Self-organisation and scale-dependent feedbacks in freshwater vegetation

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Introduction: Spatial self-organisation is the process where large-scale ordered spatial patterns emerge from disordered initial conditions through local interactions. These interactions can impose various feedbacks upon the organisms and the environment. Recently, it was reviewed that regular pattern formation is a general phenomenon rather than a peculiarity [1]. However, examples of pattern formation in river vegetation were not present despite several authors have demonstrated some plants can have a very significant impact on river channel form and adjustment [2]. The current study has the aim to prove the existence of spatial self-organisation within freshwater macrophyte patches in lowland rivers by showing a power-law distribution of the vegetation. Furthermore, we show a density-dependence of the positive and negative feedbacks acting upon the vegetation as a condition of self-organisation. As a result of these feedbacks, sediment abundance and biogeochemistry changes in presence of vegetation.

Methods: A vegetation survey was performed in August 2008 in the Zwarte Nete, a typical lowland river in the Scheldt catchment in Belgium. We used a total station (Sokkia set 510k) for mapping vegetation and measuring bed topography. A detailed map of the river topography was derived from all these data in ArcMap 9.2. The patches were reconstructed on a second layer, from which patch sizes and distribution were calculated, enabling comparison between vegetation and topography. Also, a mimics experiment was conducted to show the impact of the vegetation on the river as well as a transplantation experiment to show the impact of the river on the vegetation.

Results: The patch size distribution is linear on a log-log scale strongly indicating the system to be spatial self-organising (Fig. 1). In situ, the river bed altitude of vegetated zones exceeds markedly adjacent non-vegetated zones implying a link between vegetation presence and increased sedimentation. This scale-dependent feedback was proven with the mimic experiment. The deceleration of the current inside and behind the mimics created ideal conditions for sediment to settle which was characterised by a significantly higher percentage of organic matter with a low C/N ratio, generally described for as a positive condition for plants to grow. A negative feedback adjacent to the mimics in terms of erosion was not found despite a 30% increase in stream velocity was present. Knowing that macrophytes' occurrence and photosynthesis is strongly influenced by stream velocity, enhancement of it can be regarded as a negative condition for the plants. Both these positive and negative feedbacks on the plants were confirmed by a transplantation experiment. These scale-dependent feedbacks are, in turn, density dependent: both patch length and width had a significant effect on sedimentation intensity and sediment height but not on erosion.