Article

The Interrelationship Between Soil Properties, Topography, Environmental Features and Soil Water Contents

Hyunje Yang [1], Hyeonju Yoo [1], Honggeun Lim [1], Jaehoon Kim [1] and Hyung Tae Choi [1,*]

Supplementary Materials

Table S1. 21 environmental covariates from geographically referenced database used in this study.

Environmental covariates	Unit	Data type	Source	Definition	Description
Elevation	m	Continuous	DEM	Height above sea level	
Slope	%	Continuous	DEM	Steepness of a surface	
Aspect	°	Continuous	DEM	Orientation of slope in degrees	
Catchment area (CA)	m²	Continuous	DEM	Upper catchment area related to the corresponding point	
Topographic wetness index (TWI)	-	Continuous	DEM	Index of quantifying topographic effects on hydrological processes	$\ln(\alpha/\tan(\beta))$, where α is the total catchment area of unit contour length and β is slope gradient (Sorensen et al., 2006)
Topographic position index (TPI)	-	Continuous	DEM	Index of classifying slope position and landform types	Index of topographical information using the vicinity of the corresponding cell in DEM. Positive value means ridge, negative value means valleys, and zero means flat area or constant slope (De Reu et al., 2013)
Profile curvature (ProC)	-	Continuous	DEM	Slope curvature parallel to the slope	Curvature parallel to the direction of the maximum slope. A positive profile curvature value means convex up, and zero value means flat surface. Profile curvature is analyzed with the ArcGIS spatial analysis tools.

Plan curvature (PlanC)	-	Continuous	DEM	Slope curvature perpendicular to the slope	Curvature perpendicular to the direction of the maximum slope. A positive plan curvature value means laterally convex, and zero value means linear surface. Plan curvature is analyzed with the ArcGIS spatial analysis tools.
Bedrock	-	3 categories	GM	Types of bedrock	Igneous, Sedimentary, Metamorphic
Forest type (FT)	-	3 categories	FTM	Dominant tree type	Coniferous, Broadleaf, Mixed
Tree density class (TDC)	-	3 categories	FTM	Stand density of forest	Crown closure of trees which height are over 8 m; High (>70 %), Middle (>50 %, ≤70 %), Low (≤50 %)
Average DBH class (ADC)	-	4 categories	FTM	Averaged value of dominant DBHs of forest stand	Index of average value of dominant DBHs. Trees corresponding to the dominant DBHs encounter more than 50% of the crown closure; Small (<6 cm), Medium (≥6 cm, <18 cm), Large (≥18 cm, <30 cm), Giant (≥30 cm)
Forest stand age class (FAC)	-	9 categories	FTM	Averaged value of dominant ages of forest stand	Index of average tree age. Tree ages corresponding to each class encounter more than 50% of the crown closure; class 1 (1 to 10), class 2 (11 to 20), class 3 (21 to 30), ... , class 8 (71 to 80), and class 9 (over 81)
Soil texture class (STC)	-	12 categories	FSSM	12 Soil texture classes by USDA textural triangle	Clay (c), Silty clay (sic), Silty clay loam (sicl), Clay loam (cl), Silt loam (sil), Silt (si), Loam (l), Sandy clay (sc), Sandy clay loam (scl), Sandy loam (sl), Loamy sand (ls), Sand (s)
Total soil depth (TSD)	cm	Continuous	FSSM	Total soil layer depth from surface to bedrock	Considering the relatively shallow soil layer in South Korea, the maximum soil depth is 100 cm.
Stone contents (StC)	%	5 categories	FSSM	Gravel fraction or gravel contents	Gravel is >2 mm in diameter; class 1 (<5 %), class 2 (5~15 %), class 3 (15~30 %), class 4 (30~50 %), and class 5 (≥50 %)
Hardness	kg cm^2	Continuous	FSSM	Resistance of soil to deformation	
Slopeform	-	4 categories	FSSM	Curvature of slope	Convex, Concave, Linear, and Complex
Rock exposure (RE)	-	4 categories	FSSM	Ratio of an exposed bedrock at the ground surface	
Weathering	-	3 categories	FSSM	Weathering of soil parent material	Highly weathered, Moderately weathered, and slightly weathered

Landform	-	5 categories	FSSM	Morphological characteristics of land	Flat, Gentle slope, Lower concave segment, Cliff face, and Upper convex segment (detailed explanation is in Lim et al., 2020)

Abbreviations: DEM; digital elevation map; GM, geologic map; FTM, forest type map; FSSM, forest site and soil map.

Table S2. Variable importance of forest stand and soil physical and chemical properties in PTF.

Soil layer Depth	pF	Importance measurements*	Bulk density	Hydraulic conductivity	Sand fraction	Clay fraction	Organic matter	Dominant tree height	Dominant tree DBH	Average DBH	Tree density
10 cm	0	Feature	0.530	0.063	0.102	0.051	0.125	0.037	0.026	0.035	0.031
		Permutation	0.638	0.036	0.127	0.034	0.140	0.009	0.005	0.006	0.006
	1.8	Feature	0.052	0.130	0.397	0.067	0.188	0.071	0.027	0.030	0.037
		Permutation	0.024	0.179	0.424	0.042	0.266	0.045	0.005	0.004	0.011
	2.7	Feature	0.052	0.123	0.495	0.069	0.144	0.035	0.024	0.033	0.025
		Permutation	0.021	0.137	0.571	0.062	0.199	0.004	0.002	0.003	0.001
30 cm	0	Feature	0.747	0.030	0.045	0.029	0.058	0.024	0.022	0.026	0.019
		Permutation	0.913	0.004	0.027	0.008	0.038	0.003	0.003	0.003	0.002
	1.8	Feature	0.052	0.166	0.405	0.040	0.206	0.051	0.022	0.026	0.031
		Permutation	0.028	0.286	0.404	0.018	0.218	0.029	0.003	0.003	0.010
	2.7	Feature	0.038	0.181	0.493	0.053	0.131	0.032	0.022	0.024	0.027
		Permutation	0.008	0.262	0.521	0.045	0.145	0.007	0.003	0.003	0.006

* Feature, feature importance; Permutation, permutation importance. Used models: PTF-10-pF0, PTF-10-pF1.8, PTF-10-pF2.7, PTF-30-pF0, PTF-30-pF1.8, and PTF-30-pF2.7.

Table S3. Variable importance of environmental covariates from digital elevation map and geologic map.
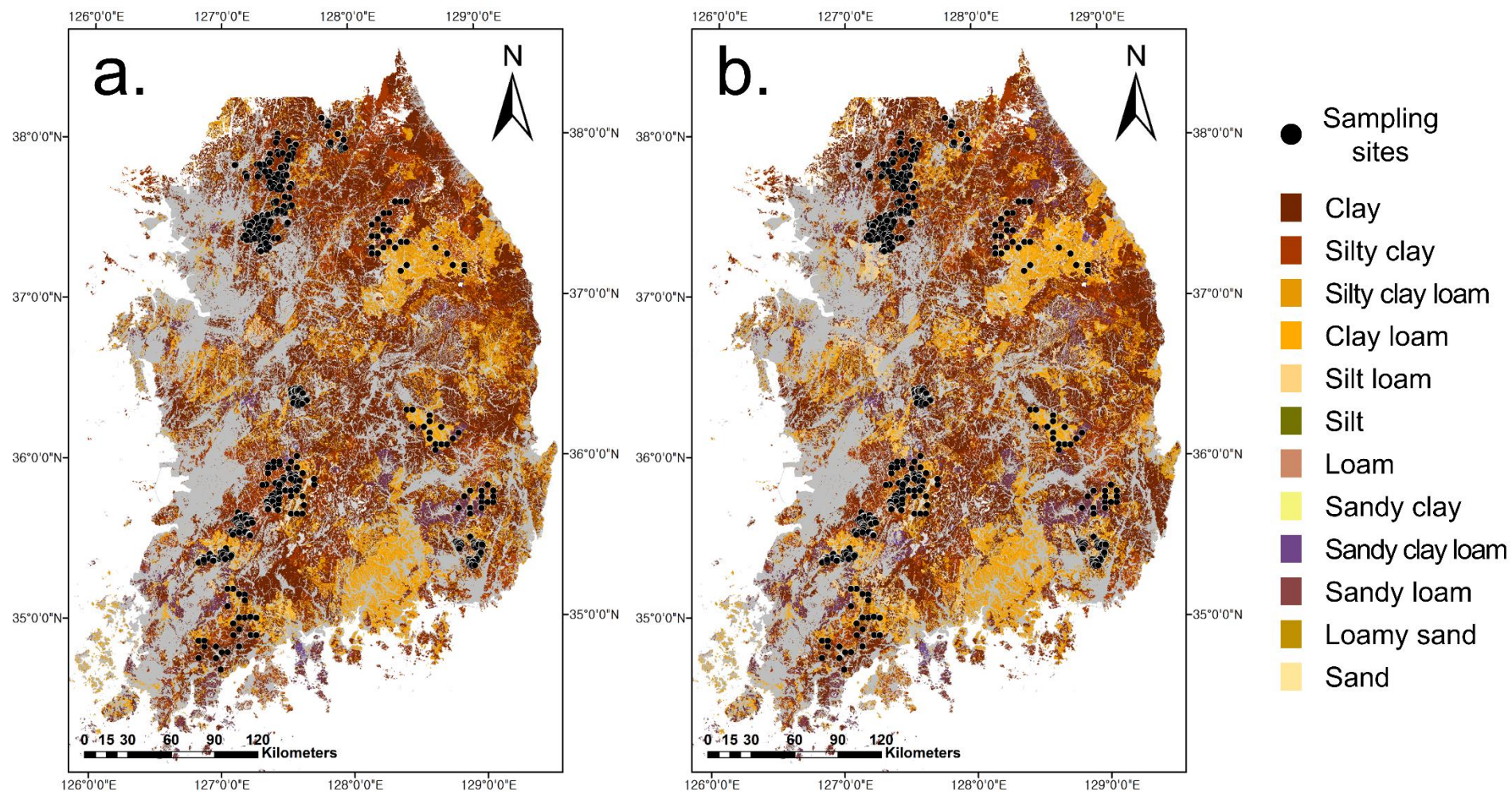
Soil layer Depth	pF	Importance measurements*	Elevation	Slope	Aspect	Catchment area	TWI	TPI	Profile curvature	Plan curvature	Bedrock
10 cm	0	Feature	0.380	0.044	0.104	0.019	0.028	0.052	0.041	0.045	0.012
		Permutation	0.666	0.005	0.085	0.000	0.002	0.010	0.005	0.005	0.007
	1.8	Feature	0.222	0.047	0.054	0.018	0.025	0.099	0.037	0.036	0.024
		Permutation	0.196	0.018	0.019	0.002	0.003	0.094	0.006	0.005	0.070
	2.7	Feature	0.270	0.035	0.053	0.015	0.024	0.067	0.030	0.030	0.017
		Permutation	0.335	0.003	0.018	0.001	0.002	0.036	0.003	0.003	0.022
30 cm	0	Feature	0.378	0.054	0.079	0.020	0.034	0.070	0.048	0.042	0.019
		Permutation	0.653	0.009	0.042	0.001	0.001	0.028	0.006	0.003	0.016
	1.8	Feature	0.183	0.042	0.043	0.018	0.024	0.100	0.029	0.028	0.047
		Permutation	0.194	0.010	0.017	0.002	0.002	0.066	0.003	0.002	0.118
	2.7	Feature	0.209	0.030	0.040	0.015	0.023	0.067	0.026	0.026	0.042
		Permutation	0.279	0.003	0.011	0.001	0.005	0.038	0.002	0.003	0.079

* Feature, feature importance; Permutation, permutation importance. Used models: DSM-10-pF0, DSM-10-pF1.8, DSM-10-pF2.7, DSM-30-pF0, DSM-30-pF1.8, and DSM-30-pF2.7.

Table S4. Variable importance of environmental covariates from forest type map and forest site and soil map.
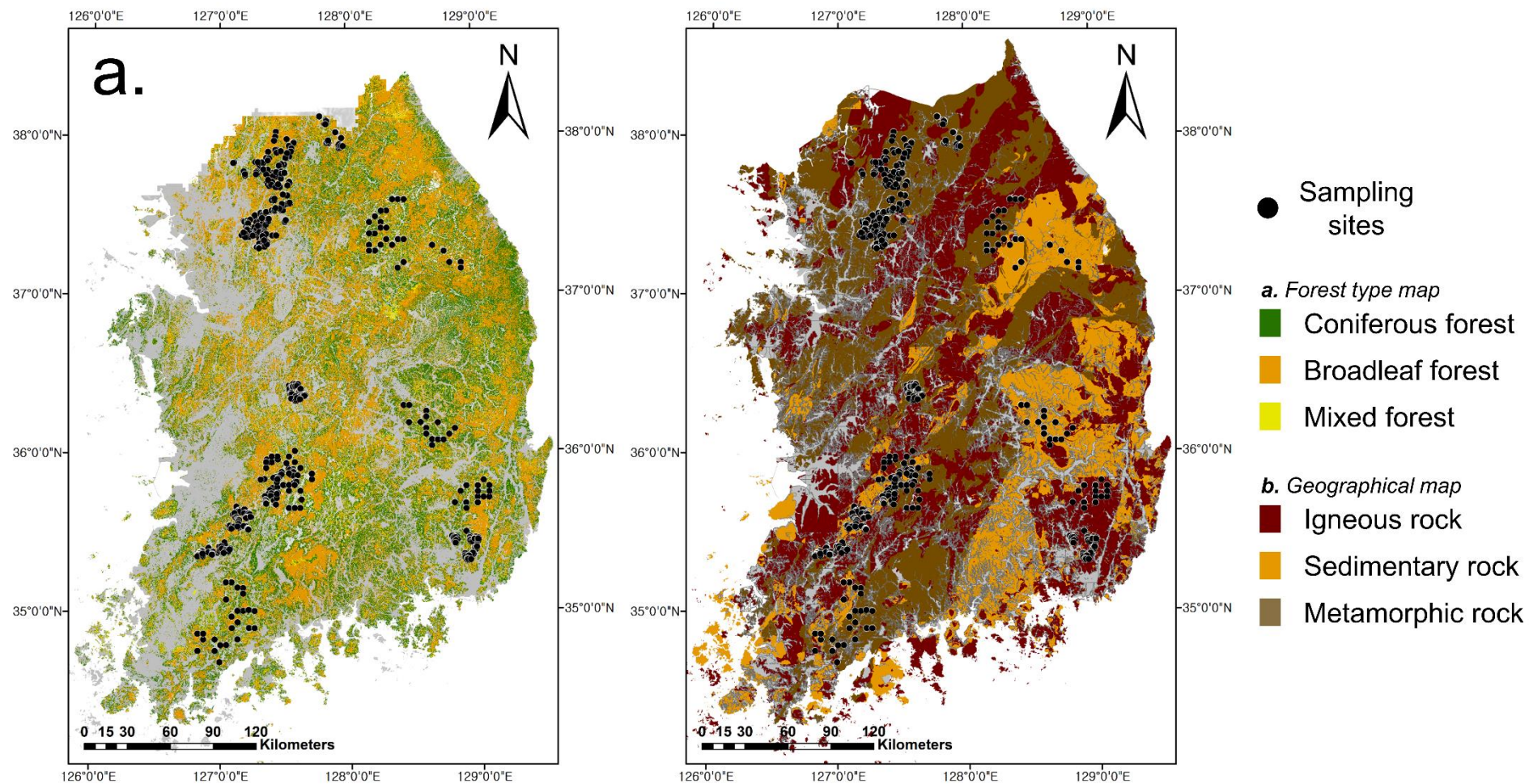
Soil layer Depth	pF	Importance measurements*	Forest type	TDC*	ADC*	FAC*	STC*	Soil depth	Stone contents	Hardness	Slope form	Rock exposure	Weathering	Landform
10 cm	0	Feature	0.026	0.003	0.007	0.017	0.067	0.060	0.013	0.039	0.007	0.008	0.010	0.018
		Permutation	0.035	0.000	0.001	0.004	0.077	0.028	0.006	0.053	0.001	0.001	0.003	0.006
	1.8	Feature	0.016	0.005	0.007	0.015	0.275	0.053	0.011	0.007	0.010	0.011	0.012	0.017
		Permutation	0.017	0.002	0.001	0.008	0.502	0.028	0.003	0.002	0.002	0.002	0.004	0.015
	2.7	Feature	0.012	0.004	0.006	0.015	0.319	0.047	0.008	0.007	0.012	0.008	0.012	0.011
		Permutation	0.013	0.001	0.001	0.009	0.521	0.022	0.002	0.003	0.002	0.001	0.001	0.002
30 cm	0	Feature	0.011	0.003	0.005	0.011	0.084	0.058	0.016	0.017	0.010	0.011	0.010	0.020
		Permutation	0.004	0.000	0.001	0.004	0.168	0.026	0.007	0.009	0.002	0.004	0.004	0.010
	1.8	Feature	0.008	0.003	0.005	0.012	0.349	0.046	0.016	0.011	0.006	0.011	0.008	0.011
		Permutation	0.003	0.001	0.001	0.006	0.524	0.024	0.008	0.003	0.001	0.006	0.002	0.004
	2.7	Feature	0.007	0.003	0.005	0.010	0.407	0.037	0.013	0.011	0.006	0.008	0.005	0.010
		Permutation	0.003	0.001	0.001	0.004	0.534	0.018	0.006	0.005	0.001	0.003	0.001	0.003

* Feature, feature importance; Permutation, permutation importance; TDC, tree density class; ADC, average DBH class; FAC, forest stand age class; STC, soil texture class. Used models: DSM-10-pF0, DSM-10-pF1.8, DSM-10-pF2.7, DSM-30-pF0, DSM-30-pF1.8, and DSM-30-pF2.7.
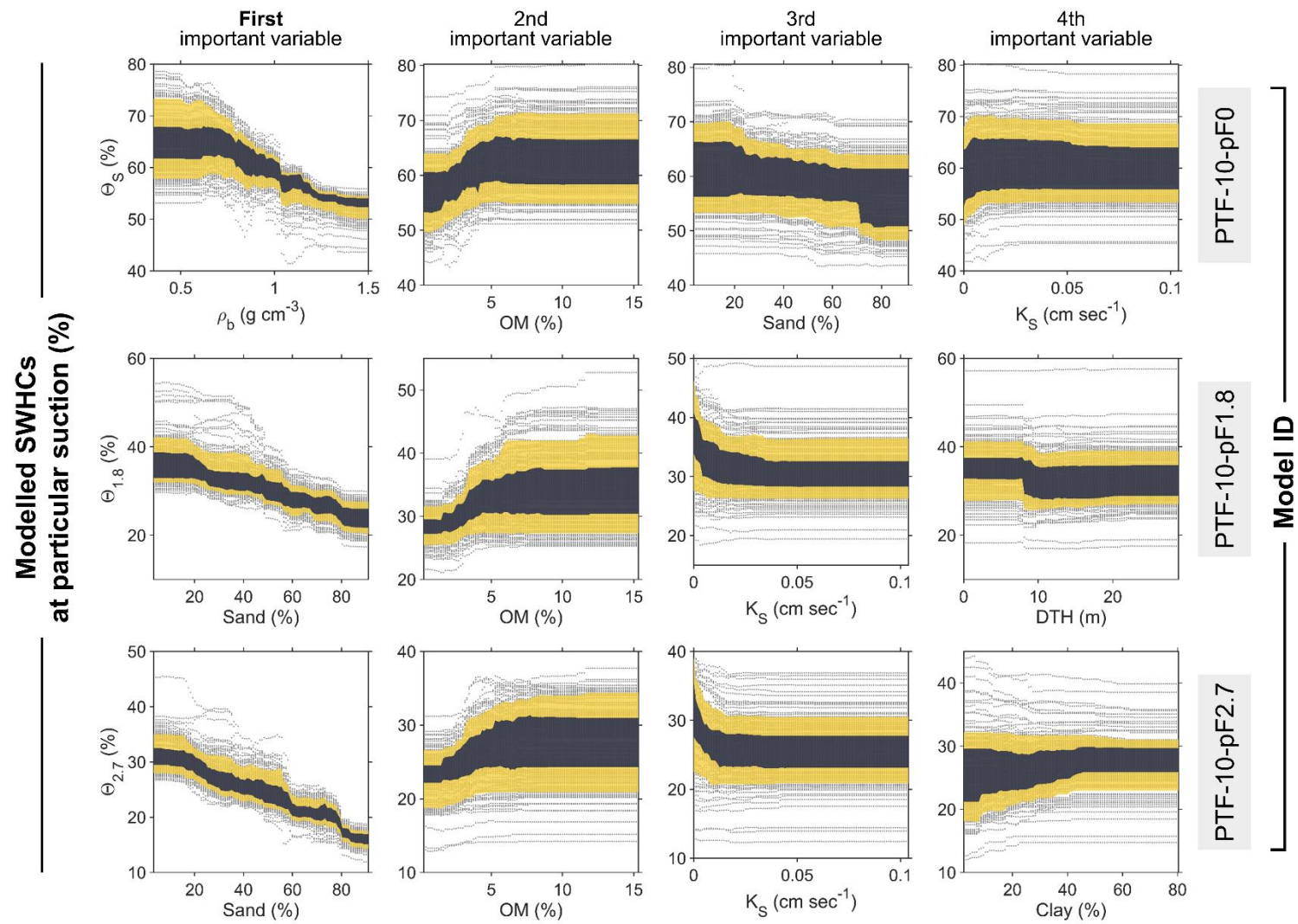
Figure S1. Spatial distribution of 971 soil sampling sites with soil texture map at (a) 10 cm soil depth and (b) 30 cm soil depth.
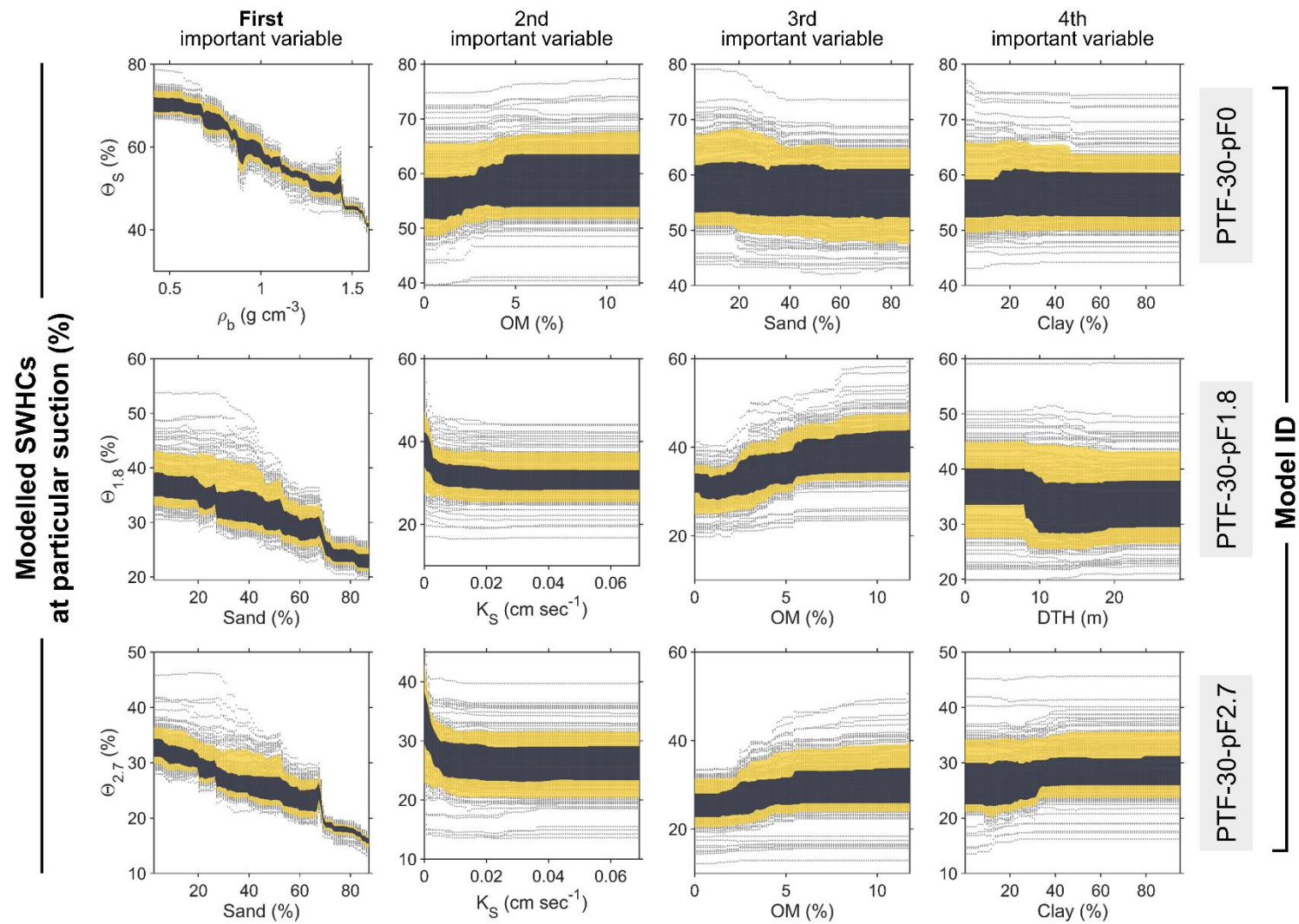
Figure S2. Spatial distribution of 971 soil sampling sites with (a) forest type map and (b) geographical map.
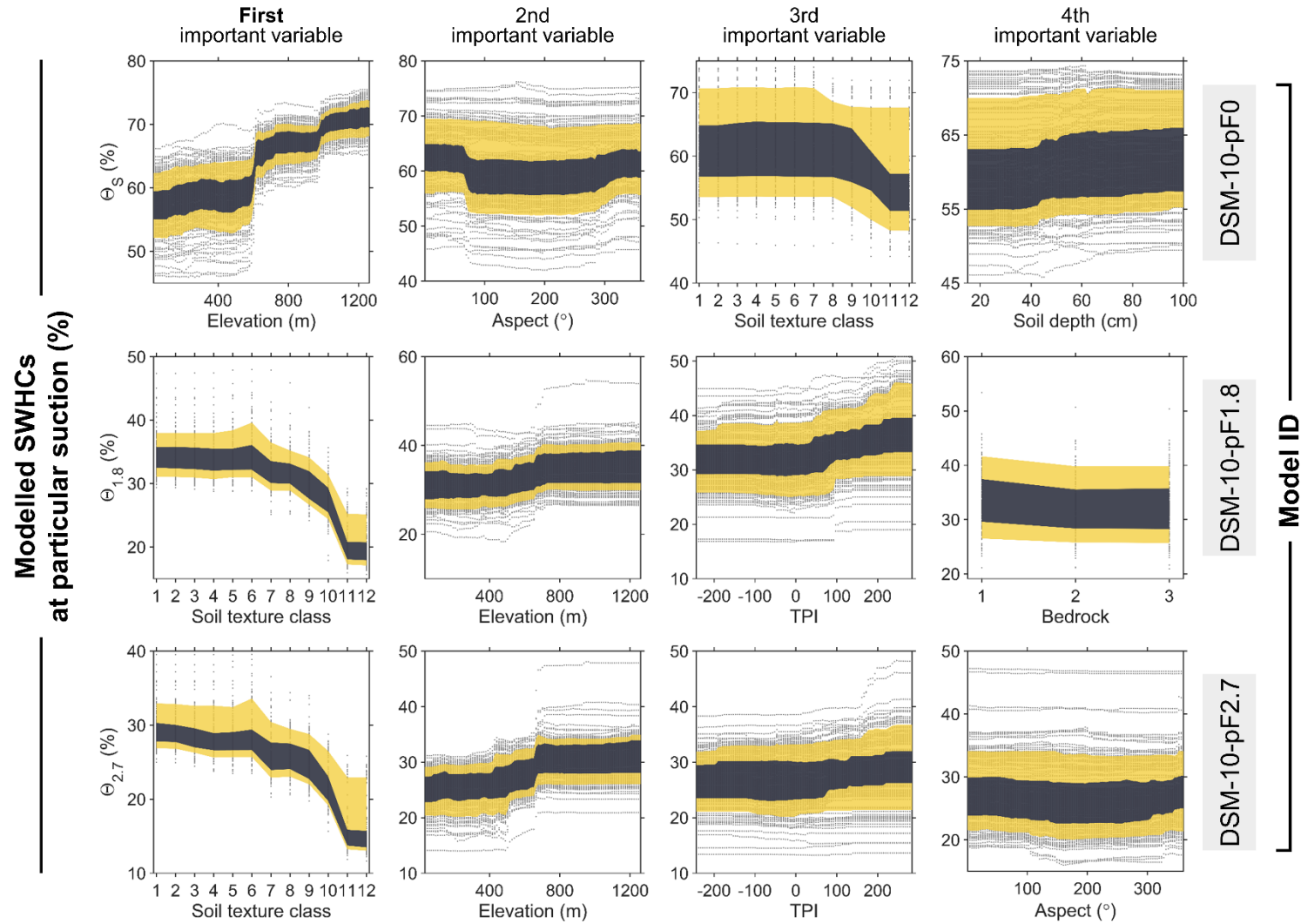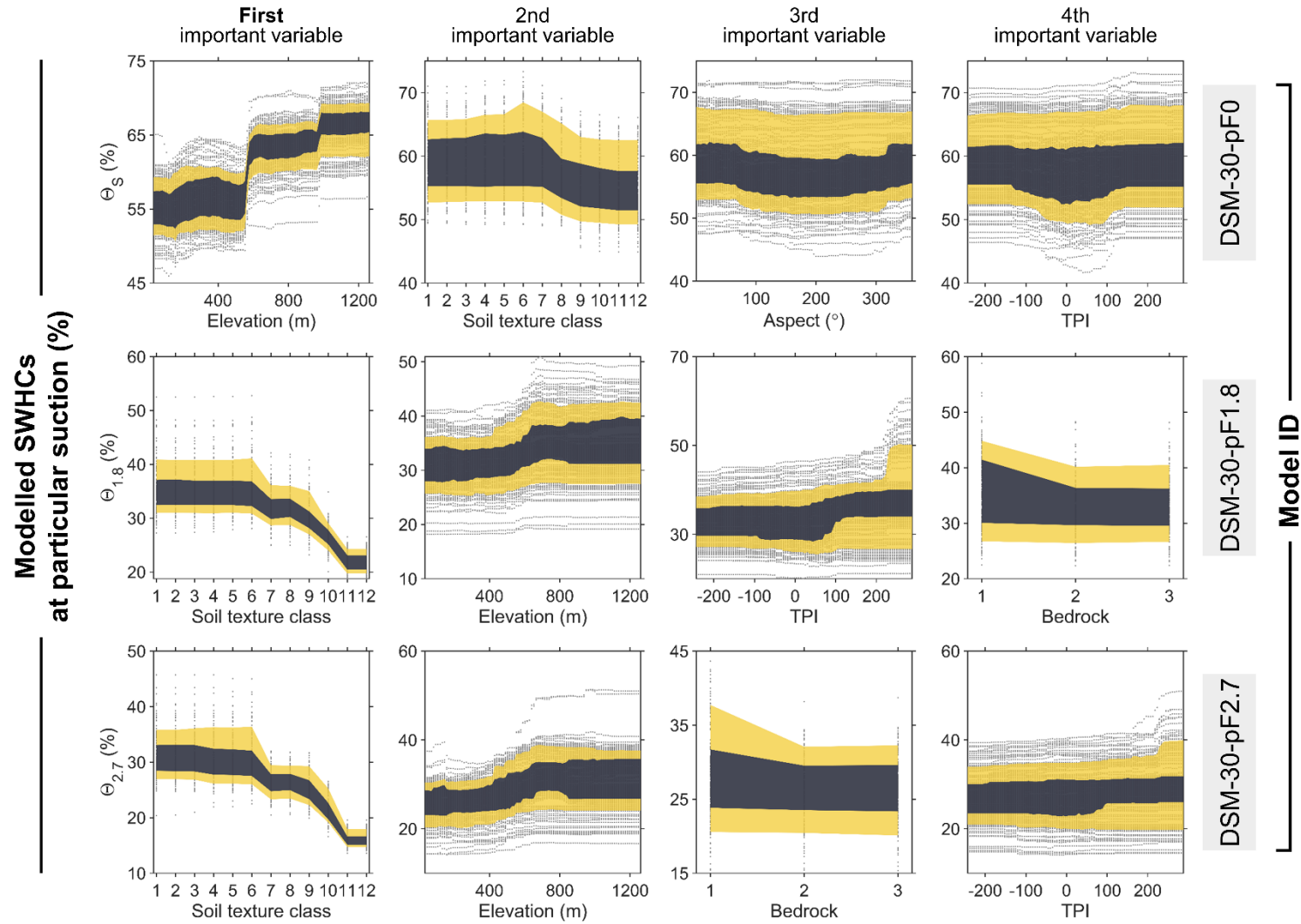
Figure S3. Modelled SWHCs changes across 4 important variables from sensitivity analysis and developed PTF models for soil depth at 10 cm.

Figure S4. Modelled SWHCs changes across 4 important variables from sensitivity analysis and developed PTF models for soil depth at 30 cm.

Figure S5. Modelled SWHCs changes across 4 important variables from sensitivity analysis and developed DSM models for soil depth at 10 cm. Soil texture class is 1: clay, 2: silty clay, 3: silty clay loam, 4: clay loam, 5: silt loam, 6: silt, 7: loam, 8: sandy clay, 9: sandy clay loam, 10: sandy loam, 11: loamy sand, and 12: sand. Bedrock is 1: igneous, 2: sedimentary, and 3: metamorphic rock.

Figure S6. Modelled SWHCs changes across 4 important variables from sensitivity analysis and developed DSM models for soil depth at 30 cm. Soil texture class is 1: clay, 2: silty clay, 3: silty clay loam, 4: clay loam, 5: silt loam, 6: silt, 7: loam, 8: sandy clay, 9: sandy clay loam, 10: sandy loam, 11: loamy sand, and 12: sand. Bedrock is 1: igneous, 2: sedimentary, and 3: metamorphic rock.

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