Supplementary Material

List of Figures

List of Tables

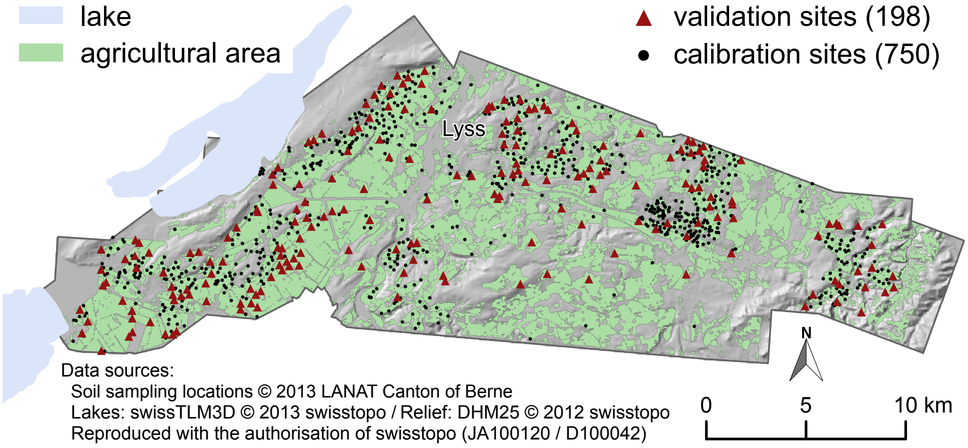

Figure S1: Location of sites in the Berne study region shown as an example for topsoil clay content (0–10 cm). Black dots are locations used for model calibration, locations with red triangles were used for model validation.

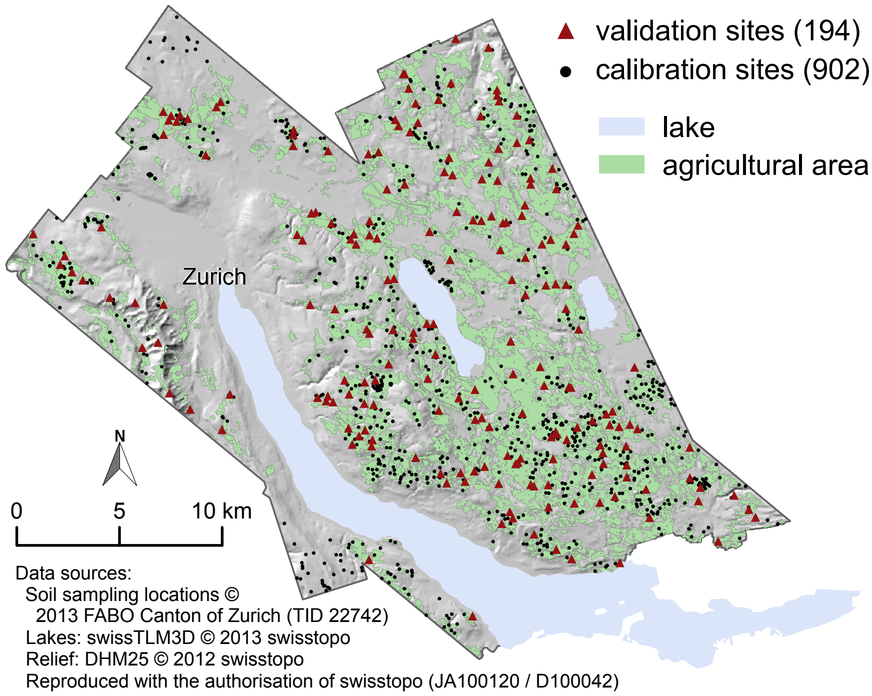

Figure S2: Location of sites in the Greifensee study region shown as an example for topsoil clay content (0–10 cm). Black dots are locations used for model calibration, locations with red triangles were used for model validation.

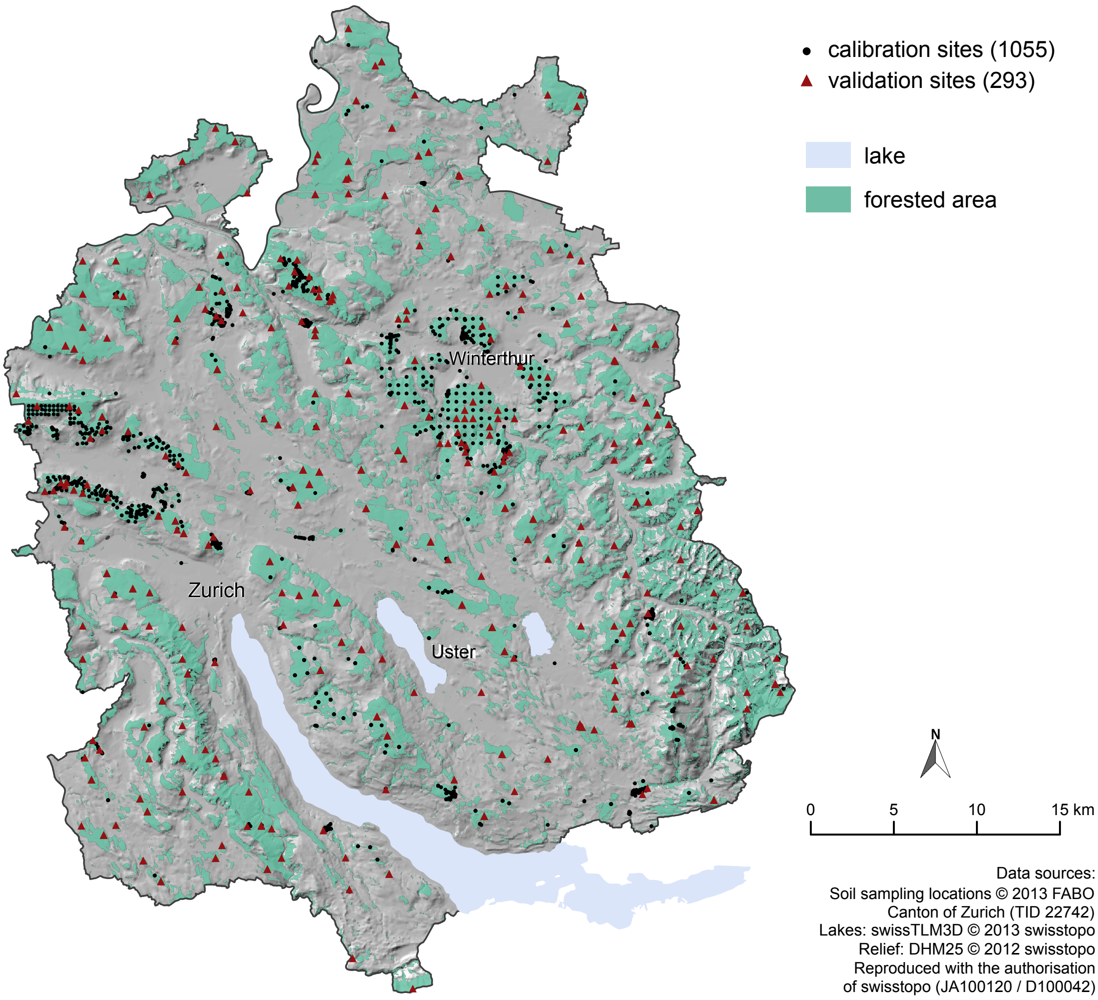

Figure S3: Location of sites in the ZH forest study region shown as an example for topsoil effective cation exchange capacity (ECEC, 0–20 cm). Black dots are locations used for model calibration, locations with red triangles were used for model validation.

Table S1: Details on soil analysis methods and remarks on soil data harmonization for modelled soil properties, more information can be found in Walthert et al. (2016) (F: percentage of field estimates, PTF: percentage of observations calculated by pedotransfer functions [PTF], a: study region Be: Berne, Gr: Greifensee, Zf: ZH forest, SOM: soil organic matter, SD: soil depth, BD: density of fine soil fraction $\leq$ 2 mm).

property	r	soil analysis method	soil data harmonization	F [%]	PTF [%]	unit
texture	Be, Gr	sedimentation (ELF, 1996; Ribi, 2014), field estimates (ordinal data, Brunner et al., 1997; Jäggli et al., 1998)	Accordance of field estimates and pipette measurements: RMSE 7.1–9.8 % for clay and 8.2–13.2 % for silt depending on source/survey (Walthert et al., 2016)	Be: 78 Gr: 48		wt.%
gravel	Be, Gr	volumetric content of coarse fragments > 2 mm estimated in the field (ordinal data, Brunner et al., 1997; Jäggli et al., 1998)		Be: 100 Gr: 100		vol.%
pH	Be, Gr, Zf	potentiometric measurements in H_2O or $CaCl_2$, partly field-moist samples (Zf), field estimates (ordinal data by pH indicator solution, ELF, 1996; Jäggli et al., 1998; Ribi, 2008; Walthert et al., 2004)	robust linear regression to transfer H_2O measurements to $CaCl_2$, calibrated on 227 samples (60 sites): $pH_{CaCl_2} = 1.00{*}pH_{H_2O} - 0.46$, RMSE 0.195, SS_{mse} 0.945 computed on 55 samples (12 sites) not used for model calibration. Accordance of field estimates and pH_{CaCl_2}: RMSE 0.521, SS_{mse} 0.726.	Be: 72 Zf: 30 (field-moist)	Be: 9 Gr: 10	–
SOM	Be, Gr	oxidation with $K_2Cr_2O_7$ / H_2SO_4 (ELF, 1996), field estimates (ordinal data, Brunner et al., 1997; Jäggli et al., 1998)	accordance of field estimates with measurements: RMSE 6.822 %, SS_{mse} 0.745 for Be, RMSE 3.51 %, SS_{mse} 0.786 for Gr.	Be: 77 Gr: 33		wt.%
ECEC	Zf	1 M ammonium chloride extraction (FAC, 1989; Walthert et al., 2004, 2013), 0.5 M ammonium acetate and 0.02 EDTA extraction at pH 4.65 (Lakanen and Erviö, 1971; ELF, 1996)	robust linear regression to estimate ECEC from Ca, Mg, K and Al measured by ammonium acetate/EDTA extraction with 604 samples (198 sites), R^2 0.939, RMSE 2.650 log $mmol_c$, computed on 142 samples (49 sites) not used for calibration (Nussbaum and Papritz, 2015).		Zf: 9	$mmol_c\,kg^{-1}$
SD	Be, Gr	Plant exploitable (effective) soil depth (SD) estimated in field (ordinal data, Jäggli et al., 1998)	SD derived from horizon thickness d_i, presence of waterlogging horizon qualifiers (g: $w_i = 0.33$, gg: $w_i = 0.33$, r: $w_i = 0.1$) and C horizon (parent material, $w = 0$) by $SD = \sum_{i=1}^{n} d_i\,(1 - s_i)\,w_i$ where $w_i = 1$ in case of absence of mentioned qualifiers and s_i volumetric gravel content [%] of horizon i.	Gr: 100	Be: 100	cm
BD	Zf[1]	density of fine soil faction (diameter $\leq$ 2 mm) sampled by volumetric cores (Brunner et al., 1997; Walthert et al., 2004)	robust linear regression with samples from Be, Gr and Swiss forests (Nussbaum et al., 2016) with SOM, soil depth and land use as covariates, calibrated on 757 samples (245 sites) with RMSE 0.253 Mg m^{-3}, SS_{mse} 0.508 computed on 279 samples (81 sites) not used for calibration. Where SOM was missing PTF with sampling depth and land use only, calibrated on 1040 samples (308 sites) with RMSE 0.333 Mg m^{-3}, SS_{mse} 0.147 computed on same 279 samples (latter PTF used only to transfer samples to comparable depth intervals).		Zf: 98	Mg m^{-3}

[1] BD was used in Be, Gr and Zf to convert data related to soil horizons to fixed-depth intervals (see Sect. 2.2).

Table S2: Details on geodata sets and derived covariates (r: pixel size for raster datasets or scale for vector datasets, a: limited to study region Be: Berne, Gr: Greifensee or Zf: ZH forest, n: number of covariates per dataset).

geodata set	r	a	n	description and details on covariate derivations
Soil				adapted 30 physiographic units of soil overview map (Nussbaum et al., 2014), evidence on drained wetlands from historic maps, presence of drainage networks on agricultural land, evidence on anthropogenic interventions in soil (e.g. soil ameliorations), potential for agricultural production for different crops.
Soil overview map (FSO, 2000a)	1:200000		8	
Wetlands Wild maps (ALN, 2002)	1:50000	Gr	1	
Wetlands Siegfried maps (Wüst-Galley et al., 2015)	1:25000	Gr	1	
Agricultural suitability (LANAT, 2015)	1:25000	Be	1	
Anthropogenic soil interventions (AWEL, 2012)	1:5000	Gr	1	
Drainage networks (ALN, 2014b)	1:5000	Gr	2	
Parent material				geological/geotechnical map units (partly aggregated a priori), sheets of geological map (Swisstopo, 2016) coarsely harmonized through legend matching and aggregation, $CaCO_3$ index based on geotechnical map (BAFU and GRID-Europe, 2010), closest distance between soil sampling point and geological line or polygon object on Zurich geological map (ALN, 2014a, drumlins, moraines of different glacial stages), approximate ice level during last glaciation, presence of aquifer, aquifer covered by impermeable layer, areas suitable for gravel exploitation.
Geological overview map (Swisstopo, 2005)	1:500000	Be	4	
Map of last glacial maximum (Swisstopo, 2009)	1:500000		1	
Geotechnical map (BFS, 2001)	1:200000		2	
Geological map (ALN, 2014a)	1:50'000		7	
Geological maps (Swisstopo, 2016)	1:25000	Be	1	
Groundwater map (AWEL, 2014; AWA, 2014b)	1:25000	Gr	2	
Hydrogeological infiltration zones (AWA, 2014a)	1:25000	Be	2	
Mineral raw materials (AGR, 2015)	1:25000	Be	1	
Climate				mean annual/monthly temperature and precipitation, cloud cover, sunshine duration, radiation, degree days, continentality index (Gams, 1935), temperature variation, ratio of actual to potential evapotranspiration and site water balance (Grier and Running, 1977; Gurtz et al., 1999), NH_3 concentration in air, NO_2 immissions of years 2000, 2005, 2010.
MeteoSwiss 1961–1990 (Zimmermann and Kienast, 1999)	25/100 m		33	
MeteoTest 1975–2010 (Remund et al., 2011)	250 m		38	
Air pollutants (BAFU, 2011)	500 m	Zf	2	
NO_2 immissions (AWEL, 2015)	100 m	Gr	3	
Vegetation				vegetation map units (aggregated a priori with ecograms), maximal potential to grow deciduous trees (vegetation map), percentage of coniferous trees derived from spectral imagery FSO (2000b) and species composition data of National Forest Inventory (Brassel and Lischke, 2001, NFI,), canopy height (difference of digital terrain to surface model), spectral reflectance in green, red, near infrared, band ratios, normalized difference vegetation index (NDVI, Kriegler et al., 1969) of SPOT5 and DMC, bands of Landsat7, 180 hyperspectral bands in solar reflected wavelength from 470 to 2420 nm of two fully processed and mosaiked (Jehle et al., 2010; Hueni et al., 2013) flight lines sampled by the APEX imaging spectrometer (flight campaings 09/2013, 04/2014, spectral resolution of 0.6–11 nm, Schaepman et al., 2015), with indicator covariate to account for different sampling dates (at overlap only mosaic from 04/2014 with contiguous larger area was used).
Landsat7 scene (USGS EROS, 2013)	30 m		9	
DMC mosaic (DMC, 2015)	22 m		4	
SPOT5 mosaic (Mathys and Kellenberger, 2009)	10 m	Zf	12	
APEX images (Schaepman et al., 2015)	2m	Gr,Be	180	
Share of coniferous trees (FSO, 2000b)	25 m	Zf	1	
Vegetation map (Schmider et al., 1993)	1:5000	Zf	2	
Species composition (Brassel and Lischke, 2001)	25 m	Zf	1	
Digital surface model (Swisstopo, 2011)	2 m	Zf	1	
Topography				elevation, slope angle, northing and easting aspects, planar, profile and combined curvatures (all with smoothed versions and standard deviations in circular neighbourhoods of different radii), topographic position indices (Zimmermann, 2000; Jenness, 2006), terrain ruggedness indices (Riley et al., 1999), roughness (Evans et al., 2014), dissection (Evans, 1972), surface to area ratio (Berry, 2002), multi-resolution valley bottom flatness (Gallant and Dowling, 2003), multi-resolution ridge top flatness (Gallant et al., 2013), positive and negative openness (Yokoyama et al., 2002), convergence indices (Kiss, 2004), LS factor (Van Remortel et al., 2004), vector ruggedness measure (Hobson, 1972), surface convexity (Iwahashi and Pike, 2007), flow accumulation area, flow length, topographic wetness indices by single and multi-flow algorithms (Tarboton, 1997) and vertical/horizontal distance to existing water bodies (BAFU, 2009, scale 1:25000).
Digital elevation model (Swisstopo, 2011)	25 m		62	
Digital terrain model (Swisstopo, 2013)	2 m		134	

Table S3: Descriptive statistics of soil properties for **Berne** study regions by soil depth [cm] (N: number of samples, Ns: number of sampling sites, set: calibration dataset (c), independent validation dataset (v), Min: observed minimum, Max: observed maximum, μ: mean, σ: standard deviation, SOM: soil organic matter, SD: effective soil depth, units see Table S1).

response	depth	set	N	Ns	Min	Max	Median	μ	σ
clay	0-10	c	750	750	0.000	65.690	15.000	17.396	7.316
		v	198	198	2.000	53.930	15.000	17.670	7.650
	10-30	c	771	771	0.000	76.200	15.000	17.919	8.383
		v	198	198	2.200	53.930	15.750	18.501	8.397
	30-50	c	733	733	0.000	76.200	16.180	18.433	9.145
		v	198	198	0.000	67.000	16.000	18.794	9.516
	50-100	c	741	741	0.000	76.200	16.000	17.832	9.864
		v	198	198	0.000	48.550	16.000	17.281	9.016
silt	0-10	c	753	753	2.000	75.000	25.000	27.581	10.531
		v	198	198	5.000	75.000	25.000	28.953	12.991
	10-30	c	776	776	1.800	75.000	25.000	28.505	11.541
		v	198	198	4.400	75.000	25.000	29.828	12.583
	30-50	c	736	736	2.000	75.000	26.000	29.807	12.618
		v	198	198	4.400	75.000	25.000	31.441	15.413
	50-100	c	743	743	2.000	75.000	27.143	31.004	15.261
		v	198	198	4.400	75.000	25.000	31.334	16.320
gravel	0-10	c	836	836	0.000	25.000	2.000	2.711	3.178
		v	198	198	0.000	15.000	2.000	2.556	2.773
	10-30	c	836	836	0.000	24.000	2.000	2.960	3.607
		v	198	198	0.000	29.000	2.000	2.907	3.676
	30-50	c	834	834	0.000	40.000	2.000	3.764	5.359
		v	198	198	0.000	50.000	2.000	3.705	5.455
	50-100	c	827	827	0.000	45.500	1.600	4.838	7.448
		v	198	198	0.000	51.000	2.100	4.779	6.660
SOM	0-10	c	788	788	0.300	61.900	4.000	8.470	10.251
		v	198	198	0.900	57.400	4.000	7.191	7.507
	10-30	c	787	787	0.490	65.400	2.900	8.630	12.785
		v	198	198	0.875	46.500	3.000	6.018	7.356
	30-50	c	702	702	0.000	81.100	1.000	10.532	18.674
		v	198	198	0.000	50.000	1.000	4.266	8.242
	50-100	c	480	480	0.000	85.000	1.000	15.711	25.414
		v	197	197	0.000	72.220	0.800	5.720	12.807
pH	0-10	c	728	661	4.500	8.500	6.300	6.375	0.761
		v	211	198	4.600	8.600	6.400	6.410	0.842
	10-30	c	723	657	4.400	8.500	6.304	6.371	0.755
		v	211	198	4.301	8.671	6.390	6.404	0.848
	30-50	c	713	647	4.300	8.700	6.400	6.414	0.803
		v	211	198	4.300	9.000	6.504	6.482	0.931
	50-100	c	716	650	3.676	9.100	6.500	6.472	0.875
		v	211	198	4.300	9.000	6.731	6.609	1.016
SD	–	c	838	838	12.750	224.000	70.000	72.946	31.454
		v	198	198	8.000	170.100	71.536	76.115	33.084

Table S4: Descriptive statistics of soil properties for **Berne** study region by soil depth [cm], continued (CV: coefficient of variation σ/μ, CV_r: robust coefficient of variation [ratio of inter quantile range to median], Skew: coefficient of skewness, α: effective range of experimental sample variogram [km], SSVR: spatially structured variance ratio $1 - nugget/sill_{tot}$, [Vaysse and Lagacherie, 2015], Tr: transformation of response, sqrt: transformed by square root, ln: transformed by natural logarithm, SOM: soil organic matter, SD: effective soil depth available to plants, units see Table S1).

response	depth	set	CV	CV_r	Skew	α	SSVR	Tr
clay	0-10	c	0.421	0.600	1.723	16.000	0.720	
		v	0.433	0.667	1.449			
	10-30	c	0.468	0.600	2.219	8.100	0.708	
		v	0.454	0.603	1.474			
	30-50	c	0.496	0.575	1.715	5.700	0.644	
		v	0.506	0.691	1.356			
	50-100	c	0.553	0.725	1.290	3.700	0.575	
		v	0.522	0.666	0.668			
silt	0-10	c	0.382	0.354	1.857	1.800	1.000	
		v	0.449	0.200	2.157			
	10-30	c	0.405	0.454	1.635	2.300	0.973	
		v	0.422	0.349	1.727			
	30-50	c	0.423	0.433	1.231	4.200	0.812	
		v	0.490	0.445	1.240			
	50-100	c	0.492	0.568	0.893	3.700	0.786	
		v	0.521	0.699	1.068			
gravel	0-10	c	1.172	1.000	2.545	8.900	0.613	sqrt
		v	1.085	1.500	2.205			
	10-30	c	1.219	1.625	2.377	8.900	0.436	sqrt
		v	1.265	1.694	3.212			
	30-50	c	1.424	2.500	2.543	4.700	0.529	sqrt
		v	1.472	2.500	4.286			
	50-100	c	1.540	4.375	2.421	2.400	0.910	sqrt
		v	1.394	3.298	2.771			
SOM	0-10	c	1.210	0.750	2.233	4.100	0.888	ln
		v	1.044	0.956	2.914			
	10-30	c	1.481	1.138	2.225	3.800	0.918	ln
		v	1.222	1.137	2.533			
	30-50	c	1.773	6.244	1.894	2.600	0.974	ln
		v	1.932	2.250	3.215			
	50-100	c	1.618	23.420	1.375	2.200	1.000	ln
		v	2.239	2.344	3.006			
pH	0-10	c	0.119	0.190	0.082	2.900	0.640	
		v	0.131	0.203	0.081			
	10-30	c	0.119	0.186	0.047	6.200	0.592	
		v	0.132	0.216	0.053			
	30-50	c	0.125	0.188	-0.065	4.500	0.634	
		v	0.144	0.230	-0.029			
	50-100	c	0.135	0.185	-0.253	4.500	0.671	
		v	0.154	0.229	-0.225			
SD	–	c	0.431	0.703	0.464	–	–	
		v	0.435	0.663	0.488			

Table S5: Descriptive statistics of soil properties for **Greifensee** study region by soil depth [cm] (N: number of samples, Ns: number of sampling sites, set: calibration dataset (c), independent validation dataset (v), Min: observed minimum, Max: observed maximum, μ: mean, σ: standard deviation, SOM: soil organic matter, SD: effective soil depth, units see Table S1).

response	depth	set	N	Ns	Min	Max	Median	μ	σ
clay	0-10	c	913	902	8.000	59.520	25.000	26.412	7.402
		v	194	194	12.000	48.700	25.000	25.242	7.023
	10-30	c	913	902	8.000	58.750	25.150	26.434	7.386
		v	194	194	12.000	59.400	25.000	25.505	7.626
	30-50	c	864	853	6.400	64.200	25.420	26.637	8.174
		v	183	183	9.150	46.259	25.000	25.506	8.021
	50-100	c	852	841	2.400	60.400	25.585	25.912	8.970
		v	183	183	2.884	47.620	25.160	24.988	9.168
silt	0-10	c	913	902	12.300	60.000	31.990	32.383	6.189
		v	198	198	12.250	55.000	32.000	32.664	6.855
	10-30	c	913	902	17.000	60.000	32.000	32.524	6.273
		v	198	198	12.250	55.000	32.002	32.728	6.854
	30-50	c	866	855	15.000	65.900	32.250	33.312	7.365
		v	198	198	1.500	61.400	32.000	32.856	8.062
	50-100	c	852	841	4.600	71.000	33.000	34.239	9.062
		v	198	198	7.700	69.000	32.025	32.867	9.093
gravel	0-10	c	743	743	0.000	35.000	6.000	7.534	6.365
		v	193	193	0.000	25.000	8.000	8.580	6.095
	10-30	c	744	744	0.000	35.000	7.500	8.120	6.691
		v	193	193	0.000	25.000	9.000	9.333	6.489
	30-50	c	739	739	0.000	56.250	8.400	9.967	8.795
		v	195	195	0.000	41.000	11.000	11.619	8.920
	50-100	c	719	719	0.000	65.000	11.240	12.707	10.901
		v	195	195	0.000	60.000	14.200	14.952	11.909
SOM	0-10	c	1255	1141	0.900	32.000	4.400	5.285	3.264
		v	453	277	1.000	44.700	4.820	5.554	3.653
	10-30	c	1165	1051	0.500	49.000	4.000	4.803	3.673
		v	453	277	1.000	44.700	4.600	5.315	3.731
	30-50	c	723	689	0.000	65.000	1.000	2.278	4.957
		v	134	119	0.000	38.600	1.480	2.806	5.659
	50-100	c	443	409	0.000	68.188	1.000	2.198	5.935
		v	134	119	0.000	51.700	1.400	2.867	6.841
pH	0-10	c	1210	1078	3.286	8.082	6.718	6.535	0.616
		v	452	277	4.220	7.800	6.200	6.209	0.730
	10-30	c	1121	989	3.286	7.805	6.686	6.521	0.621
		v	452	277	4.220	7.642	6.199	6.224	0.730
	30-50	c	412	379	4.431	8.137	6.794	6.671	0.720
		v	135	119	3.886	8.286	6.531	6.433	0.722
	50-100	c	371	338	4.164	8.383	6.775	6.708	0.713
		v	135	119	3.886	8.286	6.597	6.494	0.723
SD	–	c	745	745	19.000	204.000	65.000	67.032	23.270
		v	198	198	12.000	184.000	66.000	70.394	22.820

Table S6: Descriptive statistics of soil properties for **Greifensee** by soil depth [cm], continued (CV: coefficient of variation σ/μ, CV_r: robust coefficient of variation [ratio of inter quantile range to median], Skew: coefficient of skewness, α: effective range of experimental sample variogram [km], SSVR: spatially structured variance ratio $1 - nugget/sill_{tot}$, [Vaysse and Lagacherie, 2015], Tr: transformation of response, sqrt: transformed by square root, ln: transformed by natural logarithm, SOM: soil organic matter, SD: effective soil depth available to plants, units see Table S1).

response	depth	set	CV	CV_r	Skew	α	SSVR	Tr
clay	0-10	c	0.280	0.315	1.007	4.800	0.465	
		v	0.278	0.349	0.703			
	10-30	c	0.279	0.330	0.932	5.400	0.475	
		v	0.299	0.450	0.894			
	30-50	c	0.307	0.401	0.519	1.500	0.485	
		v	0.314	0.465	0.278			
	50-100	c	0.346	0.462	0.166	3.200	0.381	
		v	0.367	0.517	0.022			
silt	0-10	c	0.191	0.217	0.883	3.300	0.425	
		v	0.210	0.248	0.452			
	10-30	c	0.193	0.236	0.842	2.600	0.498	
		v	0.209	0.266	0.439			
	30-50	c	0.221	0.272	0.808	3.100	0.357	
		v	0.245	0.290	0.392			
	50-100	c	0.265	0.328	0.774	2.300	0.515	
		v	0.277	0.318	0.566			
gravel	0-10	c	0.845	1.667	0.939	1.400	0.525	sqrt
		v	0.710	1.125	0.474			
	10-30	c	0.824	1.333	0.799	1.600	0.426	sqrt
		v	0.695	1.056	0.436			
	30-50	c	0.883	1.536	1.115	1.400	0.519	sqrt
		v	0.768	1.000	0.767			
	50-100	c	0.858	1.406	0.927	1.900	0.530	sqrt
		v	0.796	1.206	0.879			
SOM	0-10	c	0.618	0.550	3.395	2.500	0.611	ln
		v	0.658	0.521	5.392			
	10-30	c	0.765	0.708	4.091	3.400	0.747	ln
		v	0.702	0.602	5.207			
	30-50	c	2.176	1.200	6.289	3.800	0.123	ln
		v	2.017	0.579	4.866			
	50-100	c	2.701	1.641	6.064	1.500	0.998	ln
		v	2.386	0.643	5.455			
pH	0-10	c	0.094	0.134	-0.855	1.700	0.734	
		v	0.118	0.198	-0.146			
	10-30	c	0.095	0.138	-0.813	2.200	0.692	
		v	0.117	0.198	-0.157			
	30-50	c	0.108	0.173	-0.505	2.400	0.540	
		v	0.112	0.158	-0.492			
	50-100	c	0.106	0.158	-0.536	2.200	0.542	
		v	0.111	0.153	-0.490			
SD	–	c	0.347	0.569	0.896	3.300	0.267	
		v	0.324	0.481	0.824			

Table S7: Descriptive statistics of soil properties of **ZH forest** by soil depth [cm] (N: number of samples, Ns: number of sampling sites, set: calibration dataset (c), independent validation dataset (v), Min: observed minimum, Max: observed maximum, μ: mean, σ: standard deviation, CV: coefficient of variation σ/μ, CV_r: robust coefficient of variation, [ratio of inter quantile range to median], Skew: coefficient of skewness, α: effective range of experimental sample variogram [km], SSVR: spatially structured variance ratio $1 - nugget/sill_{tot}$, [Vaysse and Lagacherie, 2015], Tr: transformation of response, ln: transformed by natural logarithm, ECEC: effective cation exchange capacity, units see Table S1).

response	depth	set	N	Ns	Min	Max	Median	μ	σ	CV	CV_r	Skew	α	SSVR	Tr
ECEC	0-20	c	1316	1055	17.364	780.000	149.333	170.157	100.202	0.589	0.952	1.169	1.100	1.000	ln
		v	528	293	17.760	492.385	121.382	150.404	94.018	0.625	1.002	1.077			
	40-60	c	545	379	22.673	361.191	124.671	129.479	67.608	0.522	0.896	0.491	0.500	0.923	ln
		v	269	119	27.318	326.885	113.804	120.929	64.282	0.532	0.831	0.790			
pH	0-20	c	1804	1475	2.585	7.650	4.842	5.137	1.352	0.263	0.539	0.262	3.200	0.890	
		v	561	293	2.786	7.400	4.374	4.781	1.131	0.237	0.395	0.757			
	40-60	c	953	693	3.050	7.810	5.165	5.269	1.282	0.243	0.480	0.198	5.700	0.491	
		v	329	119	3.240	7.740	5.221	5.350	1.313	0.245	0.495	0.202			
BD	0-20	c	780	551	0.411	1.510	0.870	0.870	0.066	0.076	0.079	0.788	62.700	0.631	
		v	294	119	0.659	1.129	0.855	0.855	0.059	0.069	0.070	0.203			
	40-60	c	469	368	0.908	1.550	1.133	1.140	0.060	0.053	0.046	1.885	0.400	0.887	
		v	201	119	1.028	1.537	1.133	1.138	0.055	0.049	0.035	3.113			

Table S8: Cross-validation (CV) statistics for models by study region and soil depth computed on the same CV subsets for all methods, except for RF where out-of-bag predictions were used. (RMSE: root mean squared error [units see Table S1], SS_{mse} : mean squared error skill score, lasso: grouped least absolute shrinkage and selection operator, georob: robust external-drift kriging, geoGAM: geoadditive model, BRT: boosted regression trees, RF: random forest, MA: model average, NA: no convergence of georob algorithm).

	depth	lasso		georob		geoGAM		BRT		RF		MA	
	[cm]	RMSE	SS_{mse}	RMSE	SS_{mse}	RMSE	SS_{mse}	RMSE	SS_{mse}	RMSE	SS_{mse}	RMSE	SS_{mse}
Berne													
clay	0-10	6.418	0.230	5.592	0.415	5.623	0.408	5.814	0.368	4.569	0.609	5.264	0.482
	10-30	7.855	0.121	6.762	0.348	7.124	0.277	6.952	0.311	5.333	0.595	6.394	0.417
	30-50	8.735	0.087	7.615	0.306	7.530	0.321	7.938	0.246	6.125	0.551	7.189	0.381
	50-100	9.848	0.002	8.669	0.227	9.002	0.166	9.085	0.150	6.960	0.501	8.259	0.298
silt	0-10	10.518	0.001	9.286	0.221	9.379	0.206	9.351	0.210	7.444	0.500	8.732	0.311
	10-30	11.157	0.064	9.955	0.255	9.996	0.249	10.216	0.215	7.884	0.533	9.342	0.344
	30-50	11.387	0.184	10.094	0.359	10.333	0.328	10.546	0.301	8.101	0.587	9.538	0.428
	50-100	14.032	0.153	12.826	0.293	13.095	0.263	13.769	0.185	10.165	0.556	12.132	0.367
gravel	0-10	2.997	0.110	2.425	0.417	2.714	0.270	2.848	0.196	2.138	0.547	2.474	0.393
	10-30	3.284	0.170	2.703	0.438	2.807	0.393	3.079	0.270	2.322	0.585	2.663	0.454
	30-50	4.990	0.132	4.336	0.345	4.613	0.258	4.616	0.257	3.641	0.538	4.246	0.371
	50-100	7.220	0.059	6.310	0.281	6.367	0.268	6.785	0.169	5.195	0.513	6.071	0.335
SOM	0-10	6.712	0.571	5.025	0.759	5.472	0.715	5.059	0.756	3.969	0.850	4.662	0.793
	10-30	8.507	0.557	6.318	0.755	6.579	0.735	6.669	0.728	5.082	0.842	5.866	0.789
	30-50	19.559	-0.099	12.337	0.563	14.695	0.380	9.781	0.725	7.863	0.822	9.229	0.755
	50-100	27.293	-0.156	43.426	-1.926	23.872	0.116	14.125	0.690	10.760	0.820	13.879	0.701
pH	0-10	0.533	0.509	0.458	0.637	0.483	0.597	0.500	0.567	0.391	0.736	0.447	0.655
	10-30	0.541	0.486	0.467	0.617	0.495	0.570	0.495	0.570	0.389	0.735	0.447	0.649
	30-50	0.610	0.423	0.524	0.574	0.535	0.556	0.550	0.531	0.423	0.722	0.488	0.630
	50-100	0.681	0.393	0.582	0.557	0.606	0.519	0.613	0.508	0.471	0.710	0.541	0.617
SD	–	28.790	0.161	26.782	0.274	27.097	0.257	27.992	0.207	21.012	0.553	25.148	0.360
Greifensee													
clay	0-10	6.423	0.246	5.986	0.345	5.985	0.345	6.055	0.330	4.735	0.590	5.564	0.434
	10-30	6.438	0.239	5.999	0.340	6.000	0.339	6.258	0.281	4.832	0.571	5.631	0.418
	30-50	7.738	0.103	7.047	0.256	6.992	0.267	7.409	0.178	5.555	0.538	6.603	0.347
	50-100	8.602	0.079	7.899	0.224	7.976	0.208	8.259	0.151	6.229	0.517	7.376	0.323
silt	0-10	6.001	0.059	5.384	0.242	5.436	0.228	5.663	0.162	4.327	0.511	5.088	0.323
	10-30	6.109	0.051	5.590	0.205	5.570	0.211	5.779	0.151	4.429	0.501	5.241	0.301
	30-50	7.144	0.058	6.603	0.195	6.725	0.165	6.944	0.110	5.205	0.500	6.210	0.288
	50-100	8.877	0.039	8.092	0.202	8.471	0.125	8.714	0.074	6.588	0.471	7.791	0.260
gravel	0-10	5.985	0.115	5.552	0.238	5.575	0.232	5.797	0.169	4.471	0.506	5.182	0.336
	10-30	6.229	0.132	5.646	0.287	5.725	0.267	6.145	0.155	4.651	0.516	5.386	0.351
	30-50	8.144	0.142	8.045	0.162	7.606	0.251	7.900	0.192	6.112	0.516	7.161	0.336
	50-100	10.481	0.074	9.326	0.267	9.708	0.206	9.964	0.163	7.640	0.508	8.944	0.326
SOM	0-10	3.046	0.128	2.630	0.350	3.921	-0.444	2.915	0.202	2.210	0.541	2.588	0.371
	10-30	3.468	0.107	3.068	0.302	4.249	-0.339	3.314	0.185	2.396	0.574	2.934	0.361
	30-50	4.932	0.009	4.631	0.126	4.915	0.016	4.666	0.113	3.329	0.548	4.290	0.250
	50-100	6.206	-0.096	NA	NA	12.140	-3.193	5.152	0.245	3.966	0.553	5.023	0.282
pH	0-10	0.549	0.204	0.461	0.438	0.518	0.291	0.500	0.338	0.379	0.620	0.447	0.472
	10-30	0.546	0.225	0.462	0.445	0.519	0.302	0.513	0.316	0.386	0.614	0.450	0.475
	30-50	0.632	0.228	0.546	0.423	0.581	0.347	0.640	0.208	0.470	0.573	0.533	0.451
	50-100	0.623	0.234	0.520	0.468	0.634	0.207	0.604	0.282	0.461	0.580	0.522	0.463
SD	–	20.759	0.203	19.560	0.292	18.526	0.365	20.105	0.253	15.433	0.560	17.715	0.420
Zurich													
ECEC	0-20	83.288	0.309	68.589	0.524	73.800	0.431	73.661	0.451	53.449	0.711	66.399	0.554
	40-60	50.873	0.433	37.079	0.699	46.296	0.530	40.890	0.634	31.315	0.785	38.965	0.667
pH	0-20	0.939	0.517	0.785	0.663	0.874	0.582	0.841	0.613	0.619	0.790	0.748	0.694
	20-60	0.943	0.458	0.719	0.685	0.786	0.624	0.775	0.635	0.581	0.795	0.680	0.719
bd	0-20	0.059	0.205	0.049	0.449	0.053	0.352	0.051	0.415	0.038	0.670	0.046	0.515
	20-60	0.051	0.282	0.044	0.462	0.045	0.430	0.053	0.218	0.039	0.575	0.043	0.489

Table S9: Ratio [%] of squared bias to mean squared error (MSE) calculated for independent validation data (leg. map: legacy soil map 1:5 000, lasso: grouped least absolute shrinkage and selection operator, georob: robust external-drift kriging, geoGAM: geoadditive model, BRT: boosted regression trees, RF: random forest, MA: model average, NA: no convergence of georob algorithm).

area	response	depth [cm]	leg. map	lasso	georob	geoGAM	BRT	RF	MA
Berne	clay	0-10		0.497	2.795	2.396	1.272	0.924	1.695
		10-30		0.570	1.556	1.206	0.025	0.280	0.764
		30-50		0.045	0.077	0.190	0.022	0.057	0.026
		50-100		0.377	0.753	1.198	1.551	1.897	1.305
	silt	0-10		1.035	3.832	0.036	0.129	0.184	0.540
		10-30		0.736	1.064	0.055	0.090	0.041	0.202
		30-50		0.281	0.751	0.000	0.024	0.000	0.017
		50-100		0.058	0.444	0.376	0.747	0.938	0.504
	gravel	0-10		3.690	0.390	0.233	1.455	2.247	0.053
		10-30		3.643	0.573	0.470	0.248	1.145	0.052
		30-50		5.153	1.241	0.051	1.053	1.003	0.028
		50-100		8.369	1.106	0.103	0.760	1.133	0.057
	SOM	0-10		2.042	0.353	0.362	0.704	1.061	0.068
		10-30		0.105	1.180	0.032	2.794	5.486	1.609
		30-50		8.433	0.934	0.103	8.350	14.196	4.245
		50-100		12.137	1.425	2.393	7.269	10.268	1.388
	pH	0-10		0.883	0.242	0.562	0.126	0.313	0.402
		10-30		0.778	0.194	0.227	0.222	0.379	0.353
		30-50		1.515	0.039	0.731	0.019	0.352	0.272
		50-100		3.605	0.308	1.155	0.447	3.288	1.667
	SD	–		2.059	4.671	2.808	3.002	3.003	2.841
Greifen-see	clay	0-10	10.500	0.897	1.341	1.120	0.497	1.063	1.038
		10-30	12.700	0.198	0.177	0.299	0.065	0.234	0.200
		30-50	11.500	1.080	0.000	0.020	0.018	0.122	0.117
		50-100	14.300	0.495	0.056	0.027	0.001	0.007	0.007
	silt	0-10		0.071	0.002	0.036	0.000	0.014	0.001
		10-30		0.029	0.042	0.000	0.370	0.007	0.042
		30-50		0.300	0.104	0.213	0.488	0.459	0.312
		50-100		2.079	0.981	1.265	1.545	1.924	1.594
	gravel	0-10	26.900	13.198	5.548	0.200	0.004	0.570	2.240
		10-30	19.800	14.220	0.067	0.264	0.687	1.141	1.842
		30-50	9.600	14.539	6.562	1.379	1.477	1.519	4.158
		50-100	0.400	16.701	7.589	1.385	2.463	2.081	5.164
	SOM	0-10		5.954	0.002	3.532	0.766	0.759	1.388
		10-30		8.024	0.217	2.789	0.981	0.432	1.181
		30-50		6.717	3.632	5.074	0.470	0.719	2.684
		50-100		5.775	NA	0.028	1.402	1.291	1.739
	pH	0-10		6.285	4.702	4.252	4.931	6.038	5.532
		10-30		4.715	4.694	4.600	4.023	5.564	5.084
		30-50		6.604	4.615	5.982	5.020	7.798	6.450
		50-100		5.570	2.378	2.897	5.097	5.551	4.438
	SD	–	4.400	0.064	1.064	0.003	0.007	0.798	0.261
ZH forest	ECEC	0-20		2.839	1.540	0.707	0.692	0.754	0.243
		40-60		0.244	10.645	1.484	4.575	3.755	5.355
	pH	0-20		1.116	1.348	0.314	0.460	2.414	1.202
		40-60		0.687	3.136	1.623	0.143	0.000	0.094
	BD	0-20		4.475	0.043	0.033	0.040	0.407	0.189
		40-60		0.181	0.672	0.154	0.198	1.352	0.000

Table S10: Optimal model parameters selected by minimizing RMSE in 10-fold cross-validation or out-of-bag for RF for **Berne** study region by soil depth [cm] (λ: lasso shrinkage parameter, p_l: number of covariates with non-zero coefficients, p_g: number of covariates in final georob model, σ_n^2: nugget effect, σ_p^2: partial sill, α: effective range [m], ψ: robustness tuning parameter, p_{tot}: total number of covariates in final geoGAM, p_s: number of smooth effects in final geoGAM, n_t: number of boosting iterations in BRT, i: interaction depth, pp: percentage of covariates with non-zero importance, m_{try}: number of covariates randomly sampled as candidates at each split in RF).

		lasso		georob					geoGAM		BRT			RF	model averaging weights				
response	depth	λ	p_l	p_g	σ_n^2	σ_p^2	α	ψ	p_{tot}	p_s	n_t	i	pp	m_{try}	lasso	georob	geoGAM	BRT	RF
clay	0-10	0.617	16	14	19.26	21.46	26870.2	1.75	17	15	98	5	44.9	273	0.172	0.198	0.197	0.190	0.242
	10-30	0.869	12	39	22.55	1.34×10^4	1.71×10^7	1.75	5	3	40	6	26.3	325	0.170	0.198	0.188	0.193	0.251
	30-50	1.204	7	9	33.84	22.90	6998.3	1.75	12	10	48	3	17.7	191	0.171	0.197	0.199	0.189	0.244
	50-100	1.969	1	28	37.41	34.66	1073.0	1.75	7	7	14	20	33.4	304	0.175	0.198	0.191	0.189	0.247
silt	0-10	1.303	5	6	28.71	39.30	1.44×10^4	1.75	5	3	28	8	27.0	75	0.173	0.196	0.194	0.194	0.244
	10-30	1.021	13	7	39.16	47.43	1.25×10^4	1.75	7	2	30	11	34.8	181	0.174	0.195	0.194	0.190	0.246
	30-50	0.784	16	22	59.69	48.07	7072.1	1.75	7	3	32	11	36.7	113	0.175	0.197	0.193	0.189	0.246
	50-100	1.226	15	16	94.59	65.43	1290.7	1.75	8	3	24	20	44.9	274	0.180	0.197	0.193	0.183	0.248
gravel	0-10	0.052	26	28	0.33	0.20	2897.5	1.75	10	2	84	7	47.6	119	0.174	0.212	0.186	0.183	0.244
	10-30	0.058	28	22	0.35	0.23	2928.3	1.75	15	9	152	3	44.1	92	0.172	0.206	0.195	0.184	0.243
	30-50	0.106	15	21	0.62	0.25	3759.9	1.75	10	4	22	18	39.9	109	0.177	0.200	0.187	0.192	0.243
	50-100	0.138	20	26	0.89	0.51	3644.3	1.75	13	6	38	7	30.1	131	0.176	0.197	0.193	0.188	0.245
SOM	0-10	0.033	24	29	0.09	0.10	2385.7	1.75	11	5	184	5	56.5	141	0.153	0.204	0.182	0.203	0.258
	10-30	0.039	29	34	0.14	0.09	1857.4	1.75	13	8	106	6	49.5	337	0.153	0.206	0.191	0.195	0.256
	30-50	0.537	5	16	0.60	1.78×10^4	3.98×10^9	1.75	14	10	150	5	53.0	384	0.119	0.189	0.157	0.238	0.296
	50-100	0.566	11	11	6.32	2.42×10^5	1.52×10^9	1.75	11	6	118	5	45.6	116	0.161	0.002	0.118	0.311	0.408
pH	0-10	0.045	20	22	0.12	0.13	1114.7	1.75	13	5	250	1	27.7	232	0.176	0.204	0.194	0.187	0.240
	10-30	0.040	30	20	0.13	0.13	1176.6	1.75	7	1	100	6	48.6	121	0.174	0.202	0.191	0.191	0.243
	30-50	0.045	30	19	0.20	0.14	3541.3	1.75	10	6	144	9	64.0	391	0.171	0.199	0.195	0.189	0.246
	50-100	0.041	26	34	0.12	0.24	416.9	1.75	19	12	190	14	74.8	288	0.171	0.200	0.192	0.190	0.247
SD	–	1.782	25	22	619.62	101.10	4634.1	1.75	10	4	28	16	42.3	183	0.181	0.194	0.192	0.186	0.247

Table S11: Model parameters for **Greifensee** and **ZH forest** study regions (for description see Table S10, NA: no convergence of georob algorithm).

		lasso		georob					geoGAM		BRT			RF	model averaging weights				
response	layer	λ	p_l	p_g	σ_n^2	σ_p^2	α	ψ	p_{tot}	p_s	n_t	i	pp	m_{try}	lasso	georob	geoGAM	BRT	RF
Greifensee																			
clay	0-10	0.517	21	25	3.29	33.37	279.4	1.75	12	5	134	2	30.0	455	0.180	0.193	0.193	0.191	0.244
	10-30	0.514	22	27	4.82	31.90	259.2	3.00	11	5	44	8	37.8	245	0.182	0.195	0.195	0.187	0.242
	30-50	0.930	11	26	1.72	48.34	158.1	1.75	10	7	32	14	44.4	273	0.177	0.195	0.196	0.185	0.247
	50-100	0.836	13	25	51.10	16.52	7074.3	1.75	17	15	164	1	21.6	225	0.179	0.195	0.193	0.186	0.247
silt	0-10	0.656	6	27	6.02	22.59	279.3	1.75	15	12	28	11	34.1	316	0.177	0.197	0.195	0.187	0.245
	10-30	0.662	7	25	1.42	30.36	237.0	1.75	11	8	16	42	51.8	414	0.178	0.194	0.195	0.188	0.245
	30-50	0.798	8	37	2.26	40.87	233.0	1.75	7	5	40	9	37.1	256	0.180	0.195	0.192	0.186	0.248
	50-100	1.224	4	38	6.40	60.18	270.8	1.75	6	4	12	12	21.8	413	0.181	0.199	0.190	0.185	0.244
gravel	0-10	0.111	20	22	1.19	0.00	3.6	1000.00	10	4	36	10	41.0	212	0.183	0.193	0.191	0.189	0.245
	10-30	0.100	22	24	0.11	1.05	191.7	1000.00	11	5	48	3	20.0	284	0.182	0.197	0.193	0.184	0.244
	30-50	0.128	21	43	1.45	0.41	2244.8	1.75	10	6	40	2	12.0	410	0.185	0.184	0.193	0.191	0.247
	50-100	0.163	19	20	1.56	0.72	1339.3	1.75	11	6	44	2	13.1	53	0.180	0.197	0.188	0.189	0.246
SOM	0-10	0.021	38	48	0.01	0.14	240.8	1.75	27	22	90	20	71.7	168	0.179	0.207	0.180	0.187	0.247
	10-30	0.036	21	49	0.01	0.19	279.5	1.75	19	14	24	18	40.2	147	0.175	0.198	0.191	0.183	0.253
	30-50	0.077	39	6	0.46	0.16	2739.5	1.75	14	12	12	11	15.7	78	0.178	0.190	0.178	0.189	0.264
	50-100	0.596	11	NA	NA	NA	NA	NA	11	8	36	16	44.8	382	0.250	0.000	0.057	0.301	0.392
pH	0-10	0.030	35	36	0.04	0.25	214.1	1.75	17	11	160	10	72.1	250	0.173	0.205	0.183	0.189	0.250
	10-30	0.031	29	42	0.04	0.24	260.9	1.75	16	9	134	7	62.3	131	0.175	0.207	0.184	0.186	0.248
	30-50	0.045	28	25	0.03	0.29	279.8	1.75	11	8	32	6	26.8	50	0.179	0.208	0.195	0.177	0.241
	50-100	0.061	25	25	0.04	0.27	319.5	1.75	7	1	86	3	30.3	98	0.180	0.216	0.177	0.186	0.243
SD	–	0.712	49	45	32.38	323.81	6.0	1000.00	14	11	44	5	27.9	384	0.180	0.191	0.202	0.186	0.242
Zurich																			
ECEC	0-20	0.023	33	45	0.01	0.19	207.4	1.75	11	6	72	42	75.3	128	0.170	0.200	0.185	0.187	0.257
	40-60	0.014	53	59	0.01	0.09	211.7	1.75	13	3	124	16	85.7	120	0.158	0.216	0.173	0.196	0.256
pH	0-20	0.029	46	38	0.05	0.79	89.0	1.75	20	16	96	18	81.2	127	0.169	0.203	0.182	0.189	0.257
	40-60	0.029	44	41	0.07	0.77	188.8	1.75	30	24	780	2	77.3	138	0.157	0.206	0.189	0.192	0.256
bd	0-20	0.007	8	26	0.00	0.00	276.6	1.75	7	2	36	18	65.0	320	0.166	0.199	0.184	0.193	0.258
	40-60	0.009	6	9	0.00	0.00	1048.4	1.75	4	3	24	7	32.1	290	0.181	0.209	0.203	0.173	0.235

References

AGR: Geoprodukt Geologische Rohstoffkarte ADT, Metadaten komplett. Amt für Gemeinden und Raumordnung des Kantons Bern, www.be.ch/geoportal, last access: 04.04.2017, 2015.

ALN: Historische Feuchtgebiete der Wildkarte 1850. Amt für Landschaft und Natur des Kantons Zürich, http://www.aln.zh.ch/internet/baudirektion/aln/de/naturschutz/naturschutzdaten/geodaten.html, last access 29.03.2017, 2002.

ALN: Geologische Karte des Kantons Zürich nach Hantke et. al 1967, GIS-ZH Nr. 41. Amt für Landschaft und Natur des Kantons Zürich, http://www.gis.zh.ch/Dokus/Geolion/gds_41.pdf, last access: 15.02.2015, 2014a.

ALN: Meliorationskataster des Kantons Zürich, GIS-ZH Nr. 148. Amt für Landschaft und Natur des Kantons Zürich., http://www.geolion.zh.ch/geodatensatz/show?nbid=387, last access 29.03.2017, 2014b.

AWA: Geoprodukt Versickerungszonen VSZ, Metadaten komplett. Amt für Wasser und Abfall des Kantons Bern, www.be.ch/geoportal, last access: 04.04.2017, 2014a.

AWA: Geoprodukt Grundwasserkarte GW25, Metadaten komplett.Amt für Wasser und Abfall des Kantons Bern, www.be.ch/geoportal, last access: 04.04.2017, 2014b.

AWEL: Hinweisflächen für anthropogene Böden, GIS-ZH Nr. 260. Amt für Abfall, Wasser, Energie und Luft des Kanton Zürich, http://www.geolion.zh.ch/geodatensatz/show?nbid=985, last access 29.03.2017, 2012.

AWEL: Grundwasservorkommen, GIS-ZH Nr. 327. Amt für Abfall, Wasser, Energie und Luft des Kanton Zürich, http://www.geolion.zh.ch/geodatensatz/show?nbid=723, last access 29.03.2017, 2014.

AWEL: NO_2-Immissionen, GIS-ZH Nr. 82, Amt für Abfall, Wasser, Energie und Luft des Kanton Zürich, http://geolion.zh.ch/geodatensatz/show?nbid=783, last access 29.03.2017, 2015.

BAFU: Strukturierung und Adressierung des Gewässernetzes 1:25'000 nach Modell gwn25-07. Bundesamt für Umwelt, http://www.bafu.admin.ch/wasser/13462/13496/15011, last accessed 07.06.2016, 2009.

BAFU: Luftbelastung: Karten Jahreswerte, Ammoniak und Stickstoffdeposition, Jahresmittel 2007 (modelliert durch METEOTEST), http://www.bafu.admin.ch/luft/luftbelas-tung/schadstoffkarten, last access 15.02.2015, 2011.

BAFU and GRID-Europe: Swiss Environmental Domains. A new spatial framework for reporting on the environment, Environmental studies 1024, Federal Office for the Environment FOEN, Berne, URL http://www.bafu.admin.ch/publikationen/publikation/01564/index.html?lang=en, 2010.

Berry, J.: Use surface area for realistic calculations?, Geoworld, 15, 2002.

BFS: GEOSTAT Benützerhandbuch, Bundesamt für Statistik, Bern, 2001.

Brassel, P. and Lischke, H., eds.: Swiss National Forest Inventory: Methods and models of the second assessment, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, 2001.

Brunner, J., Jäggli, F., Nievergelt, J., and Peyer, K.: Kartieren und Beurteilen von Landwirtschaftsböden, FAL Schriftenreihe 24, Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz (FAL), 1997.

DMC: Disaster Monitoring Constellation International Imaging, http://www.dmcii.com, last access: 03.02.2015, 2015.

ELF: Schweizerische Referenzmethoden der Forschungsanstalten Agroscope – Boden- und Substratuntersuchungen zur Düngeberatung, Loseblattordner E1.011.d 1, Forschungsanstalten Agroscope ART und ACW, Zürich und Changins, Ausgabe 1996 mit Änderungen von 1997 bis 2009, Version 2015, Methode "AAE-10", 1996.

Evans, I. S.: General geomorphometry, derivatives of altitude, and descriptive statistics, in: Spatial Analysis in Geomorphology, edited by Chorley, R. J., pp. 17–90, Harper & Row, 1972.

Evans, J. S., Oakleaf, J., and Cushman, S.: A Toolbox for Surface Gradient Modeling, http://evansmurphy.wix.com/evansspatial, last accessed 04.04.2017, 2014.

FAC: Methoden für Bodenuntersuchungen, no. 5 in Schriftenreihe der FAC, Liebefeld, Eidgenössische Forschungsanstalt für Agrikulturchemie und Umwelthygiene (FAC), 1989.

FSO: Swiss soil suitability map. BFS GEOSTAT. Swiss Federal Statistical Office, `http://www.bfs.admin.ch/bfs/portal/de/index/dienstleistungen/geostat/datenbeschreibung/digitale_bodeneignungskarte.html`, last access 15.02.2015, 2000a.

FSO: Tree composition of Swiss forests. BFS GEOSTAT. Swiss Federal Statistical Office, `http://www.bfs.admin.ch/bfs/portal/de/index/dienstleistungen/geostat/datenbeschreibung/waldmischungsgrad.html`, last access 15.02.2015, 2000b.

Gallant, J., Dowling, T., and Austin, J.: Multi-resolution Ridge Top Flatness (MrRTF, 3" resolution). v1, CSIRO. Data Collection, doi:10.4225/08/512EEA6332EEB, 2013.

Gallant, J. C. and Dowling, T. I.: A multiresolution index of valley bottom flatness for mapping depositional areas, Water Resour Res, 39, doi:10.1029/2002WR001426, 2003.

Gams, H.: Zur Geschichte, klimatischen Begrenzung und Gliederung der immergrünen Mittelmeerstufe, Veröff. Geobot. Eidgenöss. Tech. Hochsch., Stift. Rübel Zürich, 12, 163–204, 1935.

Grier, C. G. and Running, S. W.: Leaf Area of Mature Northwestern Coniferous Forests: Relation to Site Water Balance, Ecology, 58, 893 – 899, doi:10.2307/1936225, 1977.

Gurtz, J., Baltensweiler, A., and Lang, H.: Spatially distributed hydrotope based modelling of evapotranspiration and runoff in mountainous basins, Hydrol Processes, 13, 2751–2768, 1999.

Hobson, R. D.: Surface roughness in topography: a quantitative approach, in: Spatial analysis in geomorphology, edited by Chorley, R. J., pp. 221–245, Harper & Row, 1972.

Hueni, A., Lenhard, K., Baumgartner, A., and Schaepman, M. E.: Airborne prism experiment calibration information system, IEEE Trans Geosci Remote Sens, 51, 5169–5180, doi:10.1109/tgrs.2013.2246575, 2013.

Iwahashi, J. and Pike, R. J.: Automated classifications of topography from DEMs by an unsupervised nested-means algorithm and a three-part geometric signature, Geomorphology, 86, 409–440, doi:10.1016/j.geomorph.2006.09.012, 2007.

Jäggli, F., Peyer, K., Pazeller, A., and Schwab, P.: Grundlagenbericht zur Bodenkartierung des Kantons Zürich, Tech. rep., Volkswirtschaftsdirektion des Kantons Zürich und Eidg. Forschungsanstalt für Agrarökologie und Landbau Zürich Reckenholz FAL, 1998.

Jehle, M., Hueni, A., Damm, A., D'Odorico, P., Weyermann, J., Kneubühler, M., and Meuleman, K.: APEX – current status, performance and validation concept, in: Sensors, 2010 IEEE, pp. 533–537, doi:10.1109/ICSENS.2010.5690122, 2010.

Jenness, J.: Topographic Position Index (TPI) v. 1.2, `http://www.jennessent.com`, last access: 04.04.2017, 2006.

Kiss, R.: Determination of drainage network in digital elevation models, utilities and limitations, Journal of Hungarian Geomathematic, 2, 2004.

Kriegler, F. J., Malila, W. A., Nalepka, R. F., and Richardson, W.: Preprocessing Transformations and Their Effects on Multispectral Recognition, in: Remote Sensing of Environment, VI, p. 97, 1969.

Lakanen, E. and Erviö, R.: A comparison of eight extractants for the determination of plant available micronutrients in soils, Acta Agralia Fennica, 123, 223–232, 1971.

LANAT: Geoprodukt Landwirtschaftliche Eignungskarte LWEK74, Metadaten komplett. Amt für Landwirtschaft und Natur, Kanton Bern, URL `http://files.be.ch/bve/agi/geoportal/geo/lpi/LWEK74_1974_01_LANG_DE.PDF`, last access: 04.04.2017, 2015.

Mathys, L. and Kellenberger, T.: Spot5 RadcorMosaic of Switzerland, Tech. rep., National Point of Contact for Satellite Images NPOC: Swisstopo; Remote Sensing Laboratories, University of Zurich, Zurich, 2009.

Nussbaum, M. and Papritz, A.: Transferfunktionen Nährstoffmesswerte, Bericht, ETH Zürich, Soil and Terrestrial Environmental Physics, doi:10.3929/ethz-a-010810702, version 2, mit kl. Änderung 27. Nov. 2016, 2015.

Nussbaum, M., Papritz, A., Baltensweiler, A., and Walthert, L.: Estimating soil organic carbon stocks of Swiss forest soils by robust external-drift kriging, Geosci Model Dev, 7, 1197–1210, doi:10.5194/gmd-7-1197-2014, 2014.

Nussbaum, M., Papritz, A., Zimmerman, S., and Walthert, L.: Pedotransfer function to predict density of forest soils in Switzerland, J Plant Nutr Soil Sci, 179, 321–326, doi:10.1002/jpln.201500546, 2016.

Remund, J., Frehner, M., Walthert, L., Kägi, M., and Rihm, B.: Schätzung standortspezifischer Trockenstressrisiken in Schweizer Wäldern, 2011.

Ribi, A.: Messung des pH-Wertes in einer Boden-$CaCl_2$-Suspension, Standard-Arbeitsanweisung Labor AN 104 (Version 2), Gewässerschutzlabor Amt für Abfall, Wasser, Energie und Luft, Baudirektion Kanton Zürich (Prüfleiter: Christian Balsiger), Zürich, 2008.

Ribi, A.: Körnung der Feinerde, Standard-Arbeitsanweisung Labor FB 122 (Version 1), Fachstelle Bodenschutz, Amt für Landschaft und Natur, Baudirektion Kanton Zürich (Prüfleiter: Ubald Gasser), Zürich, 2014.

Riley, S., De Gloria, S., and Elliot, R.: A Terrain Ruggedness that Quantifies Topographic Heterogeneity, Intermountain Journal of Science, 5, 23–27, 1999.

Schaepman, M., Jehle, M., Hueni, A., D'Odorico, P., Damm, A., Weyermann, J., Schneider, F., Laurent, V., Popp, C., Seidel, F., Lenhard, K., Gege, P., Küchler, C., Brazile, J., Kohler, P., Vos, L., Meuleman, K., Meynart, R., Schläpfer, D., and Itten, K.: Advanced radiometry measurements and Earth science applications with the Airborne Prism Experiment (APEX), Remote Sens Environ, 158, 207–219, doi:10.1016/j.rse.2014.11.014, 2015.

Schmider, P., Küper, M., Tschander, B., and Käser, B.: Die Waldstandorte im Kanton Zürich Waldgesellschaften, Waldbau Naturkunde, vdf Verlag der Fachvereine an den schweizerischen Hochschulen und Techniken, Zürich, 1993.

Swisstopo: Geologische Karte der Schweiz 1:500000, URL `http://www.swisstopo.admin.ch/internet/swisstopo/de/home/products/maps/geology/geomaps/gm500.html`, last access: 07.06.2016, 2005.

Swisstopo: Switzerland during the Last Glacial Maximum 1:500 000, URL `http://www.swisstopo.admin.ch/internet/swisstopo/en/home/products/maps/geology/geomaps/LGM-map500.html`, last access: 07.06.2016, 2009.

Swisstopo: Höhenmodelle, URL `http://www.swisstopo.admin.ch/internet/swisstopo/de/home/products/height.html`, last access: 07.06.2016, 2011.

Swisstopo: swissAlti3D. Das hoch aufgelöste Terrainmodell der Schweiz, `http://www.swisstopo.admin.ch/internet/swisstopo/de/home/products/height/swissALTI3D.html`, last access: 07.06.2016, 2013.

Swisstopo: GeoCover, Zugang zu flächendeckende geologische Datensätze für alle, URL `https://shop.swisstopo.admin.ch/de/products/maps/geology/GC_VECTOR`, last access: 14.11.2016, 2016.

Tarboton, D. G.: A new Method for the Determination of Flow Directions and Upslope Areas in Grid Digital Elevation Models, Water Resour Res, 33, PP. 309–319, doi:199710.1029/96WR03137, 1997.

USGS EROS: USGS Land Remote Sensing Program, Landsat 7 Scene 01.09.2013. U.S. Geological Survey's Earth Resources Observation and Science Center, 2013.

Van Remortel, R. D., Maichle, R. W., and Hickey, R. J.: Computing the LS factor for the Revised Universal Soil Loss Equation through array-based slope processing of digital elevation data using a C++ executable, Computers and Geosciences, 30, 1043–1053, doi:10.1016/j.cageo.2004.08.001, 2004.

Vaysse, K. and Lagacherie, P.: Evaluating Digital Soil Mapping approaches for mapping GlobalSoilMap soil properties from legacy data in Languedoc-Roussillon (France), Geoderma Regional, 4, 20–30, doi:10.1016/j.geodrs.2014.11.003, 2015.

Walthert, L., Zimmermann, S., Blaser, P., Luster, J., and Lüscher, P.: Waldböden der Schweiz. Band 1. Grundlagen und Region Jura, Eidg. Forschungsanstalt WSL and Hep Verlag, Birmensdorf and Bern, 2004.

Walthert, L., Pannatier, E. G., and Meier, E. S.: Shortage of nutrients and excess of toxic elements in soils limit the distribution of soil-sensitive tree species in temperate forests, For Ecol Manage, 297, 94–107, doi:10.1016/j.foreco.2013.02.008, 2013.

Walthert, L., Bridler, L., Keller, A., Lussi, M., and Grob, U.: Harmonisierung von Bodendaten im Projekt "Predictive mapping of soil properties for the evaluation of soil functions at regional scale (PMSoil)" des Nationalen Forschungsprogramms Boden (NFP 68), Bericht, Eidgenössische Forschungsanstalt WSL und Agroscope Reckenholz, Birmensdorf und Zürich, doi: 10.3929/ethz-a-010801994, 2016.

Wüst-Galley, C., Grünig, A., and Leifeld, J.: Locating organic soils for the Swiss greenhouse gas inventory, Agroscope Science 26, Agroscope, Zurich, URL https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/klima-climatereporting-referenzen-cp2/wuest-galley_c_gruenigaleifeldj2015.pdf.download.pdf, last access: 29.03.2017, 2015.

Yokoyama, R., Shirasawa, M., and Pike, R. J.: Visualizing Topography by Openness: A New Application of Image Processing to Digital Elevation Models, Photogramm Eng Remote Sens, 68, 257–265, 2002.

Zimmermann, N. E.: Calculation of Topographic Position, http://www.wsl.ch/staff/niklaus.zimmermann/programs/aml4_1.html, last access: 15.02.2015, 2000.

Zimmermann, N. E. and Kienast, F.: Predictive mapping of alpine grasslands in Switzerland: Species versus community approach, J Veg Sci, 10, 469–482, doi:10.2307/3237182, 1999.