**#READ.ME**

This ensemble of scripts aims to assess the current and projected P cycle in EU agricultural soils using the calibrated DayCent model at European level and data-derived soil properties, advanced input data sets, and representative management practices. The description of the model and assumptions can be found either in the article or in the supplementary material. In case you want to know individual model parameters not described in the manuscript or the referred literature, contact the author of the study.

Data analysis was conducted in r, using the following packages:

**LIST OF PACKAGES AND VERSION**

Packages without specified installation are available on CRAN repository.

library(raster) v3.5-29

library(rasterVis) v0.51.2

library(ggplot2) v3.3.6

library(sf) v1.0-7

library(tidyverse) v1.3.1

library(readxl) v1.4.1

library(rgeos) v0.5-9

library (rgdal) v1.5-32

library (dplyr) v1.0.10

library (sp) v1.4-7

library("xlsx") v0.6.5

library(terra)v. 1.6-17

The folder includes the following scripts:

**1\_current.R**

**2\_projection.R**

**3\_P\_EU.qgz**

**1\_current.R**

This script allows to calculate the average annual P flows used to determine the P budget for the period 2010–2019. In detail the script loads the rasterstack with the current P balance flows (Current\_EU.tif) and the current P balance (Pbal\_EU.tif). It then calculates the current average yearly values for:

1. P input (mineral + organic)
2. mineral P input
3. organic P input
4. P input through weathering of parent rock
5. Net P erosion
6. P export via grain harvest and residue removal
7. organic P leaching
8. Available P pool (shown as resin extractable (Model output) and transformed to Olsen extractable using Steinfurth et al. 2021)
9. Total P pool
10. P balance

These average values were used in the manuscript text, and the individual raster files of the individual flows incorporated in Figures 2, 3, 4, 5, S10, and Table S3.

**2\_projection.R**

This script enables the assessment of projected phosphorus (P) flows depending on the agricultural management practice scenarios. The raster stacks encompass the P flows of the agricultural management practice scenarios applied at 100% of the agricultural areas for the periods 2020–2029 and 2040–2049. The scenarios include the business as usual (BAU), increased use of cover crops (CC), increased use of cover crops that fix nitrogen (CC\_nfix), reduced mineral P input (lowPmin), and reduced organic P input (lowPorg).

Additionally, raster files depicting the available P (in Olsen extractable P) for the period 2010–2019 and the bulk density were loaded to calculate the three different target areas (Pav\_suff, leach, Peros\_max) where the scenarios would be applied at (lines 134-152). These areas were used for cropping, masking, and merging the scenario raster files with the BAU raster file (lines 130-834). The resulting merged raster files were then used to calculate the average annual flows used in the manuscript text, values presented in Figures 6, S11, S12, S13, and Tables S4 and S5.

Then we analyzed how the target areas evolve over time (from 2010-2019 to 2040-2049) depending on the agricultural management (lines 838-904) and identified which agricultural management practice scenario resulted in the lowest erosion, the lowest P balance, and the highest P export (lines 907-937). This analysis resulted in Figure 7, and Table S6.

**3\_P\_EU.qgz**

The QGIS project includes the raster files showing current P flows, the target areas, and the agricultural management practice scenario that resulted in the lowest P balance, the lowest P erosion, and the highest P export:

1. Figure 2. Average yearly P inputs to agricultural soils from manure (a) and from mineral fertilizers application (b) in the decade 2010–2019.
2. Figure 3. Average P export of EU and UK agricultural soils by crop harvest (a) and net P erosion (kg P ha−1 year−1) (b) in the period 2010–2019.
3. Figure. 4. Average P balance for the period 2010–2019 (a), average P balances from running the model with a high maximum sorption capacity (1.5-times) and maximal sorption affinity.
4. Figure 5. Average PTotal (a) and PAvailable pools (based on the Olsen method) (b) in the agricultural topsoil (0–30 cm) of the EU and UK for the period 2010–2019.
5. Figure 7. Agricultural management practice scenario that resulted in the lowest P balance (a), the lowest P erosion (b), and the highest P export (c) for the target area defined by PAvailable > 22 mg P kg−1 at the periods 2020–2029 and 2040–2049.
6. Figure S2. Ratio of PAvailable / PTotal in the agricultural topsoil (0-30 cm) of the EU and UK.
7. Figure S11. Target area of PAvailable > 22 mg P kg-1, which is expected to supply sufficient P to the crops.
8. Figure S12. Target area of PAvailable > 40 mg P kg-1, which is at higher risk of P leaching.
9. Figure S13. Target area defined by regions with high P erosion (> 1 g P kg-1).

**References**

Steinfurth, K., Hirte, J., Morel, C., Buczko, U., 2021. Conversion equations between Olsen-P and other methods used to assess plant available soil phosphorus in Europe – a review. Geoderma 401 (December 2020), 115339. https://doi.org/10.1016/j. geoderma.2021.115339.