Forest SOC monitoring in Estonia – challenges and needs for the future

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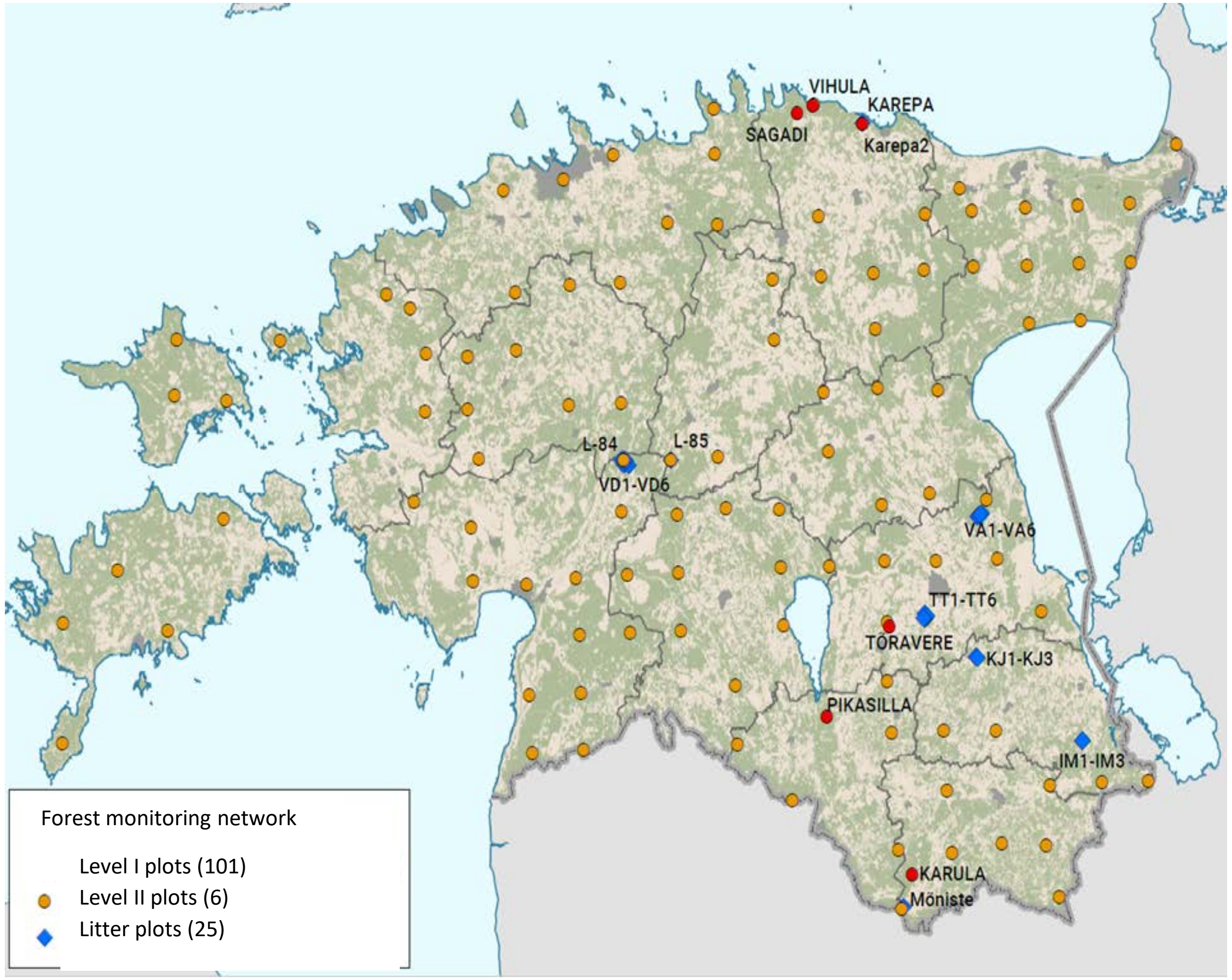
Challenges and needs with a contribution from Alex Kmoch, University of Tartu

NorForSoil: Integrating Soil Monitoring in Nordic Forests – data harmonization, future designs and studies to examine soil function at different scales; 8.-9.2.2023 kick-off in Ås, Norway

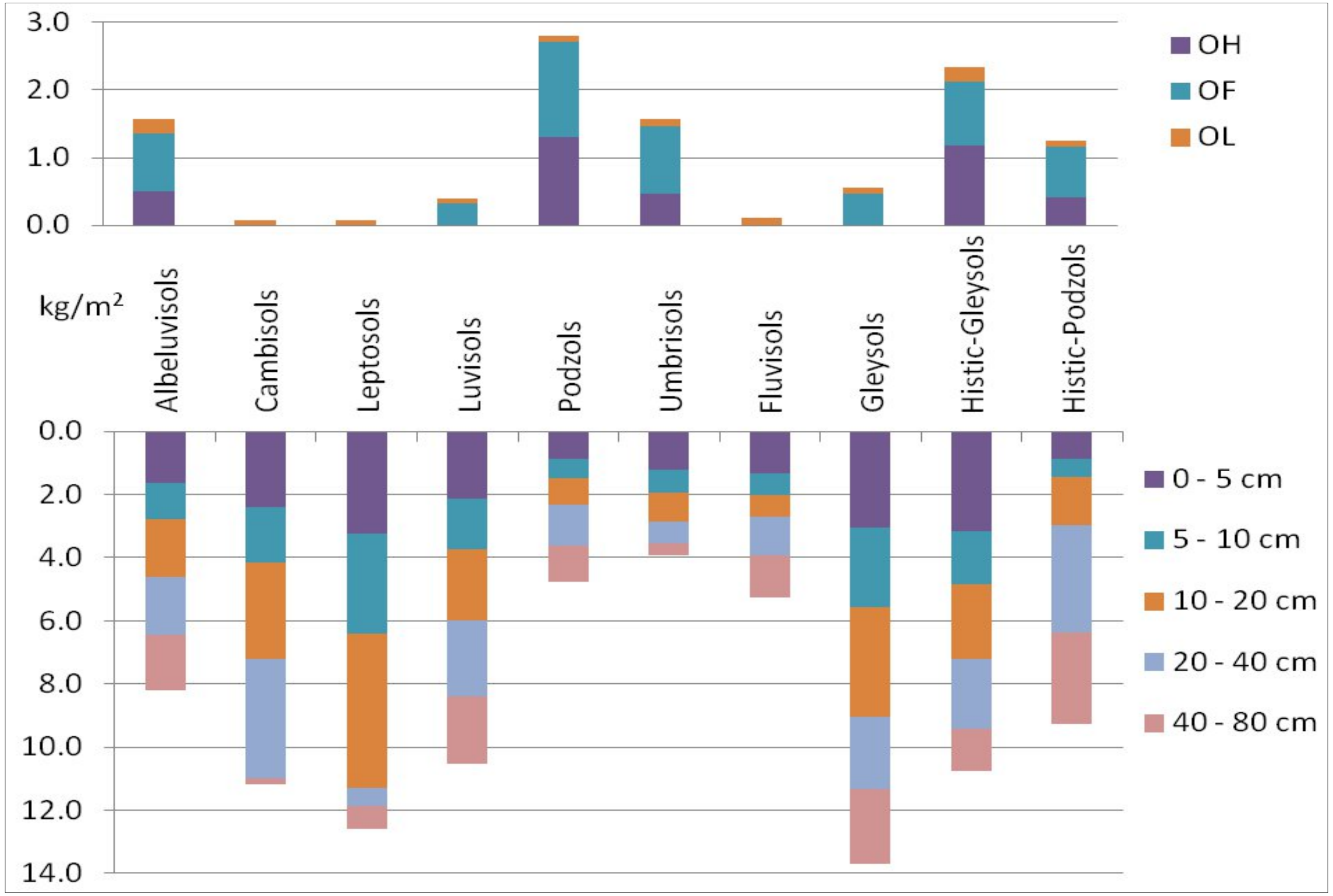
Forest SOC monitoring is conducted by Estonian Environment Agency

- Part of the state monitoring program (Forest monitoring sub-program)
- Estonian forest monitoring is part of the Pan-European *ICP Forests* program
- Soil monitoring
  - ✓ Level I sites: 1990–1994 and 2006–2008
  - ✓ Level II sites: 1996 and 2009
  - ✓ Additional forest litter plots: 2017
- Next soil survey: 2020–2025: 101+6 (I and II sites)
- All three surveys followed the ICP methodology



C stocks in forest soils

- The highest SOC stocks were accumulated in Sapric (56.9 kg/m^2) and Fibric Histosols (45.7 kg/m^2)
- In Histic Podzols and Histic Gleysols, the SOC stocks were 19.1 and 18.1 kg/m^2, accordingly
- SOC stock in mineral soils is varied between 5.5 (Umbrisols) and 14.6 (Gleysols) kg/m^2
- The majority (80-98%) of organic carbon of mineral and peaty soils are deposited in a 40 cm superficial layer.



E. Asi, T. Timmusk, V. Apuhtin, R. Kõlli (2012). Organic carbon accumulation in different forest soil types of Estonia

Modelling SOC changes in forest soils

- Implementing Yasso model for forest mineral soils
  - ✓ Yasso07 model overestimated C stocks in Estonian forest soils
  - ✓ Additional measurements of C fluxes have been conducted for model parametrization and validation

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Towards complete and harmonized assessment of soil carbon stocks and balance in forests: The ability of the Yasso07 model across a wide gradient of climatic and forest conditions in Europe

Laura Hernández [a,*], Robert Jandl [b], Viorel N.B. Blujdea [c], Aleksi Lehtonen [d], Kaie Kriiska [e], Iciar Alberdi [a], Veiko Adermann [f], Isabel Cañellas [a,j], Gheorghe Marin [g], Daniel Moreno-Fernández [a,j], Ivika Ostonen [e], Mats Varik [h], Markus Didion [i]

Table 2

Total average C stock (Mg C ha^{-1}) and change (Mg C ha^{-1} yr^{-1}) for soil, litter and dead wood estimated using the Yasso07 model for each country and type of forest. Period covered, spin up period and number of plots used for the application of Yasso07 (N_y) and for validation (N_v) are detailed. Standard error of the mean (SEM) is also listed. C stock observed and the ranges for each case study are shown. Negative changes indicate losses, positive values gains.

Country (region/Nyv)	Type of forest	Period		SOC stock Yasso07 simulated values (±SEM)	SOC change Yasso07 simulated values (±SEM or range)	Range of observed values (2.5 & 97.5 percentile)	Observed SOC change (±SEM)
		Period covered	Spin up period				
Estonia (N_y = 4300; $N_v \geq 200$)							
	All	1990–2013	Steady state	79.4 (±3.10)	0.10 (±0.02)	(65.0–113.3)[a]	–

Further Yasso model implementation based on Estonain data
is in process in cooperation Allan Sims from Estonian University of Life Sciences

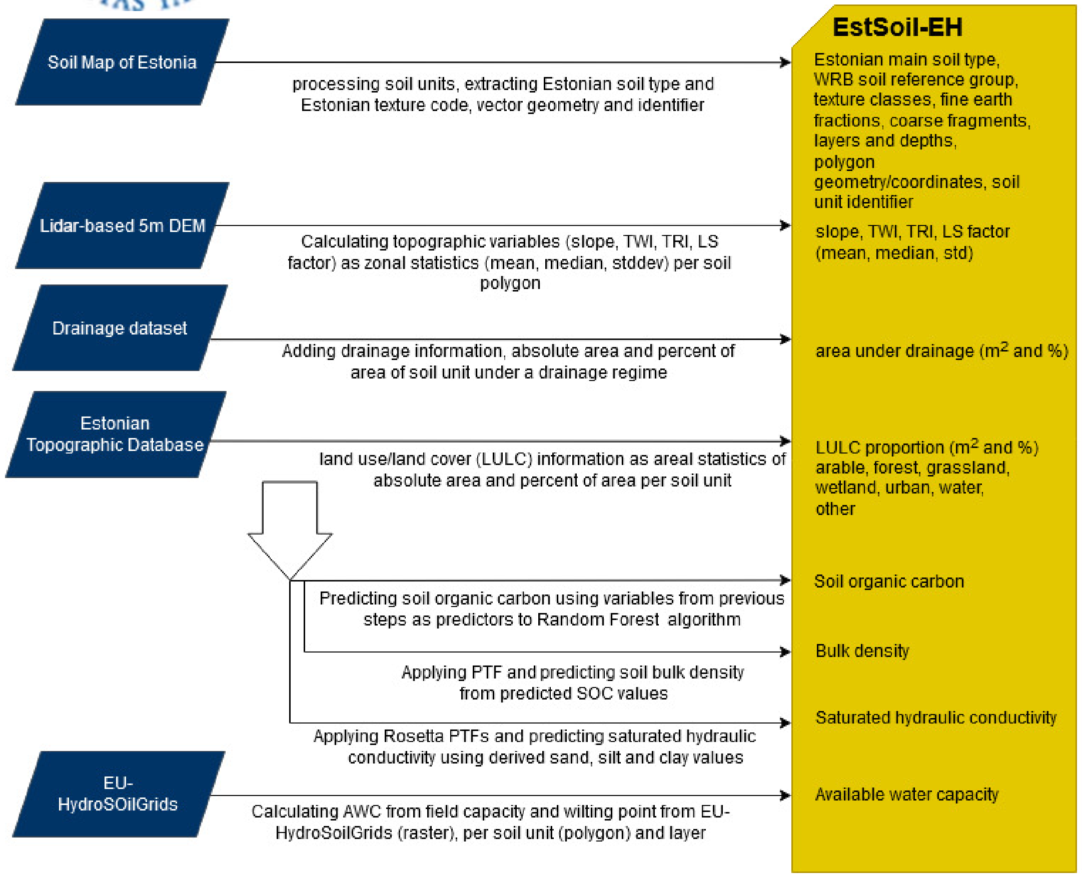
Estonian Soil Map

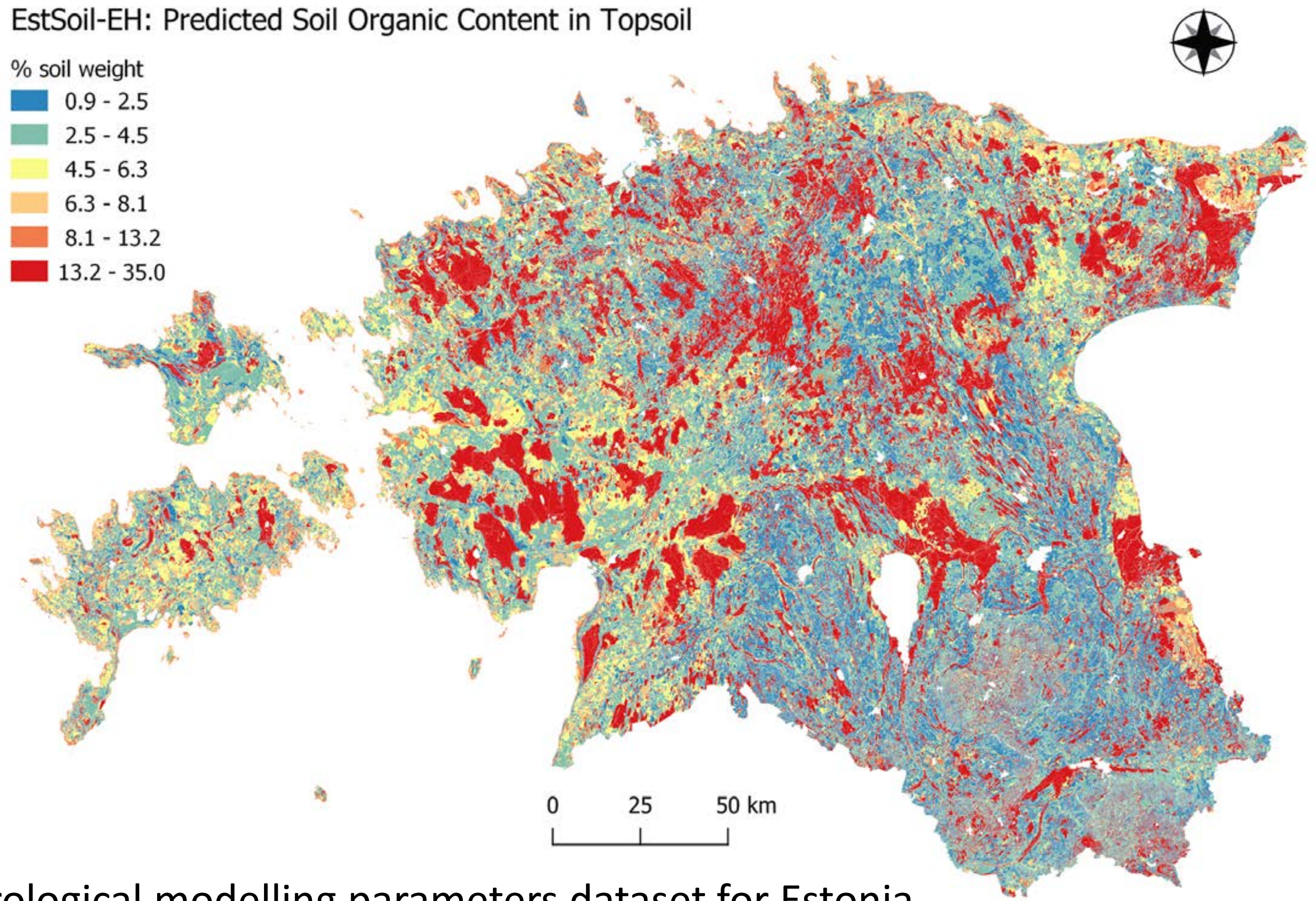
- Estonian large scale (1:10 000 soil map) is based on surveys conducted in 1958–1989
- Digitalized and available at: https://geoportaal.maaamet.ee/eng/Spatial-Data/Estonian-Soil-Map-p316.html
- Area of histosols needs updating, partly mineralized

- Monitoring reports and data are available on web page of Estonian environmental monitoring system

https://kese.envir.ee/kese/welcome.action

Modelling-EstSoil-EH

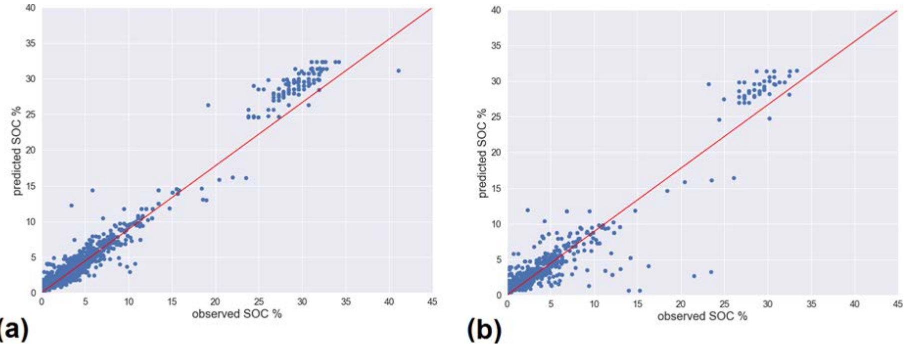


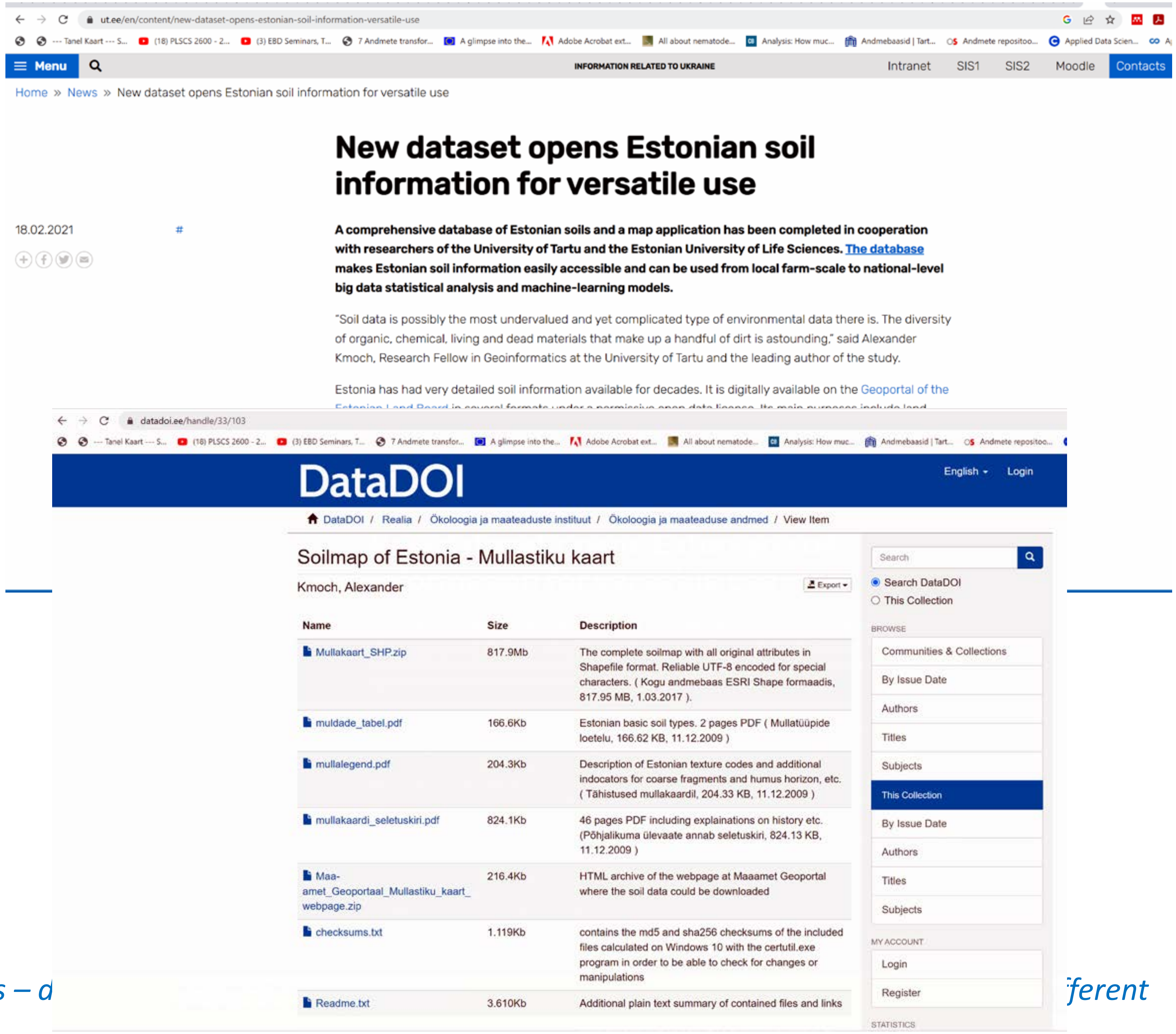


Kmoch et al 2021 EstSoil-EH: a high-resolution eco-hydrological modelling parameters dataset for Estonia
https://doi.org/10.5194/essd-13-83-2021

Landscape Geoinformatics Lab

Israfilbayov, Y.2023 Soil organic carbon prediction with machine learning (MSc thesis, supervisor A. Kmoch)





Some specific publications

- Kõlli et al 2004. **Organic carbon pools in Estonian forest soils.** Baltic Forestry 10, 19-26

- Noreika et al. 2019 **Forest biomass, soil and biodiversity relationships originate from biogeographic affinity and direct ecological effects**, https://doi.org/10.1111/oik.06693
  In this study they disentangle the indirect effects of the species pool and direct ecological effects on the complex relationships among wood volume, soil conditions and diversities of different plant and fungal groups in 100 old-growth forest sites (10 × 10 m)

- Kmoch et al 2021 EstSoil-EH: a high-resolution eco-hydrological modelling parameters dataset for Estonia https://doi.org/10.5194/essd-13-83-2021

- Kriiska, K 2019. **Variation in annual carbon fluxes affecting the soil organic carbon pool and the dynamics of decomposition in hemiboreal coniferous forests**. PhD thesis https://dspace.ut.ee/handle/10062/64800
  Additional measurements (soil respiration, fine root biomass and production, decomposition…) at ICP sites

Challenges and needs for the future

- Data analyses (joint campaigns between the institutions)
- Missing metadata: better ways to characterize the environmental variables - when and where the soil sample was taken, the history of forest management, etc.
- New ideas which spatially distributed (and ideally continuous) covariates can serve as predictors (e.g., remotely-sensed spectral indicators, topographical variables etc.)
- Next-generation monitoring, sensing, sampling protocols
- Harmonization of sampling protocols
- Using data sampled in different ways, at different depths, by following different methodologies…