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A New Conceptual Model for Establishment of Riparian Trees at the Bar Scale, in Gravel-Bed Rivers

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The recruitment of riparian trees in the active channel of alluvial rivers is a fundamental process for understanding the morphological and ecological pattern and process in fluvial ecosystems. There is agreement that initial seedling success on gravel bars depends on a continuous availability of soil moisture through the first growing season. The currently accepted hypothesis for salicaceous tree (willows and poplars) establishment is the "Recruitment Box Model" (RBM) of Mahoney and Rood (1998), which proposes that the mechanisms of water supply to the seedlings depend on river stage, based on three rather strong assumptions: (i) seedlings are obligate phreatophytes, (ii) alluvial water tables are horizontal, (iii) the capillary fringe above the table has a constant height. This conceptual model applies only at the reach scale, as it does not incorporate any local variables at the within-the-bar scale, but for river stage. Accordingly, it assumes spatial homogeneity among and within bars, and is not able to predict observed differences in establishment success between sites located at the same elevation above water stage, either on the same or a different bar.

Different authors have stated that *Populus* seedlings are not obligate, but only facultative phreatophytes. I propose that the other two assumptions behind the RBM are tenable, but only in the case of sand-bed rivers, where the bed material is highly homogenous in grain size. As a consequence, pore size distributions are also spatially uniform, creating homogeneous capillary fringes, and impeding preferential flows, thus resulting in almost horizontal water tables. Conversely, the huge 3-D variability of sedimentary deposits in gravel-bed rivers should invalidate these postulates. In such systems, down- and upwelling flow fields are ubiquitous, and both the water table position and the height of the capillary fringe show a large spatial variability, at the within-the-bar scale. Consequently, new concepts are needed in order to understand the mechanisms of riparian vegetation recruitment at the bar scale, for the case of gravel bed rivers; models developed for sand-bed streams should not be applicable, due to the very different biophysical conditions.

Meier (2008) found that initial establishment of cottonwood seedlings in a wandering gravel-bed river in Montana, at the bar scale, was controlled by two variables directly related to moisture availability during their first growing season: The content of finer material in the root zone, which controls water holding capacity by capillarity, and the thickness of the coarse surface layer (CSL) of clean gravel, which acts as a threshold, impeding establishment when too thick. Meier (2008), Meier and Hauer (2010), and Edmaier et al. (2010) also confirmed a second, more important effect of the CSL: it acts as a mulch, sharply decreasing evaporation at the surface, thus maintaining higher values of soil moisture within the bar, over longer periods. Contrary to the notions behind the RBM, the vertical distance to the water table, or its surrogate, the elevation difference with respect to river stage, did not explain recruitment success.

Here, I combine all of these ideas into a conceptual model for explaining recruitment success of riparian trees on gravel-bed rivers, at the within-the-bar scale. I present results from Montana and Chilean Patagonia that confirm the hypothesized role of the different controlling variables, and describe their spatial variability. Specifically, I discuss the role of capillarity in the root zone, the different effects of the CSL, the behaviour of alluvial water tables, and their spatial variation on unit, unforced, medial bars. All of these results corroborate the assertion that gravel bars are very dissimilar environments for vegetation establishment than sand beds, and thus need to be modelled differently.