PSC-JRC Collaborative Doctoral Programme

The PSC-JRC Collaborative Doctoral Programme is a hosted by ETH Zurich, University of Zurich and the Joint Research Center (JRC). The JRC's mission is to support EU policy and decision-making. Launched in 2019, the programme awarded four fellowships in "Bio-economy and forests" and "Soil and land use change". The doctoral candidates are enrolled in the Science and Policy PhD programme coordinated by PSC.

www.plantsciences.uzh.ch/en/research/fellowships/jrc.html

Modelling the phosphorus cycle in European agricultural soils

The DayCent model is used to simulate agricultural management practices in Europe.

By Anna Muntwyler

Phosphorus (P) is an essential nutrient for all crops, yet its excessive use as a fertiliser and subsequent diffuse loss leads to deterioration of water quality, eutrophication, and loss of biodiversity. At the same time, rock P is a critical raw material due to its importance for food production, finite geological deposits, and unequal regional distribution. As a consequence, nutrient management is addressed by numerous environmental policies such as the European Commission's Farm to Fork Strategy that seek to reduce nutrient losses by at least 50% and the use of fertilisers by at least 20% by 2030. But what effect do these policies have? One way to find out is by using an ecosystem process-based model as tool to depict the P cycle in agriculture soils, investigate the effects of management practices and climate change, and ultimately assess policy interventions that affect biogeochemical cycles. Therefore, the objective of this research was to find out how to model the P cycle at high spatial resolution across European agriculture using a calibrated process-based model.

We used the DayCent model due to its detailed representation of soil biogeochemistry, its validated nitrogen and carbon submodels, and its ability to simulate agricultural management practices. DayCent is a terrestrial ecosystem model designed to simulate fluxes of C and N among the atmosphere, vegetation, and soil. To calibrate and assess the P submodel it was essential to use measured field observations from four long-term experiments. They provide stabilised conditions and hold key information about the trends and dynamics of the different soil nutrient pools over time. Although further model assessment and development are needed, DayCent has demonstrated its capability to predict the main P fluxes over time under a wide variety of management practices and European conditions (Muntwyler et al., 2023).

After calibrating and testing the DayCent model, we proceeded to do a large-scale Europe wide integration using e.g., advanced input data sets and representative management practices (Muntwyler et al., 2024). The results depicted a surplus P budget (Fig. 1), P fluxes, and soil P pools consistent with literature and national statistics. Through agricultural management scenarios, we revealed a range of potential changes in the P budget by 2030 and 2050, influenced by the interlink of P with biogeochemical carbon and nitrogen cycles.

Thus, we developed a powerful assessment tool capable of (i) identifying areas with P surplus or deficit at high spatial resolution of 1 km^2, (ii) pinpointing areas where a change in agricultural management would be most urgent to reach policy goals in terms of environmental pollution, food security and resource efficiency of a critical raw material, and (iii) assessing the response of the P cycle to modifications in agricultural management.

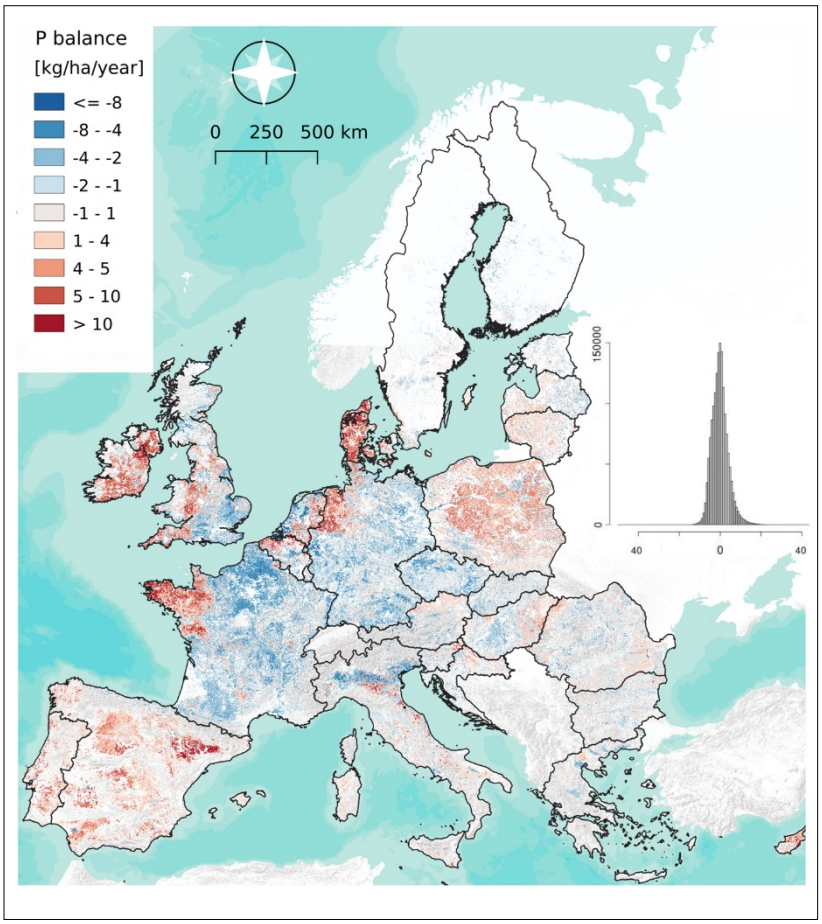

Figure 1: Average P balance for the period 2010–2019. The histograms display the frequency distribution of the P balances of the EU and the UK at pixel level (Muntwyler et al., 2024).

Fellow: Anna Muntwyler

Supervisors
Stephan Pfister and Steffanie Hellweg, Institute for Environmental Engineering (IfU), (ESD, ecological systems design), ETH Zurich

Emanuele Lugato and Panos Panagos, European Commission, Joint Research Centre, Ispra, Italy

References

Anna Muntwyler, Panos Panagos, Francesco Morari, Antonio Berti, Klaus A. Jarosch, Jochen Mayer, Emanuele Lugato (2023) Modelling phosphorus dynamics in four European long-term experiments. *Agricultural Systems*, Volume 206, 2023, 103595, ISSN 0308-521X, https://doi.org/10.1016/j.agsy.2022.103595.

Anna Muntwyler, Panos Panagos, Stephan Pfister, Emanuele Lugato (2024). Assessing the phosphorus cycle in European agricultural soils: Looking beyond current national phosphorus budgets. *Science of The Total Environment* 906: 167143. https://doi.org/10.1016/j.scitotenv.2023.167143.

Q&A

What data was used and how was it obtained?
The P submodel calibration and testing is based on data from four long-term experiments in northern Italy and Switzerland, operational since the 1960s and 1970s. The data provided necessary information on a variety of factors, including soil types, mineral and organic fertilizer treatments, crop rotations, and irrigation practices. We accessed the data by contacting the research centres that conduct long-term field experiments. To calibrate and assess the phosphorus submodel it was essential to use measured field observations from four long-term experiments. They provide stabilised conditions and hold key information about the trends and dynamics of the different soil nutrient pools over time.

The input data needed to run the DayCent model at the EU level were derived from open access state-of-the-art datasets with a detailed representation of agricultural management such as observed meteorological data and data-derived soil characteristics from the EU Soil Observatory, official statistics for land management practices, and the calibrated values for the P submodel (Fig. 2).

Who can or should use the data?
The results can be used by researchers in agronomy, soil science and environmental science, environmental modellers and data scientists, as well as stakeholders in policy interested in the effect of agricultural management on the nutrient cycle. Agricultural managers can use these findings to optimise fertilisation practices, while policymakers can employ the model for crafting environmentally sustainable and economically feasible agricultural policies.