

1 **Supplementary Information for**
2 **Global patterns and drivers of soil total phosphorus concentration**

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18 **Table S1. Summary of 11 global or regional databases used to compile our database.**

Database source	Number of source papers	Number of observations
Hou et al., unpublished	98	1693
He et al., unpublished	98	262
Wang et al., 2021	100	962
Adams et al., 2020	1	20
Hou et al., 2020	77	73
Deiss et al., 2018	15	99
Hou et al., 2018	41	381
Yan et al., 2018	33	67
Augusto et al., 2017	212	1068
Deng et al., 2017	64	107
Gama-Rodrigues et al., 2014	22	24

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21 **Table S2. Summary of additional data search from underrepresented regions.**

Category	Keywords	Number of identified studies	Number of included studies	Number of observations
Soil order	Histosols; Andisols; Vertisols.	71	7	46
Biome	Tundra; Desert.	91	9	80
Region	Africa; Siberia; Sahara; Central Asia.	476	20	205
Country	Canada; Russia; Pakistan; Iran; Kazakhstan; Uzbekistan; Kyrgyzstan; Turkmenistan; Tajikistan; Afghanistan; Iraq; Saudi Arabia; Bahrain; Qatar; United Arab Emirates; Oman; Yemen; Sri Lanka; Maldives; South Africa; Angola; Namibia; Botswana; Zambia; Zimbabwe; Madagascar; Democratic Republic of Congo; Central African Republic; Chad; Niger; Mali; Mauritania; Morocco; Algeria; Libyan Arab Jamahiriya; Egypt.	580	24	210
Sum		1218	60	541

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Table S3 Gridded data used in present study.

Group	Variables	Brief description	Original resolution	Data source
Parent material	Parent material	global lithological map database	50 km	http://dx.doi.org/10.1594/PANGAEA.788537
Climate	Mean annual temperature	30-yr (1981 to 2010) annual average temperature	1 km	http://worldclim.org/bioclim
	Mean annual precipitation	30-yr (1981 to 2010) annual average precipitation	1 km	http://worldclim.org/bioclim
	Biomes	Whittaker's Biomes	1 km	https://sedac.ciesin.columbia.edu
Soil	Soil organic carbon	Soil organic carbon content	250 m	https://openlandmap.org
	Soil pH	Soil pH	250 m	https://openlandmap.org
	Soil clay	Soil clay content	250 m	https://openlandmap.org
	Soil sand	Soil sand content	250 m	https://openlandmap.org
	Soil order	Taxonomy soil order class	250 m	https://openlandmap.org
	Soil bulk density	Soil bulk density	250 m	https://openlandmap.org
	Soil depth	Soil depth	10 km	http://globalchange.bnu.edu.cn/research/data
Plants	Net primary production	Annual terrestrial primary production for 2018 (Derived from Landsat)	1 km	http://www.ntsug.umt.edu
Topography	Slope	Slope gradient in percent derived from the DEM	250 m	https://openlandmap.org
	Elevation	Land surface elevation	250 m	https://openlandmap.org

26 **Table S4 Statistical model performance with five-fold cross validation.** Using
27 the assembled soil total P measurements, we applied three generalized linear models: Cubist model, Boosted tree
28 model, and random forest model. R^2 and root-mean-square error (RMSE) were calculated from five-fold cross-
29 validation to assess model performance.

Models	R^2	RMSE
Random forest	65%	288.8
Cubist	57%	310.1
Boosted tree	45%	327.2
Ridge regression	18%	423.9
Lasso regression	17%	438.1
Glm regression	18%	437.9

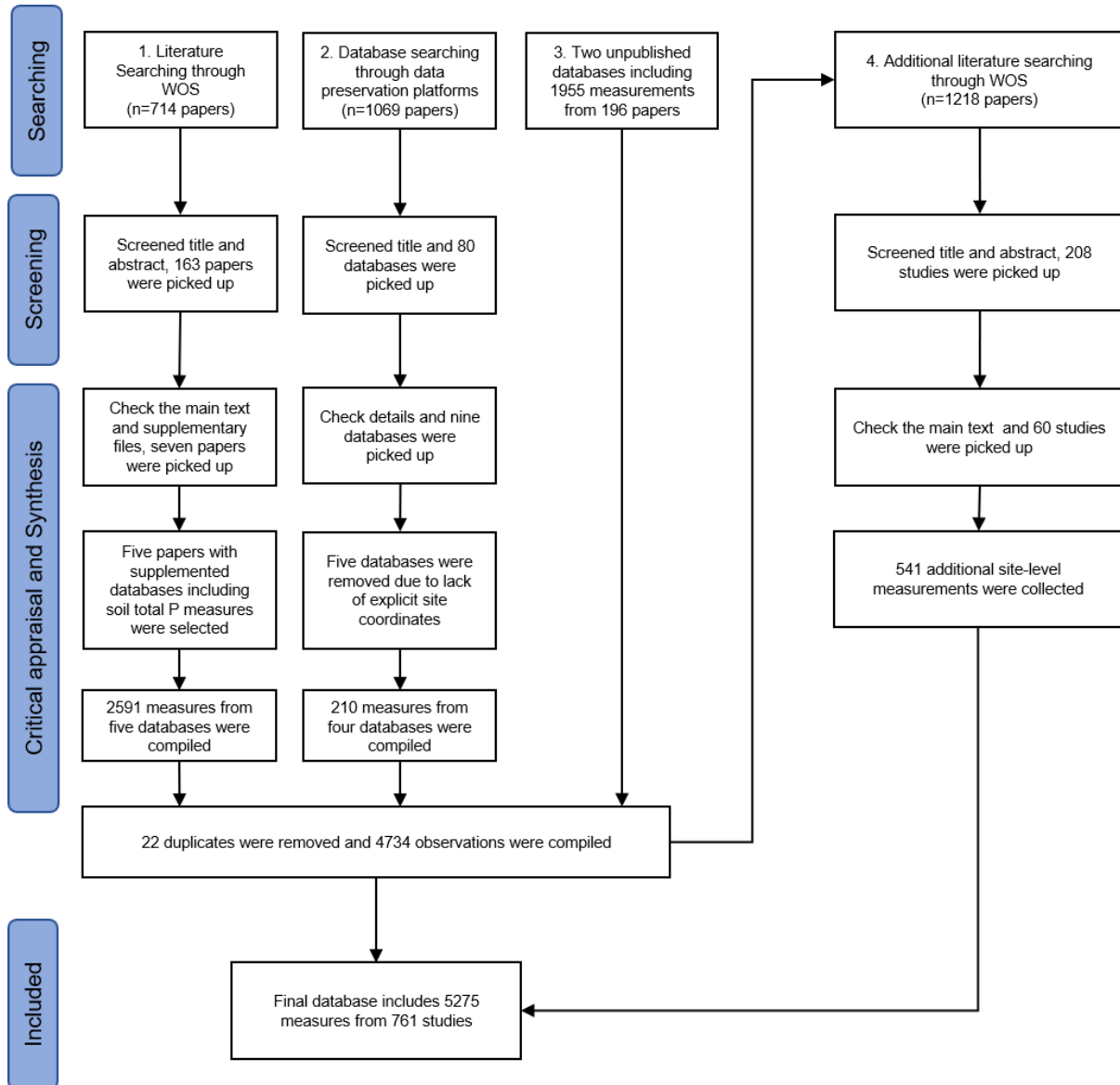
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31 **Table S5 Representatives of the soil total P concentration database**

	Global distribution	Our database
Soil orders		
Alfisols	9.90%	10.50%
Andisols	0.70%	1.80%
Aridisols	11.10%	3.80%
Entisols	15.60%	8.80%
Geilsols	18.40%	5.50%
Histosols	1.40%	0.60%
Inceptisols	16.30%	29.20%
Mollisols	7.40%	9.20%
Oxisols	5.80%	6.50%
Spodosols	4.90%	2.80%
Ultisols	6.60%	20.50%
Vertisols	2.00%	0.90%
Parent material		
Acid plutonic rocks	6.70%	7.60%
Basic plutonic rocks	1.00%	0.10%
Intermediate plutonic rocks	0.40%	2.30%
Acid volcanic rocks	1.10%	1.70%
Basic volcanic rocks	4.10%	4.60%
Intermediate volcanic rocks	2.00%	1.80%
Carbonate sedimentary rocks	7.80%	9.50%
Mixed sedimentary rocks	18.60%	15.10%
Siliciclastic sedimentary rocks	18.60%	22.20%
Unconsolidated sediments	23.60%	22.10%
Metamorphics	14.40%	10.40%
Pyroclastics	0.60%	1.40%
Evaporites	0.30%	0.10%

32 Global data: USDA for soils, and Hartmann and Moosdorf (2012) for geology. Global data were recalculated for
 33 a sum of 100%.

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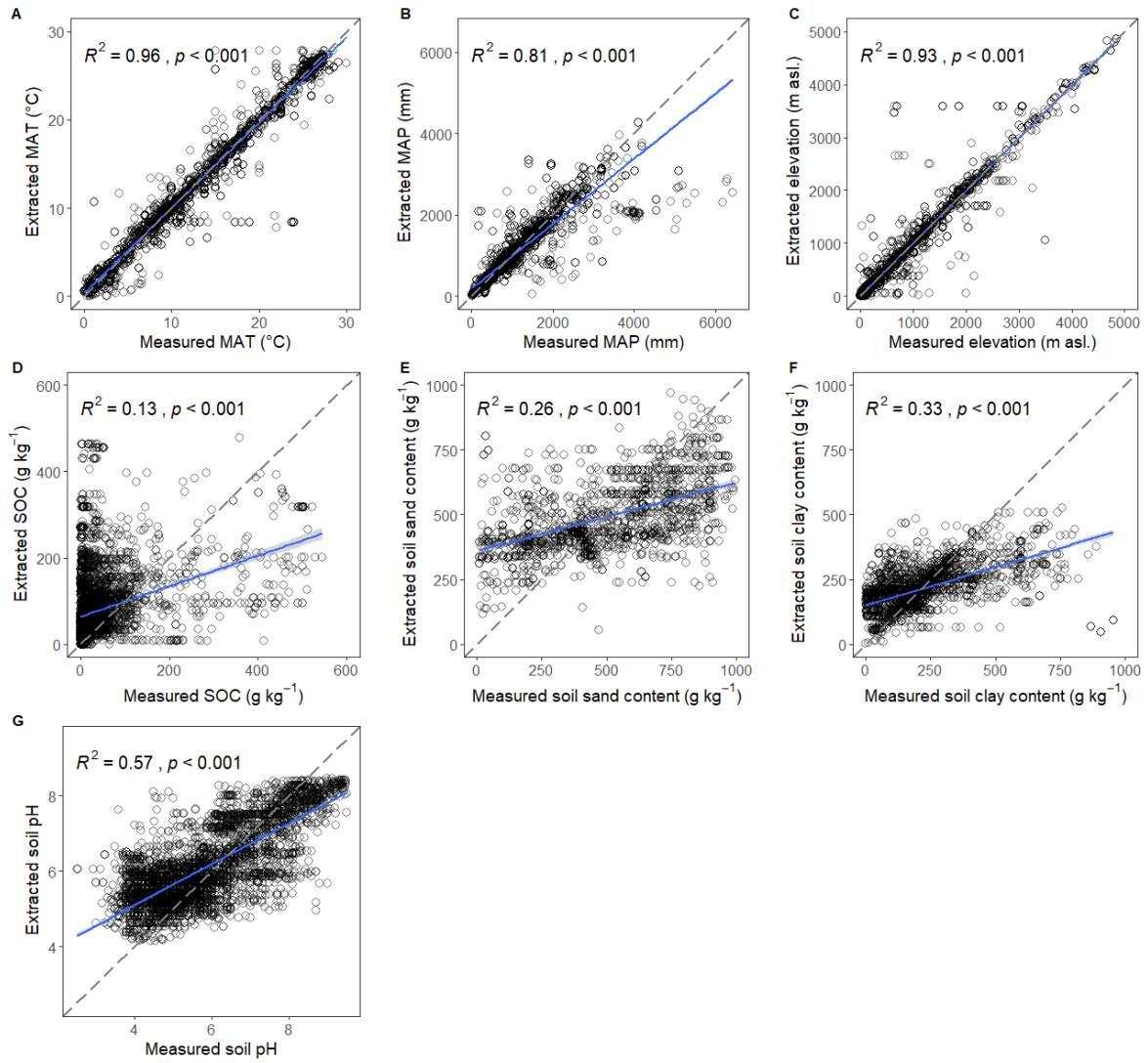


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36 **Fig. S1. PRISMA flow diagram showing the procedure used for selection of studies for synthesis.**

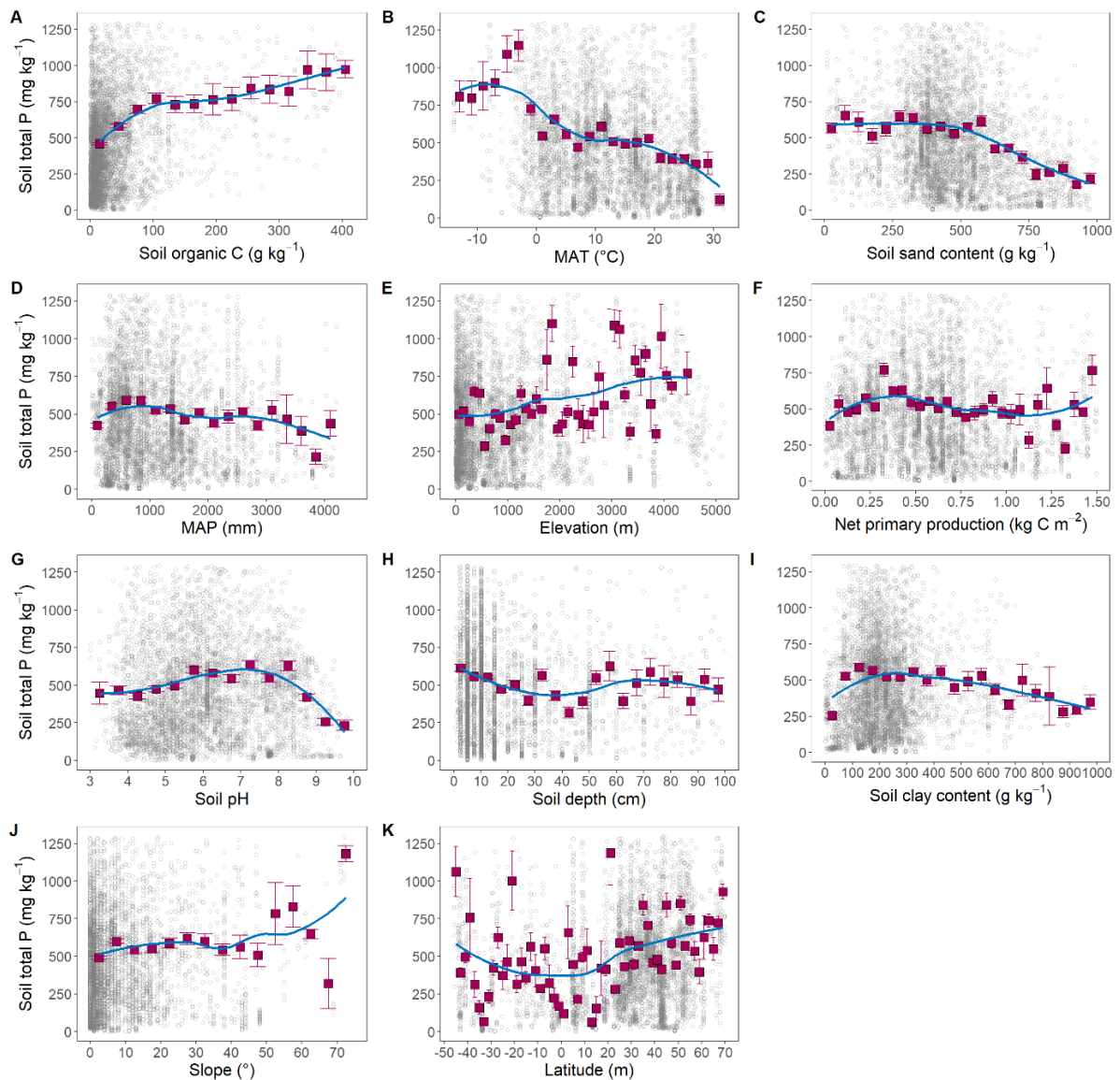
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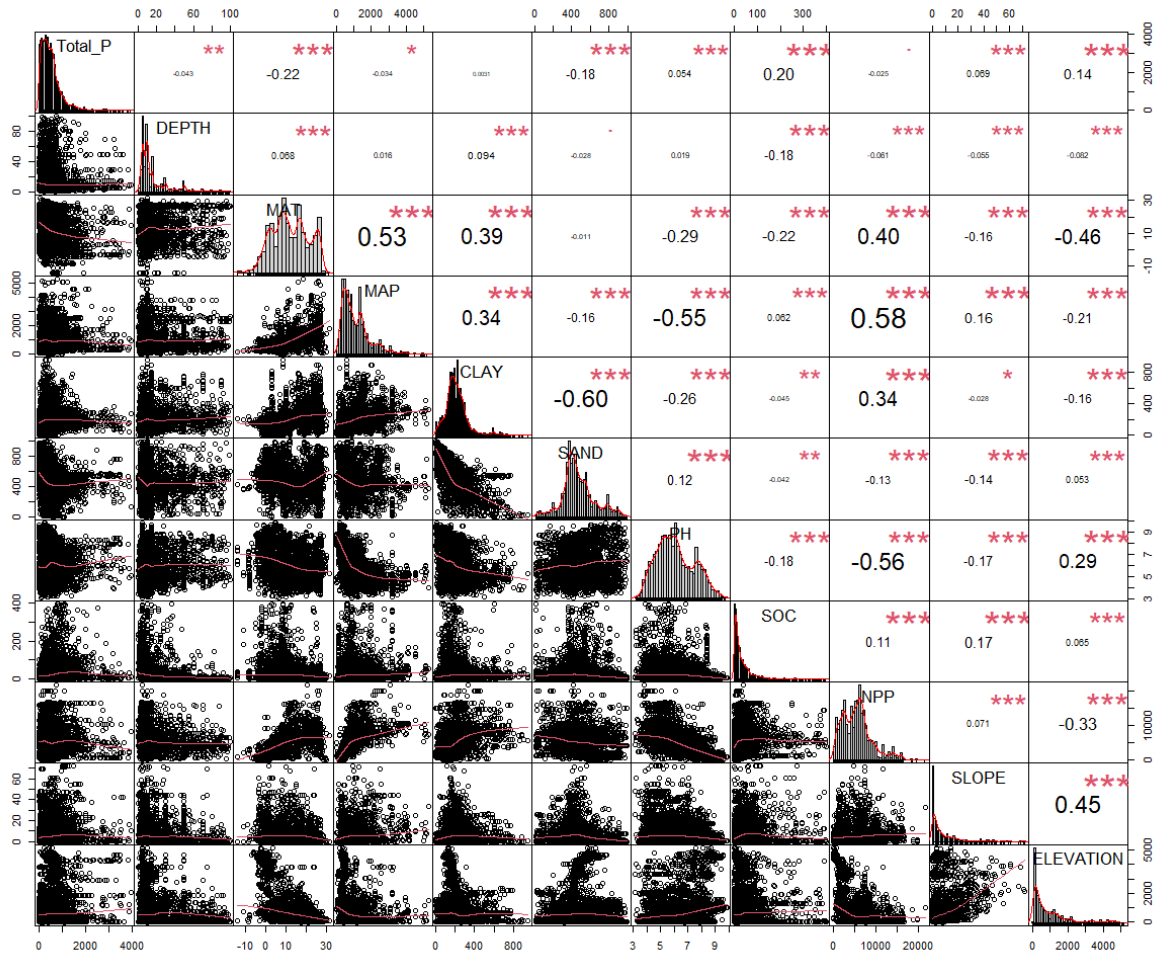
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40 **Fig. S2. Validation of predictor values extracted from global maps.** (A) Mean annual temperature, (B) mean
 41 annual precipitation, (C) elevation, (D) soil organic C concentration, (E) soil sand content, (F) soil clay content,
 42 and (G) soil pH. Dashed line is the 1:1 line. Blue line and shaded area indicate the regression line and 95%
 43 confidence interval, respectively.



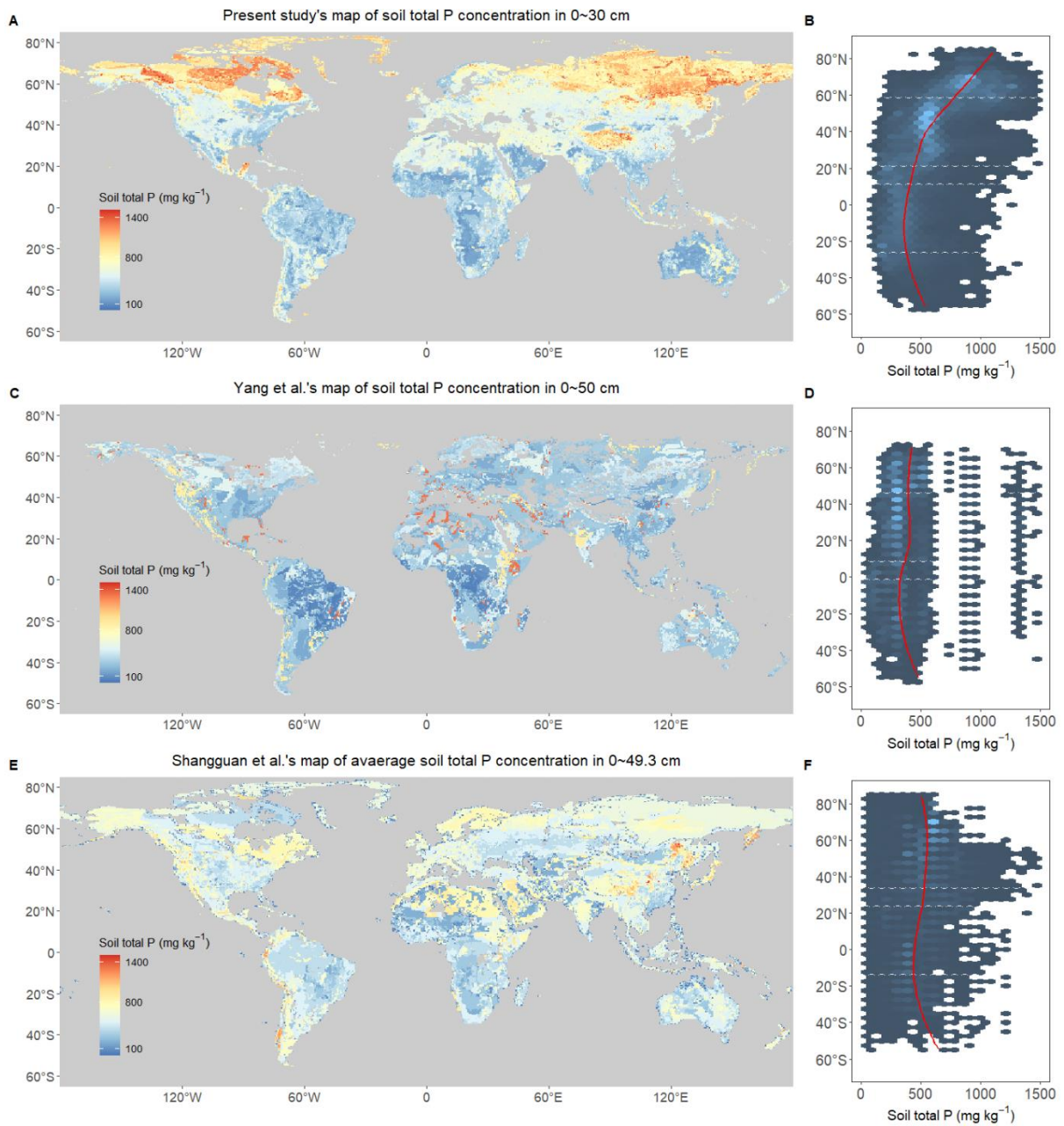
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Fig. S3. The relationship between soil total P concentration and predictors and latitude. Soil total P concentration in relation to SOC concentration, MAT, soil sand content, MAP, elevation, net primary production, soil pH, soil depth, soil clay content, slope, and latitude (A, B, C, D, E, F, G, H, I, J, K, respectively). Purple boxes and error bars represent the mean values and standard errors, respectively, of binned soil total P concentration measures by every 30 g kg⁻¹ for SOC concentration, every 2°C for MAT, every 50 g kg⁻¹ for soil sand content, every 250 mm year⁻¹ for MAP, every 200 m for elevation, every 0.05 kg C m⁻² for net primary production, every 0.5 pH variation, every 5 cm soil depth, every 50 g kg⁻¹ clay content, every 5° slope, and every 2° latitude, respectively. Solid blue lines indicate results of local polynomial regressions based on the binned mean values. For visualization, we chose to limit the y-axis to 1300 mg kg⁻¹.



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Fig. S4. Pearson correlations among soil total P concentration and numeric predictors. * $P < .01$, ** $P < .01$, * $P < .001$.**

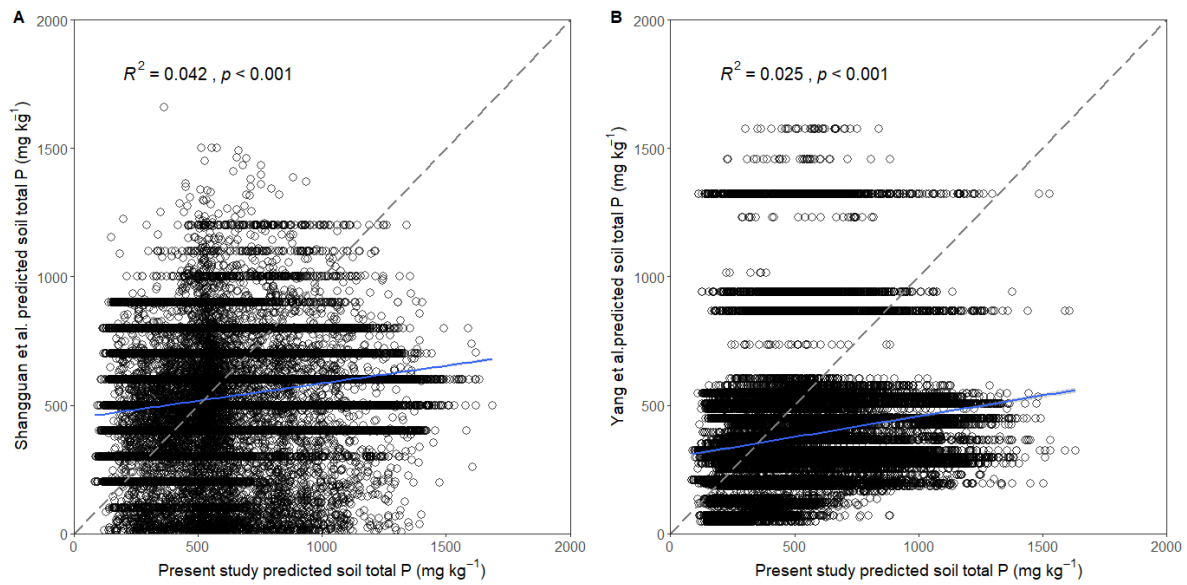


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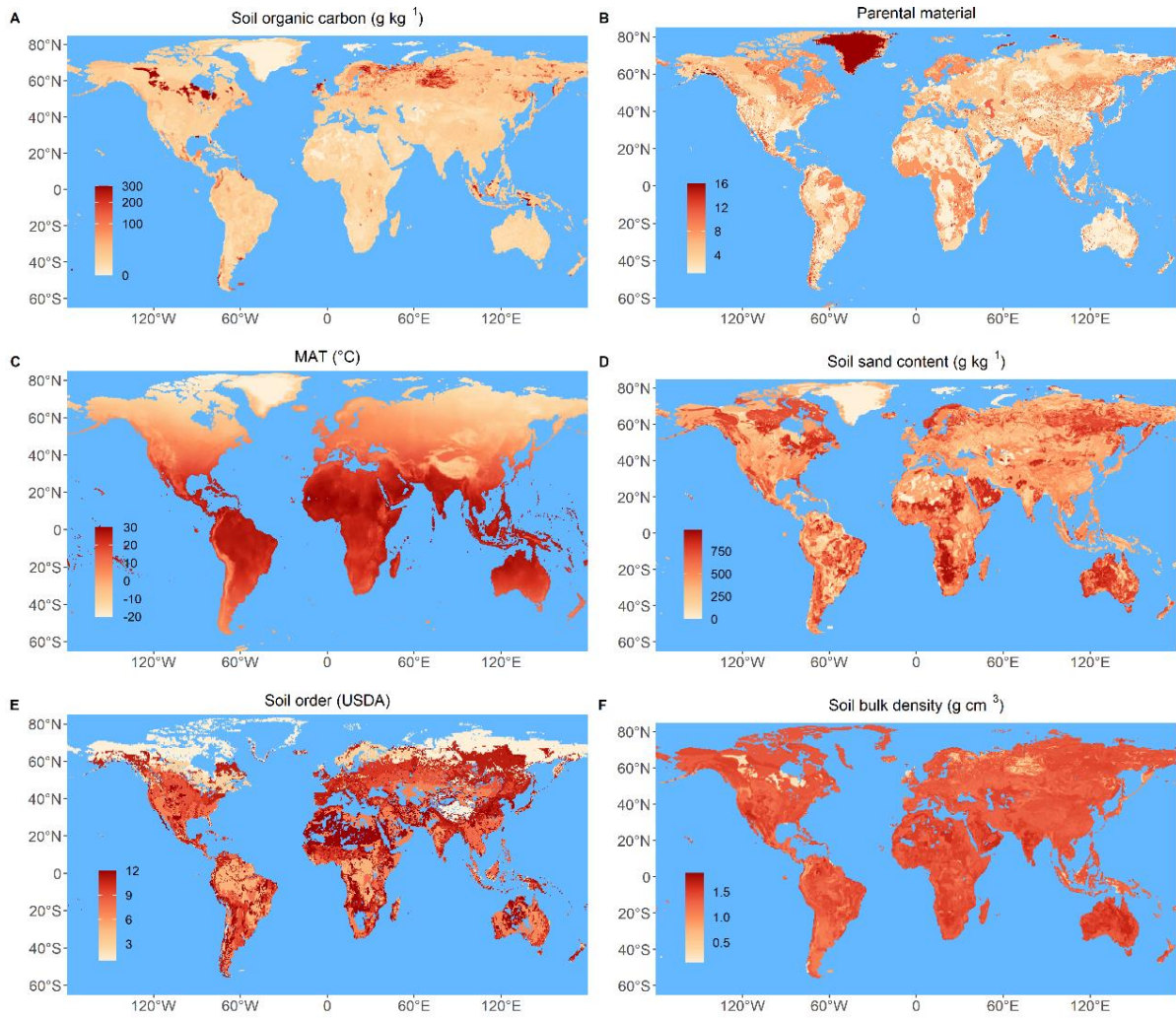
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Fig. S5. Comparison of soil total P concentration maps in the present and previous studies. For comparison, these maps are presented with the same color scale and value limits, i.e. 0~1500 mg kg^{-1} .



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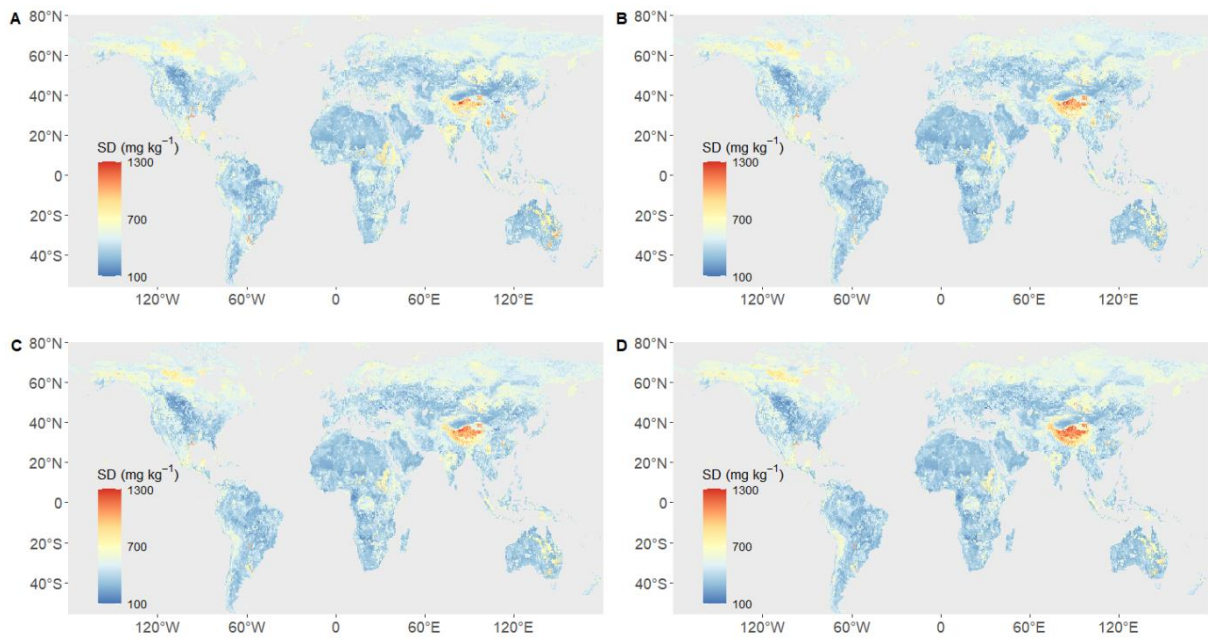
Fig. S6. Relationship between our predicted global topsoil total P concentration map and two previous predicted maps, respectively. Panel A indicates the correlation between our predicted topsoil total P concentration and Shangguan et al.'s predictions. Panel B indicates the correlation between our predicted topsoil total P concentration and Yang et al.'s predictions. The dashed lines indicate the 1:1 line; the blue lines indicate the regression line.



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71 **Fig. S7. Global patterns of five important predictors of soil total P concentration and soil bulk density in**
 72 **the topsoil.** These five predictors included (A) soil organic C concentration (SOC), (B) parent material, (C) mean
 73 annual temperature (MAT), (D) soil sand content, and soil USDA order (E).

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76 **Fig. S8. Standard deviation of predicted total P concentrations.** Panels A, B, C, D indicate the standard
 77 deviation of the soil total P concentrations at 0-10, 10-20, 20-30, and 30-100 cm soil depth, respectively.

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79 **Supplementary Text 1 Data source references**

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