ARPHA Conference Abstracts 8: e149225
doi: 10.3897/aca.8.e149225

Conference Abstract

Using eLTER observational data to simulate forested ecosystem functions

Evangelia A. Koukianaki[‡], Maria ?. Lilli[‡], Dionissis Efstathiou[‡], Bradley Matthews[§], Karl Knaebel[§], Gisela Pröll[§], Johannes Kobler[§], Thomas Dirnböck[§], Jaana Bäck[|], Michael Mirtl[¶], Nikolaos P. Nikolaidis[‡]

‡ Technical Univesity of Crete, Chania, Greece
§ Environment Agency Austria, Vienna, Austria
| University of Helsinki, Helsinki, Finland
¶ Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany

Corresponding author: Evangelia A. Koukianaki (ekoukianaki@tuc.gr)

Received: 10 Feb 2025 | Published: 28 May 2025

Citation: Koukianaki EA, Lilli M?, Efstathiou D, Matthews B, Knaebel K, Pröll G, Kobler J, Dirnböck T, Bäck J, Mirtl M, Nikolaidis NP (2025) Using eLTER observational data to simulate forested ecosystem functions. ARPHA Conference Abstracts 8: e149225. https://doi.org/10.3897/aca.8.e149225

Abstract

The world today faces many environmental challenges related to climate change, biodiversity loss, water and soil pollution. These multiple stressors act simultaneously over a range of temporal and spatial scales, resulting in significant losses of ecosystem services that eventually affect societal well-being and humanity. While immediate impacts sometimes receive considerable attention, little is known about their long-term and systemic effects and cross-scale interactions. Closing these knowledge gaps requires an improved, transdisciplinary understanding of the multifaceted environmental system, in order to develop appropriate mitigation measures (Mirtl et al. 2018).

Forested ecosystems cover 31% of the Earth's terrestrial surface and 4.06 billion ha total area (UN FAO, 2023). Forests are the richest habitats in terms of biodiversity and they provide essential ecosystem functions (biomass production, water supply, climate regulation, pollination, fire and climate change mitigation, recreation) (Brockerhoff et al. 2017, Chapin et al. 2011, Ding et al. 2021). Shifts in ecosystem functions due to changes in climate, land use and above ground biodiversity cause soil to degrade. The assessment of the impacts of climate change can be achieved through modeling of soil functions in the earth's critical zone (Banwart et al. 2019) (Fig. 1). The sites belong to the

temperate and boreal forests of Europe with long-term monitoring data (>25 years) that can be used to fully assess ecosystem services.

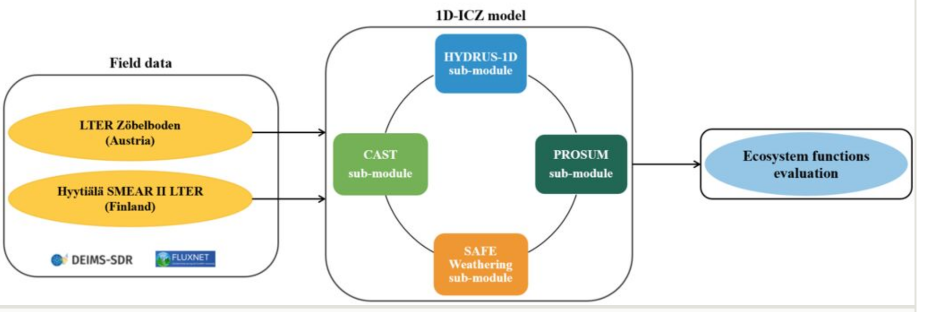

Figure 1. doi

Schematic representation of the methodological approach used in the study.

The 1D-ICZ model links soil aggregate formation and soil structure development to nutrient dynamics, plant nutrition, water flow and mass transport. It simulates and quantifies four of the main ecosystem functions by accounting for interactions between water flow, solute transport, soil structure, carbon and nutrient dynamics and plant biomass production. It is comprised of four sub-modules (HYDRUS-1D, CAST, PROSUM and chemical weathering and bioturbation) linked together to simulate the interactions of biotic and abiotic processes above and below ground in order to simulate predominant soil functions as well as the dynamics of soil hydraulic conductivity and water holding capacity (Giannakis et al. 2017, Kotronakis et al. 2017).

Complex biogeochemical models such as the 1D-ICZ require extensive time series and detailed biogeochemical data to calibrate and simulate the soil-plant-water-atmosphere interactions (Table 1). Such data are not widely available, though can be found in well-instrumented ecosystem monitoring sites such as the sites belonging to the LTER (Long-Term Ecosystem Research), eLTER (European Long-Term Ecosystem, critical zone and socio-ecological Research (eLTER), 2023), FLUXNET (FLUXNET 2023) and ICOS (Integrated Carbon Observation System (ICOS), 2023) networks and research infrastructures. In this study, the model was initialized and calibrated during a 25-year period (1996-2020) using long term observations derived from the eLTER Repositories and from FLUXNET (only for Hyytiälä). Soil samples were collected from 3 different locations in each site and underwent Water Stable Aggregate (WSA) fractionation analysis in order to simulate the soil dynamics.

The 1D-ICZ model simulated two mature forested ecosystems, Zöbelboden (temperate mountain forest in Central Europe) and Hyytiälä (boreal forest in Northern Europe) capturing the biomass production, soil structure and geochemistry. Temperature and light were found to be the primary limiting factors of plant growth in both sites, and precipitation a limiting factor only at Hyytiälä. The soils of the two sites are quite different with Zöbelboden having higher silt-clay content (74%) while Hyytiälä's soils are very sandy (69%). The difference in silt-clay content is reflected in the WSA distribution which in combination with below ground C content (which is mostly in the cPOM (coarse particulate organic matter) fraction) shows very strong aggregation processes which relate to soil fertility. Regarding the quantification of ecosystem functions; in Zöbelboden, the annual average gross primary production (GPP) is estimated at 15.6 tC/ha/yr, the C stock at 82.6 tC/ha and N stock at 3.8 tN/ha while in Hyytiälä, the annual average GPP estimated at 11.6 tC/ha/yr and, the C and N stocks at 38.6 tC/ha and 1.3 tN/ha respectively (Table 2).

Table 1.

Required input data for each sub-module of 1D-ICZ model.

Parameter name/description	Timestep	Units	Model
Precipitation	Monthly	m	HYDRUS-1D
Evapotranspiration	Monthly	m	HYDRUS-1D
Air temperature	Monthly	?	HYDRUS-1D PROSUM
Bulk density	-	g cm^{-3}	HYDRUS-1D
	-	kg m^{-3}	CAST
Soil depth	-	m	HYDRUS-1D
		cm	CAST
Soil chemistry: Ca, Mg, Na, K, $H^{?}$, F?, NO_3?, PO_4^{3}?, DOC, $NH_4^{?}$	Initial (month)	mol L^{-1}	Excel Tool for HYDRUS-1D
Precipitation chemistry: Ca, Mg, Na, K, $H^{?}$, Al, F?, SO_4^{2}?, NO_3?, PO_4^{3}?, DOC, $NH_4^{?}$	Monthly	mol L^{-1}	Excel Tool for HYDRUS-1D
Porosity	-	-	CAST
Clay content (for each soil layer)	-	%	CAST
Silt-clay content (for each soil layer)	-	%	CAST
C stock distribution	-	tC/ha	CAST
Average daytime PAR (photosynthetic active radiation)	Monthly	µmol m^{-2} s^{-1}	PROSUM

Table 2.

Parameters for Zöbelboden and Hyytiälä derived from the model.

>

	Zöbelboden	Hyytiälä
WSA_AC3 (%)	99.2	87.6
WSA_AC2 (%)	0.7	9.0
WSA_AC1 (%)	0.1	3.3
Sand (%)	26.2	69.1
Silt-clay (%)	73.8	30.9

	Zöbelboden	Hyytiälä
Above ground C (tC/ha)	15.6	11.6
Below ground C (tC/ha)	82.6	38.6
cPOM (tC/ha)	71.8	25.5
Below ground N (tN/ha)	3.8	1.3
cPOM (tN/ha)	3.3	0.8
C to N (below ground)	21.7	29.7

Keywords

Long-term observations, ecosystem functions, hydrobiochemistry simulation, soil dynamics, calibration

Presenting author

Evangelia A. Koukianaki

Presented at

ORAL

Acknowledgements

The authors acknowledge the funding support of the eLTER PLUS project (Grant agreement No. 871128, EU Horizon 2020 Research and Innovation action).

Conflicts of interest

The authors have declared that no competing interests exist.

References

- Banwart S, Nikolaidis N, Zhu Y, Peacock C, Sparks D (2019) Soil Functions: Connecting Earth's Critical Zone. Annual Review of Earth and Planetary Sciences 47 (1): 333-359. https://doi.org/10.1146/annurev-earth-063016-020544
- Brockerhoff EG, Barbaro L, Castagneyrol B, Forrester DI, Gardiner B, González-Olabarria JR, et al. (2017) Forest biodiversity, ecosystem functioning and the provision of ecosystem services. Biodiversity and Conservation 26: 3005-3035. https://doi.org/10.1007/s10531-017-1453-2

- Chapin FS, Matson PA, Vitousek PM (2011) Degradation in Ecosystem Services. Principles of Terrestrial Ecosystem Ecology. Springer https://doi.org/10.1007/978-1-4419-9504-9
- Ding J, Delgado-Baquerizo M, Wang J, Eldridge DJ (2021) Ecosystem functions are related to tree diversity in forests but soil biodiversity in open woodlands and shrublands. Journal of Ecology 108: 4158-4170. https://doi.org/10.1111/1365-2745.13788
- European Long-Term Ecosystem, critical zone and socio-ecological Research (eLTER), (2023) https://elter-ri.eu/. Accessed on: 2023-10-18.
- FLUXNET (2023) https://fluxnet.org/. Accessed on: 2023-10-03.
- Giannakis GV, Nikolaidis NP, Valstar J, Rowe EC, Moirogiorgou K, Kotronakis E, et al. (2017) Integrated Critical Zone Model (1D-ICZ): A Tool for Dynamic Simulation of Soil Functions and Soil Structure. In: Banwart SA, et al. (Ed.) Quantifying and Managing Soil Functions in Earth's Critical Zone: Combining Experimentation and Mathematical Modelling. 142. Advances in Agronomy, 353-384 pp. https://doi.org/10.1016/bs.agron.2016.10.009
- Integrated Carbon Observation System (ICOS), (2023) https://www.icos-cp.eu/. Accessed on: 2023-10-18.
- Kotronakis E, Giannakis GV, Nikolaidis NP, Rowe EC, Valstar J, Paranychianakis NV, et al. (2017) Modeling the Impact of Carbon Amendments on Soil Ecosystem Functions Using the 1D-ICZ Model. In: Banwart SA, et al. (Ed.) Quantifying and Managing Soil Functions in Earth's Critical Zone: Combining Experimentation and Mathematical Modelling. 142. Advances in Agronomy, 315-352 pp. https://doi.org/10.1016/bs.agron.2016.10.010
- Mirtl M, Borer ET, Djukic I, Forsius M, Haubold H, Hugo W, et al. (2018) Genesis, goals and achievements of Long-Term Ecological Research at the global scale: A critical review of ILTER and future directions. Science of the Total Environment 626: 1439-1462. https://doi.org/10.1016/j.scitotenv.2017.12.001
- UN FAO, (2023) The state of the world's forests. https://www.fao.org/state-of-forests/en/. Accessed on: 2023-10-10.