Lomonosov Moscow State University
Faculty of Geography
Department of Geochemistry of Landscapes and Soil Geography

MICROELEMENT MOBILE FORMS IN SOUTHERN TAIGA LANDSCAPES OF THE CENTRAL FOREST STATE BIOSPHERE NATURE RESERVE (RUSSIA)

P.R. Enchilik (polimail@inbox.ru), *E.N. Aseeva, I.N. Semenkov, O.A. Samonova, A.D. Iovcheva, E.V. Terskaya, N. S. Kasimov*

EGU General Assembly
2020

Photo: Ivanov D.G.

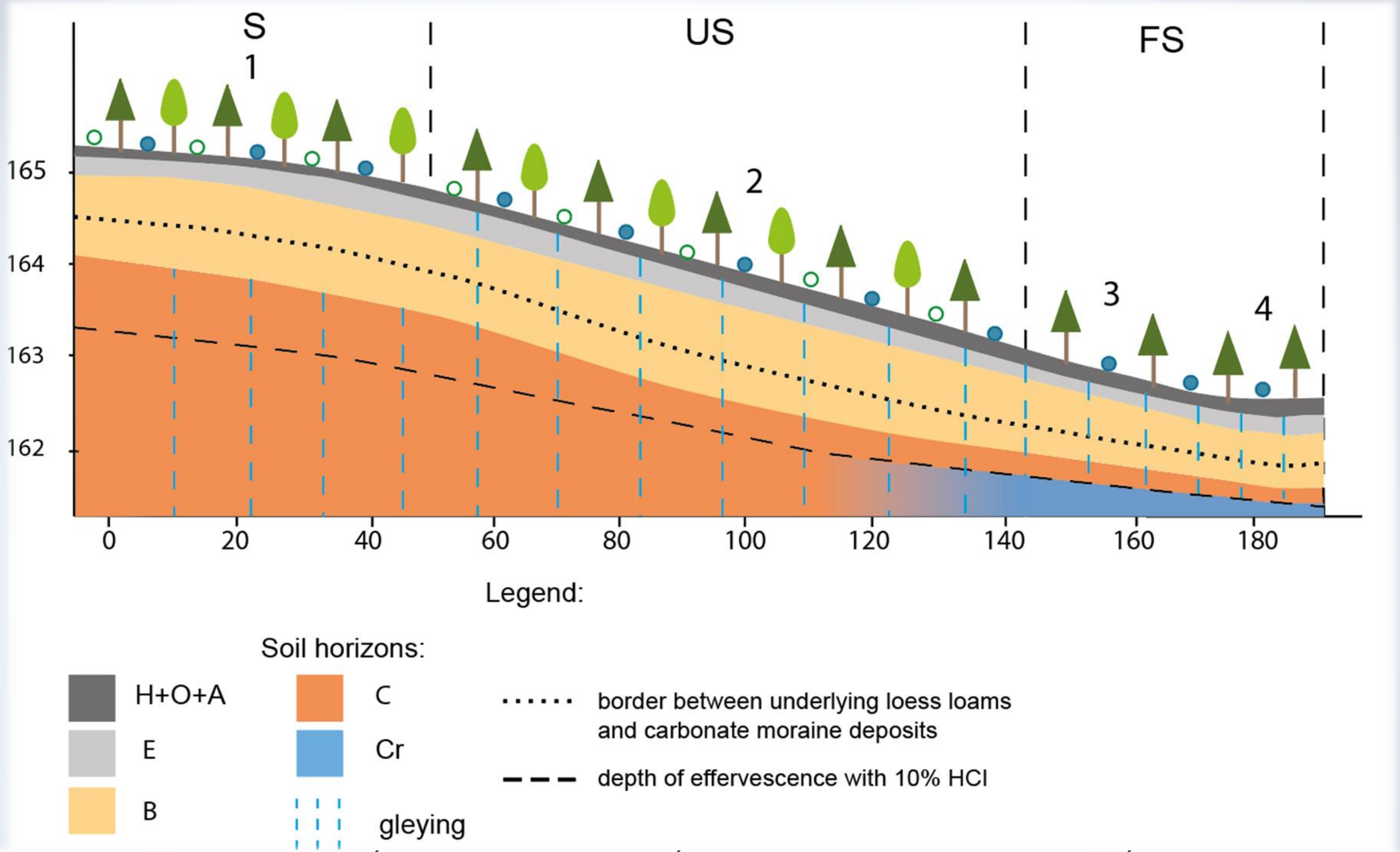
The aim is to compile geochemical model of the natural catena of the Southern Taiga zone.

Objectives:

1. To analyze vertical and spatial distribution of Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Ti, Zn and Zr total concentration and mobile fractions (exchangeable (F1), bound to organic complexes (F2) and bound to Fe and Mn hydroxides (F3));
2. To identify microelement composition of plants species and their organs;
3. To characterize biogenic migration of elements in the "plant-soil" system and identify groups of elements actively involved in the biological cycle.

Photo: Ivanov D.G.

STUDY OBJECT



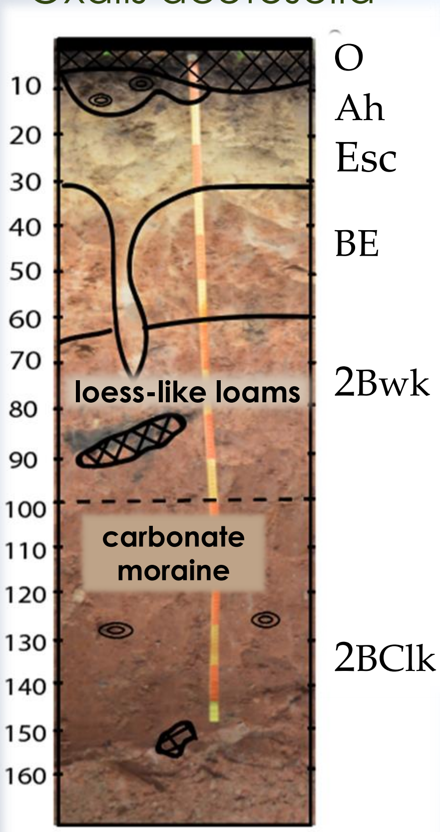
(1) – Tília cordáta+ Pícea ábies with Ácer platanoídes and Úlmus glábra - Córylus avellána - Óxalis acetosélla plant community on Endocalcaric Albic Stagnic Retisol, **(2)** – Pícea ábies+Tília cordáta+Ácer platanoídes - Córylus avellána – grass- plant community on Albic Stagnic Retisol (Humic), **(3)** – Pícea ábies with Tília cordáta and Ácer platanoídes - Vaccínium myrtíllus - Sphagnum and **(4)** – Pícea ábies with Sálix cáprea, Tília cordáta and Ácer platanoídes - Sphagnum with Óxalis acetosélla plant community on Albic Gleyic Histic Retisols.

Elements of landscapes: **S** – summit position (interfluve); **US** – middle slope position; **FS** – footslope position.

Soil horizons: **H** – Histic horizon, **O** – Folic horizon, forest litter, **A** - Umbric horizon, **E** – albic horizon, **B** – argic horizon, C – parent material, **Cr** – gletyic.

Summit:

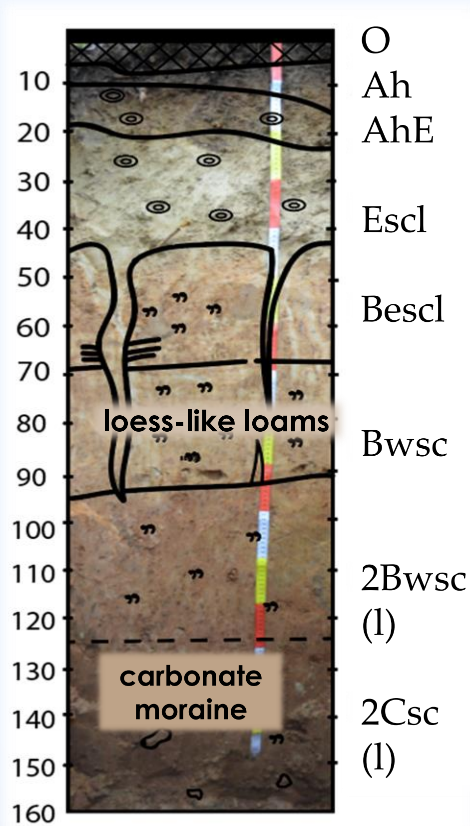
Tília cordáta+ Pícea ábies with Ácer platanoídes; Úlmus glábra - Córylus avellána - Óxalis acetosélla



Endocalcaric Albic Stagnic Retisol

Middle slope:

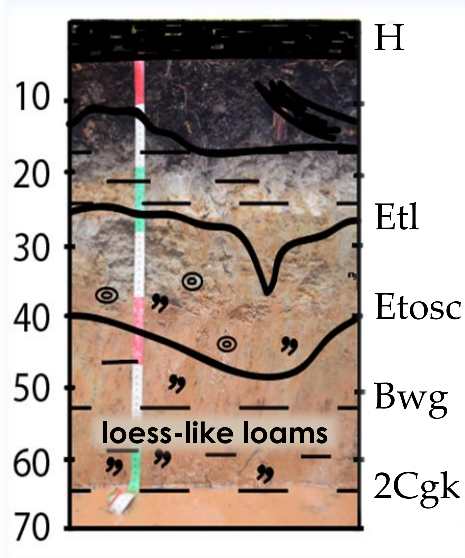
Pícea ábies+Tília cordáta+Ácer platanoídes - Córylus avellána – grass



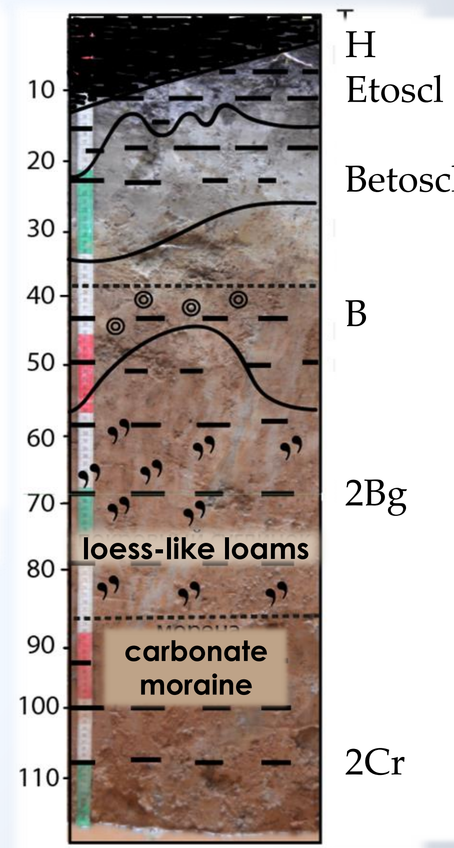
Albic Stagnic Retisol (Humic)

Footslope:

Pícea ábies with Tília cordáta and Ácer platanoídes - Vaccínium myrtíllus - Sphagnum

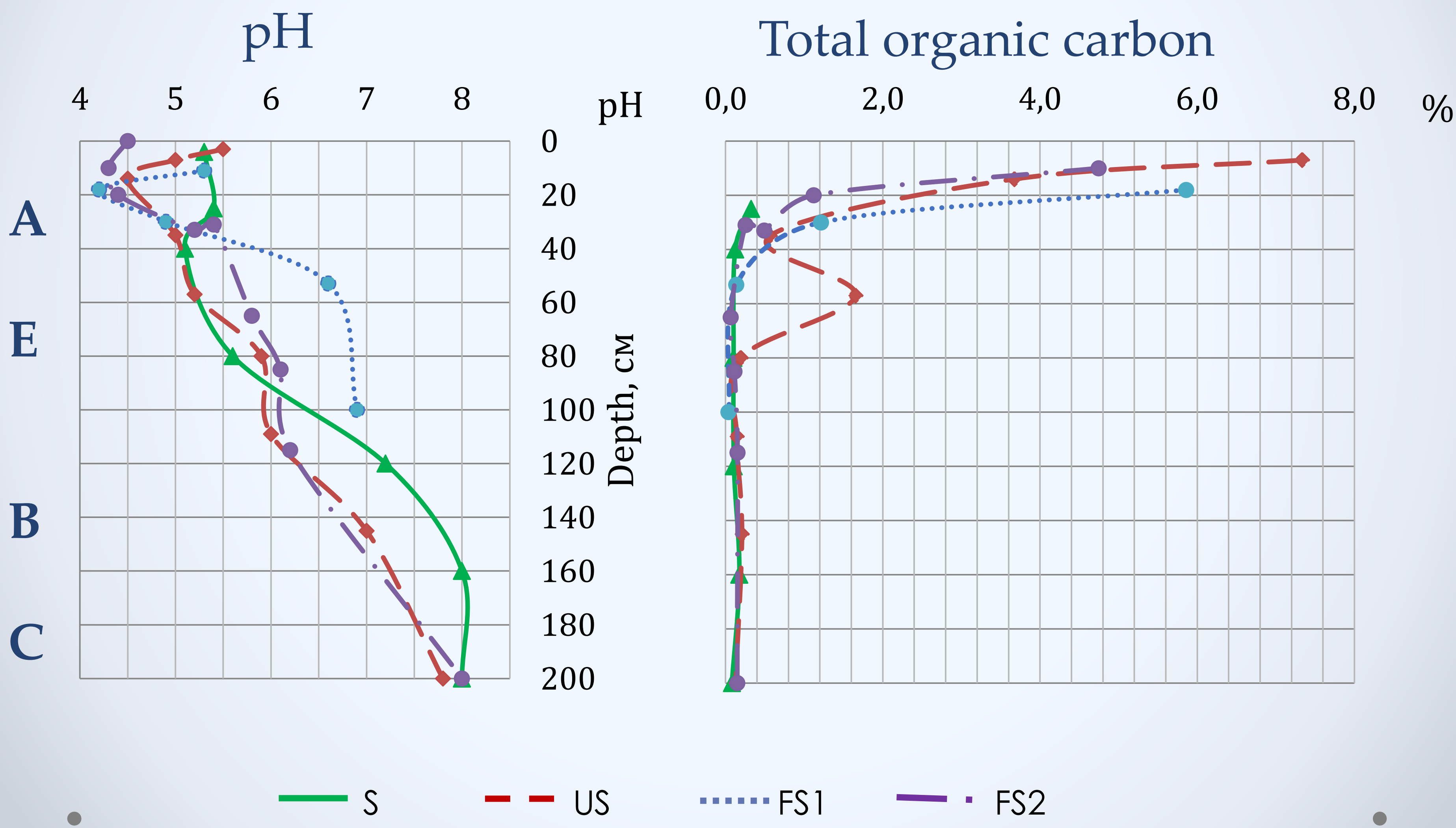


Pícea ábies with Sálix cáprea, Tília cordáta and Ácer platanoídes - Sphagnum with Óxalis acetosélla



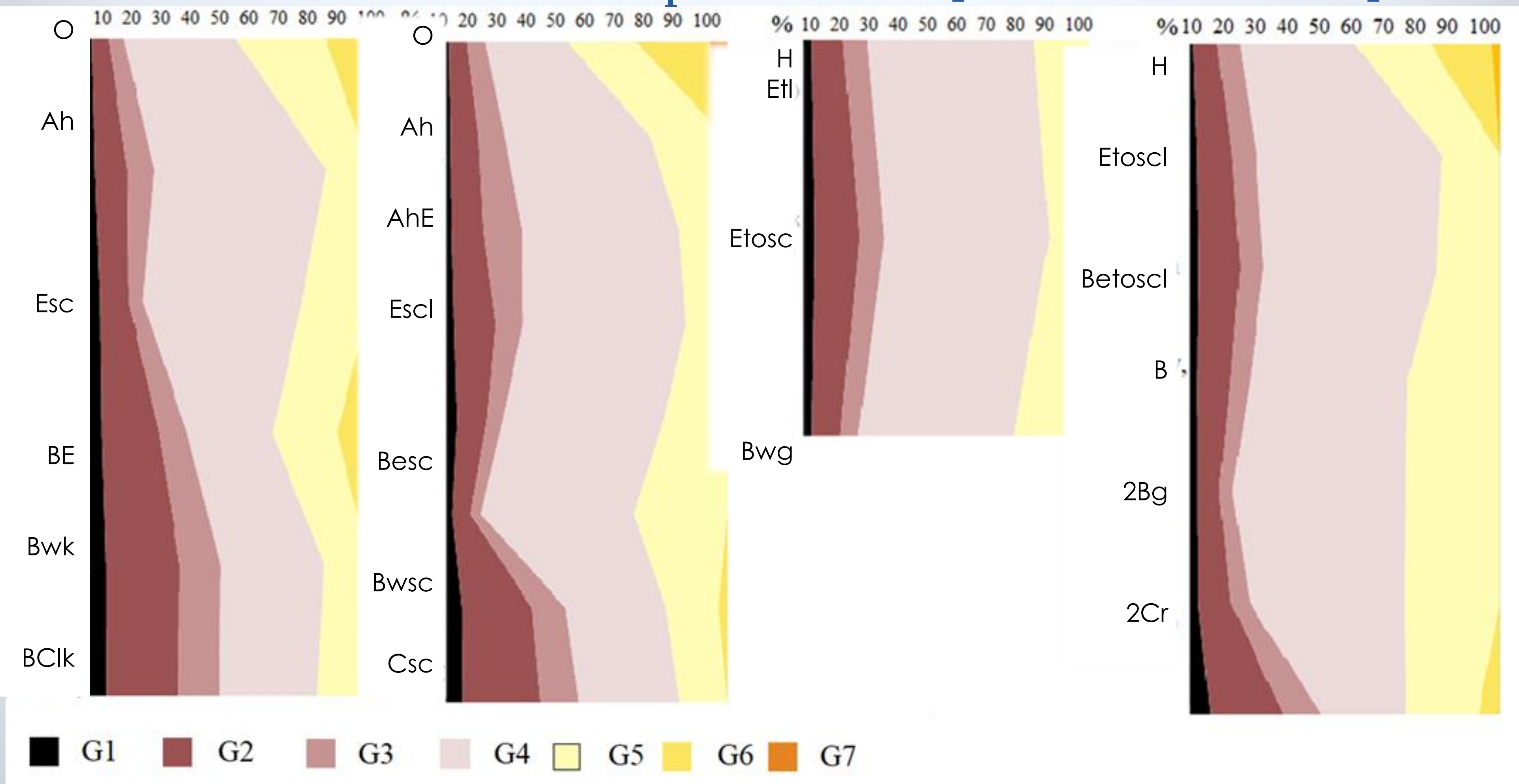
Albic Gleyic Histic Retisols

Vertical differentiation of Retisols in Southern Taiga catena:



Grain size:

Summit: **Middle slope:** **Footslope 1:** **Footslope 2:**



G1 – clay (<1 µm); G2 – very fine silt (5–1); G3 – medium silt (10–5); G4 – coarse silt (50–10); G5 –fine sand (250–50); G6 – medium sand (500–250); G7 – coarse sand (1000–500)

Average content of total ChE fractions in catena soils, mg/kg

Horizons	Co	Cr	Cu	Fe*	Mn	Ni	Pb	Sr	Ti	Zn	Zr
O	3,4	13	10	0,3	1756	7	22	49	773	81	72
A	4,5	21	8	1,2	482	9	21	90	3345	39	292
E	6,9	27	13	1,5	576	13	15	101	3488	37	347
B	8,4	38	19	1,5	685	20	15	99	3064	52	287
C	9,0	40	18	1,6	650	22	15	111	2733	60	211
Literature	3–23	5–140	5–60	0,8–4,6	100–2300	7–90	5–33	50–400	–	30–100	–

Literature data: East European Plain taiga soils (Semenkov, 2016).

Average content of exchangeable ChE fractions (F1) in catena soils, mg/kg

Horizons	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sr	Ti	Zn	Zr
O	1,03	0,04	0,38	80	1588	0,64	4,99	18	2033	29	0,05
A	0,22	0,76	0,15	307	131	0,29	2,58	4	9678	4,1	0,16
E	0,08	0,49	0,34	262	14	0,25	0,56	2	3383	1,0	0,32
B	0,02	0,14	0,41	56	8	0,50	0,43	4	76	0,7	0,06
C	0,24	0,17	0,32	46	80	0,58	0,65	25	0	1,1	0,04
Literature	<2,5	<1,1	<2,2	2–170	0,3–30	<1,3	<2	<10	–	0,3–7,0	–

Literature data: East European Plain taiga soils (Semenkov, 2016).

Average content of bound to organic complexes ChE fractions (F2) in catena soils, mg/kg

Horizons	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sr	Ti	Zn	Zr
O	2,6	0,67	4,4	2175	722	2,7	22	0	0	30,3	0,1
A	0,6	0	1,1	1124	143	0,6	7	0	0	2,5	0,3
E	1,2	0,10	0,5	400	89	0,2	1	0	0	0,1	2,0
B	3,0	0,15	0,8	332	305	2,5	2	0	0	0,6	2,8
C	3,1	0,10	0,8	133	290	4,1	3	1,0	0	0,9	2,7
Literature	0,7-1,3	<0,9	0,2–14	20–150	170–270	0,1-3,4	0,1-8,2	<19	–	0,2–6,0	–

Literature data: East European Plain taiga soils (Semenkov, 2016).

Average content of bound to Fe and Mn hydroxides ChE fractions (F3) in catena soils, mg/kg

Horizons	Co	Cr	Cu	Fe	Mn	Ni	Pb	Sr	Ti	Zn	Zr
O	2,3	0,5	4,1	1430	361	2,5	19,5	6,5	0	0	0,0
A	1,2	1,1	1,4	1789	169	0,8	8,6	0,8	0	0	0,2
E	1,4	2,5	1,7	2892	97	0,9	3,0	1,1	0	3,4	0,5
B	1,2	3,0	2,4	2291	81	2,5	2,9	1,0	0	7,6	0,6
C	1,4	2,1	1,8	1363	95	3,3	2,3	-0,1	9	6,9	0,9
Literature	2,4–6,5	2,1–3,5	0,5–7,7	3700–4500	80–530	0,7–14	2–20	<19	–	3–14	–

Literature data: East European Plain taiga soils (Semenkov, 2016).

Spatial differentiation* of ChE in soils

*Spatial differentiation Coefficient = $\frac{\text{element content in the studied position}}{\text{element content in summit position}}$

Total ChE content

Landscape	Cr	Co	Ni	Cu	Zn	Sr	Zr	Pb	Ti	Mn	Fe
A horizons											
S	**0,9**	**2,1**	**1,1**	**1,1**	**1,2**	**1,4**	**2,8**	**2,0**	**2,6**	**0,9**	**2,1**
FS	**0,2**	**0,6**	**0,5**	**0,7**	**0,4**	**0,8**	**1,7**	**1,2**	**1,3**	**0,0**	**1,3**
B horizons											
S	2,0	1,9	2,0	2,0	1,3	0,8	0,9	1,3	1,4	1,4	1,7
FS	0,9	1,0	1,1	1,1	0,8	0,9	1,6	1,1	1,4	1,3	1,1

ChE mobile fractions

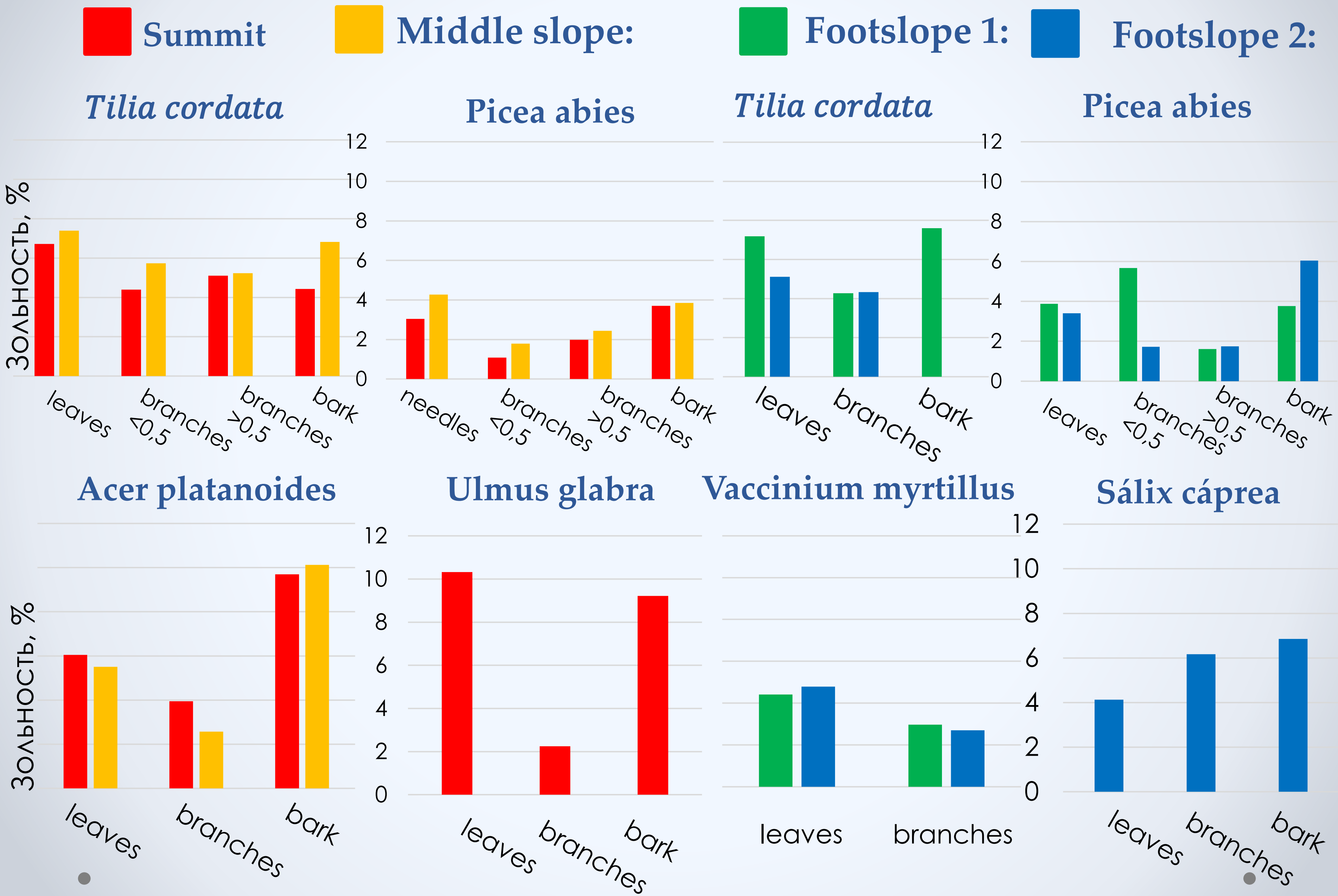
ChE mobile fractions	Landscape	Ti	Fe	Mn	Cr	Co	Ni	Cu	Zn	Sr	Zr	Pb
Exchangeable (F1)	**A horizons**											
	S	**0,6**	**0,3**	**4,0**	**0,3**	**0,2**	**1,3**	**1,2**	**5,3**	**3,3**	**1,3**	**0,4**
	FS	**0,2**	**0,2**	**0,6**	**0,0**	**0,4**	**1,3**	**2,2**	**4,0**	**5,5**	**2,9**	**1,3**
	B horizons											
	S	**na**	**0,3**	**1,2**	**0,9**	**0,6**	**3,6**	**0,7**	**1,4**	**2,6**	**0,9**	**1,3**
	FS	**na**	**1,3**	**0,7**	**1,1**	**0,5**	**2,3**	**1,8**	**1,4**	**1,6**	**1,0**	**1,2**
Bound to organic complexes (F2)	**A horizons**											
	S	**0,3**	**1,1**	**2,2**	**0,0**	**0,5**	**1,8**	**1,4**	**37,2**	**н.д.**	**0,4**	**1,1**
	FS	**0,1**	**1,0**	**0,0**	**0,0**	**0,1**	**1,9**	**2,4**	**31,1**	**н.д.**	**0,2**	**0,8**
	B horizons											
	S	**0,1**	**0,7**	**2,0**	**н.д.**	**2,2**	**20,9**	**2,8**	**na**	**0,0**	**1,2**	**2,0**
	FS	**0,6**	**1,4**	**0,5**	**н.д.**	**0,3**	**0,9**	**0,7**	**na**	**0,0**	**1,6**	**0,7**
Bound to Fe and Mn hydroxides (F3)	**A horizons**											
	S	**1,1**	**1,4**	**0,7**	**1,3**	**1,1**	**0,8**	**0,9**	**0,8**	**1,0**	**0,6**	**0,7**
	FS	**0,6**	**1,6**	**0,1**	**0,8**	**0,2**	**0,7**	**1,0**	**0,3**	**1,1**	**0,4**	**0,7**
	B horizons											
	S	**0,9**	**0,9**	**1,6**	**1,2**	**1,4**	**1,8**	**0,9**	**0,9**	**1,1**	**1,4**	**0,9**
	FS	**1,9**	**1,2**	**1,7**	**1,2**	**1,1**	**1,3**	**1,1**	**0,8**	**1,0**	**1,6**	**0,7**

Biogeochemical structure of plant communities

$$\textbf{Species ChE content Coefficient} = \frac{ChE\ content\ in\ studied\ species}{ChE\ content\ in\ reference\ species\ (Tilia\ cordata\ leaves)}$$

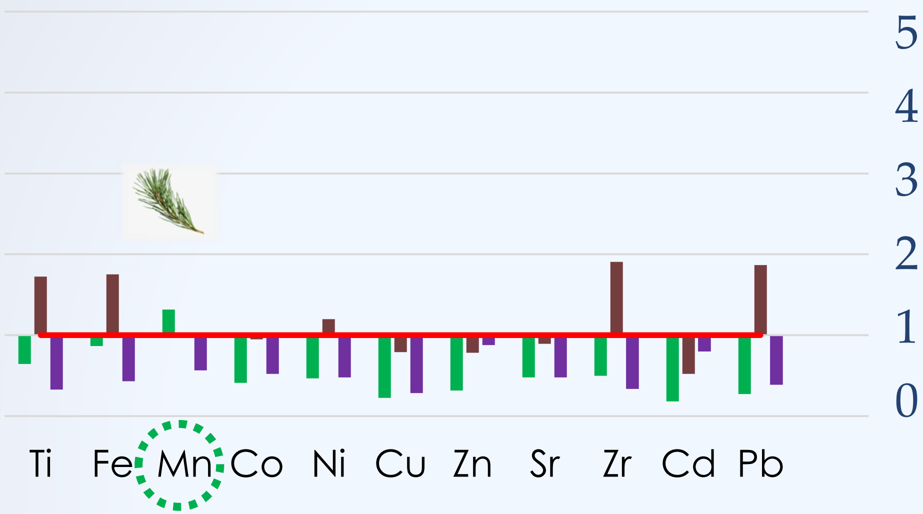
Summit:	Middle slope:	Footslope 1:	Footslope 2:
Absorb ChE:			
Acer platanoides $\mathbf{Cd_{4,7}}$ Picea abies $\mathbf{Pb_{7,97}Co_{6,4}Mn_{5,4}}$	Picea abies $\mathbf{CoMn_{4,5}}$ Pb $Cd_{3,2}$	Acer platanoides $\mathbf{Cd_{8,04}}$ Picea abies $Mn_{3,8}$, $\mathbf{Co_{4,4}}$, $\mathbf{Zn_{4,8}}$, $Sr_{3,1}$, $Cd_{3,4}$	Sálix cáprea $\mathbf{Zn_{6,9}Cd_{4,6}}$ Acer platanoides Ti, **Mn**, Zn
Anemone nemorosa $\mathbf{Ti_{11,9}}$ $\mathbf{Fe_{5,7}}$ $\mathbf{Zr_{4,08}}$ $Co_{2,79}$ $Pb_{2,69}$ Pteridium aquilinum $\mathbf{Ti_{11,6}}$ $Fe_{4,7}$ $Zr_{3,8}Cr_{3,5}Pb_{2,9}$ $Cd_{2,7}$ $Co_{2,7}$	Stellaria holostea $\mathbf{Cd_{9,7}}$ Pteridium aquilinum $\mathbf{Zr_{8,6}Cd_{5,5}Ti_{4,3}}$	Vaccinium myrtillus $\mathbf{Ti_{16,98}Zr_{12,5}Mn_{6,6}}$ $\mathbf{Co_{4,9}}$ $\mathbf{Fe_{4,7}}$	Pteridium aquilinum $Ti_{10,8}Zr_{8,9}Cr_{4,6}$ Sphagnum $\mathbf{Pb_{54,6}Ti_{38,4}}$ $\mathbf{Zr_{25,6}Cr_{18,5}Fe_{6}}$ $\mathbf{Co_{3,3}Cd_{2,5}Ni_{2,4}}$
Don't absorb ChE:			
Ulmus glabra $\mathbf{Cd_{0,1}Cr_{0,13}}Zr_{0,3}$ $Zn_{0,27}$	-	-	Picea abies ($Cu_{0,4}$)
Oxalis acetosella $Cd_{0,24}Ni_{0,3}Cr_{0,3}$	Equisetum sylvaticum Sr, $Zn_{0,4}$, Ni, Cu, Zr, $Pb_{0,3}$		Oxalis acetosella Co, Cu, $\mathbf{Cd_{0,2}}$

Studied plant ash content



ChE contents in plant organs

Picea abies (n=4)

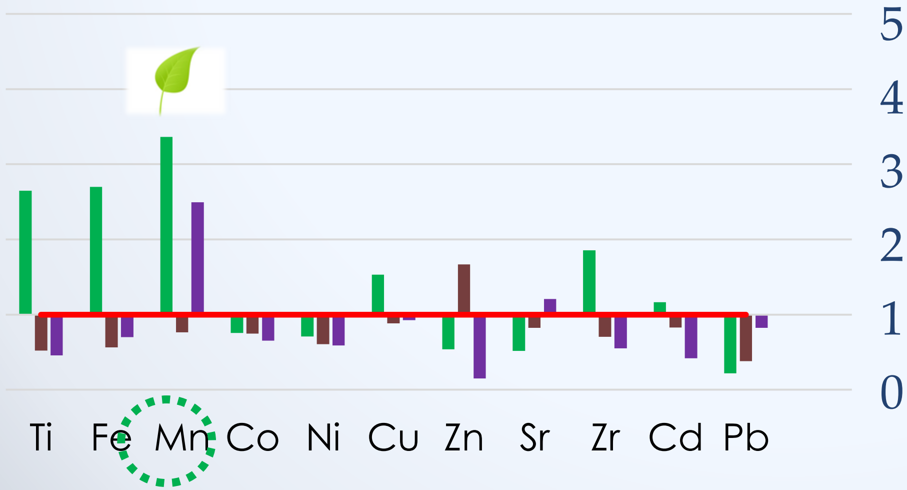


Organs ChE content Coefficient =

$$\frac{ChE\ content\ in\ studied\ organ}{ChE\ content\ in\ reference\ organ}$$

$$(branches\ > 0{,}5)$$

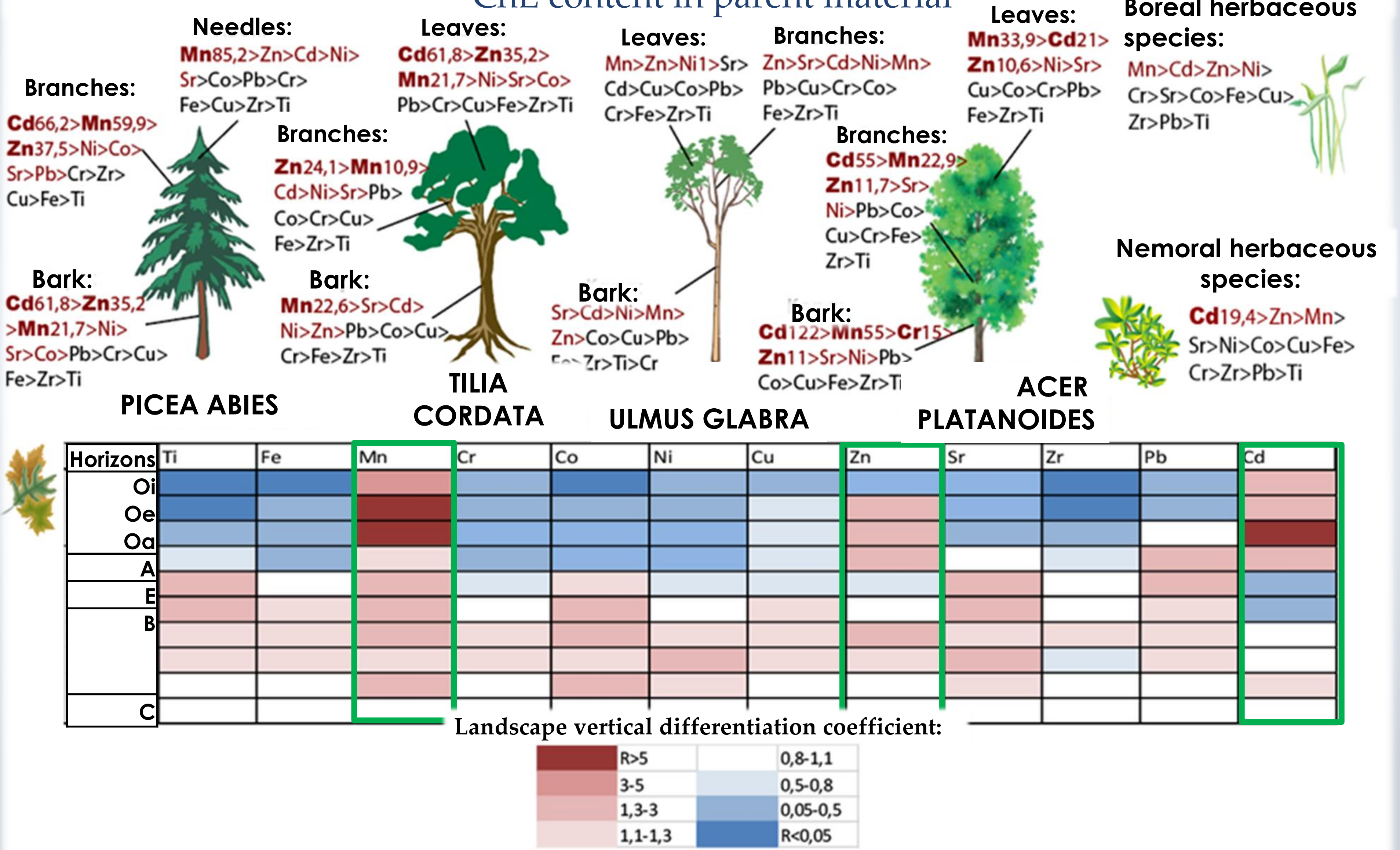
Tilia cordata (n=4)



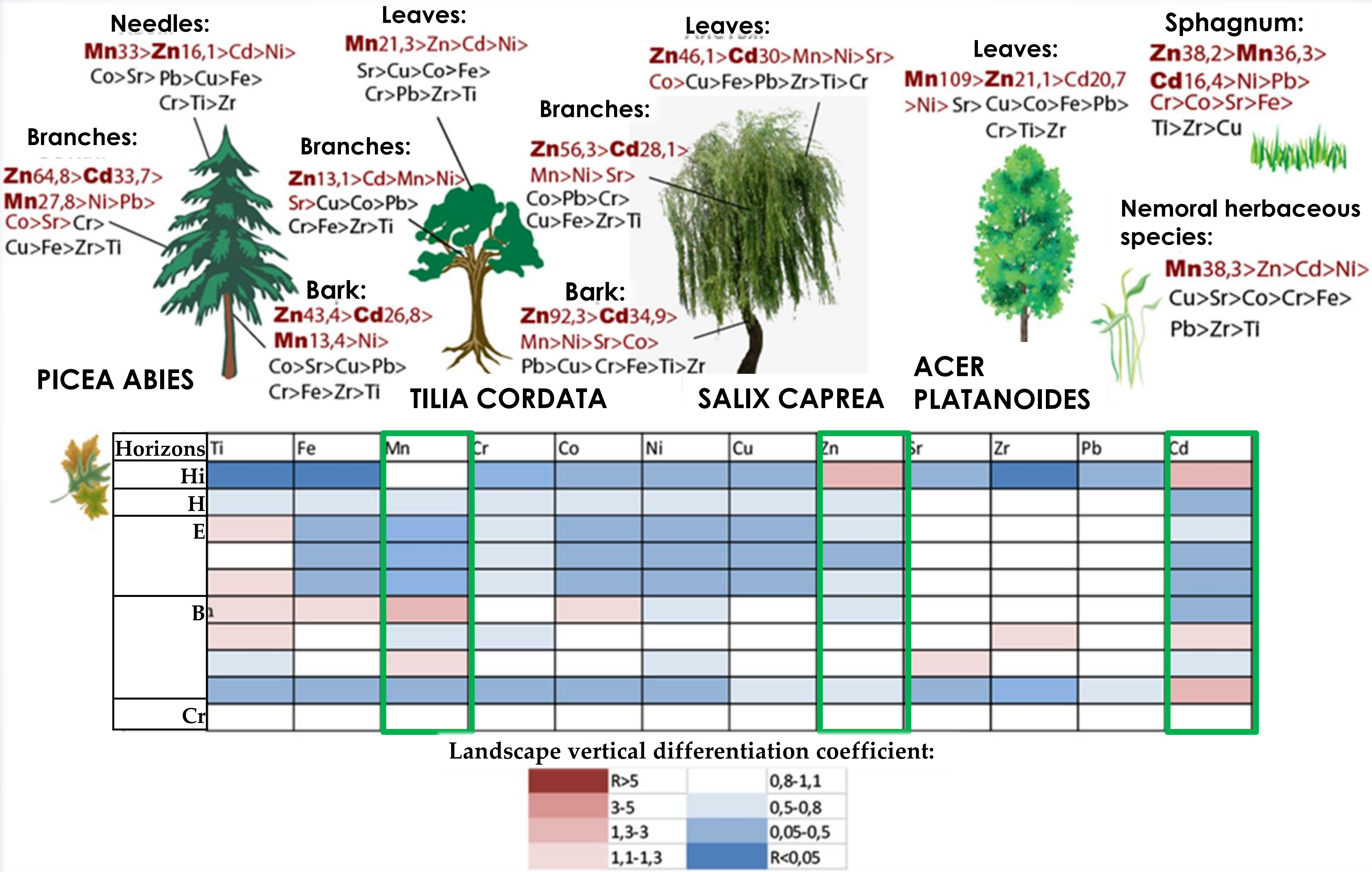
Vertical geochemical structure of summit position

Landscape vertical differentiation coefficient (R)

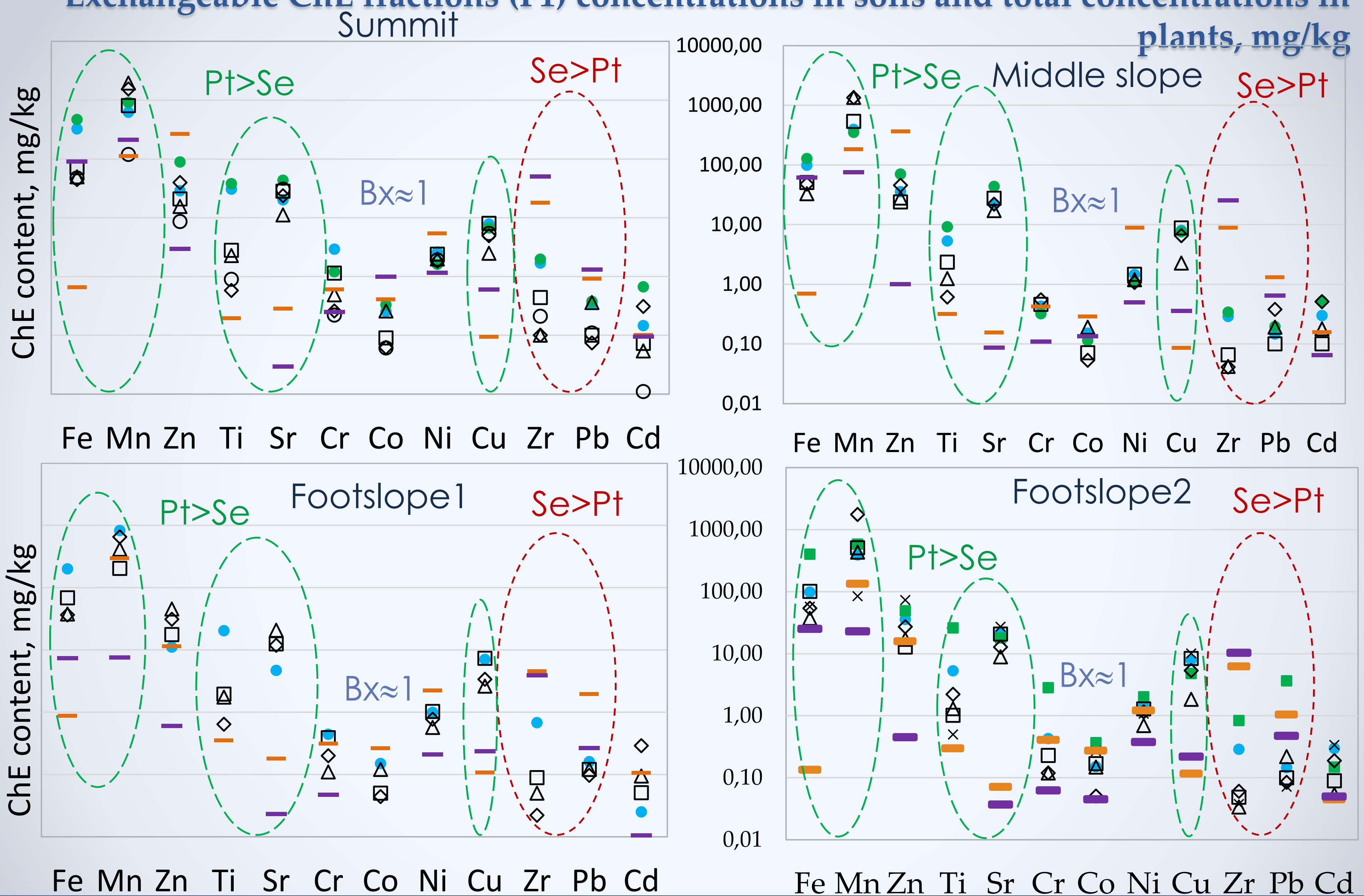
$$= \frac{\text{ChE content in the landscape component (plant organs, soils horizons)}}{\text{ChE content in parent material}}$$



Vertical geochemical structure of footslope position



Exchangeable ChE fractions (F1) concentrations in soils and total concentrations in plants, mg/kg



Tilia Cordata
Picea abies
Acer platanoides
Ulmus glabra
Salix Caprea
Nemoral herbaceous species
Boreal herbaceous species
Sphagnum

Soils horizons:
- profile average contentrations
- A-horizons average contentrations
- C-horizons average contentrations

Pt – total ChE concentration in plants
Se – exchangeable ChE concentration in soils

Summary

- Southern Taiga soils have similar concentration of Mn, Pb, Ti, and Zr and lower concentration of Co, Cu, Fe, Zn, Ni, Sr, and Cr comparing to the soils of the East European Plain
- In A- horisons concentration of metal F1 diminishes in order: Fe>Mn>Sr>Zn, Pb>Ti, Cr, Ni, Cu, Co, Zr. Concentrations of F2 and F3 show the following order: Fe>Mn>>Ti, Zr, Pb>Co>Ni, Cu, Zn>Cr, Sr and Fe>Mn>Ti>Zn, Sr, Pb>Cr>Cu, Ni, Co>Zr, respectively. Reduced content inE-horizon and/or an increased B-horizon one was found for the total contents of Co, Fe, Ni, Sr and Zn, F1 Co, Cr, Cu, Mn, Pb, Zn and Zr, F2 Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Zr, as well as F3 Co, Cr, Cu, Ti, Zn and Zr.
- Total amount of Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Ti, Zn and Zr increases in spatial differentiation in A-horizon of Retisols of Southern Taiga catena. Concentration of F1 Ni, Cu, Sr, and Zr, F2 of Ni, Cu and Zn increases in A-horizon of soils of footslope landscape. Concentration of F1 Co, Cr, Pb, Ti, and Zn, F2 — Cr, Ti, and Co, as well as F3 — Mn,Ni, Zn, Pb, and Zr reduces.
- Most tree species accumulate Mn and Zn in leaves, as well as Co and Cd. Plants of grassy-shrub layer concentrate elements with low biophilicity.
- The highest concentration of elements appears in photosynthetic plants organs in deciduous trees and concentrates in branches and bark in coniferous (spruce) trees.
- Mn, Zn, and Cd are actively involved in processes of biogenic accumulation in soils, which are characterized by accumulation in A-horizons. The uptake of Mn, Zn and Cd by plants is determined by the exchangable ChE forms (F1) contentrations in soils.