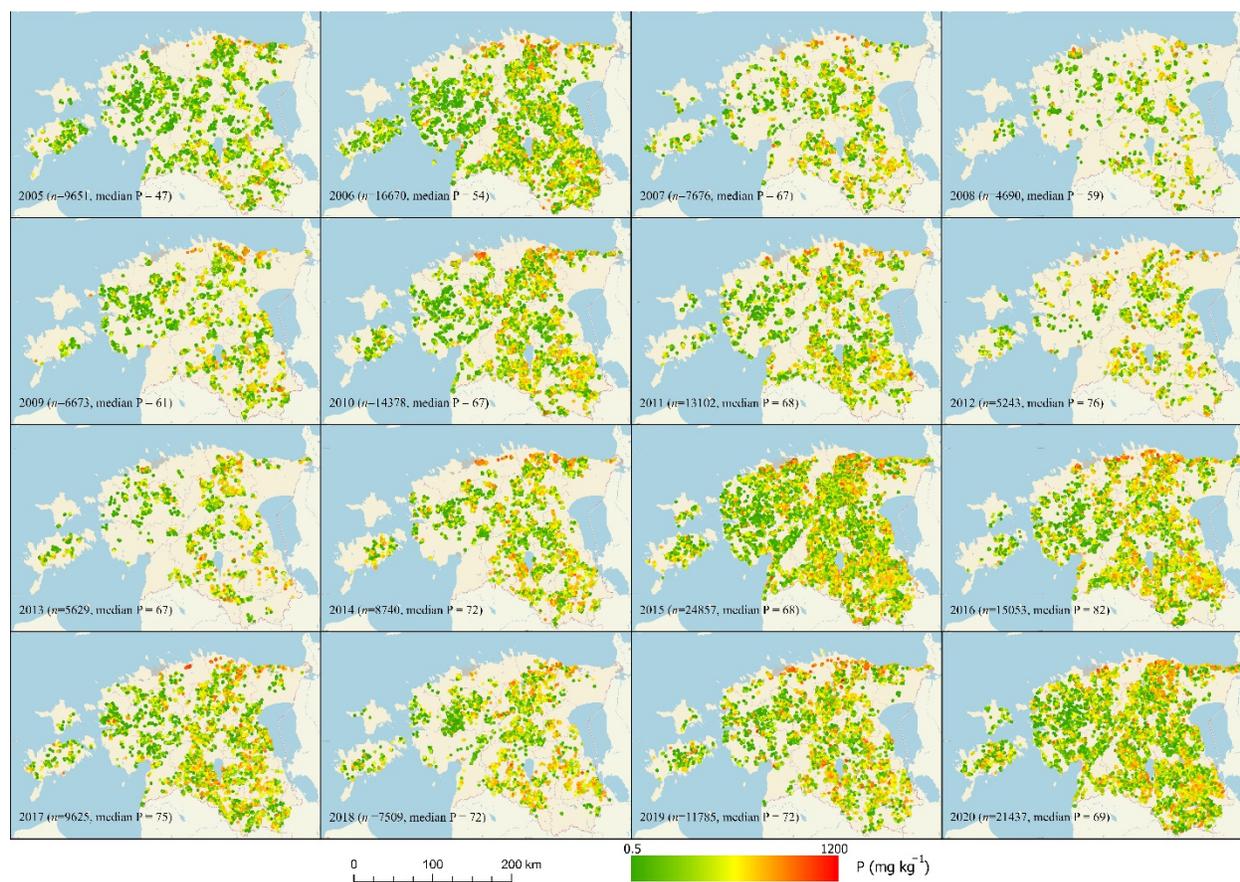


## Supplementary Materials



**Figure S1.** Topsoil plant-available  $p$  sample points taken from agricultural lands in 2005–2020. The count ( $n$ ) and median P value (mg/kg) are presented for every year. The color scale representing P value is the same for all years.

**Table S1.** Variables used in the bagging model. P is the predicted variable, and 32 variables were used to predict the P values. Index 1 after sand, silt, clay, rock, soc, bd, k, and awc indicates the upper soil layer (topsoil). Different statistics (mean, median, and standard deviation) of the topographic variables (TRI, TWI, LS, and SLP) were included in the bagging model.

Variable	Description	Database	Method
P	Topsoil plant-available phosphorus content (mg/kg)	PANDA, 2021	Measured, Mehlich-3 (M3) method used for P extraction.
sand1	Sand % (topsoil)	EstSoil-EH [49]	Classified based on soil texture type.
silt1	Silt % (topsoil)	EstSoil-EH [49]	Classified based on soil texture type.
clay1	Clay % (topsoil)	EstSoil-EH [49]	Classified based on soil texture type.
rock1	Rock % (topsoil)	EstSoil-EH [49]	Classified based on soil texture type.
soc1	Soil organic carbon % (topsoil)	EstSoil-EH [49]	Modeled by using statistical machine learning algorithms with the calculated topographic and land-use variables as predictors.
bd1	Bulk density (g/cm <sup>3</sup> ) (topsoil)	EstSoil-EH [49]	Calculated based on predicted SOC by using PTF-s.

k1	Saturated hydraulic conductivity (mm/h) (topsoil)	EstSoil-EH [49]	Modeled by using statistical machine learning algorithms by using soil texture variables as predictive variables [63].
awc1	Available water capacity (mm H <sub>2</sub> O per millimeter of soil) (topsoil)	EstSoil-EH [49]	Assimilated [64] based on EU-SoilHydroGrids 250 m resolution raster datasets [65].
unit_area	Area per mapped soil unit (sq m)	EstSoil-EH [49]	Calculated based on the Estonian Soil Map
tri_mean (stdev, median)	Terrain ruggedness index	EstSoil-EH [49]	Calculated from LiDAR DEM 5 m resolution [66]. Mean, median, and stdev calculated as zonal statistics per soil polygon.
twi_mean (stdev, median)	Topographic wetness index	EstSoil-EH [49]	Calculated from LiDAR DEM 5 m resolution [67]. Mean, median, and stdev calculated as zonal statistics per soil polygon.
slp_mean (stdev, median)	Slope (degrees)	EstSoil-EH [49]	Calculated from LiDAR DEM 5 m resolution. Mean, median, and stdev calculated as zonal statistics per soil polygon.
ls_mean (stdev, median)	Slope length–steepness factor	EstSoil-EH [49]	Calculated from LiDAR DEM 5 m resolution [68]. Mean, median, and stdev calculated as zonal statistics per soil polygon.
area_drain	Area under drainage (sq m)	EstSoil-EH [49]	Calculated based on Estonian Soil Map and official register of drainage systems by the Agricultural Board of Ministry of Rural Affairs of Estonia.
drain_pct	Percentage of area under drainage	EstSoil-EH [49]	Calculated based on Estonian Soil Map and official register of drainage systems by the Agricultural Board of Ministry of Rural Affairs of Estonia.
Longitude	Longitude (m)	Estonian Coordinate System of 1997 and EPSG 3301	Soil sampling location Y coordinate in case of P samples. Soil-land use polygon central point Y coordinate for prediction.
Latitude	Latitude (m)	Estonian Coordinate System of 1997 and EPSG 3301	Soil sampling location X coordinate in case of P samples. Soil-land use polygon central point X coordinate for prediction.
Elevation	Ground elevation (m)	LiDAR DEM 10 m resolution (Estonian Land Board, 2021)	Absolute height of soil sample location or absolute height of soil–land use polygon central point.
LU_MedP	Land-use category median P (mg/kg)	ARIB, EELIS, and ETD (Estonian Land Board, 2021)	Classified based on land-use/land-cover intensity and fertilization, 8 classes.
Soil_MedP	Soil category median P (mg/kg)	Estonian Soil Map 1:10,000 (Estonian Land Board, 2021)	Classified based on soil-type properties, 29 classes.
NatSoil_MedP	Soil category median P if land use is natural grassland (mg/kg)	EELIS, ETD, and Estonian Soil Map 1:10,000 (Estonian Land Board, 2021)	Classified based on soil-type properties, 29 classes.
Texture_MedP	Soil texture category median P (mg/kg)	Estonian Soil Map 1:10,000 (Estonian Land Board, 2021)	Classified based on soil-texture properties, 12 classes.
Parent_MedP	Quaternary sediment category median P (mg/kg)	Geological Base Map 1:400,000 (Estonian Land Board, 2020)	Classified based on sediment deposition properties, 9 classes and anthropogenic soil class.
HydSoil_MedP	Soil hydrologic group median P (mg/kg)	Estonian Soil Map 1:10,000 (Estonian Land Board, 2021)	Classified based on soil moisture properties, 4 classes.

References [49,63–68] are cited in the supplementary materials.