Luke
NATURAL RESOURCES
INSTITUTE FINLAND

Ecohydrological modeling for boreal forestry

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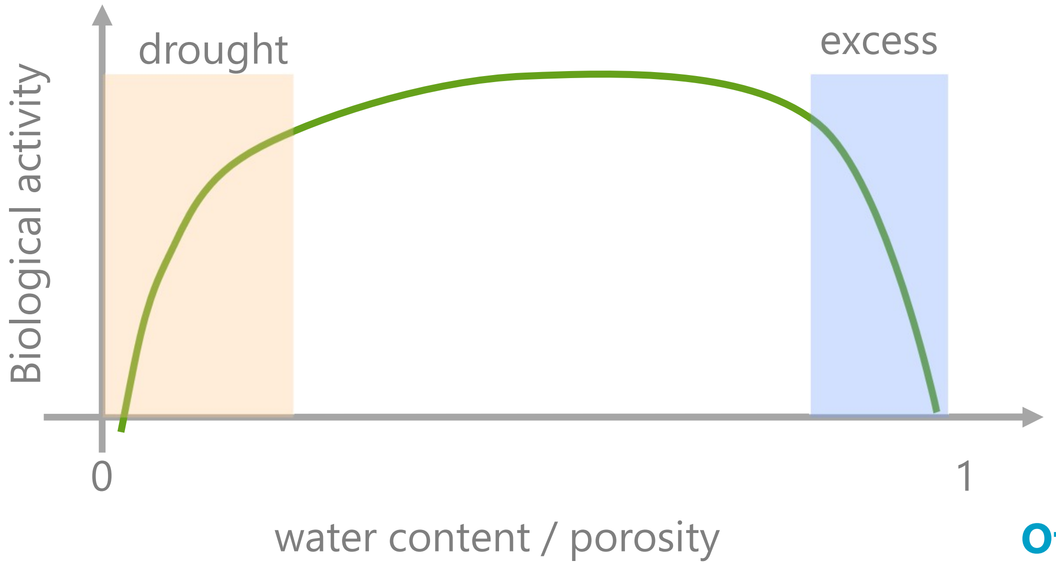
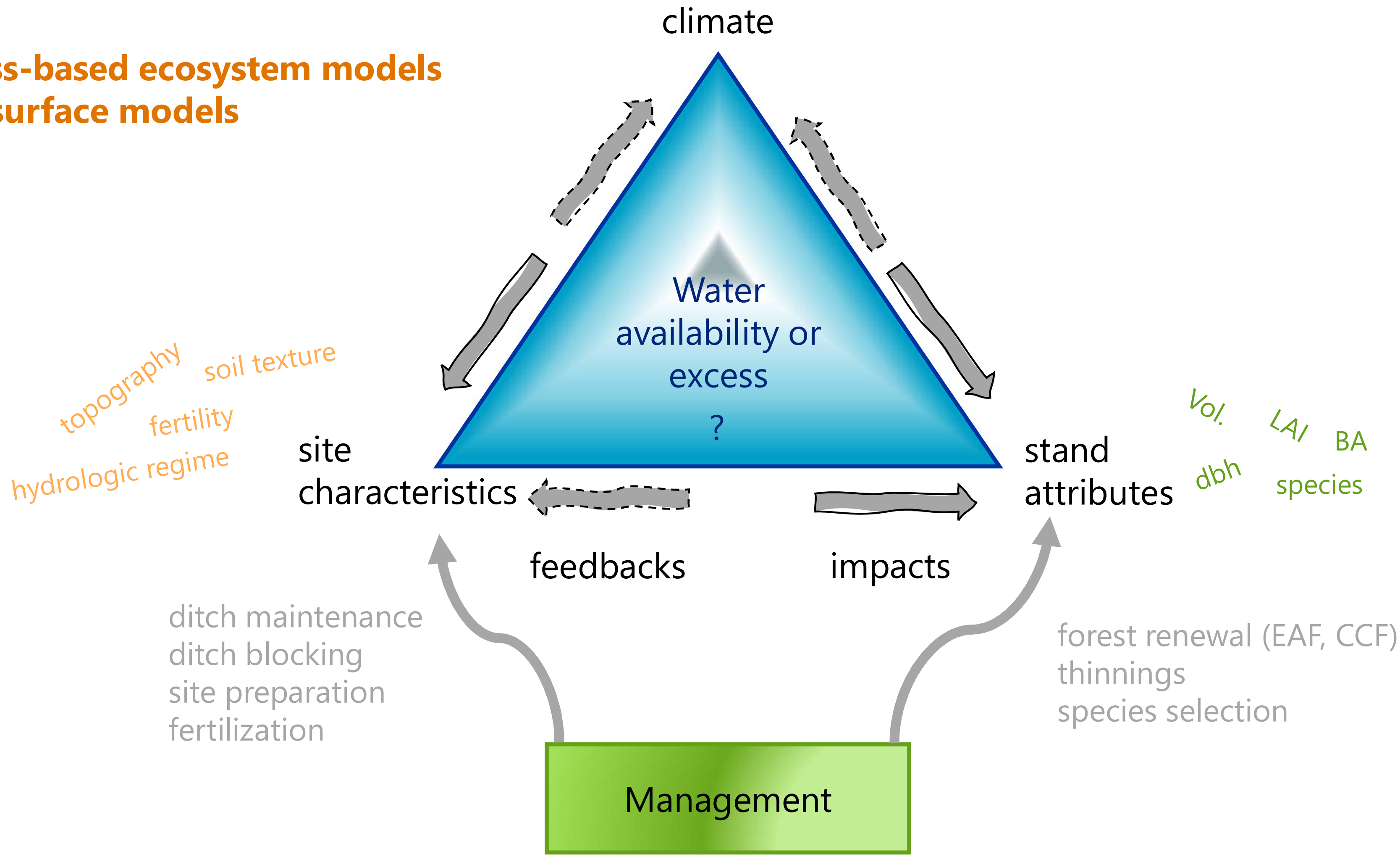
Water – the necessary evil

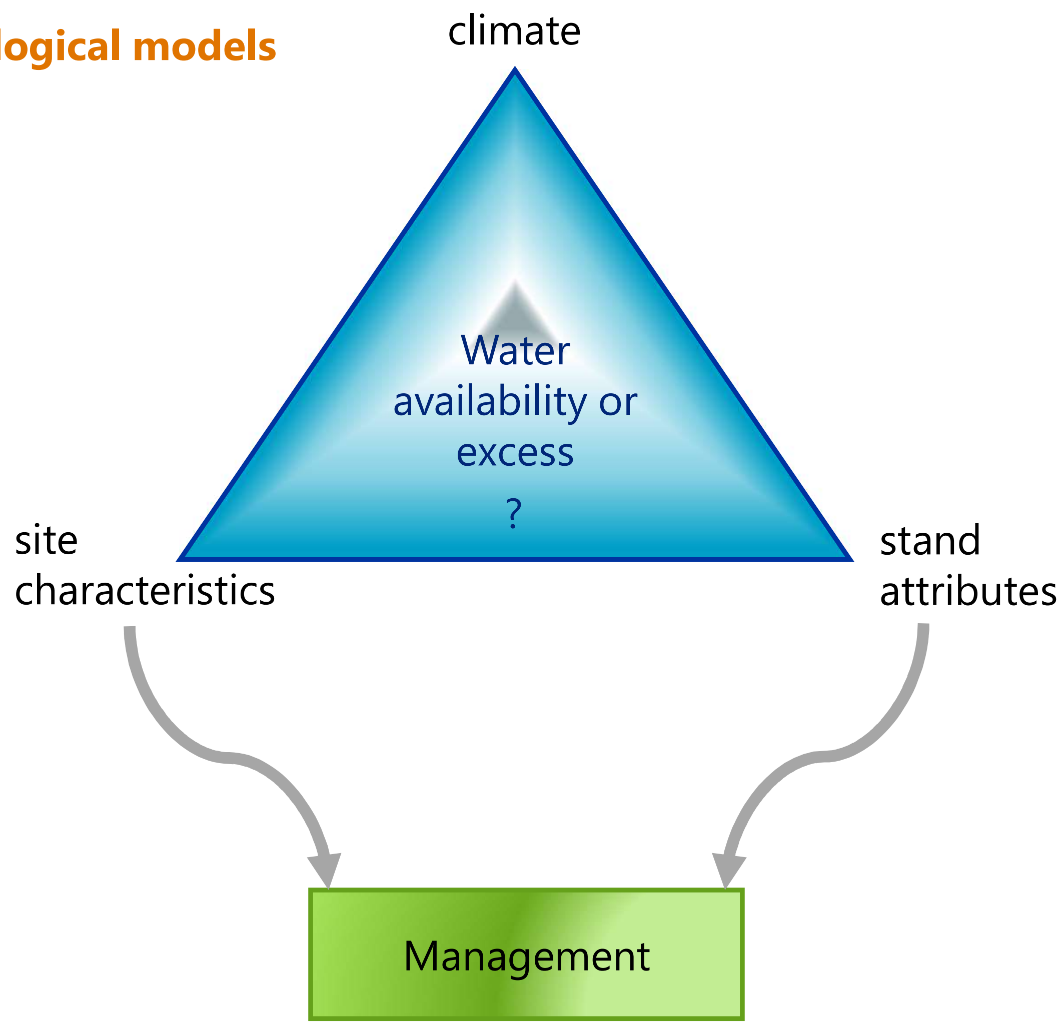


Of interest when a problem

Process-based ecosystem models
Land-surface models



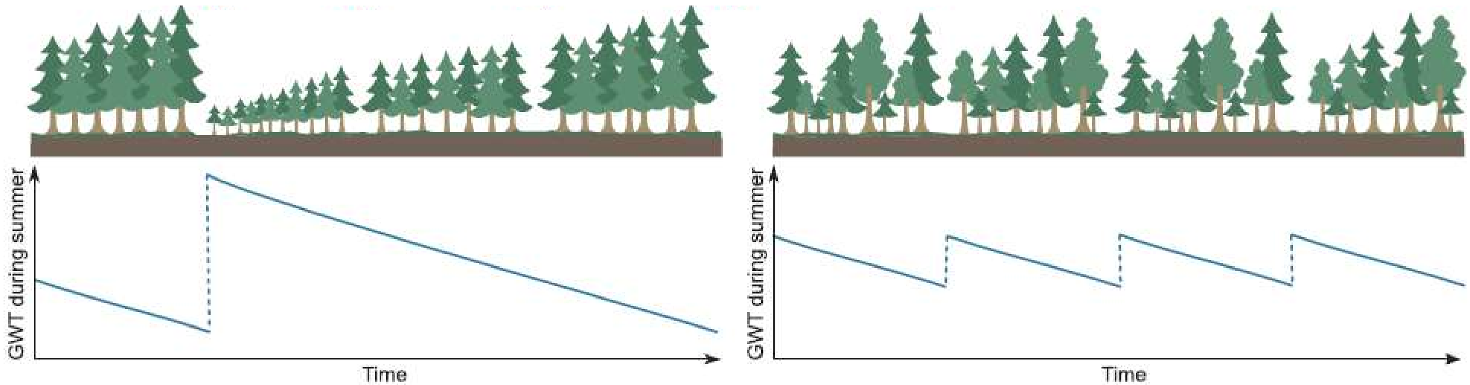
Process-based ecohydrological models



Peatland management ≈ water table management

4,7 Mha ditched from 1930's to 1980's. Spacing 20 – 60m, current depth 20 – 80cm

How WTL depends on stand attributes and peatland type across a climate gradient?



Growth = f(WTL)

GHG emissions = f(WTL)

Improved drainage by ditch maintenance: When needed & how deep is necessary?

Biological drainage == stand water use
How intense selection harvests or strip-cuttings can be used?

Nieminen et al. 2018; https://doi.org/10.1016/j.foreco.2018.04.046

Modeling water table response

Ecohydrological theory & literature

- Process-model structure, functions, parameters

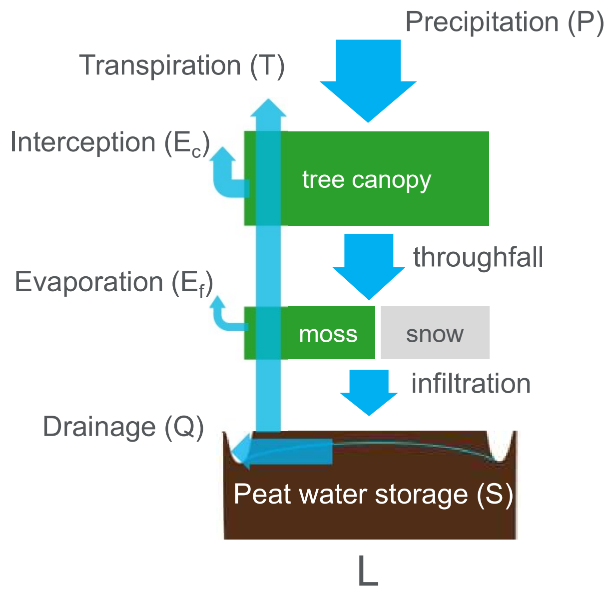
Inputs (open data):

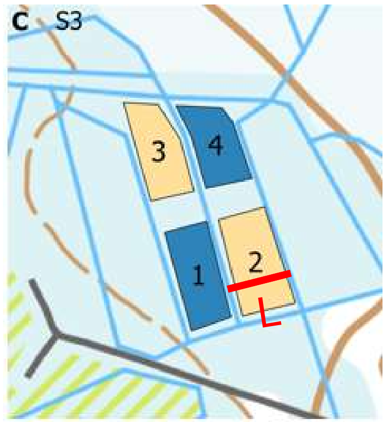
- Forest attributes: LAI, height, tree type
- Peat type: hydraulic properties
- Ditch spacing & depth
- Daily weather data

Outputs (daily):

- WTL, soil moisture, snow, ET & components, runoff

KISS for practical use





$$\frac{\partial S}{\partial t} = P - (T - E_c - E_f) - Q$$

$$\frac{\partial WTL}{\partial t} = C(WTL)\frac{\partial S}{\partial t}$$

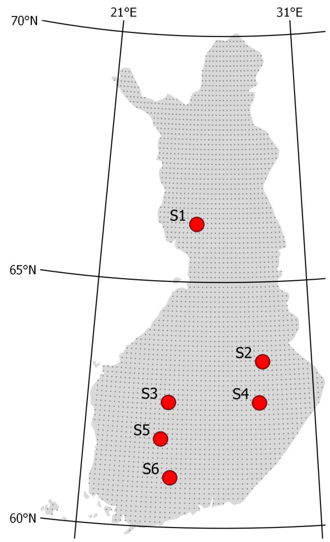
Benchmarking at field sites

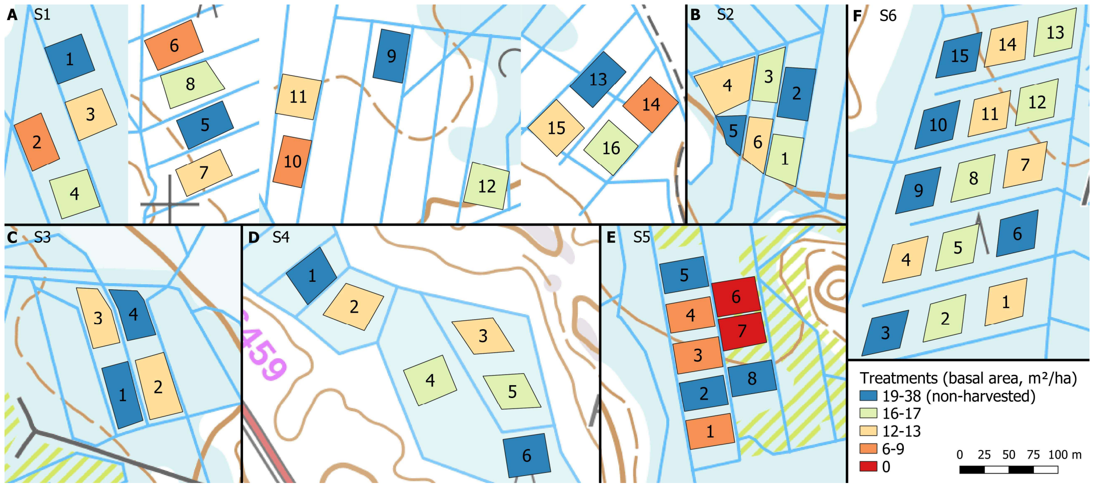
6 sites, each with 2 to 4 different BA treatments

First, model set up for each site & treatment:

- Peat type, ditch spacing, ditch depth, stand BA
- Run by local weather for 2014 – 2019

Target variable: daily WTL, aggregated to June-Oct mean, compated against observed





Leppä, K. et a. 2020. Front. Earth Sci., 8: 576510. https://doi.org/10.3389/feart.2020.576510

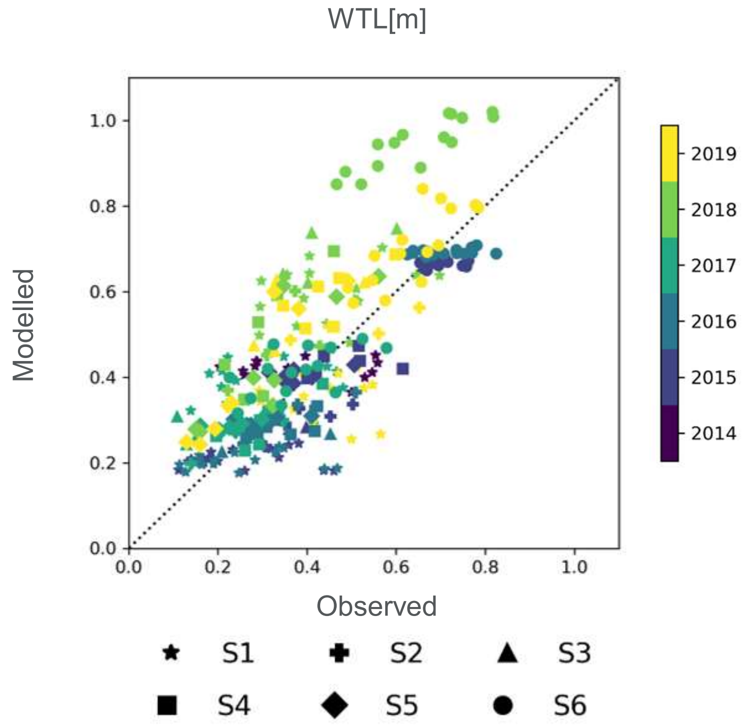
Benchmarking & factorial experiment

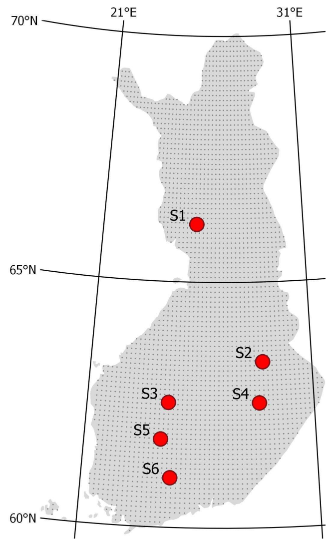
June-Oct mean WTL on the right ballpark

Next, factorial simulations:

- Basal area (BA): 6 to 30 m^2ha^{-1}, 5 levels
- deciduous fraction: 0 & 0.5
- ditch spacing: 25 & 75 m
- ditch depth: 0.3 & 1.0 m
- peat type: sphagnum/carex
- climate: south/north

Total 180 combinations





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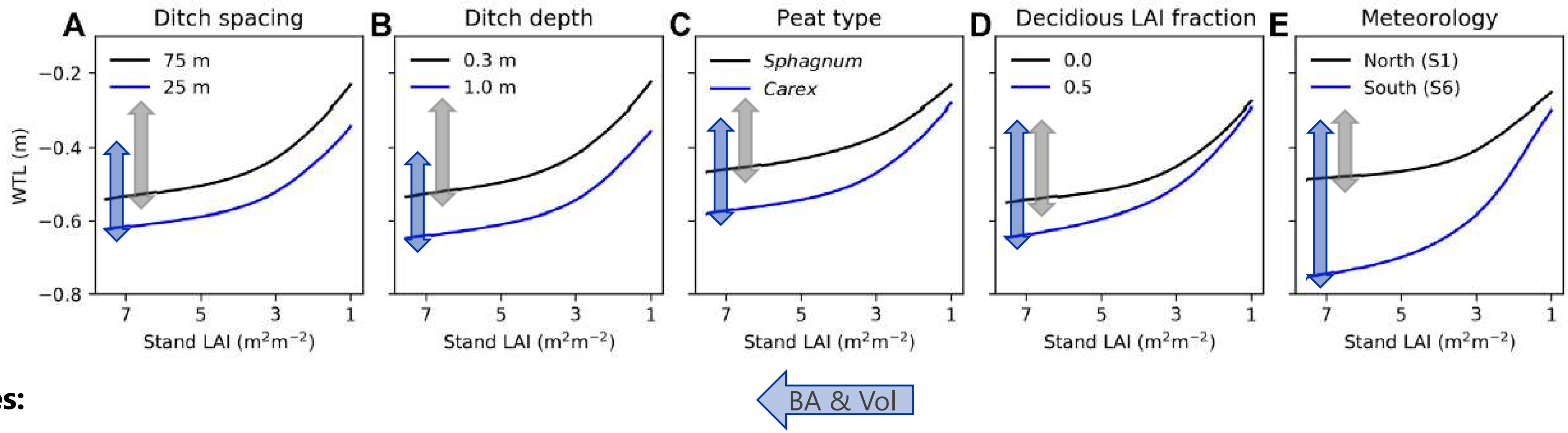
WTL vs. stand leaf-area

Deepens non-linearly with LAI,
increased interception & transpiration.

Mixed stands
Understories



Use cases:

- Productivity and GHG-balance tradeoff of alternative management (e.g. Eyvindson et al. 2023, https://doi.org/10.1139/cjfr-2022-0101, Lehtonen et al. 2023, preprint)
- New guidelines for DNM: shallow ditches are often enough (Hökkä et al. 2022, https://doi.org/10.14214/sf.10494)

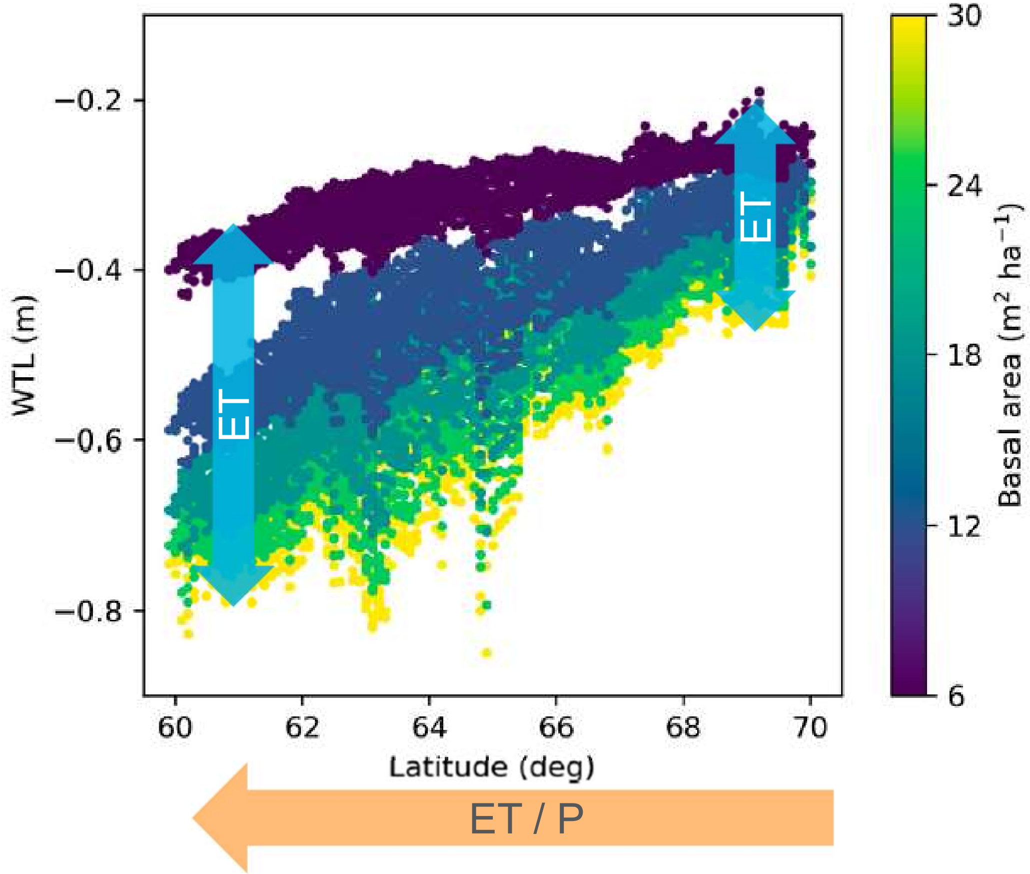
Simulations over climatic gradient in Finland

Biological drainage (ET) has great role in Southern Finland

- Strong potential for using CCF, less need for DNM
- Ditch drainage remains crucial in Northern Finland

Patterns will shift with climate change, due changing ET/P

Can WTL become too deep in the future?



Landscape soil moisture

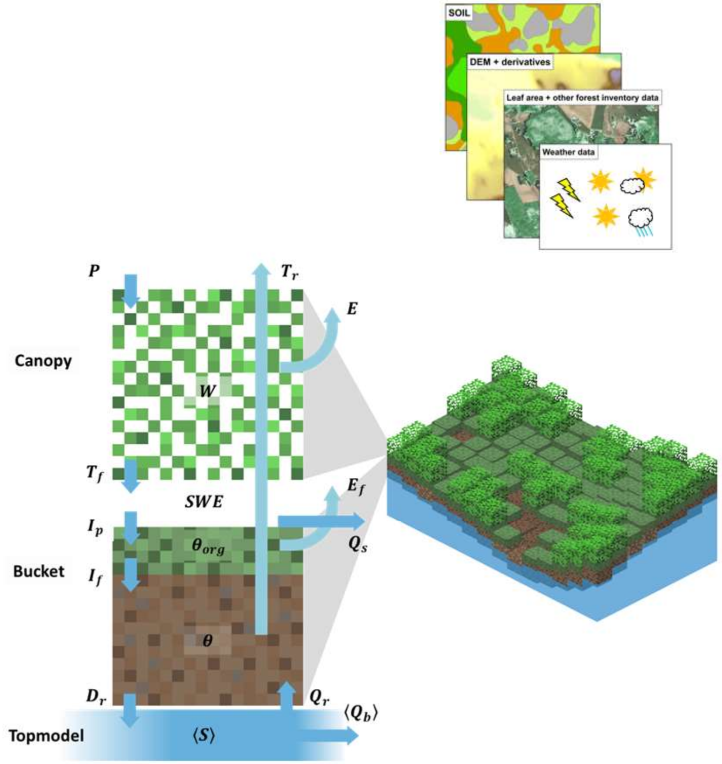
Soil strength: trafficability, harvest planning
Water availability: climate change adaptation

Excellent open data on

- Stand attributes (mNFI,16x16m)
- DEM, topographic wetness indices
- Streams, water bodies, non-forest areas

Soil hydraulic properties?

- We developed new PTF's to predict soil porosity, field capacity & wilting point from available spatial data
- Mineral forest soils: can be best estimated based on soil fertility type available in mNFI

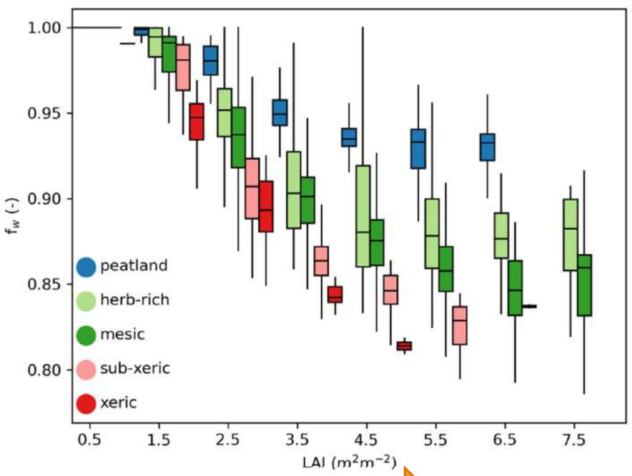


Launiainen et al. 2019; https://doi.org/10.5194/hess-23-3457-2019
Launiainen et al. 2022, https://doi.org/10.3390/f13111797

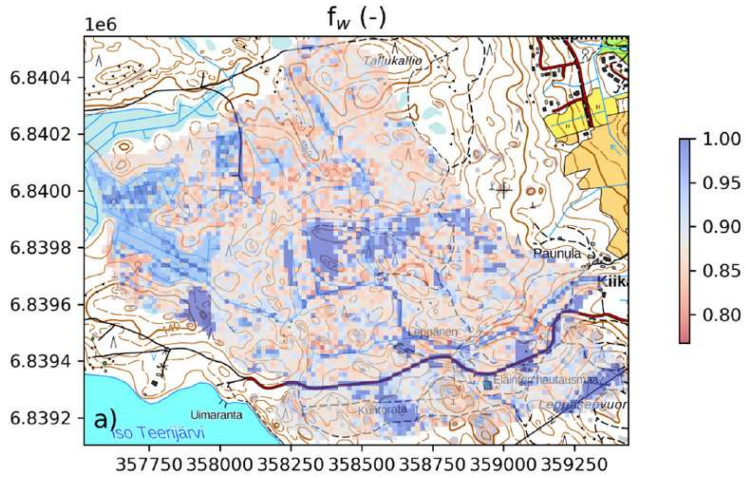
Water limitations – where most likely?

Paunulanpuro –catchment (ca. 150 ha), Orivesi, Southern Finland

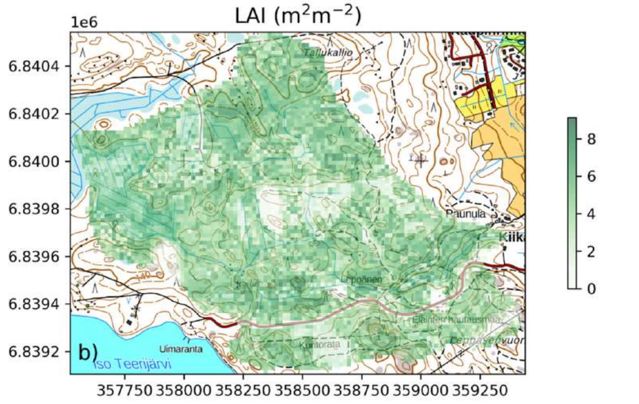
Simulated daily soil moisture for 2000 – 2015 period

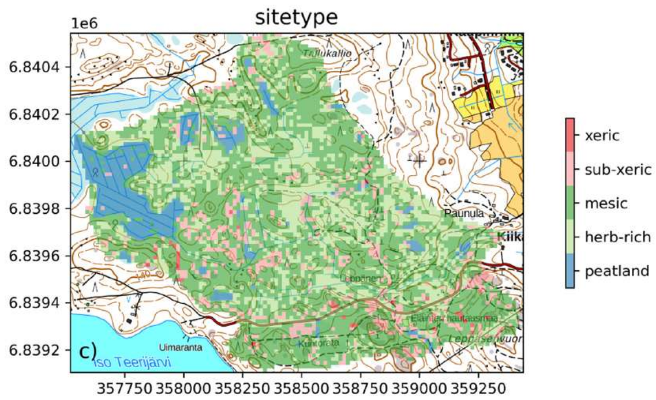


BA & Vol



Increasing water limitations→





Stand density effects modulated by soil water holding capacity, topographic position and species composition

From mNFI

Launiainen et al. 2022, https://doi.org/10.3390/f13111797

Ecosystem ecology with process-based models

pyAPES: vertically resolved view to soil-vegetation-atmosphere interface

→ ^{13}C & ^{18}O isotopes; lidar-based canopy structures

SpaFHy: distributed ecohydrology

→ high-resolution carbon budgets, merging with EO-data

NutSpaFHy: distributed nutrient balance & leaching

→ Stand growth, fertilization effects

Peatland Simulator Susi: holistic peatland forest management

→ Collaborating with Annamari Laurén (UH, peatland forestry)

Modular, open Python code

From forest structure to hydrological function – merging dense Earth Observation data and process-models (LS-HYDRO, 2023-2027)

Precision nutrient management - a tool for mitigation of climate change and environmental loading in boreal forestry (PREFER, 2022-2026)

See: https://github.com/LukeEcomod

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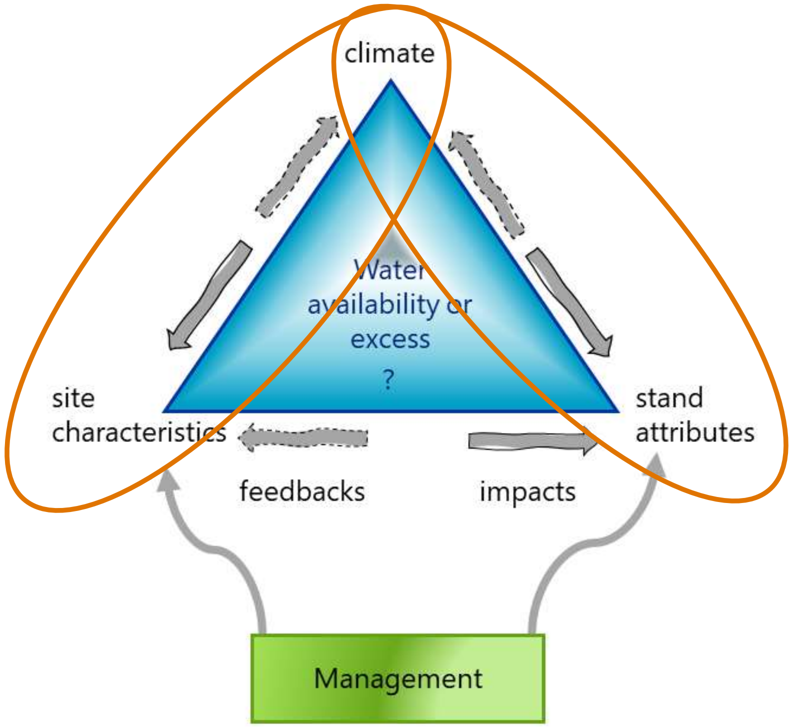
What next?

Climate-change adaptation: need to integrate ecohydrology better into forest dynamics models

- How water availability affects growth & mortality?
- How and where adapt management?

Capability to predict soil moisture and water table dynamics opens new possibilities for

- Understanding & predicting forest disturbances
- Fire risks
- Forest vehicle trafficability



Future collaboration?

Thanks & let's keep in touch!

Contact: samuli.launiainen@luke.fi
See: https://github.com/LukeEcomod

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From forest structure to hydrological function – merging dense Earth Observation data and process-models (LS-HYDRO, 2023-2027)

Precision nutrient management - a tool for mitigation of climate change and environmental loading in boreal forestry (PREFER, 2022-2026)

A novel intra-molecular isotopic approach to infer past climate and plant responses from tree-ring archives (MoleO, 2021-2025, Katja Rinne-Garmston)

Tracking isotopic signals in trees using mechanistic modeling – unraveling the climatic response of boreal forests imprinted in decadal tree ring archives (2020-2025, Kersti Leppä)

Economic and environmental feasibility of continuous cover forestry on drained organic soils (CCF-Peat, 2017-2021, Mika Nieminen)

Novel soil management practices – key for sustainable bioeconomy and climate change mitigation (SOMPA)

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Greenhouse Gas Fluxes and Earth System Feedbacks (GreenFeedBack, 2022-2026)

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