Dynamic dunes as self-organizing, living systems

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As climate change induces sea level rise and possibly heavier storms, coastal protection is in a transition phase from hard structural engineering towards soft measures, that can adapt dynamically to a changing environment. Coastal foredunes represent the most important natural flood barrier for much of the European coastline and thirty percent of all shorelines worldwide. In contrast to urban infrastructure, coastal dunes have the capacity to grow with the rising sea level due to the action of ecosystem engineers . Therefore, they are currently considered as an important nature-based solution for coastal protection. In Europe, the most important dune-building species is marram grass (*Calamagrostis – formerly Ammophila- arenaria*). It is a crucial engineers for the development of coastal dunes, as their growth depends on, and in turn influences aeolian (wind-driven) sand fluxes and hence, dune development.

Marram grass is highly tolerant to burial, with optimal growth depending on sand deposition. At short ranges, positive feedbacks are anticipated to occur when cover is not too high. Then, plants are vital and patchily distributed, since this configuration should enhance sand capture efficiency. However, at longer ranges, cover of marram grass prevent local sand deposition, lowering its vitality and hence competitive strength. The relative contribution of these negative and positive feedbacks is overall conditional to the overall sand input into the system.

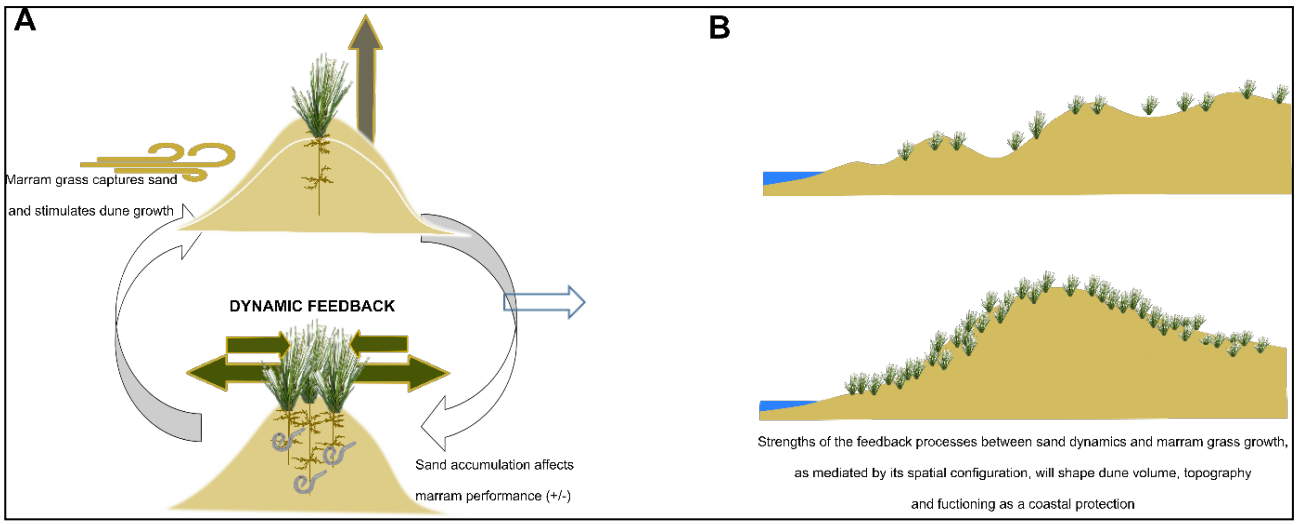

Figure 1: Conceptual figure on the role of marram grass as an engineer in foredune formation. A. Once established, the species' sand capture ability shapes local sand accumulation and make the dune increase in volume. This sand accumulation will promote the species' growth, unless burial is too severe. When sand accumulation ceases, either due to decreased input from the sea, of from shadowing effects from surrounding vegetation, the plant performance will decrease due to pathogen accumulation in the roots, after which marram grass will die off. B. These dynamic feedbacks depend on the species' spatial configuration and external environmental conditions and will eventually shape dune development, its volume and form, and, hence, its stability and resilience against storm surges under climate change. (Adapted from Bonte et al. 2021)

For a dune to be self-healing and optimally recovering after a storm event, it should be dynamic. This requires both patches with open sand and with marram grass. The dynamic coupling of vegetation development and sand fluxes is anticipated to impose a self-organisation of the dune system (Fig. 1). A more in-depth knowledge of the ecological interactions regulating the dynamics of dune-building species is therefore crucial to understand how the dune ecosystem can be used as a nature-based protection against sea level rise and extreme storm events.

During this presentation, I will

- provide a detailed look at the biological mechanisms leading to these dynamic feedbacks;
- demonstrate how West-European coastal dunes converge with respect to the cover of marram grass;
- show that this cover impacts local dune volume changes;
- give an overview on how vegetation is currently integrated in our forecasting models;
- provide an outlook for future biogeomorphological research and modelling efforts

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