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Parallel Vegetation Stripe Formation Through Hydrologic Interactions

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It has long been a challenge to theoretical ecologists to describe vegetation pattern formations such as the "tiger bush" stripes and "leopard bush" spots in Niger, and the regular maze patterns often observed in bogs in North America and Eurasia. To date, most of simulation models focus on reproducing the spot and labyrinthine patterns, and on the vegetation bands which form perpendicular to surface and groundwater flow directions. Various hypotheses have been invoked to explain the formation of vegetation patterns: selective grazing by herbivores, fire, and anisotropic environmental conditions such as slope. Recently, short distance facilitation and long distance competition between vegetation (a.k.a scale dependent feedback) has been proposed as a generic mechanism for vegetation pattern formation. In this paper, we test the generality of this mechanism by employing an existing, spatially explicit, advection-reaction-diffusion type model to describe the formation of regularly spaced vegetation bands, including those that are parallel to flow direction. Such vegetation patterns are, for example, characteristic of the ridge and slough habitat in the Florida Everglades and which are thought to have formed parallel to the prevailing surface water flow direction. To our knowledge, this is the first time that a simple model encompassing a nutrient accumulation mechanism along with biomass development and flow is used to demonstrate the formation of parallel stripes. We also explore the interactive effects of plant transpiration, slope and anisotropic hydraulic conductivity on the resulting vegetation pattern. Our results highlight the ability of the short distance facilitation and long distance competition mechanism to explain the formation of the different vegetation patterns beyond semi-arid regions. Therefore, we propose that the parallel stripes, like the other periodic patterns observed in both isotropic and anisotropic environments, are self-organized and form as a result of scale dependent feedback. Results from this study improve upon the current understanding on the formation of parallel stripes and provide a more general theoretical framework for future empirical and modeling efforts.