EGU22-7450
https://doi.org/10.5194/egusphere-egu22-7450
EGU General Assembly 2022

Innovative Nourishment Elevation Change (NEC) stations for monitoring and optimizing marshland restoration projects: prototype application in the Lagoon of Venice (Italy).

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Tidal marshes are fundamental ecosystems to be preserved and restored to maintain their vital services to the environment and human life. For this reason, many restoration projects have been implemented in the Lagoon of Venice (Italy) to reestablish former tidal marshlands. One fundamental point of the marsh restoration design is the determination of its long-term elevation. This is crucial for the ecological functioning of the system as well as the ability of the landform to keep pace with a rising sea level. Past marsh reconstruction projects have not always been successful. Significant areas become permanently submerged by the sea only few years after their construction and/or vegetation cover remains more patchy and less biodiverse than on natural marshes. Two design parameters which have not received sufficient attention in restoration projects are autocompaction of nourishment sediments and subsidence of underlying strata. To this aim, the planned elevation at the end of the nourishment phase, i.e. the volume of sediments used to build-up the marsh, must take into consideration nourishment autocompaction and land subsidence of the underlying lagoon bottom caused by the nourishment load. To enable monitoring of these dynamics of elevation change, we developed a novel Nourishment Elevation Change (NEC) station to investigate compaction and subsidence of an artificial marsh under development in the central basin of the Lagoon of Venice. Each NEC station is made of four steel bars set into the lagoon subsurface down to a 2-m depth. Their role is to keep a central steel pole free to move vertically with respect to its specific foundation level. The foundation consists of a plate resting either on the top of the pristine lagoon bottom or an anchor inserted into the subsurface to a depth of interest, e.g., 1 m. As the nourishment areas become inaccessible after its development, the pole is marked with a black-and-white striping to be able to measure its movements from a distance and equipped with a horizontal plate on top of the pole. A monitoring network consisting of 10 NECs was established in the artificial marsh area of about 61.000 m^2 before the nourishment. The NEC station elevation is monitored with a mm-accuracy topographic intersection technique using a total station. Two stable benchmarks positioned in a nearby

existing marsh are used as reference. The maximum distance between the NECs and the benchmarks amounts to 300 m. In addition, the NECs are monitored using aerial drone photogrammetry. The change over time of the distance between NEC top plate and the marsh platform allows quantifying the nourishment autocompaction. The topographic intersection surveys have been ongoing every two weeks since the nourishment started in October 2021. Over the first month of sediment filling a maximum subsidence of about 7 cm has been measured by the NEC station located closest to the nourishment pipe. The other NECs, which are not yet affected by sediment deposition, remained stable. The NEC monitoring system seems promising and will provide quantitative information on the elevation dynamics of newly created artificial marshes.