



Designing dunes in front of dikes: a hybrid blue-grey solutions for coastal safety under climate change

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Coasts are among the most densely populated of the world, with natural sand dune barriers urbanised and replaced by traditional hard coastal protection structures. Without the needed measures to adapt, the number of people exposed to floods is anticipated to increase from 15000 to 187 million worldwide by the end of the 21st century. Likewise, total economic costs are expected to increase from 0.008% to 5.3% of GDP. In Europe, the coasts of The North Sea, the Baltic Sea, and the Atlantic are anticipated to experience substantial flood risks from sea-level rise, but climate extremes are also expected to impact southern Europe Mediterranean coasts.

Future coastal management surpasses the current fixed and non-adaptive flood coastal protection setup: Hybrid NbS that can efficiently integrate static hard infrastructure with dynamic aeolian, and vegetated sediments are currently developed along urbanized areas of most of the European sandy coasts, yet still at small scales. The integration of dikes and dunes for coastal protection are a key example of such infrastructure and typically referred to as dune-dike hybrid Nature-based Solutions (DD-hybrid NbS). Such blue-grey infrastructure can provide advantages for coastal safety and protection that cannot be reached by hard (dikes, seawalls) or soft (beach nourishments, existing dunes) infrastructure alone. Key to their adaptability to sea-level rise is the integration of hard safety line (dikes) and resilient biodiverse dune systems that only function when both physical and biological boundary conditions are met. This blue-grey infrastructure will deliver an integrated, multidisciplinary coastal management system. The applications of DD-hybrid NbS even reaches out towards marine environments as the future design and installation of emerging concepts of energy/barrier islands largely relies on so far not developed roadmaps from replicated coastal solutions.

The DuneFront project is a project of 17 partner institutions from seven different European countries and funded through the Horizon Europe Programme. The key-challenge of DuneFront is to identify the biological, physical and socio-economic boundary conditions and their interactions to tailor specific marine and coastal DD-hybrid NbS to jointly safeguard the protection of human assets, activities and well-being within an enriched coastal biodiversity, surpassing traditional single coastal flood protection. DuneFront will achieve this challenge by identifying key biological, physical, and socio-economic boundary conditions, and by translating evidence from experiments and longitudinal data analyses on biodiversity, morphodynamics and safety from 12

Demonstrators along vulnerable European coasts into new roadmaps for DD-hybrid NbS design and installation. The integration of this multidisciplinary knowledge into physical and digital twins will pilot the development of a Decision-Support-System, coastal and marine infrastructure Blueprints, and the installation of new prototypes along one of the most recreated coasts. DuneFront will provide a wide range of stakeholders with design, installation and market-ripe business plans for DD-hybrid NbS. Translation of new research and innovations into the DuneFront targeted actions will occur within a full co-creation-procedure.

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