The scientific objective of the proposed ACTUAL project (Analysis of Dune Coast Morphodynamics Using Machine Learning Methods) is to assess changes occurring in the coastal zone quantitatively, and to identify potential causes of these changes, for two study areas of the southern Baltic coast, on the western and eastern sides of the Rega River estuary in Mrzezyno (Poland), where relevant dynamic morphological processes were recorded during a three-year field study.

The first scientific activity focuses on the extensive erosion of dune areas in the designated area. Therefore, within the framework of the proposed project, field surveys will be conducted to collect qualitatively new data in two different test areas. For this purpose, detailed remote sensing measurements will be made using laser scanning techniques and geodetic ground surveys. Measurements will be carried out periodically, at least once a month, and after each significant storm, which is very important in assessing the impact of short-term effects for single storm events and a series of storms with different parameters occurring in a short period after another.

The main research hypothesis is that rapid erosion of the southern Baltic dune coast occurs after extreme storm events (super storms) or as a result of overlapping sets of storms with specific characteristics and parameters and is directly related to high water levels and wave heights. This hypothesis will be tested through comparative spatial studies of the distribution of erosional material in the coastal environment and based on analysis of hydrographic and meteorological data. The leading geomorphological indicators will be evaluated using an unmanned aerial vehicle (UAV) with a GPS Real Time Kinematic (RTK) system with a Light Detection and Ranging (LiDAR) scanner and a Global Navigation Satellite Systems (GNSS) RTK receiver.

The second scientific activity will apply statistical methods using machine learning and neural networks to compile, process and analyze detailed storm data based on hydrological and meteorological data. To study the morphological changes of the selected coast, migration rates and volumetric changes within specific transverse profiles will be analyzed. Existing relationships between cause and effect will be described by models of various types, including multiple linear regression (MLR) models, one of the most popular and widely used statistical techniques for analyzing multiple variables, or the principal component analysis (PCA) method, which transforms the original data into a lower-dimensional space while comparing highly correlated variables. This analysis should identify the variables that have the strongest correlations and the greatest impact on dependent variables related to changes in shoreline morphology. Bayesian networks and machine learning with Random Forest algorithms will be used for the broader analysis.

The direct correlation between hydrological and meteorological factors and their impact on short-term beach erosion has not been studied before. It could be of great importance for developing this field of research. In recent years, machine learning techniques have been gaining popularity as probabilistic tools for both descriptive and predictive applications. The methodology proposed in the project opens up several possibilities for the future.

Therefore, using LiDAR technology for real-time modelling of 3D objects and advanced algorithms for data classification and comparison, combined with GIS systems, will allow detailed analysis of morphological changes. The juxtaposition of these data based on machine learning with hydrological and meteorological data will make it possible to build models that can be used to analyze other types of coasts.

Terrain classification using LiDAR and the acquired data will allow, in the future, based on historical data from archival aerial photographs and research conducted on the long-term variability of the land cover of the marine coastal zone of the Baltic Sea, to better understand the processes occurring on the coast as a result of storms and climate change, and thus their impact on the environment and human management of the coastal zone.