

Supporting Information for:

Humus forms and organic matter decomposition in the Swiss Alps

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Methods for soil physicochemical properties analysis

To define and characterize the organomineral horizon properties of our different humus forms, we collected soil samples during the summer of 2020 on 24 sites across two regions. On each site, we described and named soil organomineral horizons according to the Référentiel Pédologique [14] by including the following descriptors [44]: horizon depth, structure (e.g., lumpy, single grain, massive), texture (i.e., sand, silt, clay), color (Munsell soil color chart), roots abundance index, soil pH (Hellige), carbonate's reaction by HCl 6M, and coarse elements. All rock particles bigger than 2 cm in diameter were removed for each soil sample. Soil samples were air-dried at 40 °C for 4 days and sieved at 2 mm before soil physicochemical properties analysis: Soil relative humidity was assessed after drying the soils at 120 °C for three days. Soil pH was determined with a BlueLine electrode (SI Analytics, Thermo Fisher Scientific, Waltham, MA, USA) and a Metrohm 827 pH meter in distilled water (Metrohm AG, Herisau, Switzerland). Soil organic matter [46] was estimated from the loss of ignition (LOI), assessed by calcination of samples at 450 °C (Nabertherm L9/C6, Gerber Instruments, Zurich, Switzerland), and corrected by the "Howard" correction factor [47]. Soil total cationic exchange capacity (CEC) and saturation rate (S/CEC) were quantitated with cobalt hexamine trichloride [48] by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES; Optima 2100 DV, PerkinElmer, Waltham, MA, USA). Soil total carbonates (when observed in the field) were estimated by CaCO₃ dissolution after HCl 6M addition, measuring the CO₂ volume released according to the Calcimeter Bernard method. Total carbon, total nitrogen, and organic carbon (only for carbonated soils) were measured with an elemental analyzer (FLASH 2000, Thermo Fisher Scientific, Waltham, MA, USA). Soil particle size was measured with a Laser Diffraction Particle Size Analyzer with Aqueous Liquid Module (ALM) and Auto Prep Station (APS) at the University of Lausanne (LS 13 320, Beckman Coulter, Indianapolis, IN, USA).

Table S1. Sites coordinates.

Site_id	Coordinates_WGS 84
TSM1	46°30'08.818"N 8°46'27.403"E
TSM2	46°30'03.378"N 8°46'38.568"E
TSM3	46°29'56.661"N 8°46'46.235"E

TNM1	46°28'18.872"N 8°45'23.236"E
TNM2	46°28'18.273"N 8°45'39.160"E
TNM3	46°28'16.413"N 8°45'48.073"E
VSM1	46°12'49.881"N 7°02'23.317"E
VSM2	46°12'47.304"N 7°02'25.342"E
VSM3	46°12'48.612"N 7°02'30.935"E
VNM1	46°12'38.577"N 6°57'56.665"E
VNM2	46°12'41.840"N 6°57'53.334"E
VNM3	46°12'37.084"N 6°57'54.303"E
TSH1	46°30'55.210"N 8°47'43.566"E
TSH2	46°30'56.568"N 8°47'43.788"E
TSH3	46°30'57.593"N 8°47'42.317"E
TNH1	46°26'42.258"N 8°43'50.692"E
TNH2	46°26'41.289"N 8°43'53.340"E
TNH3	46°26'42.032"N 8°43'44.362"E
VSH1	46°13'20.222"N 7°03'27.947"E
VSH2	46°13'19.473"N 7°03'25.624"E
VSH3	46°13'17.731"N 7°03'28.623"E
VNH1	46°12'23.060"N 6°56'52.627"E
VNH2	46°12'21.773"N 6°56'47.083"E
VNH3	46°12'18.716"N 6°56'37.684"E

Table S2. Table summarizing soil types, associations and alliances, as well as plant species observed, by site. Only the 10 most abundant species at each site were recorded for this study. For plant taxonomy we used the following books: the *Flore de la Suisse* [39] and the *Flora Helvetica* [40].

Site	Référentiel pédologique	World Reference Base for Soil Resources	Humus system	Phytosociological alliances	Phytosociological associations	Most abundant plant species
TSM1	Organosol Insaturé	Umbrisol	Lignoform	Dicrano-Pinion	Calluno-Pinetum	<i>Picea abies</i>
						<i>Pinus sylvestris</i>
						<i>Betula pendula</i>
						<i>Vaccinium myrtillus</i>
						<i>Corylus avellana</i>
						<i>Hieracium murorum</i> aggr.
						<i>Solidago virgaurea</i>
						<i>Laserpitium gaudinii</i>
						<i>Sorbus aucuparia</i>
						<i>Lathyrus linifolius</i>
TSM2	Régosol	Leptosol	Mor	Dicrano-Pinion	Calluno-Pinetum	<i>Picea abies</i>
						<i>Pinus sylvestris</i>
						<i>Hieracium murorum</i> aggr.
						<i>Sorbus aria</i>
						<i>Sorbus aucuparia</i>
						<i>Vaccinium myrtillus</i>
						<i>Calamagrostis varia</i>
						<i>Phyteuma betonicifolium</i>
						<i>Luzula luzuloides</i>
						<i>Solidago virgaurea</i>
TSM3	Organosol Insaturé	Umbrisol	Lignoform	Dicrano-Pinion	Calluno-Pinetum	<i>Picea abies</i>
						<i>Vaccinium myrtillus</i>
						<i>Pinus sylvestris</i>

							<i>Hieracium murorum</i> aggr.
							<i>Sorbus aucuparia</i>
							<i>Corylus avellana</i>
							<i>Solidago virgaurea</i>
							<i>Sorbus aria</i>
							<i>Luzula luzuloides</i>
							<i>Rubus idaeus</i>
TNM1	Organosol Hologranique	Histosol		Lignoform	Vaccinio-Piceion	Larici-Piceetum	<i>Picea abies</i>
							<i>Oxalis acetosella</i>
							<i>Calamagrostis varia</i>
							<i>Larix decidua</i>
							<i>Dryopteris filix-mas</i>
							<i>Maianthemum bifolium</i>
							<i>Luzula sylvatica</i>
							<i>Saxifraga cuneifolia</i>
							<i>Prenanthes purpurea</i>
							<i>Hieracium murorum</i> aggr.
TNM2	Organosol Hologranique	Histosol		Lignoform	Vaccinio-Piceion	Homogyno-Piceetum	<i>Picea abies</i>
							<i>Calamagrostis varia</i>
							<i>Larix decidua</i>
							<i>Vaccinium myrtillus</i>
							<i>Maianthemum bifolium</i>
							<i>Hieracium murorum</i> aggr.
							<i>Festuca rubra</i> aggr.
							<i>Luzula sylvatica</i>
							<i>Oxalis acetosella</i>
							<i>Abies alba</i>
TNM3	Régosol	Histosol		Lignoform	Vaccinio-Piceion	Larici-Piceetum	<i>Picea abies</i>
							<i>Calamagrostis varia</i>

						<i>Corylus avellana</i>
						<i>Acer pseudoplatanus</i>
						<i>Laburnum alpinum</i>
						<i>Fagus sylvatica</i>
						<i>Calamagrostis arundinacea</i>
						<i>Polygonatum verticillatum</i>
						<i>Luzula nivea</i>
						<i>Hieracium murorum</i> aggr.
VNM1	Brunisol Dystrique	Cambisol	Mull	Abieti-Piceion	Adenostylo-Abietetum	<i>Abies alba</i>
						<i>Petasites albus</i>
						<i>Adenostyles alliariae</i>
						<i>Oxalis acetosella</i>
						<i>Picea abies</i>
						<i>Galium odoratum</i>
						<i>Dryopteris filix-mas</i>
						<i>Sorbus aucuparia</i>
						<i>Sanicula europaea</i>
						<i>Lonicera nigra</i>
VNM2	Brunisol Dystrique	Cambisol	Mull	Abieti-Piceion	Adenostylo-Abietetum	<i>Abies alba</i>
						<i>Galium odoratum</i>
						<i>Oxalis acetosella</i>
						<i>Petasites albus</i>
						<i>Sanicula europaea</i>
						<i>Hieracium murorum</i> aggr.
						<i>Picea abies</i>
						<i>Dryopteris filix-mas</i>
						<i>Veronica urticifolia</i>
						<i>Adenostyles alliariae</i>
VNM3	Brunisol Dystrique	Cambisol	Mull	Abieti-Piceion	Adenostylo-Abietetum	<i>Picea abies</i>
						<i>Abies alba</i>

						Oxalis acetosella
						Adenostyles alliariae
						Petasites albus
						Viola biflora
						Sanicula europaea
						Galium odoratum
						Dryopteris filix-mas
						Lamium galeobdolon
TSH1	Colluviosol	Regosol	Rhizoform	Nardion strictae	Hypochoerido-Nardetum	Nardus stricta
						Festuca rubra aggr.
						Carex sempervirens
						Trifolium alpinum
						Anthoxanthum alpinum
						Juncus trifidus
						Phyteuma betonicifolium
						Solidago virgaurea
						Silene nutans
						Silene rupestris
TSH2	Colluviosol	Regosol	Rhizoform	Nardion strictae	Hypochoerido-Nardetum	Nardus stricta
						Carex sempervirens
						Vaccinium vitis- idaea
						Trifolium alpinum
						Juniperus communis ssp. nana
						Anthoxanthum alpinum
						Phyteuma betonicifolium
						Rhododendron ferrugineum
						Vaccinium myrtillus
						Calluna vulgaris
TSH3	Colluviosol	Regosol	Rhizoform	Nardion strictae	Hypochoerido-Nardetum	Nardus stricta
						Trifolium alpinum

						<i>Avenella flexuosa</i>
						<i>Anthoxanthum alpinum</i>
						<i>Carex sempervirens</i>
						<i>Juncus trifidus</i>
						<i>Calluna vulgaris</i>
						<i>Phyteuma betonicifolium</i>
						<i>Juniperus communis</i> ssp. <i>nana</i>
						<i>Silene rupestris</i>
TNH1	Organosol Insaturé	Umbrisol		Rhizoform	Caricion curvulae	Carici curvulae-Nardetum
						<i>Vaccinium gaultherioides</i>
						<i>Carex curvula</i>
						<i>Festuca rubra</i> aggr.
						<i>Nardus stricta</i>
						<i>Avenella flexuosa</i>
						<i>Vaccinium myrtillus</i>
						<i>Agrostis schraderiana</i>
						<i>Trifolium alpinum</i>
						<i>Potentilla aurea</i>
						<i>Anthoxanthum alpinum</i>
TNH2	Organosol Saturé	Umbrisol		Rhizoform	Rhododendro-Vaccinion	Rhododendro ferruginei-Vaccinietum
						<i>Vaccinium gaultherioides</i>
						<i>Vaccinium myrtillus</i>
						<i>Nardus stricta</i>
						<i>Trifolium alpinum</i>
						<i>Carex sempervirens</i>
						<i>Arnica montana</i>
						<i>Leontodon helveticus</i> / <i>L. hispidus</i> aggr.
						<i>Rhododendron ferrugineum</i>
						<i>Festuca rubra</i> aggr.
						<i>Agrostis schraderiana</i>
TNH3	Organosol Insaturé	Umbrisol		Rhizoform	Rhododendro-Vaccinion	Rhododendro ferruginei-Vaccinietum
						<i>Vaccinium gaultherioides</i>

							<i>Nardus stricta</i>
							<i>Rhododendron ferrugineum</i>
							<i>Trifolium alpinum</i>
							<i>Juniperus communis</i> ssp. <i>nana</i>
							<i>Vaccinium myrtillus</i>
							<i>Arnica montana</i>
							<i>Carex curvula</i>
							<i>Avenella flexuosa</i>
							<i>Agrostis schraderiana</i>
VSH1	Brunisol Dystrique	Cambisol		Mull	Nardion strictae	Hypochoerido-Nardetum	<i>Nardus stricta</i>
							<i>Prunella vulgaris</i>
							<i>Carex sempervirens</i>
							<i>Pulsatilla alpina</i> ssp. <i>apiifolia</i>
							<i>Carlina acaulis</i>
							<i>Juniperus communis</i> ssp. <i>nana</i>
							<i>Arnica montana</i>
							<i>Vaccinium myrtillus</i>
							<i>Vaccinium gaultherioides</i>
							<i>Trollius europaeus</i>
VSH2	Brunisol Dystrique	Cambisol		Rhizoform	Nardion strictae	Geo montani-Nardetum	<i>Nardus stricta</i>
							<i>Pulsatilla alpina</i> ssp. <i>apiifolia</i>
							<i>Gentiana purpurea</i>
							<i>Agrostis capillaris</i>
							<i>Arnica montana</i>
							<i>Thymus serpyllum</i> aggr.
							<i>Carlina acaulis</i>
							<i>Vaccinium myrtillus</i>
							<i>Geum montanum</i>
							<i>Hieracium lactucella</i>
VSH3	Brunisol Dystrique	Cambisol		Rhizoform	Nardion strictae	Geo montani-Nardetum	<i>Arnica montana</i>

							<i>Nardus stricta</i>
							<i>Pulsatilla alpina</i> ssp. <i>apiifolia</i>
							<i>Vaccinium myrtillus</i>
							<i>Carlina acaulis</i>
							<i>Vaccinium gaultherioides</i>
							<i>Gentiana purpurea</i>
							<i>Agrostis capillaris</i>
							<i>Geum montanum</i>
							<i>Alchemilla vulgaris</i> aggr.
VNH1	Alocrisol Typique	Cambisol		Rhizoform	Nardion strictae	Geo montani-Nardetum	<i>Nardus stricta</i>
							<i>Avenella flexuosa</i>
							<i>Leontodon helveticus</i> / <i>L. hispidus</i> aggr.
							<i>Trifolium alpinum</i>
							<i>Gentiana purpurea</i>
							<i>Festuca rubra</i> aggr.
							<i>Vaccinium gaultherioides</i>
							<i>Homogyne alpina</i>
							<i>Carex sempervirens</i>
							<i>Vaccinium myrtillus</i>
VNH2	Alocrisol Typique	Cambisol		Rhizoform	Nardion strictae	Geo montani-Nardetum	<i>Nardus stricta</i>
							<i>Avenella flexuosa</i>
							<i>Leontodon helveticus</i> / <i>L. hispidus</i> aggr.
							<i>Trifolium alpinum</i>
							<i>Ligusticum mutellina</i> / <i>L. mutellinoides</i> aggr.
							<i>Plantago alpina</i>
							<i>Vaccinium myrtillus</i>
							<i>Agrostis capillaris</i>
							<i>Rhododendron ferrugineum</i>
							<i>Festuca rubra</i> aggr.

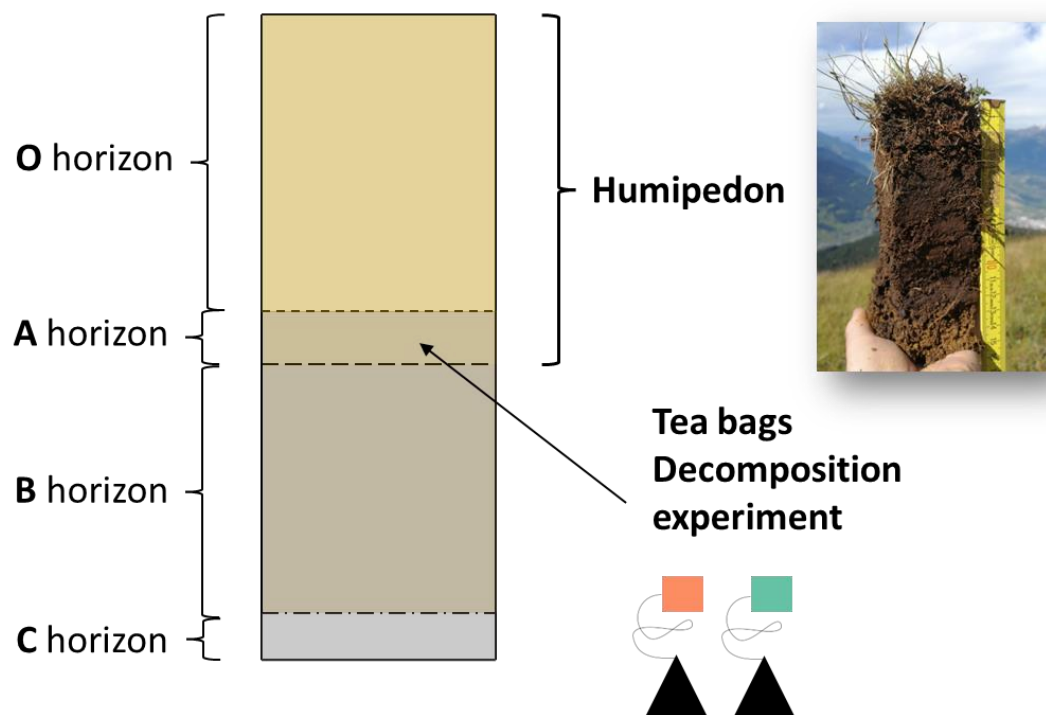


Figure S1. Concept. The Humipedon, an integral part of the pedon, is characterized by a combination of organic horizons (O) and organomineral horizons (A). Arrow shows the approximate horizon into which the tea bags were buried to study litter decomposition across sites in the Alps.

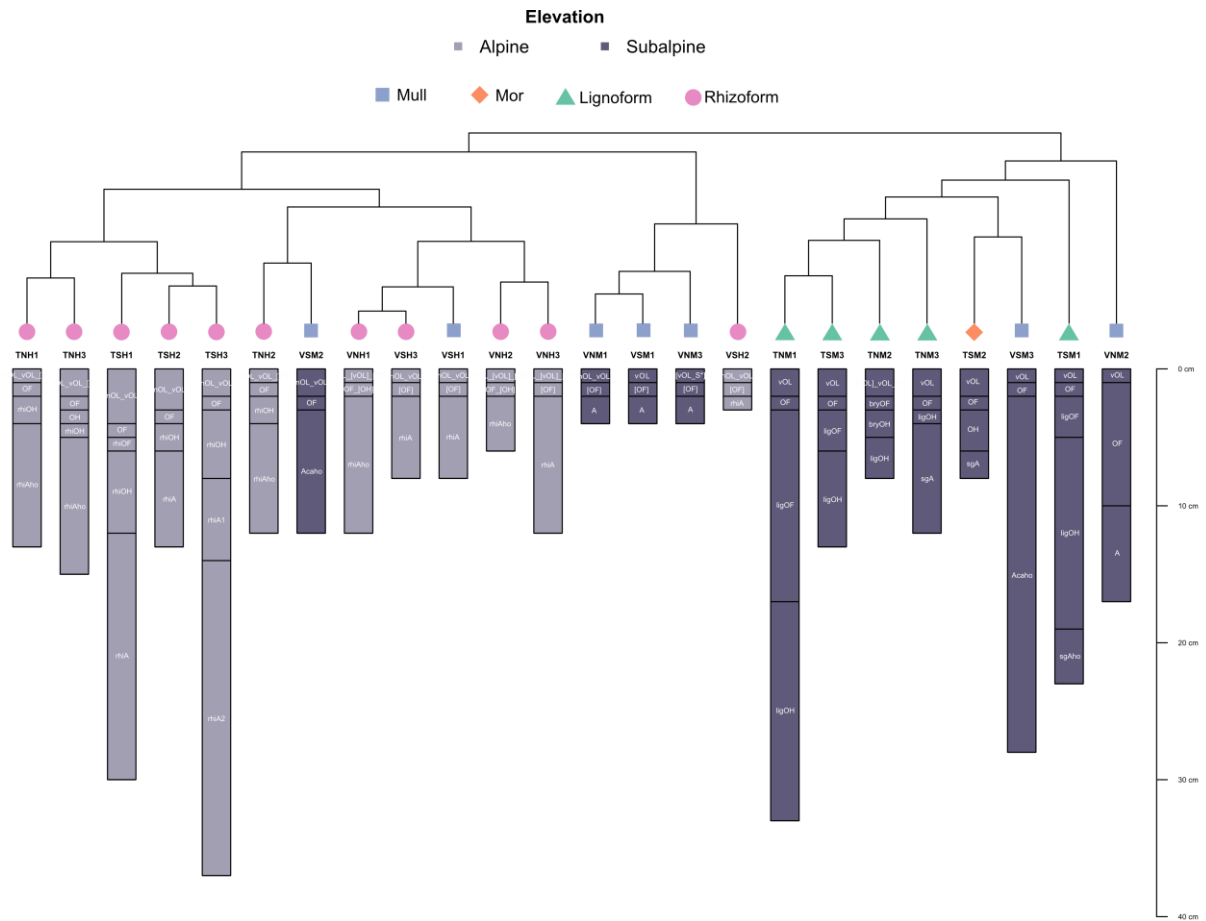


Figure S2. Humus forms and elevation. Shown is the divisive hierarchical clustering of 24 humus forms based on 11 macrorests groups of the Ponge analysis, including Monocotyledon leaves and stem (Monocot), Dicotyledon fragmented leaf, intact leaf, skeletonized leaf, dicotyledon stem (Dicot), fragmented and intact *Abies* sp., *Larix* sp., *Picea* sp., *Pinus* sp. needle, Gymnosperm cones and twig (Needle&Cones), Roots from 0–2 mm and >2 mm (Roots), Wood (Wood), Bryophytes, holorganic, mineral, mycelium, organomineral layers, and other. Colors indicate the altitude of the humus forms: Alpine (light grey) and subalpine (dark grey).

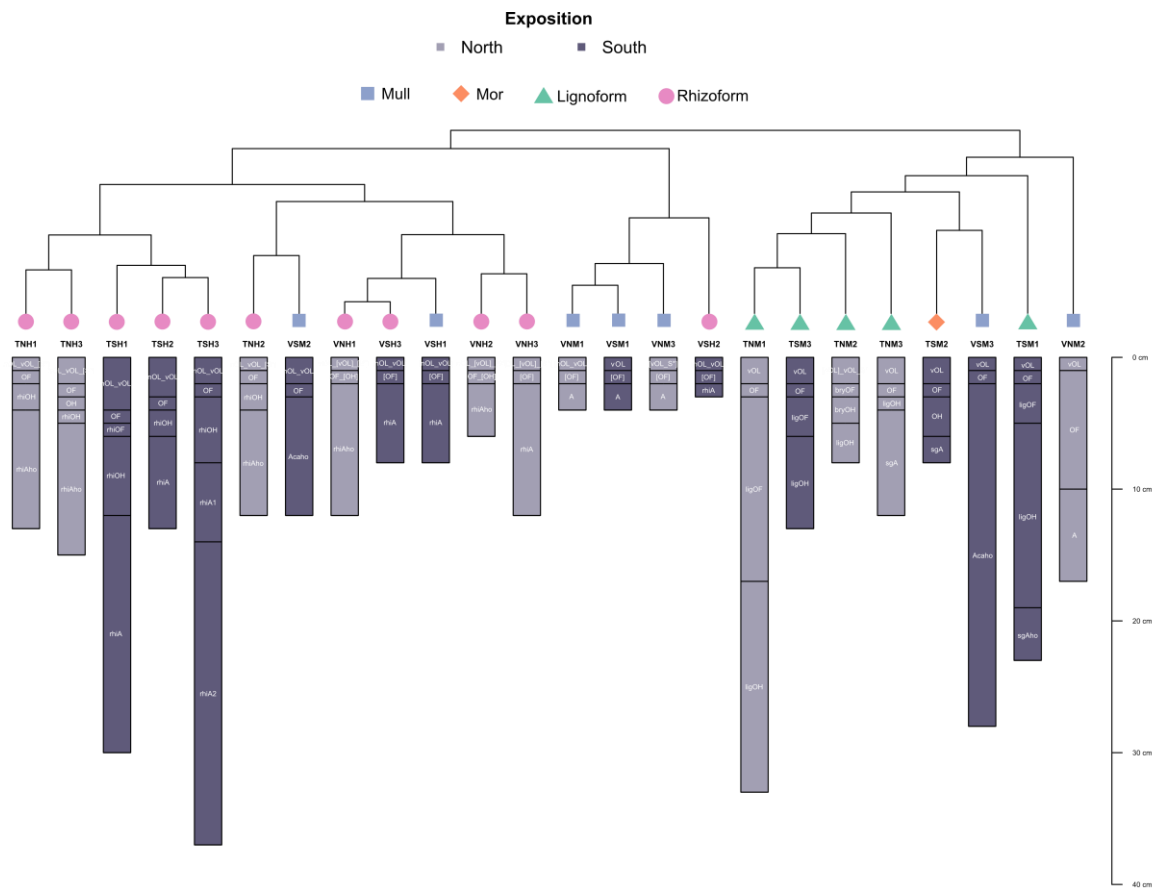


Figure S3. Humus forms and exposition. Shown is the divisive hierarchical clustering of 24 humus forms based on 11 macrorests groups of the Ponge analysis, including Monocotyledon leaves and stem (Monocot), Dicotyledon fragmented leaf, intact leaf, skeletonized leaf, dicotyledon stem (Dicot), fragmented and intact *Abies* sp., *Larix* sp., *Picea* sp., *Pinus* sp. needle, Gymnosperm cones and twig (Needle&Cones), Roots from 0–2 mm and >2 mm (Roots), Wood (Wood), Bryophytes, holorganic, mineral, mycelium, organomineral layers, and other. Colors indicate the exposition of the humus forms: north-exposed (light grey), and south-exposed (dark grey).