Modeling the impact of agriculture on coastal waters on the example of the Bay of Puck

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www.waterpuck.pl

Introduction

Anthropogenic pressure is usually evaluated by characterizing the flux of contaminants using separate models such as SWAT for surface run-off, Modflow for groundwater flow, and 3D models for presenting complex processes in the marine environment being under contaminants discharge. However, our approach is based on the assumption that different elements of the environment should be modeled at the same time and connected to each other. This was the main motivation for developing the WaterPUCK project, which is an interdisciplinary and innovative approach integrating knowledge of different disciplines into the implementation of the environmental protection policy, sustainable growth and improvement of the competitiveness of the Polish economy. WaterPUCK online toolkit enables researchers to identify the sources of nutrient and pesticide pollution, understand the main mechanisms responsible for the transport of these pollutants in surface and groundwater, calculate their flux via rivers and SGD, and directly assess the influence of pesticides and nutrient flux on the Bay of Puck ecosystem. Additionally, within the service, we present the way the different environmental data such as in situ measures and model outcomes can be operated. The study focuses on the description of the full modelling framework.

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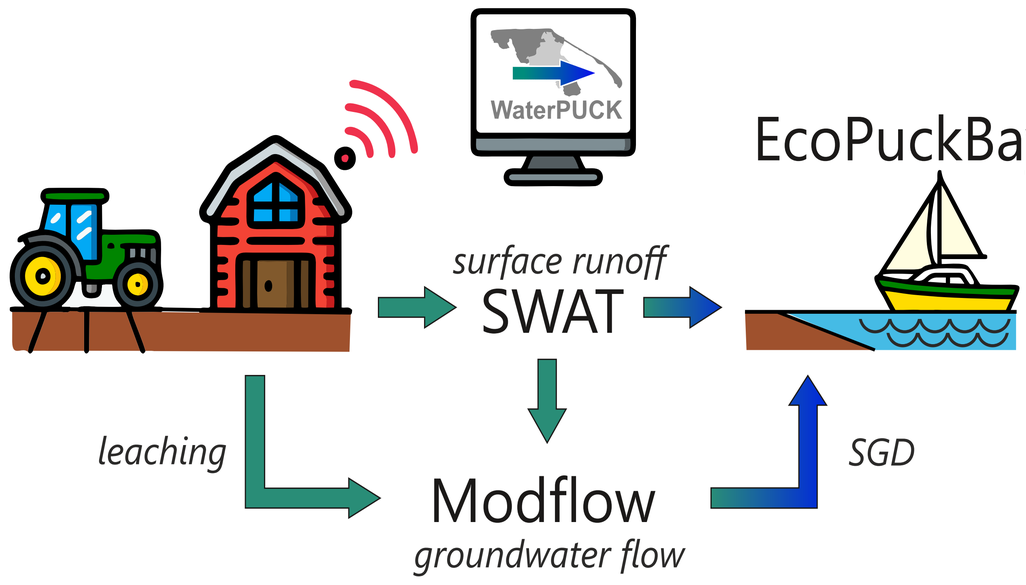

Fig.1. Simplified scheme of the WaterPUCK toolkit.

Research area

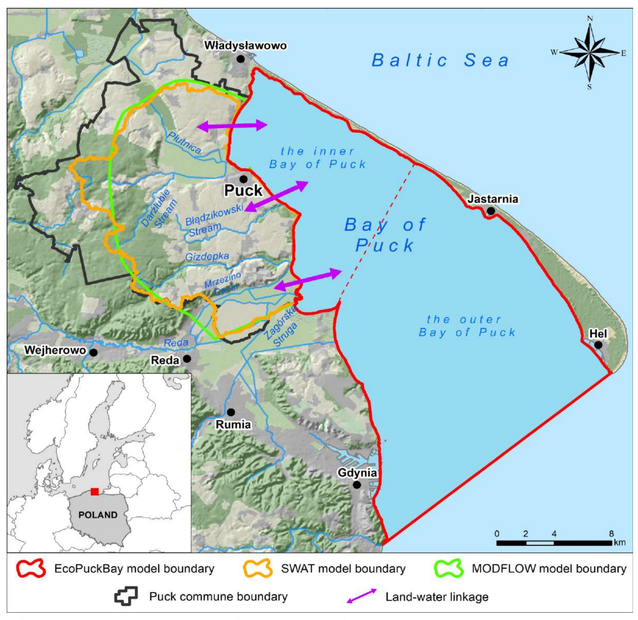

Fig.2. Map presenting location of the research area.

The Puck District and the Puck Bay are examples of a region where sustainable growth and management is a challenging task due to the region's complex structure. The Puck Bay is an inner basin of the Bay of Gdansk, which covers an area of approximately 40,000 ha. Its inner part is a shallow (average depth of 3 m), sandy seagrass bed, while the outer part's average depth is 20.5 m. The Puck Bay's salinity ranges from 3 to 7 and is known as a nursery ground and breeding area for a number of fish and bird species. The bay contains several types of habitats (from muddy to stony bottom) located at a variety of shore types (i.e., sandy beaches, gravel beds, stony outcrops, clay cliffs, vegetated river mouths, etc.). The Puck Bay is protected as a Natura 2000 site under both the birds and habitats directives. It is also a designated Baltic Sea Protected Area, and its inner waters are part of the Coastal Landscape Park. The area has also been subjected to strong anthropogenic pressure. The main sources of pollution for the Bay of Puck are rivers, SGD, atmospheric deposition, and point sources, while the coastal ecosystem controls the biogeochemical transformations of P and N compounds (e.g., phosphate, nitrate, dissolved organic nitrogen, etc.) through close coupling between water and sediments.

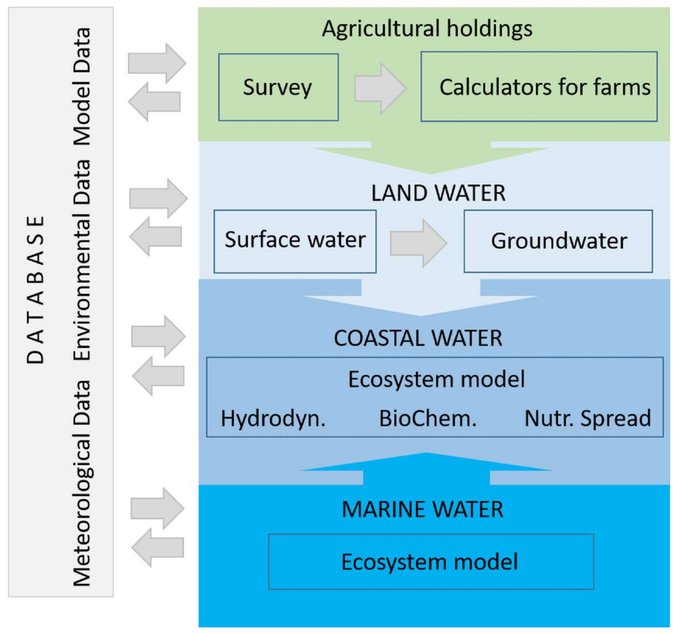

Fig.3. Structural scheme of the WaterPUCK toolkit.

Materials & Methods

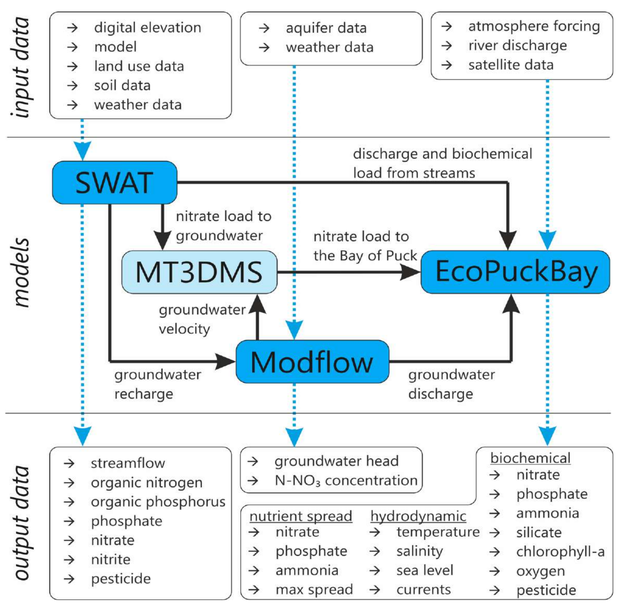

Fig.4. Schematic flowchart of the modelling system.

The method of modelling the impact of farms and land-use structure on the quality of land (surface water and groundwater) and coastal waters was developed and verified as part of the WaterPUCK project. The service is a set of computer models interconnected with each other, operating continuously, forced with meteorological data and combines four main modules:

Agricultural holdings — survey system and two calculators for farms as interactive applications;

LAND WATER — a comprehensive model of surface water run-off based on SWAT model and a numerical model of groundwater flow based on Modflow which we named GroundPuck;

COASTAL WATER — a three-dimensional numerical model of coastal ecosystem consisting of a hydrodynamic and biochemical part with a nutrient spread module based on Community Earth System Model (CESM);

MARINE WATER — a three-dimensional numerical model of the marine ecosystem providing boundary condition to COASTAL WATER module.

A schematic flowchart of the modelling system is presented. We coupled the EcoPuckBay model from the land side with two models: SWAT (surface water) and GroundPuck (groundwater). Information about the water volume discharged by rivers is being provided by the hydrological model SWAT that has been implemented as one of the WaterPUCK project's stages. The SWAT model includes the preparation of the innovative and complex hydrological model coupled with the nutrient concentration module including meteorological data (precipitation, wind, temperature, and atmospheric pressure). The transformation of precipitation data into surface run-off have been achieved with the SCS (Soil Conservation Service) curve number procedure through the accumulated run-off volume and the time of concentration (the time from the beginning of a rainfall event until the entire subbasin area contributes to flow at the outlet).

Results

Solutions that comprehensively connect the marine and land environment are essential for resource monitoring and management, especially in the coastal zone, which plays a beneficial role for humans. Moreover, considering the individual elements of the solution as separate and unconnected may lead to an under-/overestimation of the potential effects of planned regulation. Improved understanding of sea-land interactions, in the context of hazardous substances, will contribute to achieving the goals set by European legislation, which aims to improve the state of marine waters that is also the ultimate result of WaterPUCK project implementation. The systematic use of the WaterPUCK toolkit by farmers (particularly the farm balance calculator, nitrogen leaching calculator and SWAT's Calculator mode) allows for more efficient management of production means while respecting the environment. The WaterPUCK toolkit is designed so that it can be applied to other regions around the world. A necessary condition for the success of its application is to carry out the calibration process described in this study. The key was to set up the database in such a way that each of the system's component tools could easily use the necessary information for its correct operation, which was ensured in our solution.

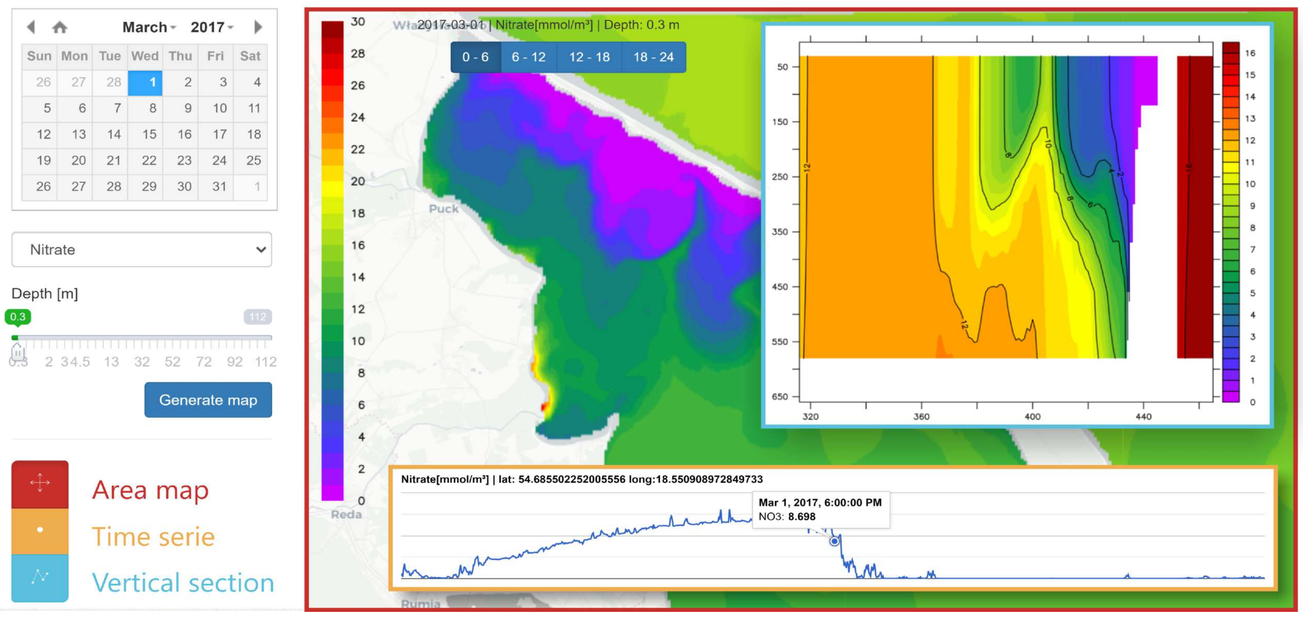

Fig.5. Presentation interface for the EcoPuckBay model data .

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