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WP2 Soil health

Team and mission

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PhD Kristina Ivashchenko

PhD Olga Gavrichkova

MD Alexandra Selezneva

PhD Ramilla Brykova (WP 1-2)

PhD Sofia Sushko (WP 1-2, 5)

Mentor

Prof. Yakov Kuzyakov

The research group focuses on the selection of sensitive soil microbial indexes and express-techniques their measurement. These soil indexes will apply for the evaluation of ecosystem services of two typical green areas in the urban environment: lawns and lawns with trees.

Content

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Results	Plans	Interactions
(June 2019-June 2020)	(June 2020-December 2020)	WP1 — A. Yaroslavtsev WP2 Soil quality — A. Paltceva WP3 — P. Konstantinov W5 – M. Slukovskaya W6 – V. Matasov

Results

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i. There were reviewed widely used microbial indexes for urban soil health assessment during the last decades: World and Russian experience.

ii. There were reviewed the soil microbial indexes and methods based on the developed criteria considering features of the urban environment for ecosystem services assessment . The list of appropriate indexes and methods were suggested.

iii. Some of the suggested microbial indexes were tested for the lawn constructions (lab experiment) and lawns with trees (open lab experiment) given particular emphasis to their drivers.

i. Microbial indexes for urban soil health: analysis of the 28 international and 48 Russian articles (review paper together with Prof. Ananyeva -> in the processes)

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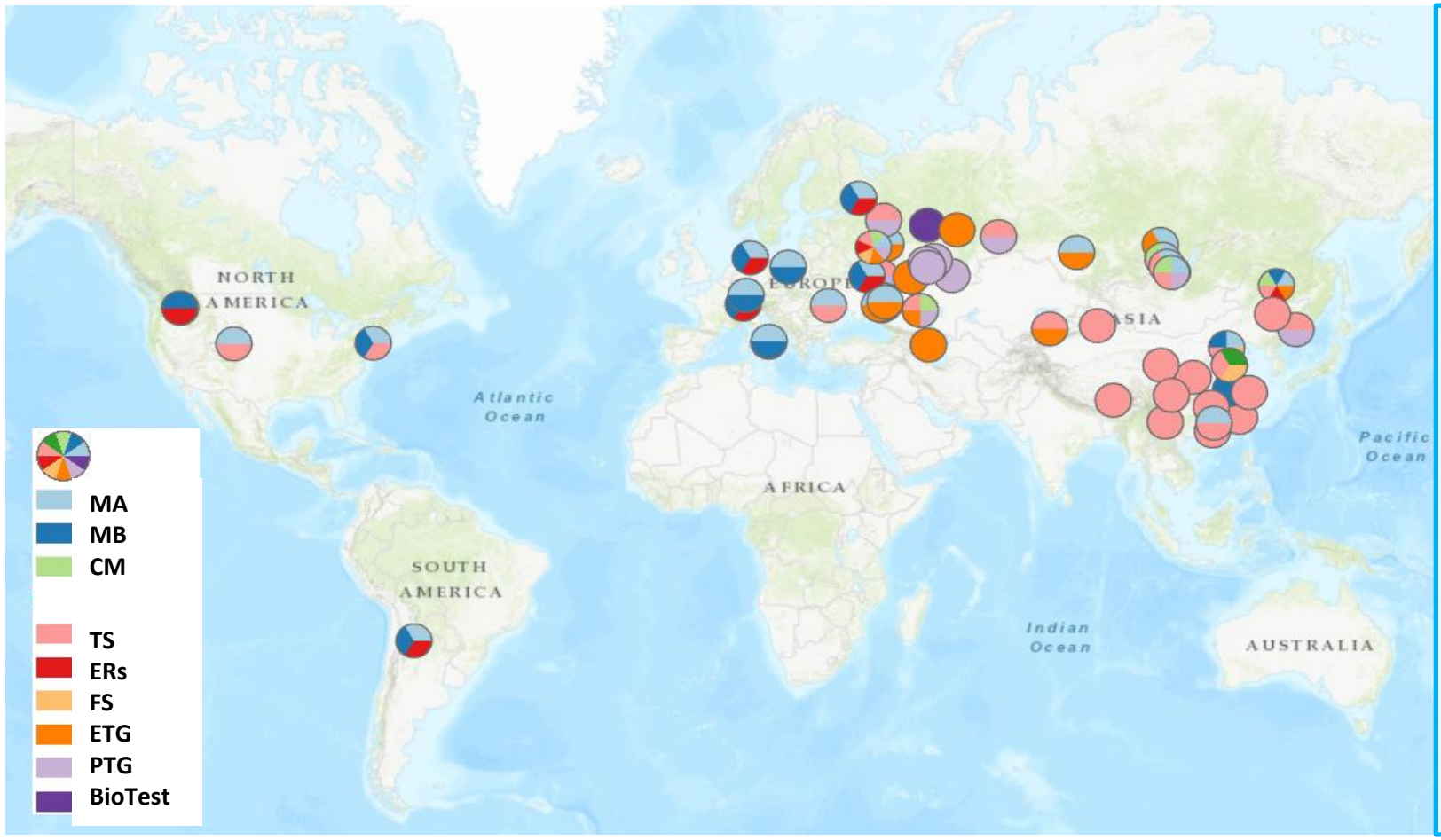
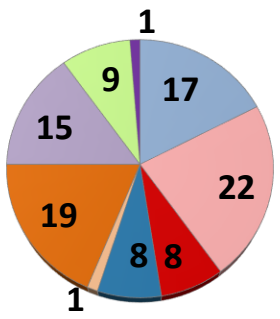
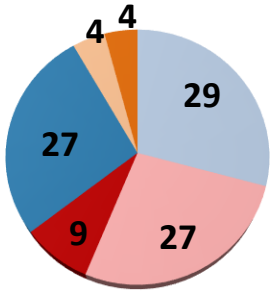


Russia



- Taxonomic structure (Petri dishes)
- Ecological-trophic groups
- Pathogens
- Microbial activity

Other countries



- Microbial biomass
- Microbial activity
- Taxonomic structure (16SRNA, ITS)

The microbiological methods applied in Russian studies are less advanced than in other countries
The functional structure of the microbial community was weakly studied for urban soils elsewhere

List of criteria for microbial indexes of urban soil health assessment

ABR	Criteria	Condition does not fulfill the criteria
a	Feasibility	Expensive equipment and extensive staff training required
b	Costs	Soil analysis cost > 3 €; Analysis <100 samples per week
c	Sensitivity	It does not sensitive to soil pollution and land use change
d	Selectivity	A lot of factors at the same time influence on index value
e	Reproducibility	There is a significant difference between the analytical replicates
f	Applying as indicator	Rarely used
g	Standardization of the methodology at the international level	No
h	Interpretation and understanding	The results are difficult to interpret for a wide audience (residents and city administration).
i	Recognition by the scientific community	Few studies using the indicator (<100 publications)
j	Evaluation and comparison of results	No open databases

Faber et al. (2013), Pulleman et al. (2012), Thiele-Bruhn et al., 2019

The list of microbial indexes (modified from Thiele-Bruhn et al., 2019) linked with soil functions and ecosystem services (according to Adhikari, Hartemink, 2016; MEA, 2005)

Index	Function	Ecosystem service	Method*	a	b	c	d	e	f	g	h	i	j
Microbial biomass carbon	Carbon pool	Carbon sequestration	SIR										
Microbial biomass carbon, nitrogen, phosphorus	Pool of C, N, P	Maintaining nutrient availability	Fumigation-extraction										
Microbial respiration / microbial activity	Organic matter mineralization Biodegradation of organic pollutants Biochemical cycles	Regulation of CO_2 in the atmosphere, contribution to climate change Maintaining nutrient availability in the soil Plant biomass production	Gas chromatography										
			Oxitop										
			Tee bags										
Community level physiological profile (CLPP)	Utilization of organic substrates, biodegradation of organic pollutants	Maintaining ecosystem resilience Maintaining functional diversity	Biolog (Spectrometry)										
			MicroResp™ (Spectrometry)										
Nitrogenase genes (nifH)	Nitrogen fixation Nitrogen cycle	Plant biomass production	MolBL										
Glomaline content as proxy of the presence of arbuscular mycorrhiza fungi	Soil structure and aggregation Plant protection against pathogens	Plant biomass production Maintaining plant resistance, including improving the water regime and their nutrition	Spectrometry										

~20 microbial indexes

Scores 1 — 3

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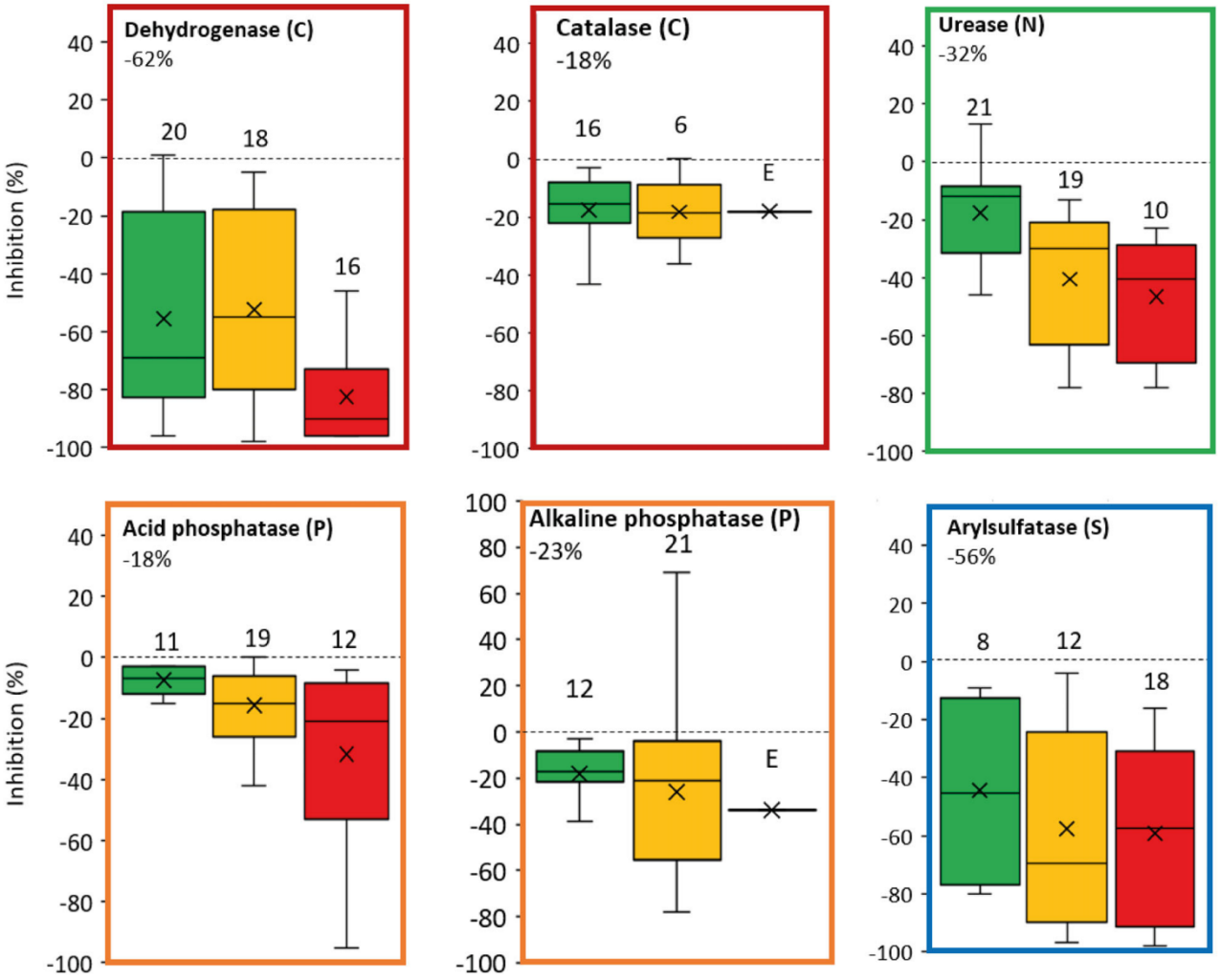
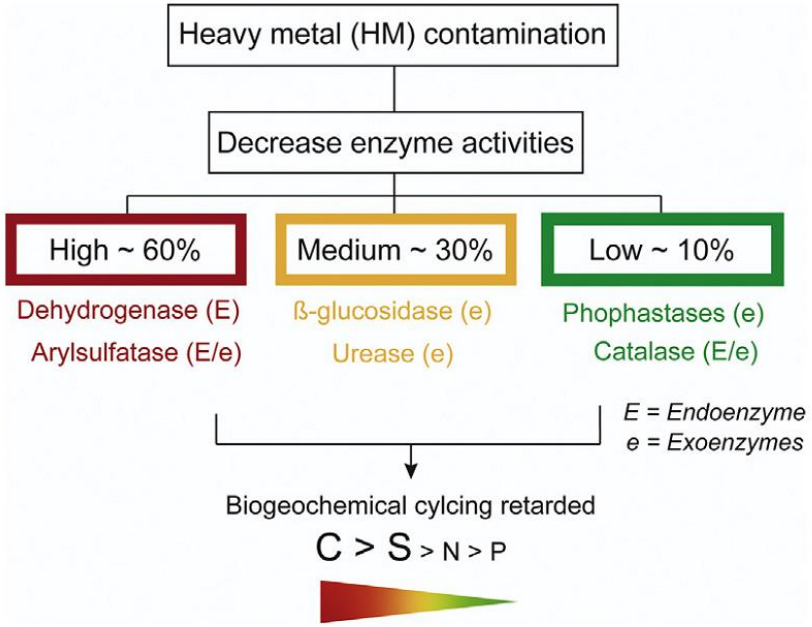
Sensitivity and selectivity of the microbial indexes (mainly Cd, Pb, Zn, and Cu contamination)

Enzyme activities depending on the three levels of metal(loid) contamination : low (green), medium (yellow), and high (red).



Short-term → intracellular enzymes
dehydrogenase

Long-term → extracellular enzymes
arylsulfatase



Aponte H., Medina J., Butler B., Meier S., Cornejo P. and **Kuzyakov Y.** Soil quality indices for metal(loid) contamination: An enzymatic perspective. Land Degrad Dev. 2020. P. 1–20. https://doi.org/10.1002/ldr.3630 (Q1).

Aponte H., Meli P., Butler B., Paolini J., Matuse F., Merinoe C., Cornejog P. and **Kuzyakov Y.** Meta-analysis of heavy metal effects on soil enzyme activities. Science of the Total Environment. 2020. 737. P. 139744. https://doi.org/10.1016/j.scitotenv.2020.139744 (Q1).

Microbiological methods: advantages and disadvantages

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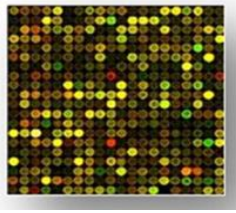
Molecular biology techniques

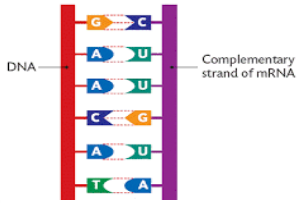
\+ Allow characterizing specific genes or taxonomic group of microbes, including noncultivated; high selectivity

\- Expensive (not suitable for monitoring)

EXMPL

GeoChip
~60K genes **$500** per sample
~180K genes **$750** per sample
Glomics company, USA



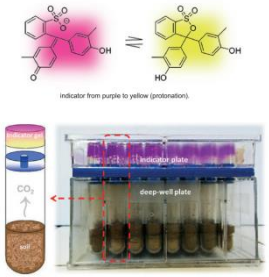


Physiological methods

\+ Not expensive and labor consuming, sensitive

\- Low selectivity

$1-10 per sample
20-50 samples per week



Specific components determination

\+ Association with certain functional group of microbes

\- difficulties with extraction

up to $200 per sample
20-50 samples per week

Strategy at the urban soil health assessment

- use the indexes, which are sensitive to the specific urban stressors and related to ecosystem services
- use the methods, which allow to determine the microbial community functioning
- develop the approach to the urban soils health assessment (sampling design and methods) considering their high heterogeneity

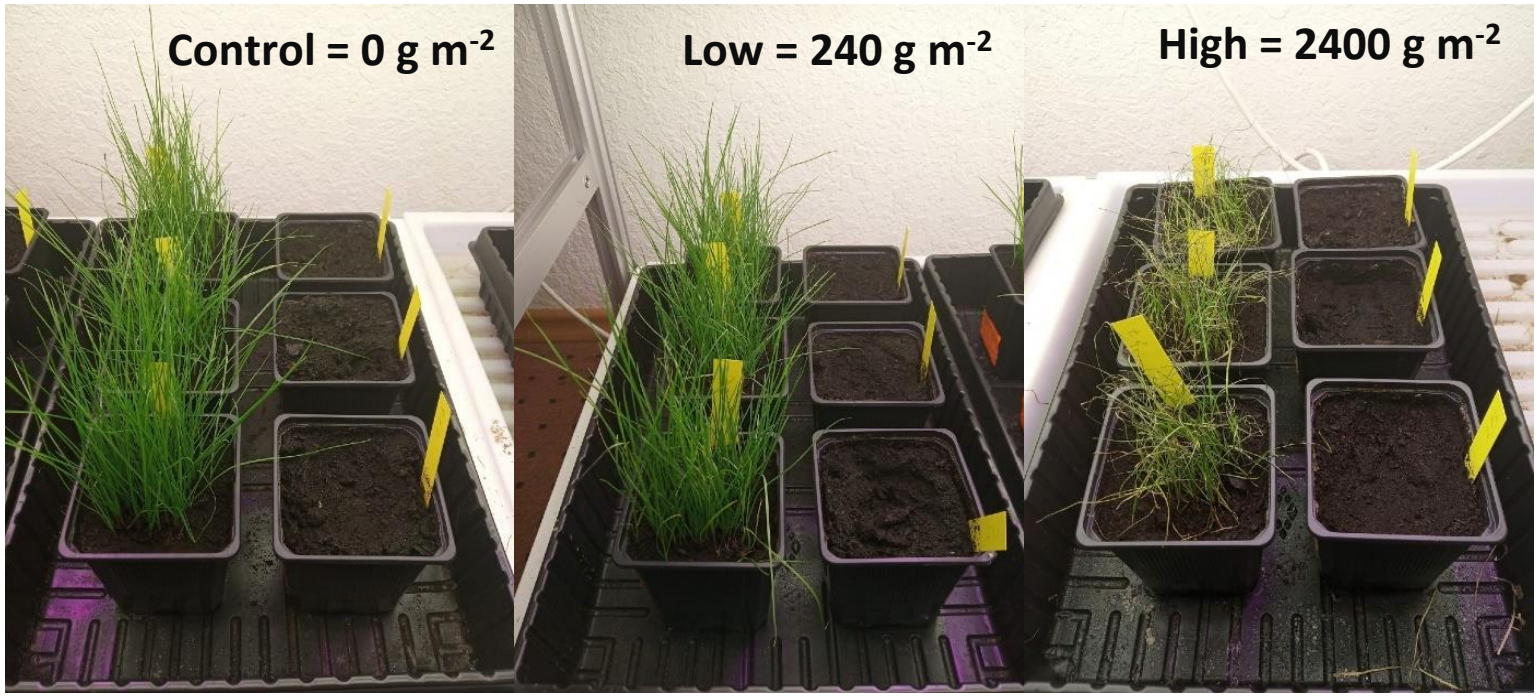
ii. The selected microbial indexes

Microbial index	Method	Ecosystem services	Devices	Availability in RUDN
Microbial biomass	Fumigation-extraction (ISO 14240-1: 1997) Substrate-induced respiration (ISO 14240-2: 1997)	Carbon sequestration ecosystem services	Gas chromatograph, C analyzer	
Microbial activity, tea bag index	Measurement of the weight loss of green and rooibos tea in soil	Nutrients' cycle, Biodegradation potential	Lipton tea bags	
Community level physiological profile	MicroResp (Chapman et al., 2007)	Maintaining functional diversity		
Enzymatic activity β-glucosidase, leucine aminopeptidase, phosphotase	Fluorogeneous glycosidase substrate (ISO / TS 22939: 2019)	Nutrients' cycle (C, N, P)	Microplate reader	
Specific enzymes laccases, dehydrogenase arylsulfatase	Spectrophotometry	Biodegradation of pollutants (xenobiotics) Nutrients' cycle (C, S)	Spectrometer	
Glomalin content	Near infrared spectroscopy (Zbíral et al., 2016)	Maintaining plant resistance, including improving the water regime and their nutrition	Near infrared spectroscopy device	communication to Zbíral

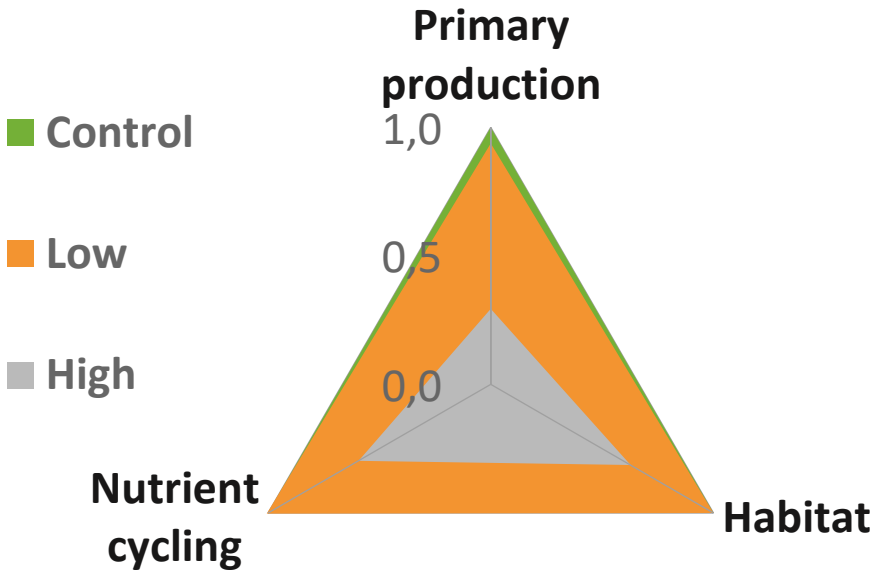
iii. Microbial indexes testing with given particular emphasis to their drivers

Driver	Microbial indexes	Experiment
a) Salinization	Microbial biomass, microbial respiration	Lawns (in lab)
b) Organic amendments and grass species	Community level physiological profile (CLPP)	
c) Tree species and state	Microbial biomass, microbial respiration, CLPP	Lawns with trees (open lab)

a) the research focused on the assessment of salt (NaCl) impact on the state of the lawn plant and soil at low and high (240 and 2400 g m^{-2}) concentrations mimicking salinization level close and far to the roads, respectively



Ecosystem services assessment

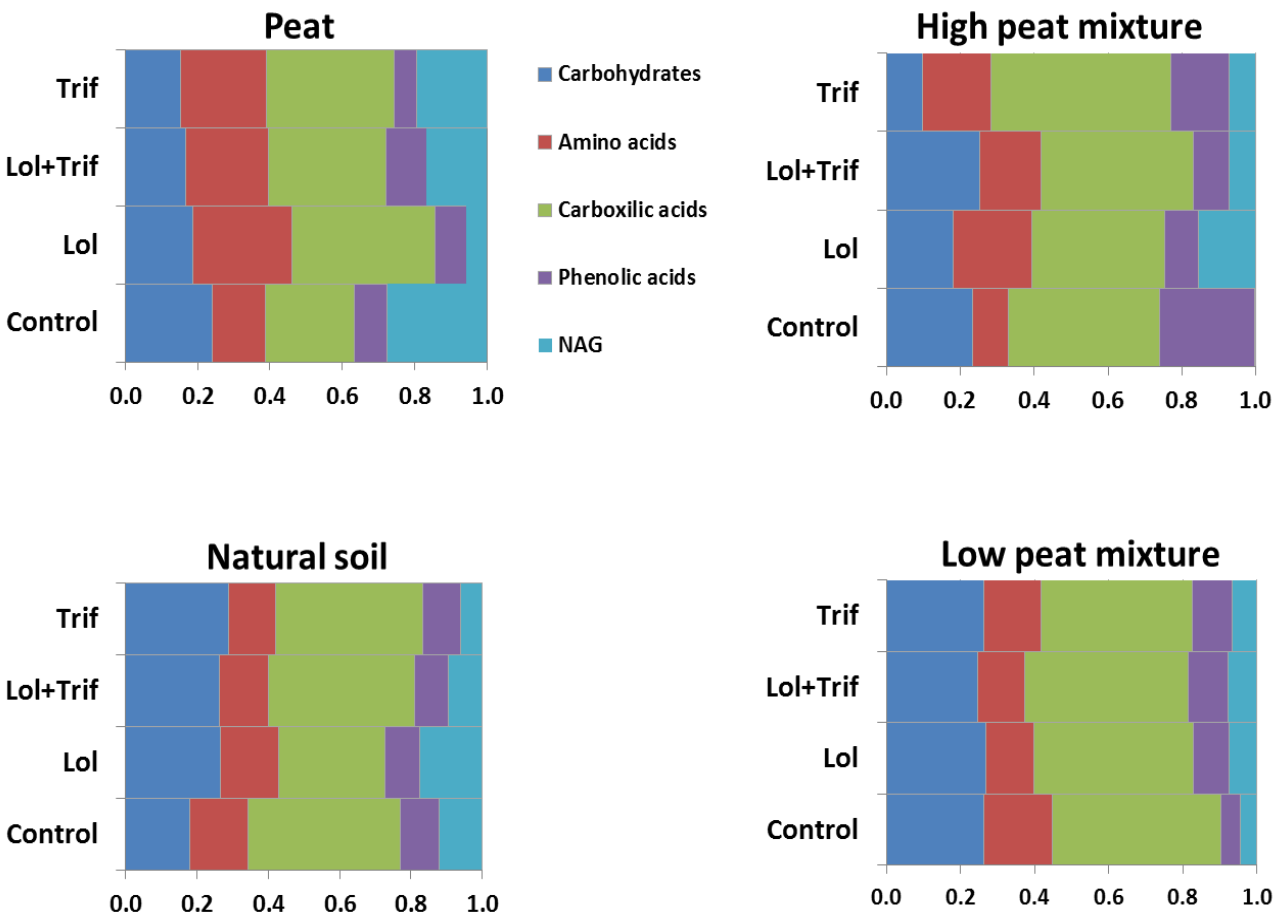


- ✓ The high salt concentration depleted on average by 80% the potential to provide primary production service, habitat for microbes and nutrient cycling
- ✓ The presence of plants mitigated the salinization effect on the microbial community of turfgrass soil

Brykova R., Ivashchenko K., Gavrichkova O., Romzaykina O., Demina S., Lepore E., Dovletyarova E. Effect of deicing salts on urban lawn components: a pot experiment. Agrochimica. July 2020 (accepted, Scopus, Q3).

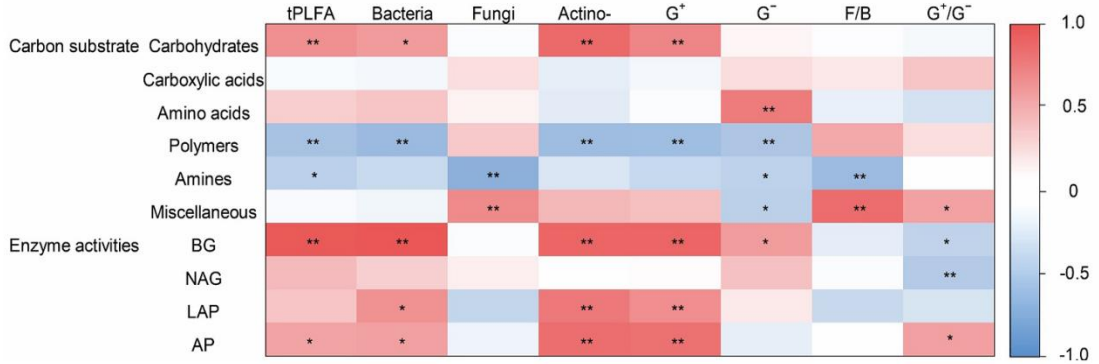
Kuzyakov Y., Gunina A., Zamanian K., Tian J., Luo Y., Xu X., Yudina A., Aponte H., Alharbi H., Ovsepyan L., Kurganova I., Ge T. and Guillaume T. New approaches for evaluation of soil health, sensitivity and resistance to degradation. Frontiers of Agricultural Science and Engineering. 2020. https://doi.org/10.15302/J-FASE-2020338 (Q3).

b) there were tested the effect on CLPP of the two lawn species (*Lolium perenne* and *Trifolium repens*) and their grass mixture under different organic-mineral materials: Peat (PT), Natural soil (NS, Albic Retisols), High peat mixture (PT:NS=70:30%) and Low peat mixture (PT:NS=30:70%)

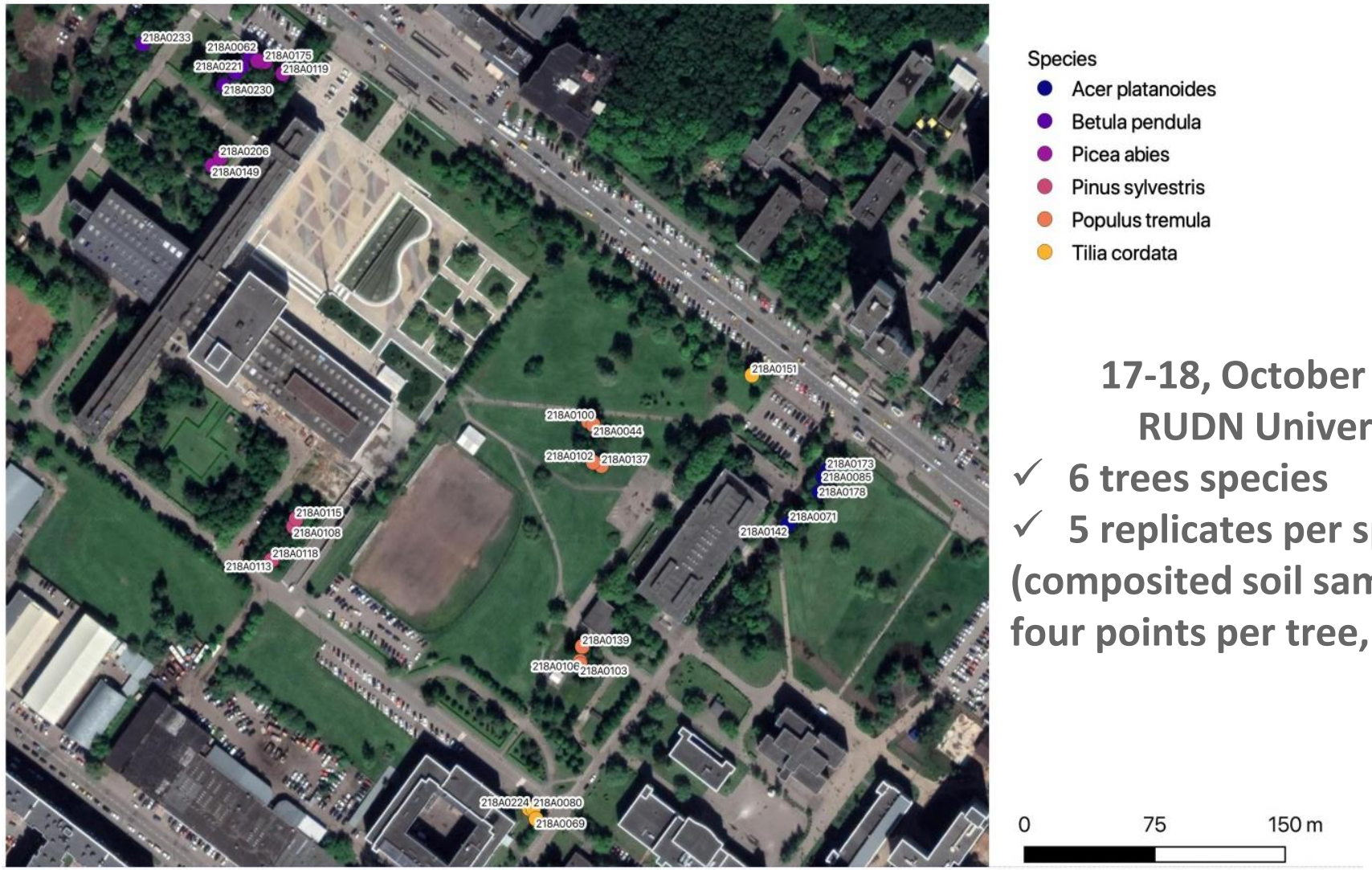


- ✓ The portion of microbial group consuming the carboxylic acids in CLPP was higher in natural soil than peat.
- ✓ The addition of the peat to the natural soil (soil-peat mixtures) led to decreasing the portion of microbial group consuming N- acetylglucosamine (chitin' monomer).
- ✓ The effect of the plants on CLPP depended on the type of materials.

Substrate utilization as proxy (*Xu et al., 2019*)

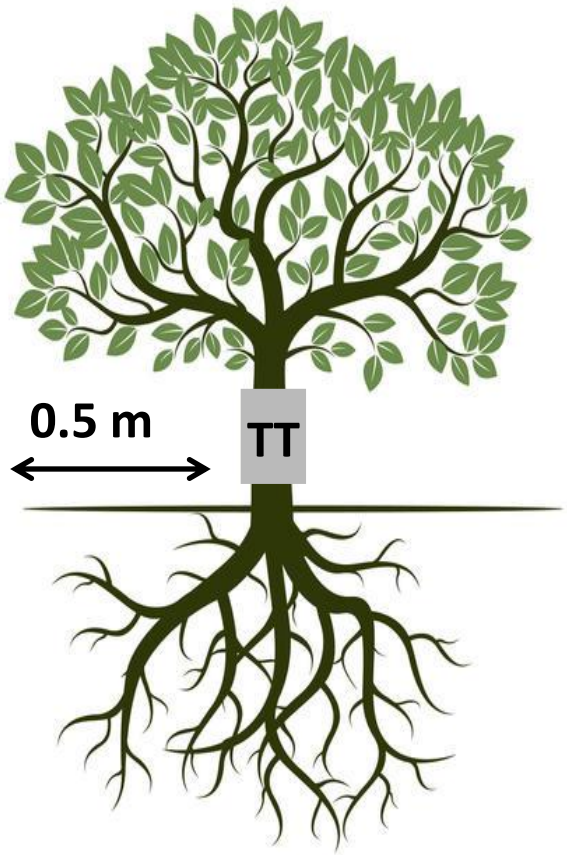


b) there were checked the relationship between soil microbial indexes and state of the trees measured based on TreeTalker, visual tree assessment, anthropogenic load (proximity to the road, compaction)

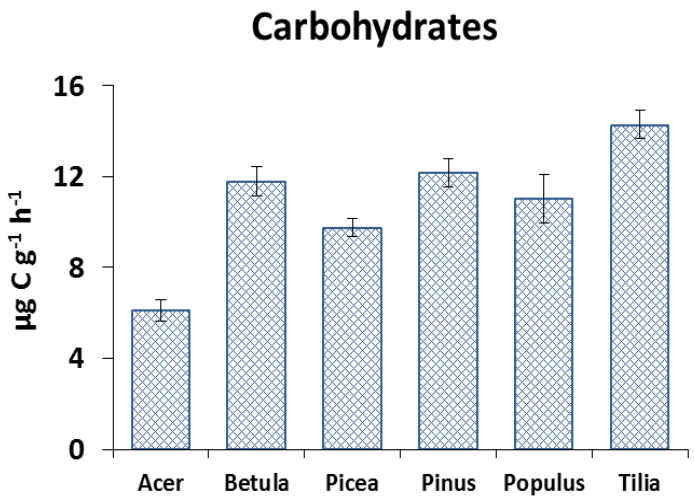


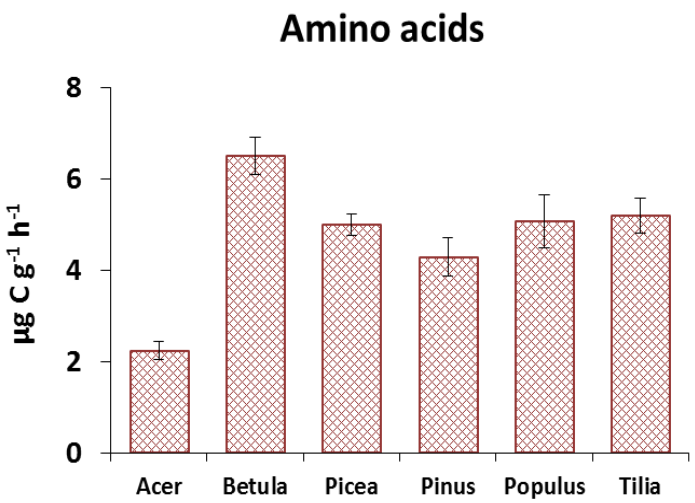
17-18, October 2019,
RUDN University

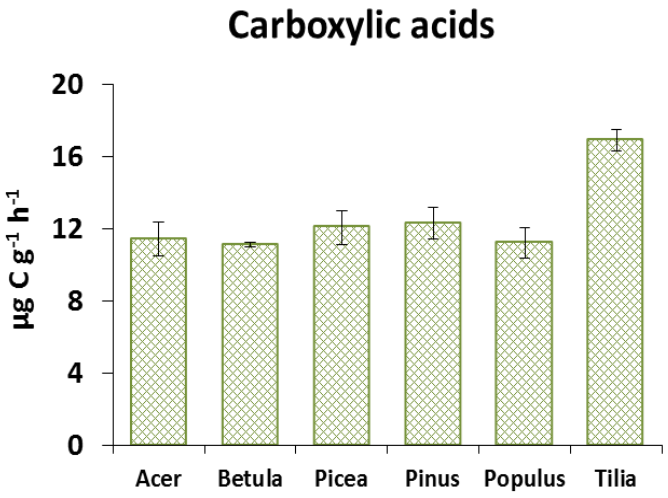
- ✓ 6 trees species
- ✓ 5 replicates per species (composited soil sample from four points per tree, 0-10 cm)

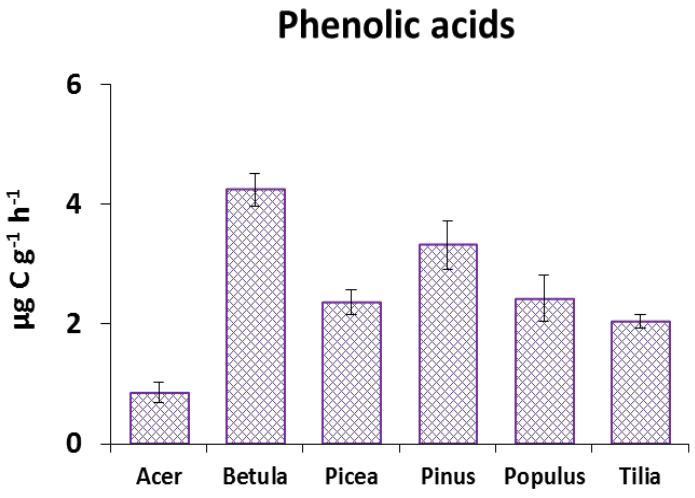


b) microbial respiration responses on carbohydrates, amino acids, carboxylic acids and phenolic acids in topsoil with different tree species









- ✓ The microbial response on carboxylic acid had the low selectivity in terms of the tree species. There was found relationship between **microbial response on oxalic acid and trunk moisture measured by TreeTalker** (r=0.6).

➡ *It has been shown that plant roots secrete oxalic acids to detoxify aluminium in the soils*

(Badri and Vivanco, 2009)

- ✓ The lowest MBC, microbial response on amino and phenolic acid was found for the soil of *Acer platanoides* site, the highest for *Betula pendula*.

Seleznyova A., **Yaroslavtcev A., Gavrichkova O., Ryazanov A.,** Kovaleva J., Ananyeva N., and **Valentini R.** Soil microbial biomass, community level physiological profiles relate to tree species and its state in urban environment. EGU2020-1064. General Assembly.

Plans and Interactions

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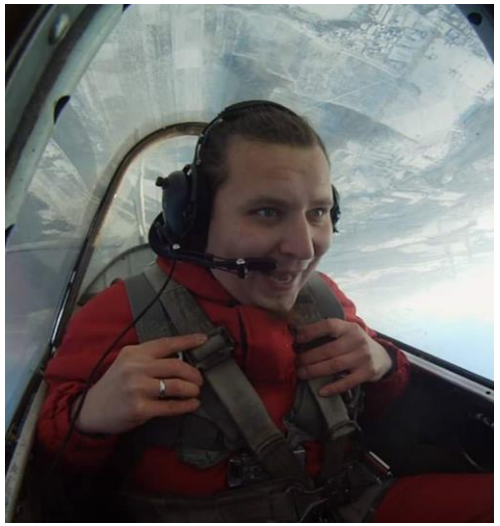
1. Applying tea bag index approach to evaluate the decomposition of soil organic matter for lawns and lawns with trees. Set up the tea bags at the soil CO_2 emission, temperature, and moisture monitoring sites in different cities: Apatity, Saint-Petersburg, Moscow, Pushchino, Rostov-on-Don (July-October 2020).

PhD Maria Korneykova

PhD Marina Slukovskaya



PhD Andrey Dolgikh

PhD Sergey Gorbov

Plans

2. A mesocosm experiment with soil constrictions of different quality (with and without amendment) and at different management regime (smart irrigation versus conventional) to study the effect of urban-related pollutants (salinity and heavy metals) on the gaseous function of the system and microbial biodegradation of soil organic matter with application of tea bag.

Plans and Interactions

3. Selection of the three types of urban soils with different pH and C contents , texture (at the RUDN University “Tree Talker” sites) for study the decomposition of the tea bags in situ and lab experiment at different temperatures and moisture to move from quality to quantity assessment (Oxitop, July-October 2020).

WP3 Urban climate

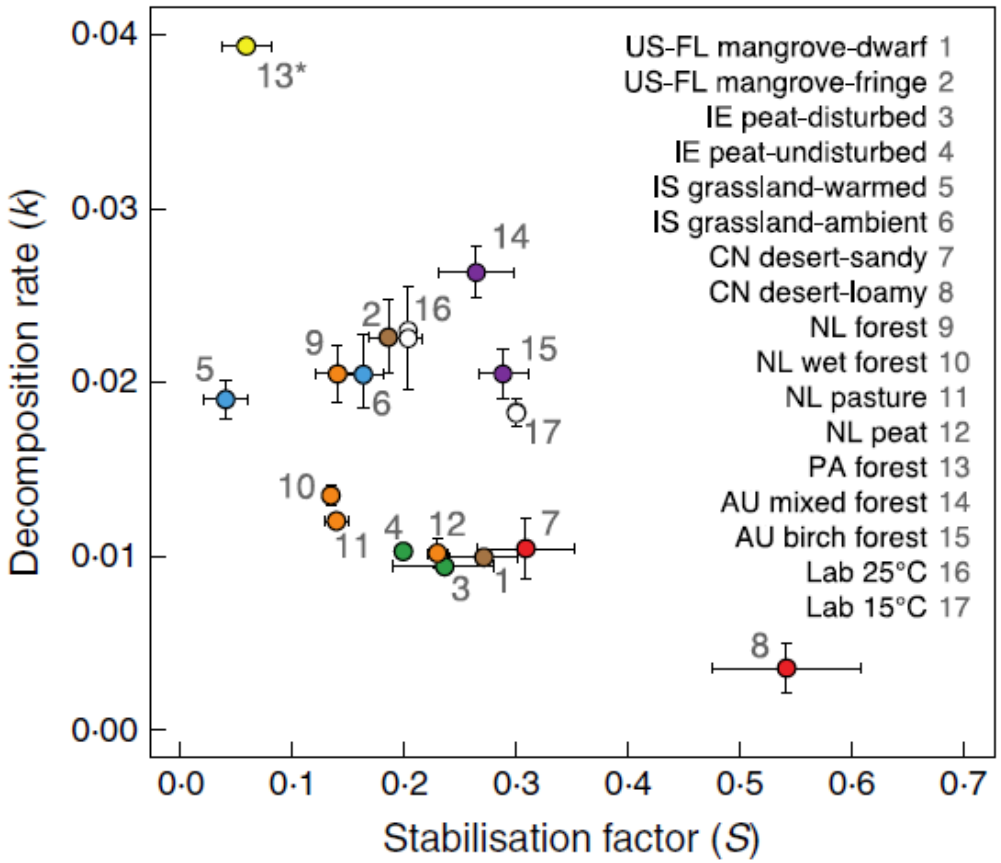
PhD Pavel Konstantinov

WP3 Urban climate

PhD Mikhail Varentsov

Tea bag approach

control the weight loss of two tea types (green and rooibos) after the 90 days in soil



to determine which part of the labile fraction of the material decomposes and which part is stabilized (S)
the weight loss of rooibos tea is an indicator of the initial decomposition rate (k)

Keuskamp et al., 2013

Will we publish these results? That doesn't sound serious!

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Science of the Total Environment 724 (2020) 138304

ELSEVIER

Contents lists available at ScienceDirect

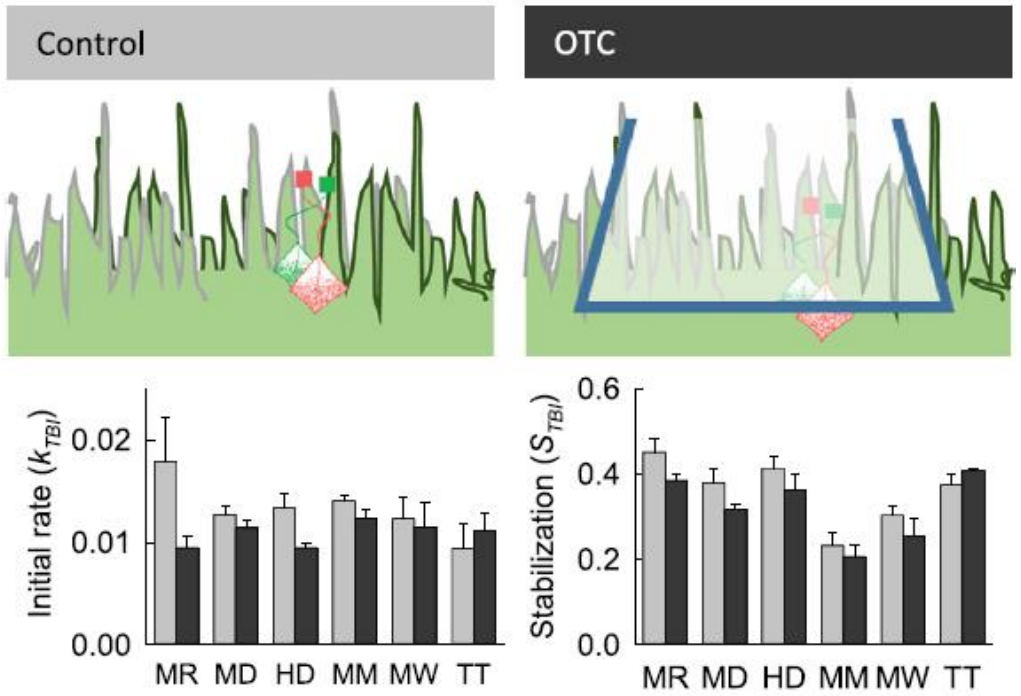
Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Decomposition rate and stabilization across six tundra vegetation types exposed to >20 years of warming

Judith M. Sarneel [a,b,c,*], Maja K. Sundqvist [d], Ulf Molau [e], Mats P. Björkman [d], Juha M. Alatalo [f,g]

[a] Department of Ecology and Environmental Sciences, Umeå University, SE-901 87 Umeå, Sweden
[b] Ecology & Biodiversity Group, Utrecht University, Padualaan 8, 3584 CH Utrecht, the Netherlands
[c] Plant Ecophysiology Group, Utrecht University, Padualaan 8, 3584 CH Utrecht, the Netherlands
[d] Department of Earth Sciences, University of Gothenburg, PO Box 460, SE-405 30 Gothenburg, Sweden
[e] Department of Biological and Environmental Sciences, University of Gothenburg, PO Box 461, SE-405 30 Gothenburg, Sweden
[f] Department of Biological and Environmental Sciences, College of Arts and Sciences, Qatar University, P.O. Box 2713, Doha, Qatar
[g] Environmental Science Center, Qatar University, P.O. Box: 2713, Doha, Qatar



- ✓ **Soil moisture, temperature and metal concentrations (Fe, Cu) explained differences in the tea bag index between vegetation types**

➡ **Especially the three way relation between soil chemistry, vegetation type and changes in the microbial community may need further attention**

Will we publish these results? That doesn't sound serious!

Received: 19 February 2017 | Revised: 19 January 2018 | Accepted: 18 April 2018
DOI: 10.1002/ldr.2982

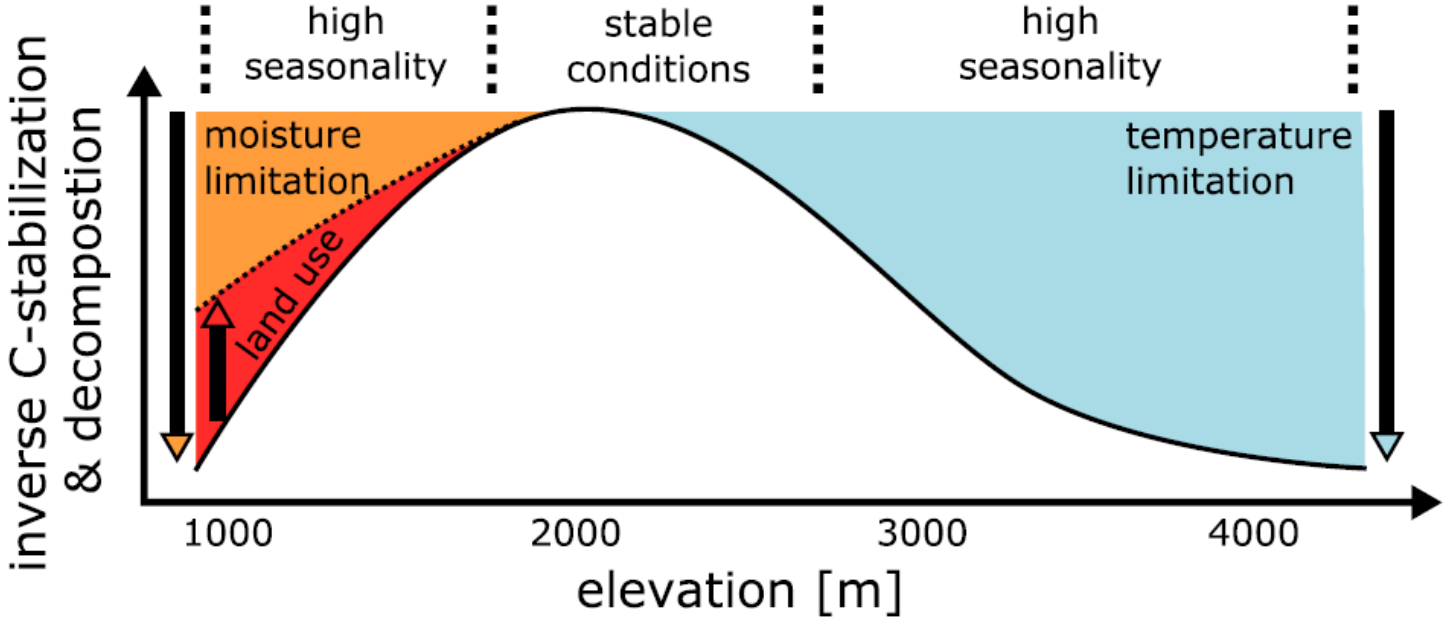
Check for updates

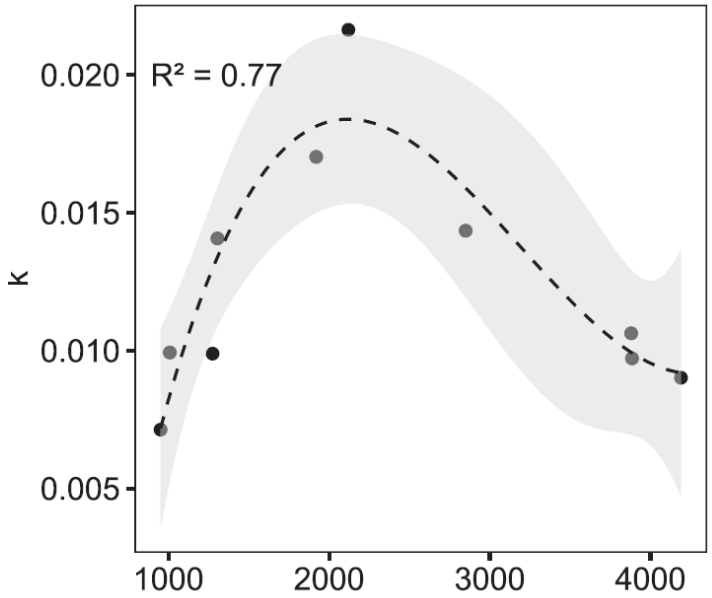
RESEARCH ARTICLE

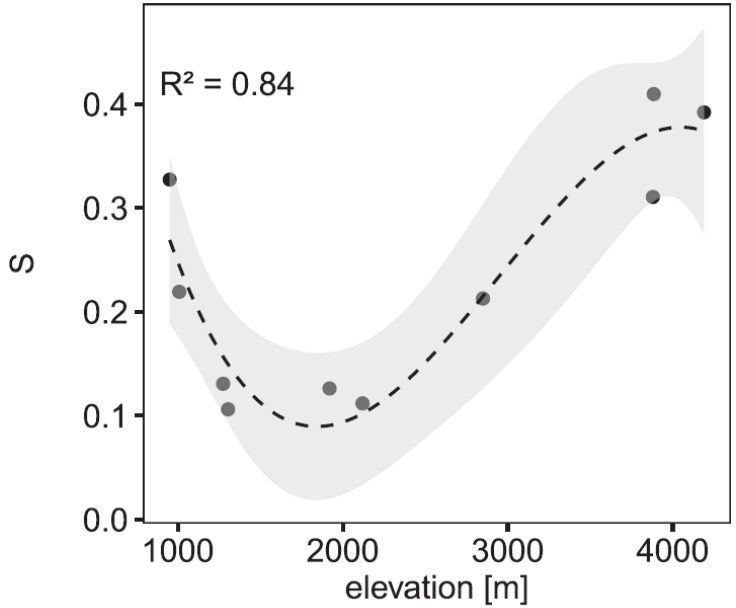
WILEY

Teatime on Mount Kilimanjaro: Assessing climate and land-use effects on litter decomposition and stabilization using the Tea Bag Index

Joscha N. Becker[1] | Yakov Kuzyakov[1,2,3]







Plans and Interactions

4. Soil sampling at the RUDN University for “Tree Talker” sites for monitoring selected microbial indexes, salinization level, heavy metals content and ecosystem services assessment

WP1

PhD Alex Yaroslavtcev

WP1

PhD Natalya Shabanova

WP 2 Soil quality

PhD Anna Paltceva

WP6

PhD Victor Matasov

Sampling design

- 1 trees species
- 2 sites with same C, pH and texture: close and far to the road
- 5 plots under the trees crown and 5 plots outside the crown

➡ 20 samples × 2 time periods (July, October 2020) = 40 samples

Microbial indexes

- Microbial biomass
- Microbial respiration
- CLPP
- Functional diversity
- Tea bag index (with soil T, W)
- Enzymes activity (C, N, P, S)

Chemical properties in soil

- electroconductivity
- Na, Cl, HCO3, pH
- DOC, DON (?)
- Heavy metals (XRF)

Chemical properties in leaves

- Cl, Na

TreeTalker measurements

Ecosystem services

- assessment
- benefits and losses
- temporal dynamic (?) of some services

Plans: publications

5. **Preparation of review «Microbial indexes of urban soils: current knowledge, approaches to determination and role in the ecosystem services assessment» (in processes, submission till December 2020).**

6. **Preparation of review «Detoxication of organic pollutants by urban soils: capacities and affecting factors» (start in December 2020).**

Project' publications

1. Aponte H., Medina J., Butler B., Meier S., Cornejo P. and **Kuzyakov Y.** Soil quality indices for metal(loid) contamination: An enzymatic perspective. Land Degrad Dev. 2020. P. 1–20. https://doi.org/10.1002/ldr.3630 (Q1).
2. Aponte H., Meli P., Butler B., Paolini J., Matuse F., Merinoe C., Cornejog P. and **Kuzyakov Y.** Meta-analysis of heavy metal effects on soil enzyme activities. Science of the Total Environment. 2020. 737. P. 139744. https://doi.org/10.1016/j.scitotenv.2020.139744 (Q1).
3. **Kuzyakov Y.**, Gunina A., Zamanian K., Tian J., Luo Y., Xu X., Yudina A., Aponte H., Alharbi H., Ovsepyan L., Kurganova I., Ge T. and Guillaume T. New approaches for evaluation of soil health, sensitivity and resistance to degradation. Frontiers of Agricultural Science and Engineering. 2020. https://doi.org/10.15302/J-FASE-2020338 (Q3).
4. **Brykova R., Ivashchenko K., Gavrichkova O**., Romzaykina O., Demina S., Lepore E., Dovletyarova E. Effect of deicing salts on urban lawn components: a pot experiment. Agrochimica. July 2020 (accepted, Scopus, Q3).
5. Ananyeva N.D., **Sushko S.V., Ivashchenko K.V., Vasenev V.I.** Soil microbial respiration of sub-taiga and forest-steppe ecosystems in European Russia: field and laboratory approaches // Eurasian Soil Science. 2020. No. 10 (accepted, Scopus, Q3).
6. **Seleznyova A., Yaroslavtcev A., Gavrichkova O., Ryazanov A.**, Kovaleva J., Ananyeva N., and **Valentini R.** Soil microbial biomass, community level physiological profiles relate to tree species and its state in urban environment. EGU2020-1064. General Assembly.

Conferences

1. EGU-2020, Vienne, Austria (4-8 May 2020)
2. Biology-21 century, Pushchino, Moscow region, Russia (September 2020)

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Thanks for attention!