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A probabilistic model to explain drainage network evolution and emerging scaling laws of river networks

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River networks have been studied in geosciences and hydrology for many theoretical and practical purposes. Self-organization into self-similar tree-like network patterns is observed in many natural phenomena including river networks, blood vessels, vascular organization in plants, lightning etc. River networks self-organize into tree-like network patterns as a result of complex landscape evolution processes. All of these patterns follow certain statistical scaling laws. There have been attempts to explain river network evolution, but it is still unclear how networks self-organize into such patterns. These power-law scaling relationships mainly include Hack's law, exceeding probability distribution for contributing area and upstream length. Although various models exist in the literature, many questions related to river-network evolution are yet to be answered. In particular, the existing models try little to explain the diversity of network characteristics. We propose a new modeling framework that explains drainage network evolution considering certain key physical processes associated with randomness. The model follows the growth of drainage networks in the headward direction based on probabilistic decisions. The model comprises two free parameters and is demonstrated using a planar matrix. The simulation results show the formation of tree-like drainage networks that exhibit power-law scaling relationships as observed in natural river networks. Furthermore, the model parameters provide flexibility to generate networks with different shapes and characteristics.