Mapping phosphorus sorption capacity in four depths with uncertainty propagation

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Phosphorus sorption capacity (PSC)

Phosphorus (P) is an important nutrient for plant growth, but also causes eutrphication in surface waters.

The soil can act as a filter, a reservior and a source of P.

The PSC of the soil regulates this behaviour, and information on PSC is therefore necessary for P management.

In slightly acidic, sandy to loamy soils, poorly crystallized Al- and Fe-oxides bind P.

We can therefore estimate PSC based on oxalate-extractable Al and Fe:

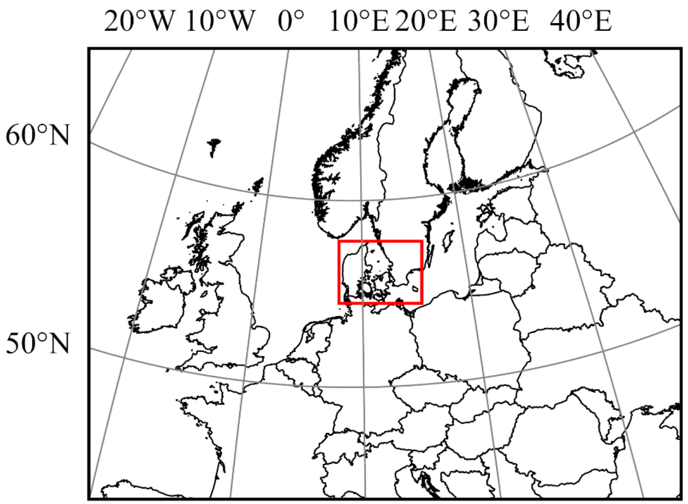
$$\mathrm{PSC} = 0.5(Al_o + Fe_o)$$

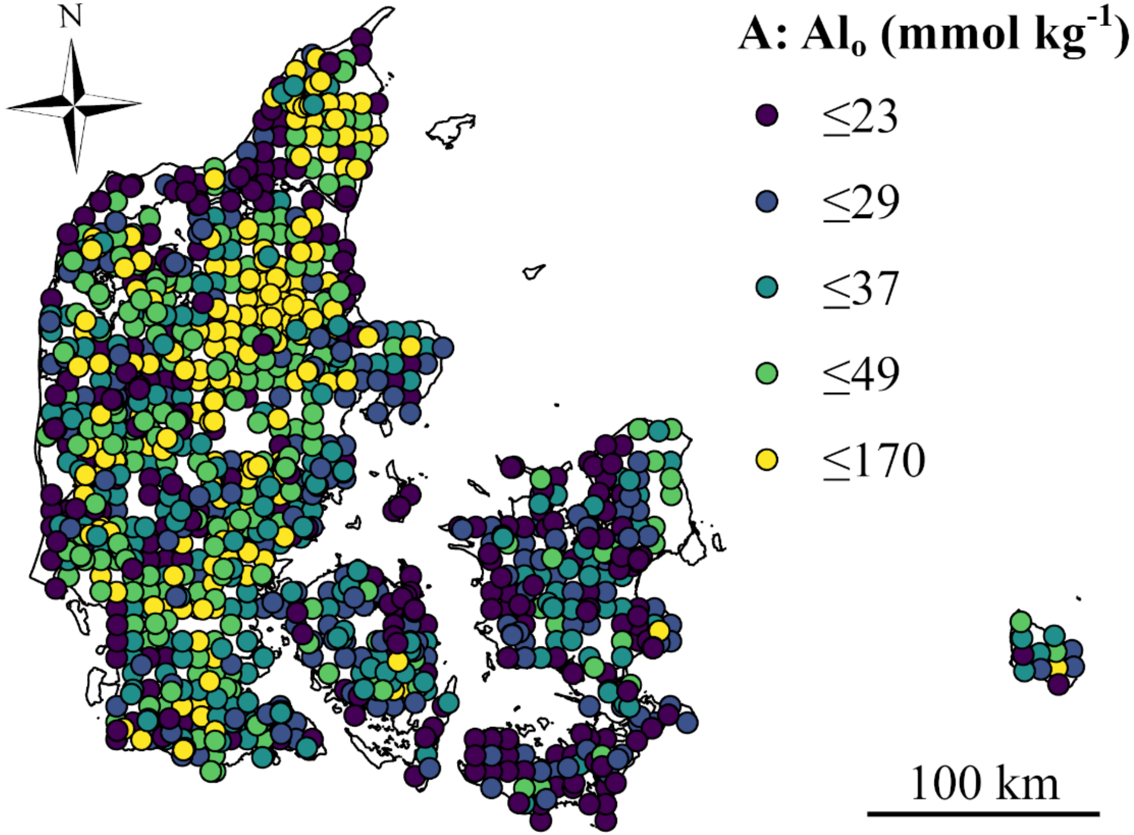
Study area and data

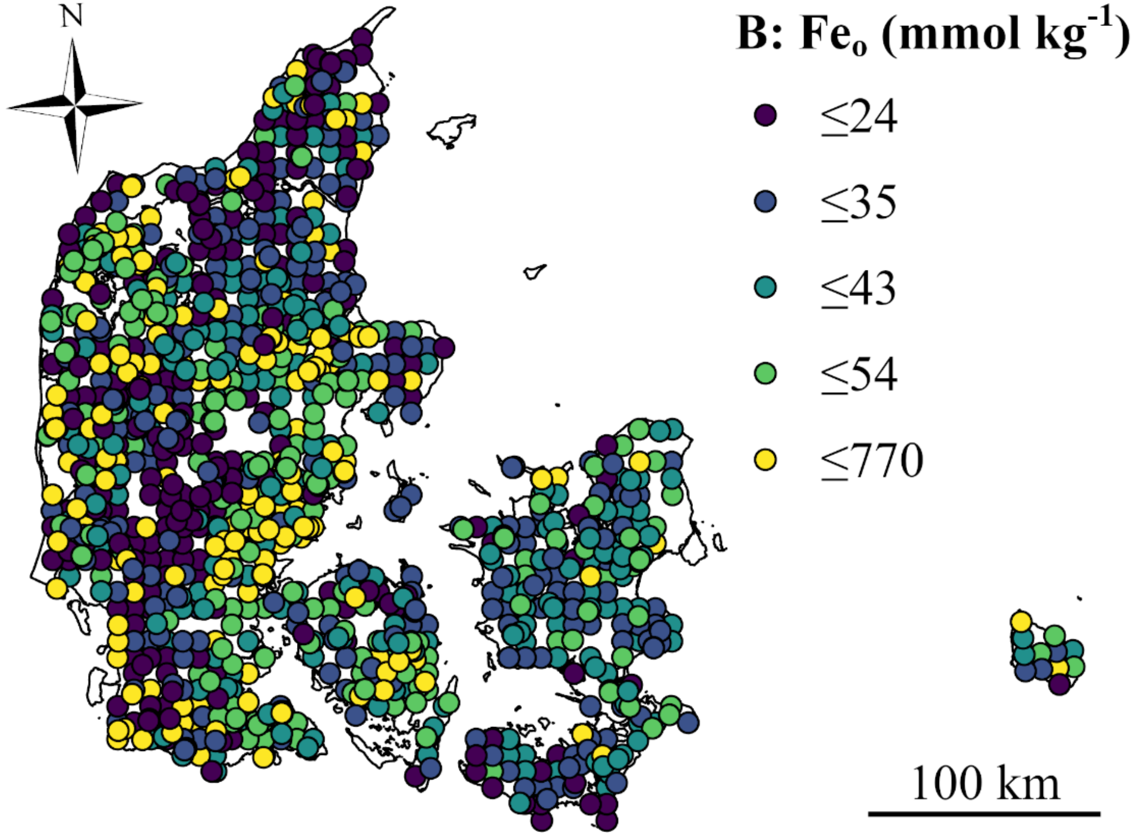
We map PSC for Denmark (45,000 km^2)

We use measurements of Al_o and Fe_o from ~1,000 locations.

Four depth intervals (0 – 25 cm, 25 – 50 cm, etc.)







Prediction and uncertainty estimation

We use quantile regression forests (QRF) to predict quantiles for Al_o and Fe_o.

We predict 100 quantiles for each property, 0.5% to 99.5%.

We propagate uncertainties by combining each all quantiles in a convolution matrix:

		Fe_o			
		$Q_{0.5}$	**$Q_{1.5}$**	**…**	**$Q_{99.5}$**
Al_o	**$Q_{0.5}$**	$Al_{Q0.5} + Fe_{Q0.5}$	$Al_{Q0.5} + Fe_{Q1.5}$	…	$Al_{Q0.5} + Fe_{Q99.5}$
	$Q_{1.5}$	$Al_{Q1.5} + Fe_{Q0.5}$	$Al_{Q1.5} + Fe_{Q1.5}$	…	$Al_{Q1.5} + Fe_{Q99.5}$
	…	…	…	…	…
	$Q_{99.5}$	$Al_{Q99.5} + Fe_{Q0.5}$	$Al_{Q99.5} + Fe_{Q1.5}$	…	$Al_{Q99.5} + Fe_{Q99.5}$

We then calculate new quantiles on the values in this matrix.

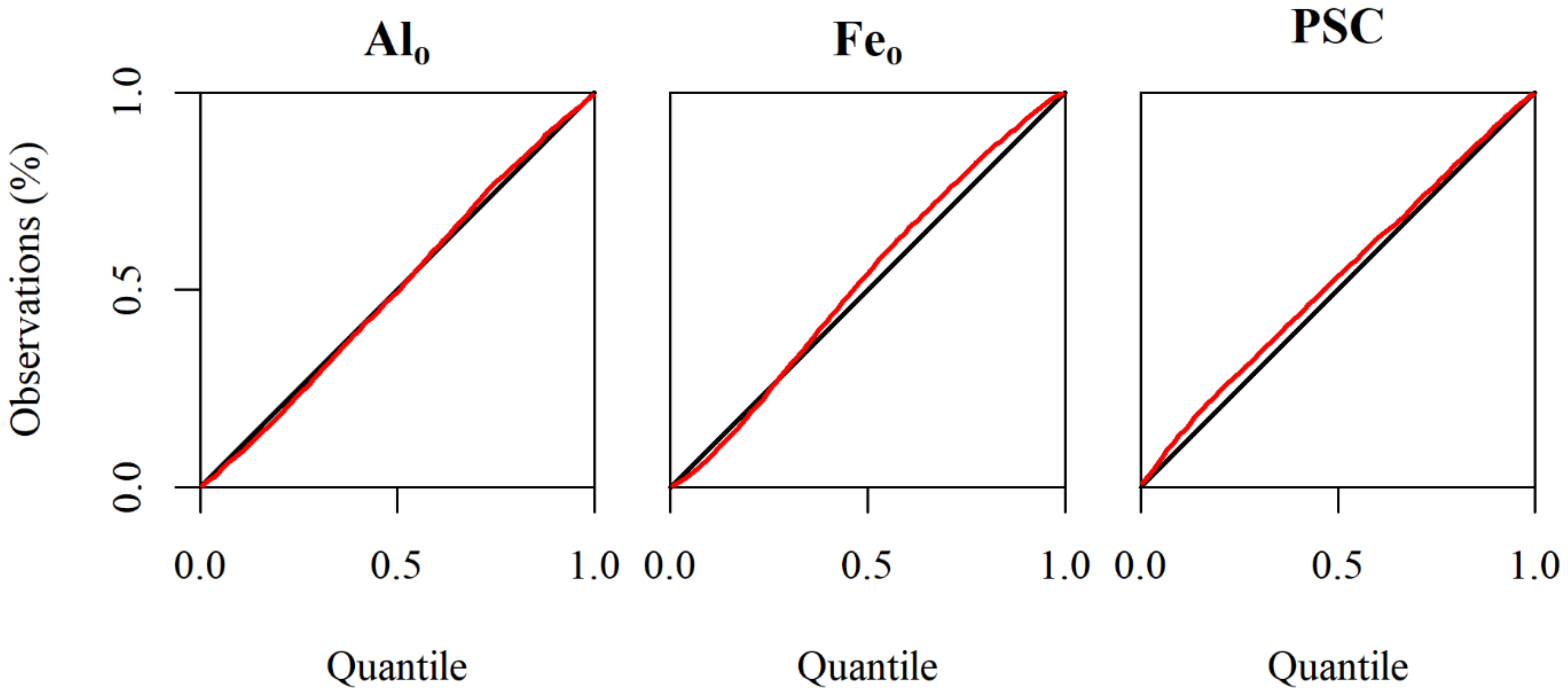
Accuracy

Predictions were moderately accurate.

R^2_w was low for Fe_o due to skewed distribution.

QRF and quantile convolution provided reliable uncertainty estimates.

Property	**$RMSE_w$ (mmol kg^{-1})**	**R^2_w**
Al_o	13.9	0.49
Fe_o	33.5	0.14
PSC	19.1	0.23

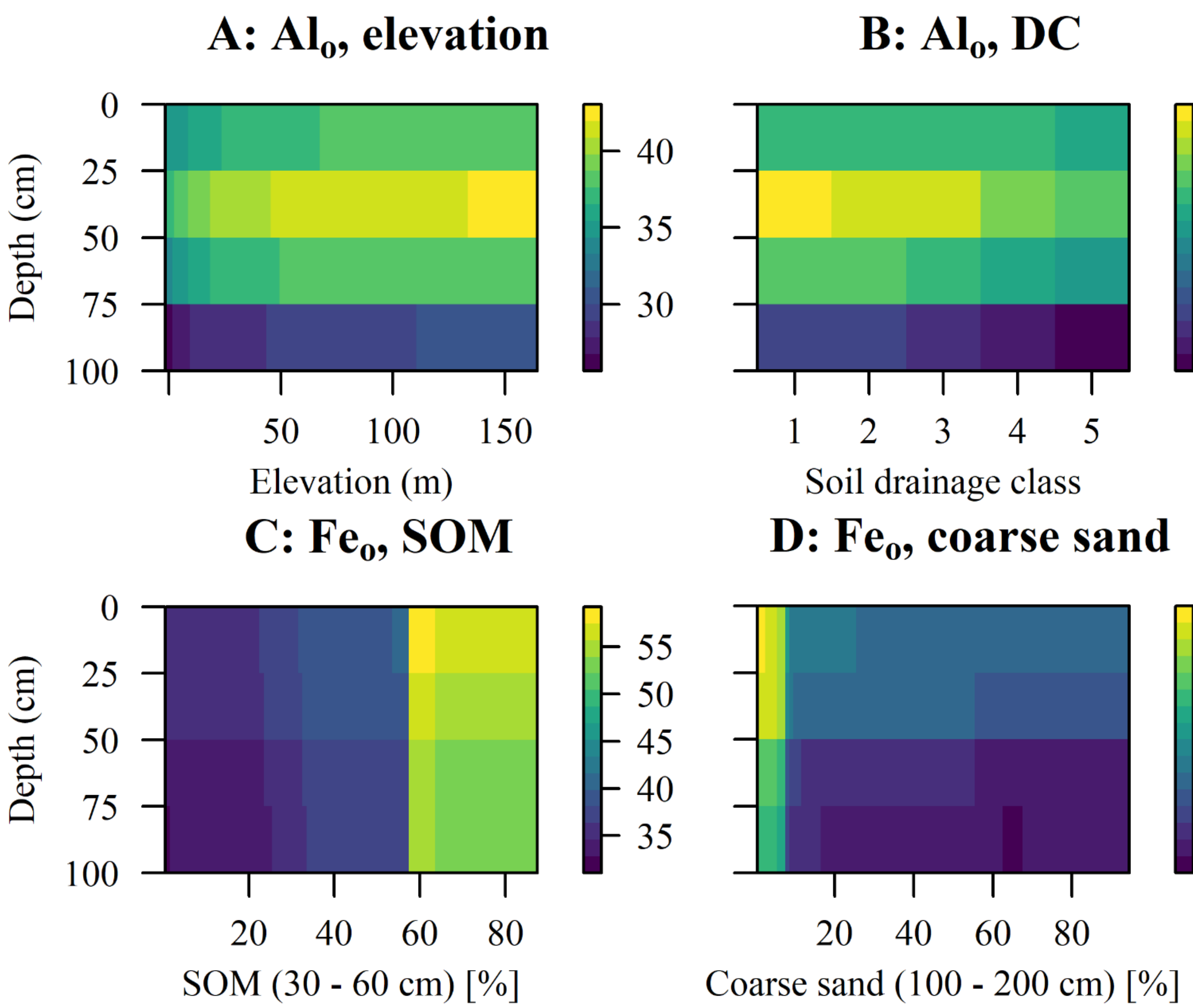


Covariate importance

Al_o was highest in well-drained soils at higher elevations.

Fe_o was high in organic and fine-grained soils.

Podzolization affected the depth distribution of Al_o.

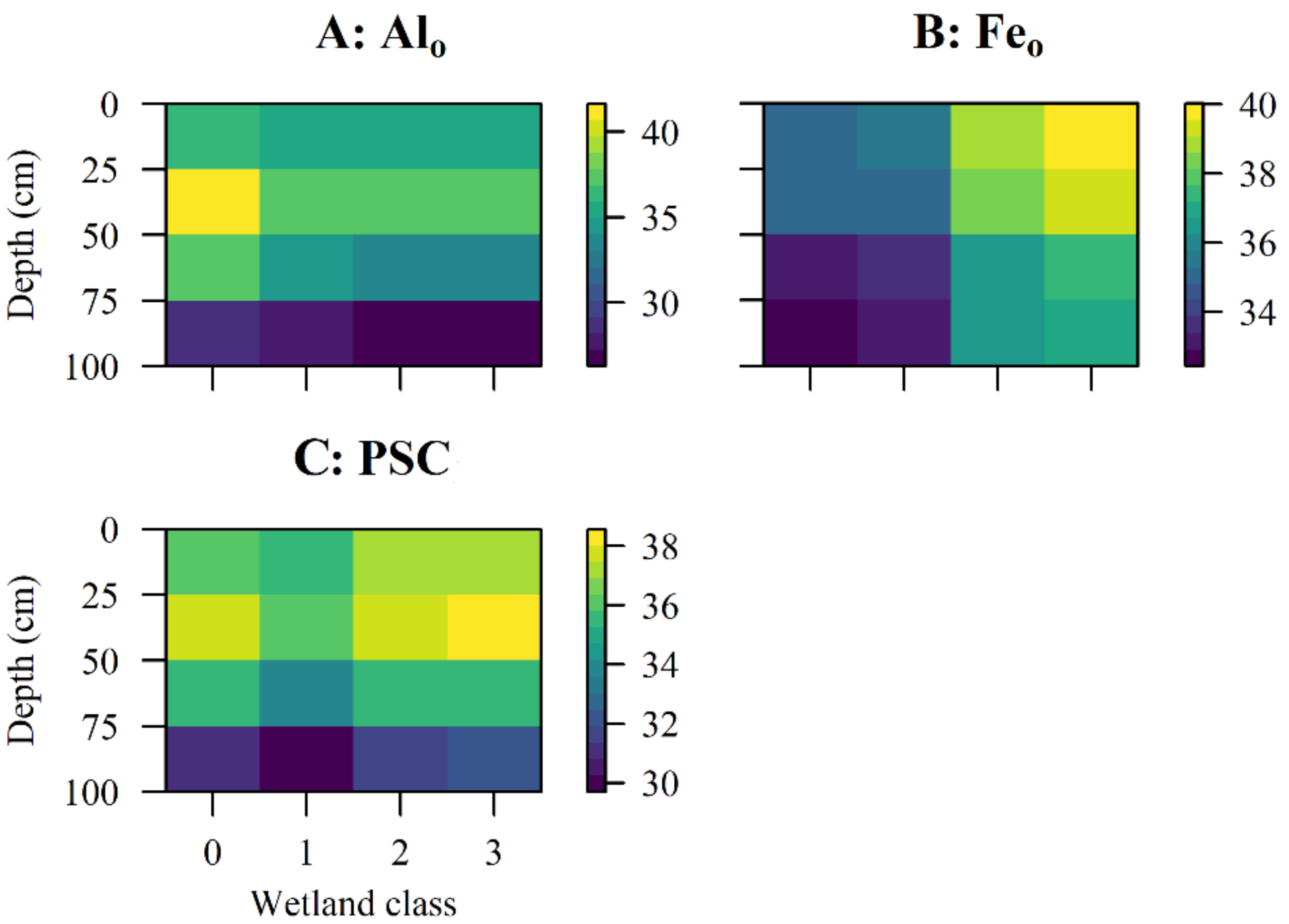


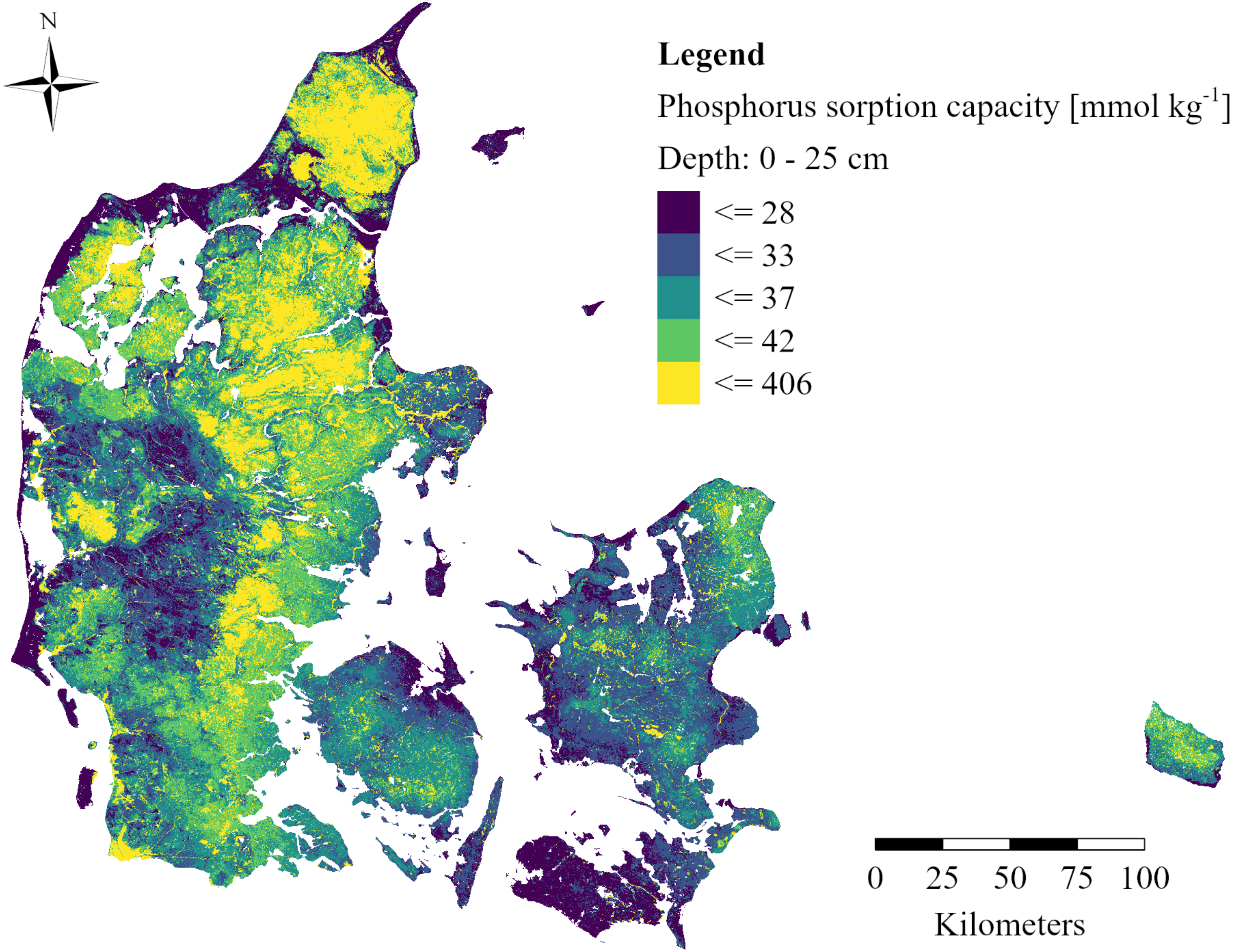
Effect of wetland classes

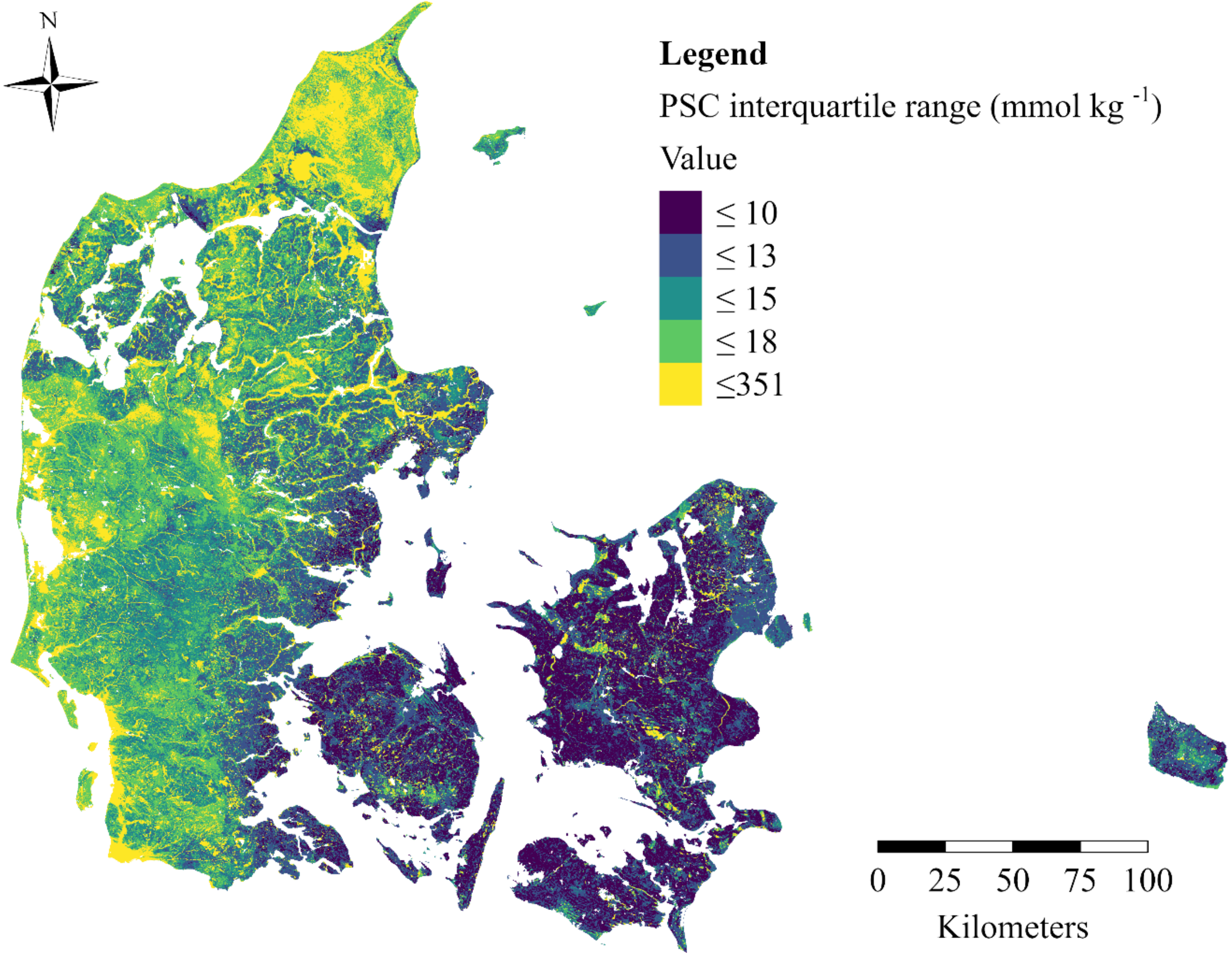
Al_o was highest in uplands (class 0) at depths 25 – 50 cm.

Fe_o was highest in the topsoil of organic wetland soils (class 3), followed by historic peatlands (class 2).

The combined effect was a low PSC in mineral wetland soils (class 1)




N
Legend
Phosphorus sorption capacity [mmol kg^{-1}]
Depth: 0 - 25 cm
<= 28
<= 33
<= 37
<= 42
<= 406
0 25 50 75 100
Kilometers

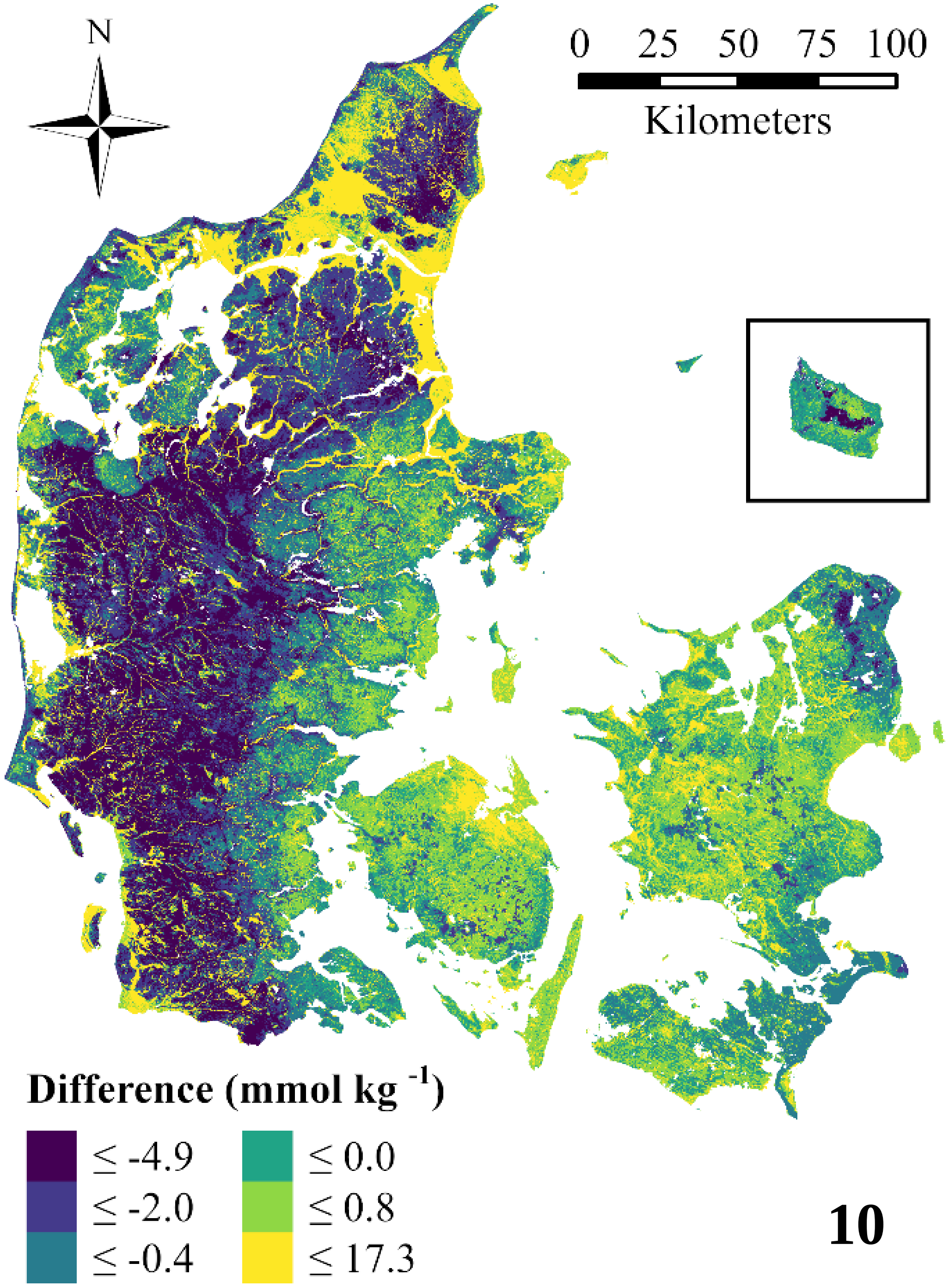

N
Legend
PSC interquartile range (mmol kg -1)
Value
≤ 10
≤ 13
≤ 15
≤ 18
≤351
0 25 50 75 100
Kilometers

Depth effects

The map shows difference in PSC between the depth intervals 0 – 25 cm and 25 – 50 cm.

In wetlands and young, loamy upland soils (eastern Denmark), PSC is highest in the topsoil.

In well-developed sandy soils (western Denmark), PSC is higher in the depth interval 25 – 50 cm.



Conclusions

Quantile regression forests and quantile convolution provided moderate accuracies and reliable uncertainty estimates for PSC.

The spatial distribution of PSC is highly complex, as we see effects from parent materials, terrain, soil texture and organic matter, wetland dynamics and soil-forming processes, such as podzolisation

Uncertainties are large in wetland areas and smallest in young, loamy upland soils.