

Fig. S1. Relationship of gross protein depolymerization and gross microbial amino acid uptake in cropland($r=0.9451$, $p<0.001$), grassland ($r=0.983$, $p<0.001$) and woodland ($r=0.965$, $p<0.001$) soils.

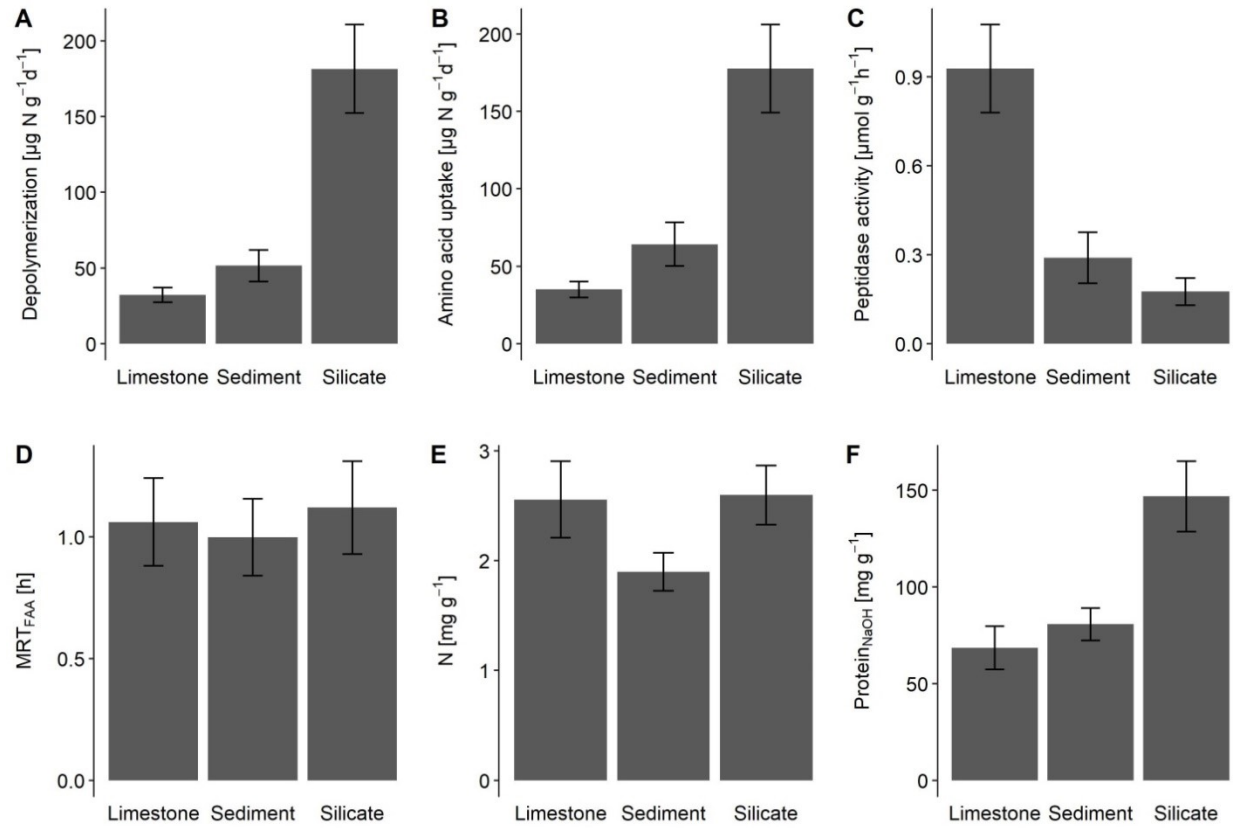


Fig. S2. Protein depolymerization rate (A), microbial amino acid uptake (B), leucine amino-peptidase activity (C), mean residence time of free amino acids (MRT_{FAA}, D), total soil N (E) and NaOH-extractable protein (F) for three different bedrock types (limestone, sediment, silicate, mean \pm 1SE, n = 26, 33, 36). Statistics are shown in Table S2.

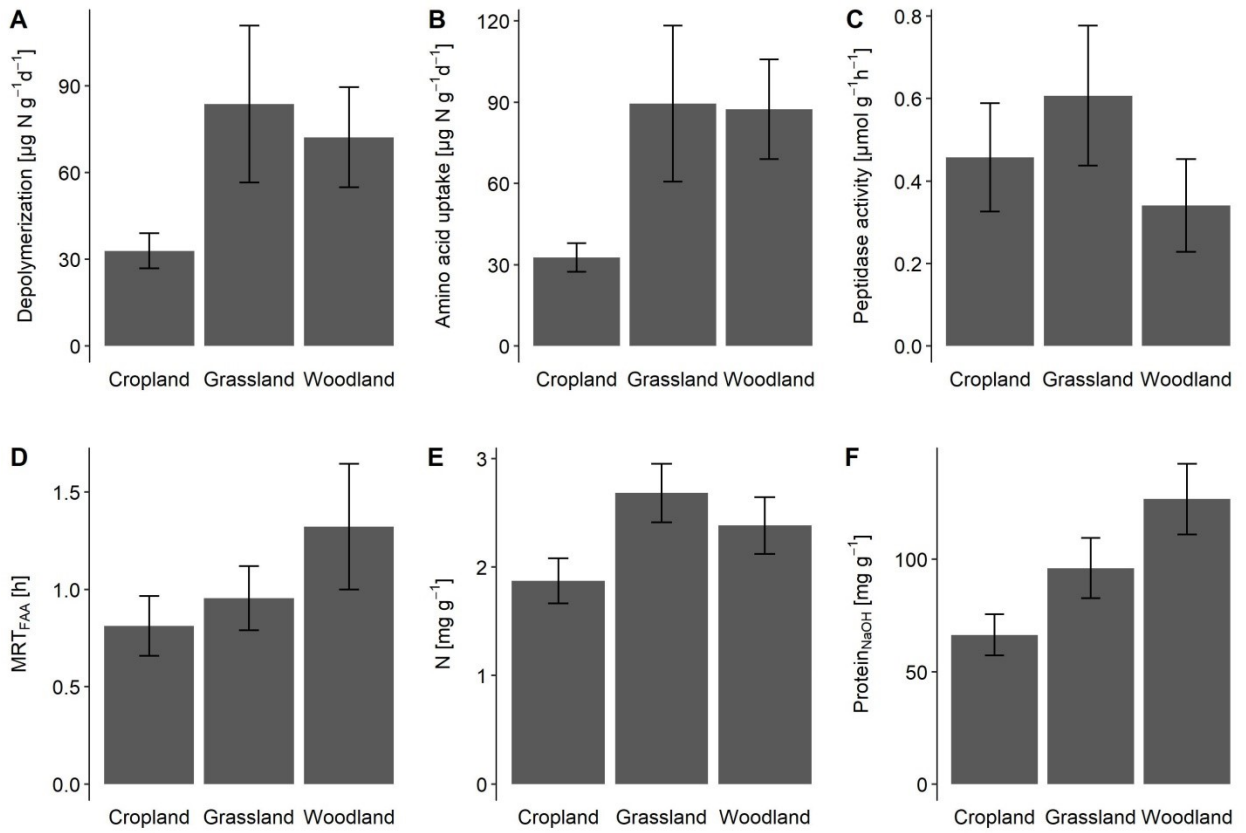


Fig. S3. Protein depolymerization (A), microbial amino acid uptake (B), leucine amino-peptidase activity (C), mean residence time of free amino acids (MRT_{FAA}, D), total soil N (E) and NaOH-extractable protein (F) for three different land use types (cropland, grassland, woodland, mean \pm 1SE, n = 22, 22, 22). Statistics are shown in Table S2.

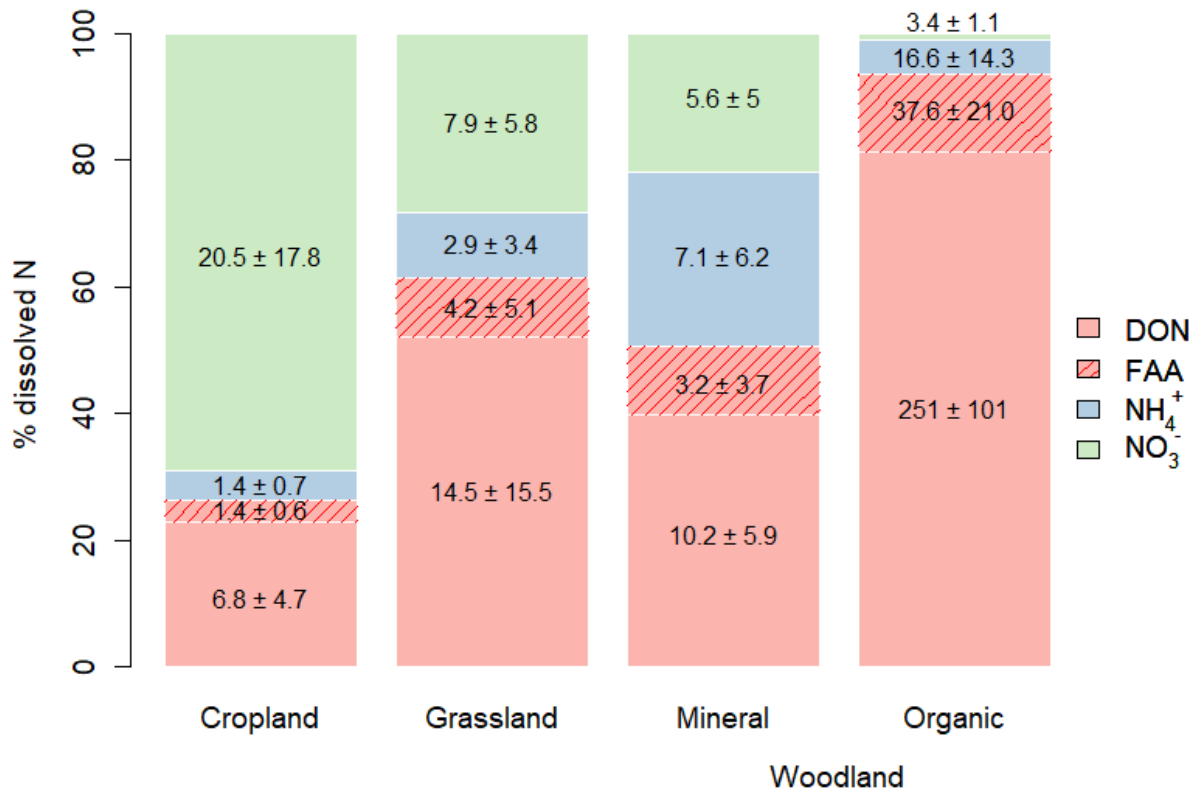


Fig. S4. Percentage of dissolved N species in total dissolved N. Composition of dissolved organic N in cropland (n = 24), grassland (n = 28) and woodland mineral soils (n = 48) as well as in woodland organic soil horizons (n = 13). Numbers indicate the average N content (mean ± 1sd) in $\mu\text{g N g}^{-1} \text{d.w.}$.

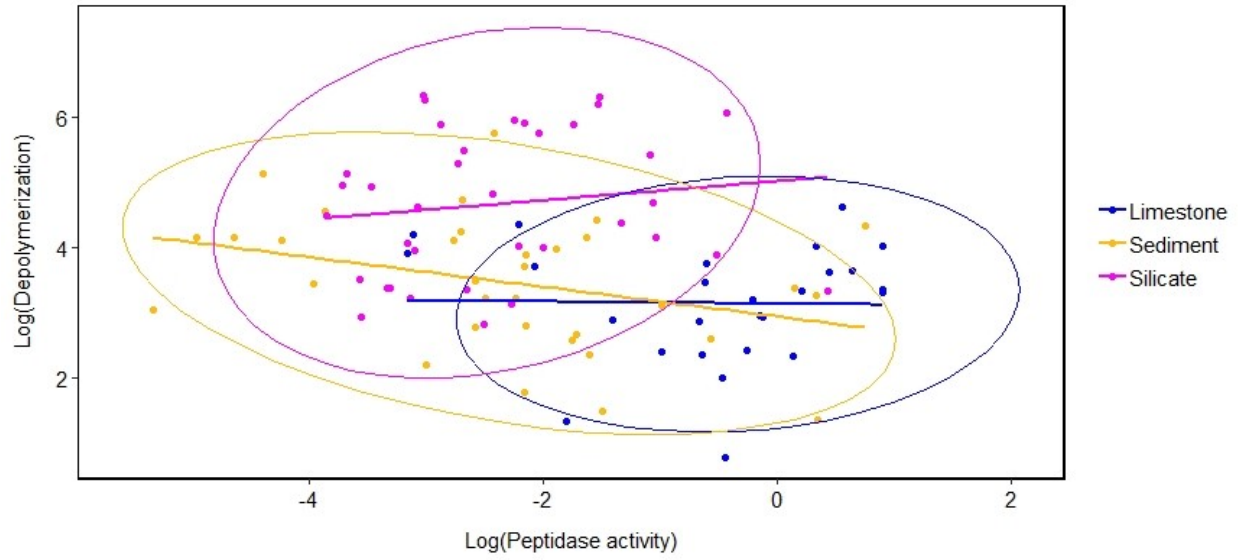


Fig. S5. Relationship of Log(peptidase activity) measured at native soil pH and log(gross protein depolymerization) in soils developed on limestone ($r=-0.021$, n.s.), sediment ($r=-0.337$, n.s.) and silicate($r=0.139$, n.s.). Ellipses indicate the 95% confidence interval.

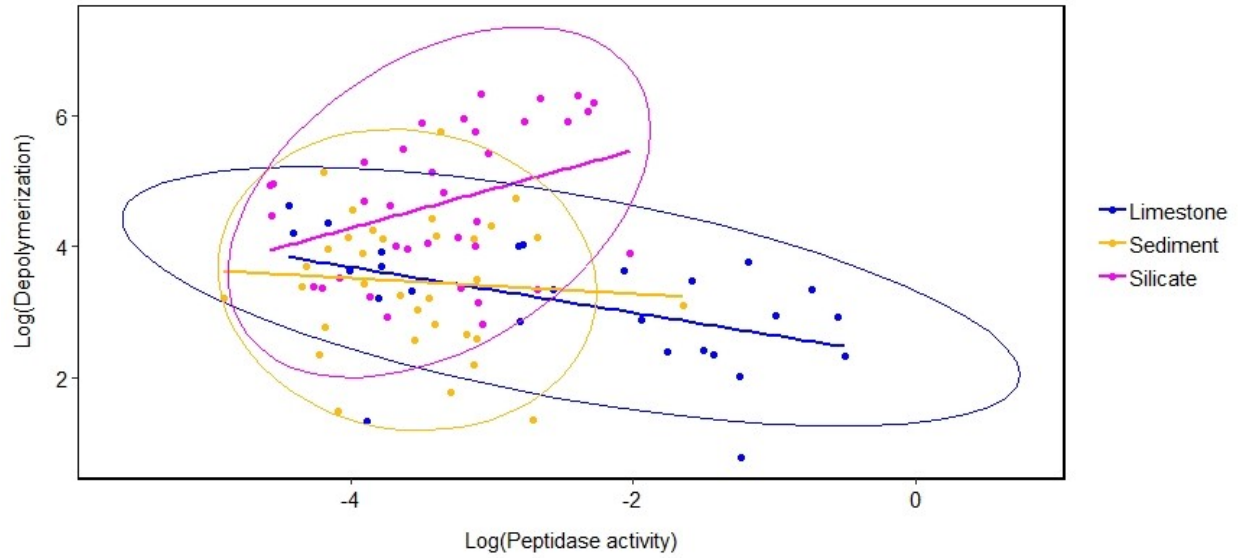


Fig. S6. Relationship of log(peptidase activity) measured at pH 5.5 and log(gross protein depolymerization) measured at natural soil pH developed in limestone ($r=-0.495$, $p<0.05$), sediment ($r=-0.070$, n.s.) and silicate($r=0.354$, $p<0.05$) soils. Ellipses indicate the 95% confidence interval.

Site	Country	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	MAT (°C)	MAP (mm y ⁻¹)	Parent material	Vegetation class	Soil type	horizon	Land use
S-J1	Spain	36.8	-5.2	684	15.1	728	Carbonate	mediterranean	Calcisol	mineral	W, G, C
S-J7	Spain	36.4	-6.0	33	17.7	620	Carbonate	mediterranean	Calcisol	mineral	W, G, C
S-F1a	Spain	43.4	-5.7	250	13.2	842	Carbonate	mesophytic (deciduous)	Leptosol	mineral	W, G
S-G3	Spain	42.6	-0.3	824	9.9	737	Sediment	thermophil	Leptosol	mineral	W, G, C
S-J4	Spain	42.0	-0.3	473	12.2	449	Carbonate	mediterranean	Gypsisol	mineral	W, G, C
S-K3	Spain	41.7	-0.2	418	13.2	415	Carbonate	xerophytic	Gypsisol	mineral	W, C
S-J6	Spain	40.6	0.5	170	16.2	549	Carbonate	mediterranean	Calcisol	mineral	W, G, C
P-J5	Portugal	38.1	-8.4	53	17	550	Sediment	mediterranean	Regosol	mineral	W, G, C
P-J3	Portugal	39.5	-8.3	48	16.8	711	Sediment	mediterranean	Podzol	mineral	W, G, C
P-G4	Portugal	40.2	-7.4	596	13.9	1050	Silicate	thermophil	Regosol	mineral	W, G, C
D-1	Germany	53.0	13.9	94	8.6	565	Sediment	mesophytic (deciduous)	Luvisol	mineral	W, G, C
D-2	Germany	54.1	11.9	6	8.7	590	Sediment	mesophytic (deciduous)	Luvisol	mineral	W, G, C
D-3	Germany	51.1	10.4	445	7.3	745	Carbonate	mesophytic (deciduous)	Cambisol	mineral	W, G, C
D-4	Germany	50.6	12.0	468	7.5	666	Sediment	mesophytic (deciduous)	Cambisol	mineral	W, G, C
D-5	Germany	48.4	9.5	796	7.2	958	Carbonate	mesophytic (deciduous)	Leptosol	mineral	W, G, C
R-1	Romania	45.8	25.5	542	8	620	Sediment	mesophytic (deciduous)	Podzol	mineral	W, G, C
R-2	Romania	45.9	25.7	707	7.2	656	Sediment	mesophytic (deciduous)	Podzol	mineral	W, G, C
R-3	Romania	47.0	26.3	428	7.6	585	Sediment	mesophytic (deciduous)	Podzol	mineral	W, G, C
R-4	Romania	47.1	26.5	415	7.5	601	Sediment	mesophytic (deciduous)	Luvisol	mineral	W, G, C
R-5	Romania	46.4	27.0	164	9.3	546	Sediment	mesophytic (deciduous)	Luvisol	mineral	W, G, C
R-6	Romania	45.0	28.5	98	10.7	460	Carbonate	Forest steppe	Chernozem	mineral	W, G, C

Site	Country	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	MAT (°C)	MAP (mm y ⁻¹)	Parent material	Vegetation class	Soil type	horizon	Land use
A-1	Austria	47.4	14.2	1572	2.4	1380	Silicate	mesophytic (coniferous)	Podzol	mineral, organic	W, G
A-2	Austria	47.4	14.2	1350	3.5	1246	Silicate	mesophytic (coniferous)	Podzol	mineral, organic	W, G
A-3	Austria	47.5	14.1	912	5.7	973	Silicate	mesophytic (coniferous)	Cambisol	mineral, organic	W, G, C
SE-01	Sweden	68.3	18.8	422	2	440	Silicate	subarctic	Podzol	mineral, organic	W
SE-02	Sweden	68.3	19.3	602	-1.2	490	Silicate	subarctic	Leptosol	mineral, organic	W
SE-03	Sweden	68.3	19.3	795	-2.1	524	Silicate	subarctic	Leptosol	mineral, organic	W
SE-04	Sweden	68.3	19.3	1012	-3.4	568	Silicate	subarctic	Leptosol	mineral	W
SE-05	Sweden	66.0	19.7	328	-0.3	537	Silicate	mires	Histosol	organic	
SE-06	Sweden	64.0	18.1	330	1	537	Silicate	mesophytic (coniferous)	Podzol	mineral, organic	W, G
SE-07	Sweden	60.4	15.2	369	4.8	657	Silicate	mesophytic (coniferous)	Podzol	mineral, organic	W, G, C
SE-08	Sweden	58.1	15.8	130	6.5	566	Silicate	mesophytic (coniferous)	Regosol	mineral, organic	W, G, C
SE-09	Sweden	57.7	13.7	331	6.4	572	Silicate	mires	Regosol	organic	W
FIN-01	Finland	67.9	24.4	309	-2	504	Silicate	mesophytic (coniferous)	Histosol	mineral, organic	W
FIN-02	Finland	67.2	26.9	249	-1.3	539	Silicate	mesophytic (coniferous)	Histosol	mineral, organic	W
FIN-03	Finland	67.8	29.6	300	7.2	749	Silicate	subarctic	Podzol	mineral, organic	W
FIN-04	Finland	67.8	29.6	300	-1	538	Silicate	subarctic	Podzol	mineral, organic	W
FIN-05	Finland	67.8	29.6	300	-1	538	Silicate	subarctic	Podzol	mineral, organic	W
FIN-06	Finland	67.8	29.6	300	-1	592	Silicate	subarctic	Podzols	mineral, organic	W
NO-01	Norway	71.0	25.8	270	-2.1	555	Silicate	arctic	Leptosol	mineral	W
NO-02	Norway	68.4	14.9	17	4.4	1283	Silicate	heaths	Leptosol	mineral, organic	W, G
NO-03	Norway	59.1	10.9	31	7.3	745	Silicate	heaths	Podzol	mineral, organic	(W), G, C

Table S1. Selected study sites across the different countries comprising the European transect, with the corresponding spatial coordinates (latitude, longitude), elevation, mean annual temperature (MAT), mean annual precipitation (MAP), soil parent material, vegetation zone, reference soil type, collected horizons (organic (o), mineral (m)) and collected land use types (woodland (W), grassland (G), cropland (C)) along the transect.

	Between bedrock				Between land use				Between horizons
	F value	Limestone	Sediment	Silicate	F value	Cropland	Grassland	Woodland	F value
pH	37.52***	c	b	a	15.63***	b	b	a	3.30**
roots	4.07*	a	ab	b	17.54***	a	b	b	-3.35**
root C:N	n.s.				19.50***	a	a	b	n.s.
Clay	17.58***	c	b	a	n.s.				NA
Silt	4.90**	b	ab	a	6.40**	ab	b	a	NA
CEC	27.86***	b	a	a	n.s.				-10.75***
Fe _{oxalate}	65.35***	a	b	c	n.s.				NA
Al _{oxalate}	14.45***	a	a	b	n.s.				NA
Fed-o	11.89***	b	a	a	n.s.				NA
SOC	9.48***	a	a	b	8.65***	a	ab	b	-11.12***
Total N	1.67*	n.s.	n.s.	n.s.	n.s.				-10.07***
Protein _{NaOH}	15.19***	a	a	b	6.41**	a	ab	b	-3.68**
% Protein _{NaOH}	24.26***	a	b	c	7.76**	a	a	b	5.00***
Total P	n.s.				19.36***	b	b	a	-3.66**
TOP	3.63**	ab	a	b	6.14**	ab	b	a	-5.59***
DOC	4.02*	ab	a	b	13.81***	a	a	b	-12.90***
DON	5.35**	a	a	b	5.79**	a	ab	b	-10.06***
DOP	36.02***	a	b	c	n.s.				-5.78***
FAA-N	22.93***	a	a	b	21.44***	a	b	b	-7.96***
NH ₄ ⁺	7.19***	a	b	b	17.91***	a	b	c	-12.17***
NO ₃ ⁻	n.s.				9.94***	b	ab	a	-5.13***
microbial C	7.43**	b	a	b	4.96*	a	b	ab	-11.22***
C:N imbalance	9.66***	b	a	b	8.51***	a	a	b	-6.57***
N:P imbalance	22.6***	b	a	a	3.72*	a	ab	b	-3.91**
PLFA _{gram+}	7.30**	a	a	b	11.41***	a	a	b	n.s.
PLFA _{gram-}	n.s.				6.27**	a	a	b	n.s.
PLFA _{Bacteria}	n.s.				8.85***	a	a	b	n.s.
PLFA _{Fungi}	n.s.				n.s.				n.s.
PLFA _{Fungi:Bacteria}	n.s.				n.s.				n.s.
Peptidase	19.31***	b	a	a	5.26**	b	b	a	-9.73***
Peptidase _{buffer}	12.94***	b	a	a	4.98**	ab	b	a	
Depoly	19.66***	a	b	b	4.69*	a	b	b	-9.67***
FAA uptake	15.51***	a	b	b	5.37**	a	b	b	-8.00***
MRT _{FAA}	n.s.				n.s.				n.s.

Levels of significance: p>0.05 n.s., p<0.05 *, p<0.01**, p<0.001***

Table S2. Effect of bedrock, land use and soil horizon on various soil parameters, peptidase activity at natural pH, gross protein depolymerization rates (Depoly), gross microbial amino acid uptake rates (FAA uptake) and mean residence time of free amino acids (MRT_{FAA}). Bedrock (limestones, sediments, silicates, n = 95) effects were obtained from one-way ANOVA and land use effects (woodland, grassland, cropland, n = 22) were obtained from two-way ANOVA. Asterisks indicate levels of significance. Significant differences between individual land use or bedrock types obtained from Tukey HSD are

indicated by different letters. Differences between mineral and organic soil horizons were obtained from paired t-tests ($n = 13$). Soil texture and mineralogy were not analyzed in organic soils (NA).

	all			cropland			grassland			woodland					
	mineral			mineral			mineral			mineral			organic		
	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein
pH	-0.417***	0.663***	-0.415***	-0.342	0.563**	-0.208	-0.502***	0.720***	-0.503**	-0.371*	0.722***	-0.313	0.057	0.483	0.318
roots	0.202	-0.111	0.307**	0.617**	-0.175	0.207	0.169	-0.144	0.477*	0.064	0.035	0.103	0.305	-0.603**	-0.541**
root C:N	-0.14	-0.196	-0.061	-0.243	-0.033	-0.278	-0.605***	-0.118	-0.484**	-0.034	-0.193	-0.198	-0.242	-0.016	-0.129
Clay	-0.224*	0.284**	-0.167	0.269	0.295	0.181	-0.473*	0.315	-0.319	-0.225	0.226	-0.118	NA	NA	NA
Silt	-0.115	0.315**	-0.148	0.342	0.154	0.319	-0.143	0.404*	-0.261	-0.272	0.27	-0.172	NA	NA	NA
CEC _{eff}	-0.219*	0.695***	0.022	0.126	0.681***	0.363	-0.429*	0.746***	-0.213	-0.098	0.694***	0.121	0.402	0.619**	0.642**
Fe _{oxalate}	0.524***	-0.273*	0.384***	0.524**	-0.238	0.653***	0.642***	-0.324	0.369	0.366*	-0.248	0.351*	NA	NA	NA
Al _{oxalate}	0.459***	-0.194	0.275**	0.498*	0.162	0.680***	0.681***	-0.232	0.402*	0.312	-0.299	0.063	NA	NA	NA
Fe _{d-o}	-0.096	0.310**	-0.075	-0.098	0.538**	0.078	-0.128	0.169	-0.385*	-0.107	0.421**	-0.034	NA	NA	NA
SOC	0.438***	0.093	0.744***	0.29	0.495*	0.578**	0.456*	0.168	0.718***	0.492	0.102	0.651***	-0.089	0.102	0.158
Total N	0.408***	0.311**	0.599***	0.366	0.529**	0.607**	0.523**	0.138	0.727***	0.384	0.388*	0.551***	0.235	0.283	0.172
Soil C:N	0.156	-0.261*	0.291**	-0.244	0.015	-0.257	0.212	0.173	0.364	0.133	-0.439**	0.078	-0.234	-0.133	-0.071
Protein	0.579***	-0.078		0.485*	0.241		0.557**	-0.226		0.699***	-0.001		0.234	0.105	
% Protein	0.26	-0.330**	0.547***	0.254	0.001	0.714***	0.246	-0.464*	0.622***	0.189	-0.344*	0.382*	0.182	-0.201	0.961***
Total P	0.342***	0.250*	0.220*	0.241	0.278	0.532**	0.613**	0.143	0.480*	0.234	0.229	0.287	0.025	0.239	-0.025
TOP	0.510***	0.14	0.415***	0.401	-0.016	0.788***	0.741***	0.012	0.554**	0.323*	0.148	0.379*	0.026	0.200	-0.046
DOC	0.18	0.001	0.236*	-0.325	0.058	-0.508	0.187	-0.266	0.020	0.178	0.241	0.237	0.078	0.773**	0.571*
DON	0.675***	-0.167	0.558***	0.119	-0.029	0.151	0.872***	-0.309	0.548**	0.672***	-0.094	0.557***	0.352	0.453	0.291
DOP	0.607***	-0.358***	0.354**	0.562**	-0.257	0.457*	0.817***	-0.411*	0.540**	0.488**	-0.439**	0.272	-0.162	0.366	-0.011
FAA-N	0.836***	-0.187	0.512***	0.475*	-0.130	0.588**	0.874***	-0.229	0.450*	0.682***	-0.167	0.504**	0.731***	0.512	0.667**
NH ₄ ⁺	0.222*	-0.213*	0.422***	0.615**	0.083	0.748***	0.200	-0.208	0.744***	0.111	-0.244	0.243	0.897***	0.254	0.145
NO ₃ ⁻	0.077	0.248*	0.057	0.174	-0.014	0.219	0.376*	0.319	0.372	-0.044	0.415**	0.127	0.490	0.180	0.179
microbial C	0.422***	0.282**	0.677***	0.221	0.625**	0.416*	0.437*	0.339	0.551**	0.423**	0.247	0.647***	0.574*	0.733**	0.778**

	all			cropland			grassland			woodland					
	mineral			mineral			mineral			mineral			organic		
	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein	Depoly	Peptidase	Protein
C:N _{imbalance}	0.125	0.075	0.209*	-0.190	0.286	-0.129	-0.054	0.453*	0.091	0.045	-0.002	0.08	-0.339	-0.212	-0.199
N:P _{imbalance}	-0.124	0.517***	0.176	-0.098	0.500*	0.304	-0.304	0.657***	-0.022	-0.090	0.695***	0.148	-0.093	-0.448	-0.153
PLFA _{gram+}	0.333**	-0.082	0.419***	0.219	0.326	0.678***	0.692***	-0.082	0.356	0.198	-0.093	0.29	0.035	-0.202	0.066
PLFA _{gram-}	0.294**	-0.064	0.363***	0.197	0.581**	0.532**	0.520**	-0.119	0.302	0.128	-0.084	0.212	-0.027	-0.184	0.037
PLFA _{Bacteria}	0.317**	-0.074	0.405***	0.006	0.487*	0.616**	0.614**	-0.100	0.335	0.185	-0.089	0.274	0.014	-0.189	0.060
PLFA _{Fungi}	0.186	-0.049	0.307**	-0.068	0.540**	0.554**	-0.068	-0.161	-0.061	0.111	-0.055	0.191	0.205	-0.202	-0.010
Fungi:Bacteria	-0.052	-0.046	0.014	0.211	0.263	0.038	-0.439*	-0.139	-0.375*	0.113	-0.155	0.112	0.008	-0.139	-0.120
Peptidase	-0.199		-0.078	-0.135		0.241	-0.250		-0.226	-0.243		-0.001	0.252		0.105
Depoly		-0.119	0.579***		-0.135	0.485*		-0.250	0.557***		-0.243	0.699***		0.252	0.234

Levels of significance: p>0.05 n.s., p<0.05 *, p<0.01 **, p<0.001 ***

Table S3. Coefficients of determination (pearson's r) for correlations of gross protein depolymerization rates (Depoly), leucine-amino peptidase activity (Peptidase) and Protein_{NaOH} for all mineral soils (n = 95), mineral horizons of cropland, grassland and woodland soils and organic woodland soil horizons. Asterisks indicate levels of significance. Soil texture and mineralogy was not analyzed in organic horizons (NA).

	Climate		Soil properties	
	Parameter estimate	p	Parameter estimate	p
Intercept	3.786	<0.01	2.257	<0.05
	-0.68*MAT	<0.001	0.727*Log(ProteinNaOH)	<0.001
	0.265*MAP	<0.05	-0.252*pH	<0.01
	-0.212*MAP:MAT	0.062		
r²	0.464		0.685	

Table S4. Linear mixed effect model of log(gross protein depolymerization rate) explained by climate and soil parameters with land use as random effect. Total model fit is given as adjusted r².

	Variance explained (%)	F value	p
MAT	29.1	47.8	<0.001
MAP	10.1	16.5	<0.001
MAT:MAP	4.6	3.7	<0.05
Land use	1.9	3.2	0.08
r²	0.425		

Table S5. Linear model of log(gross protein depolymerization rate) explained by climate, land use and interaction effects. Total model fit is given as adjusted r².