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Plant growth initiates channel erosion in flat landscapes: evidence from tidal marshes

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In many wetlands, such as river floodplains and tidal marshes, bio-physical feedbacks occur between vegetation, water flow and geomorphology. We studied to what extent these interactions lead to the spatial self-organisation of both vegetation patterns and geomorphic patterns that are typically observed in a tidal marsh. This was done using a spatial simulation model, incorporating dynamic feedbacks between plant growth, hydrodynamics and sediment transport. The model showed that two different, scale-dependent feedbacks occur. Within vegetation zones, flow velocities are reduced and sedimentation takes place, leading to a higher bottom elevation and thus less tidal inundation stress for plant growth. In contrast, in between vegetation zones, the flow is concentrated and the initial erosion of a channel takes place, leading to a lower bottom elevation and thus more tidal inundation stress for plant growth. The model shows that these scale-dependent feedbacks lead to the self-organized pattern of tidal marshes, typically consisting of a network of unvegetated, deeply-incised channels and of vegetated, elevated platforms with a levee-basin topography in between these channels. The model simulations are in good agreement with aerial photos documenting the development of vegetation and channels in tidal landscapes. In contrast to earlier studies on terrestrial landscapes, our simulations suggest that channel drainage density increases with the density of the vegetation cover. Implications of our findings for other vegetated wetland systems, such as river floodplains, are discussed.