence with historical information on past river and floodplain character and dynamics, allows an understanding to be developed of how these vegetation-driven features might be incorporated into river and floodplain management and restoration activities.

ACKNOWLEDGEMENTS

The work leading to this paper has received funding from the European Union's FP7 programme under Grant Agreement No. 282656 (REFORM).

LIST OF REFERENCES

Corenblit, D., Steiger, J., Gurnell, A.M., Naiman, R.J. (2009). Plants intertwine fluvial landform dynamics with ecological succession and natural selection: a niche construction perspective for riparian systems. Global Ecology and Biogeography, 18(4), 507-520.

Gurnell, A.M. (2014). Plants as river system engineers. Earth Surface Processes and Landforms, 39, 4-25.

Jones, C.G., Gutiérrez, J.L., Byers, J.E., Crooks, J.A., Lambrinos, J.G., Talley, T.S. (2010). A framework for understanding physical ecosystem engineering by organisms. Oikos, 119, 1862–1869.