Sediment load determines the shape of rivers

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Understanding how rivers adjust to the sediment load they carry is critical to predicting the evolution of landscapes. Presently, however, no physically based model reliably captures the dependence of basic river properties, such as its shape or slope, on the discharge of sediment, even in the simple case of laboratory rivers. Here, we show how the balance between fluid stress and gravity acting on the sediment grains, along with cross-stream diffusion of sediment, determines the shape and sediment flux profile of laminar laboratory rivers which carry sediment as bedload. Using this model, which reliably reproduces the experiments without any tuning, we confirm the hypothesis, originally proposed by Parker [1], that rivers are restricted to exist close to the threshold of sediment motion (within about 20%). This limit is set by the fluid-sediment interaction and is independent of the water and sediment load carried by the river. Thus, as the total sediment discharge increases, the intensity of sediment flux (sediment discharge per unit width) in a river saturates, and the river can only transport more sediment by widening. In this large discharge regime, the cross-stream diffusion of momentum in the flow permits sediment transport. Conversely, in the weak transport regime, the transported sediment concentrates around the river center without significantly altering the river shape. If this theory holds for natural rivers, the aspect ratio of a river could become a proxy for sediment discharge — a quantity notoriously difficult to measure in the field.

References

1. Parker G, Self-formed straight rivers with equilibrium banks and mobile bed: part 2, the gravel river. *Journal of Fluid mechanics*, **89**, 127-146, (1978)