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Floquet theory of river ecomorphodynamics

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Most of world population lives close and depends on freshwaters and related ecosystems. As dramatic consequence, 48% of all rivers worldwide are hydrologically altered. Although mankind lives by and controls river systems since millennia, a complete physically-based understanding of the links among the various processes involved still remains elusive. Three fundamental aspects control the physical state of natural rivers: flow stochasticity, sediment transport and vegetation dynamics. The present work tries to shed light on the bonds among these processes, following a temporal flow for the river dynamics. During a particularly extreme flood event any previous ecomorphological pattern is erased by the flow. However, sediment transport triggers the formation of migrating bedforms, called free bars. Through a nonlinear analysis, with center manifold projection, a long analytical expression is obtained for the bars amplitude, thus completely defining bars geometry in the parameters space. Once the formative event is extinguished, the flow rate decreases and the recently formed bars can partially emerge from water. At this point vegetation develops over the bare bars depending on flow stochasticity. As a realistic model for the flow stochasticity the compound Poisson process is considered. However, in order to make the computation analytically feasible, the stochastic time series for the discharge is replaced with an equivalent periodic one, obtained as a sequence of a typical average event of the stochastic series. In this manner, the new periodic streamflow signal, preserves the same statistical properties of its stochastic correspondent. The periodic equation for the vegetation dynamics can thus be spatially solved through Floquet theory, gaining which portion of the bar is asymptotically colonised by vegetation. In conclusion, this is the first theoretical work linking the trend of the vegetated area with the flow parameters, and confirming that high flow variability hardens vegetation growth.