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Fluvial ecosystem services in the Rhine delta distributaries between 1995 and 2035

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Mapping of ecosystem services (ES) and documenting their change over time provides important information for the societal debate and decision making on river management. Large and Gilvear (2014) showed how to score fluvial ES using imagery and tools available through Google Earth, linking observable features, or landcover to ES through inferred fluvial processes, and natural ecosystem functions. While the use of Google Earth enables application anywhere on the globe, their method is labor intensive, and involves subjective judgement as not all parameters are easily observable in spectral data, e.g. the location of embankments. In addition, the method does not take advantage of readily available spatial databases, and existing hydrodynamic model parameterizations, nor can it be used in scenario studies of future fluvial landscapes. Therefore, we aimed at the development of a generic GIS routine to extract the ecosystem services from existing spatial and hydrodynamic model data, and its application to historic and future fluvial landscapes in the Rhine delta.

Here, we consider the Rhine distributaries, sized 400 km2, where river restoration measures were carried out between 1995 and 2015 to reduce flood risk reduction and simultaneously improve the ecological status. We computed ES scores for provisioning ES (fisheries, agriculture, timber, water supply), regulating ES (flood mitigation, carbon sequestration, water quality), and supporting ES (biodiversity). Historic ES were derived for the years 1997, 2005, and 2012, based on ecotope maps for these respective years, combined with a water levels and flow velocities derived from a calibrated 2D hydrodynamic model (WAQUA). Ecotopes are defined as 'spatial landscape units that are homogeneous as to vegetation structure, succession stage, and the main abiotic factors that are relevant to plant growth'. ES for 2035 were based on scenarios of landscaping measures. Suitable locations for the measures were determined automatically using map algebra, scripted in PCRaster-Python, with existing spatial data as input. Each scenario provided an updated ecotope map and bathymetry for the whole study area. Biodiversity indices were computed for all species that are protected by policy and legal documents using the BIOSAFE model, which was adapted for automated mapping. BIOSAFE links 614 protected species in seven taxonomic to 82 ecotope classes.

Over the historic period, the ES increased, especially the biodiversity scores of birds and mammals improved by more than 10% due to the restoration measures. One of the main drivers is the creation of new side channels, and allowing natural succession to occur to a limited extent. For the future, the scenarios showed that the overall ES score varied strongly with the type of measure chosen. Floodplain smoothing and lowering negatively impacted ES, whereas embankment relocation, and side channels increased ES scores. We conclude that the automated methods provide fast insights in the historic and future developments of fluvial ES. This is useful for the decision making and natural capital mapping, but we require increased precision in defining fluvial ES, and additional quantification and validation of the methods.