Hydrologic modeling at Luke

”Process models and academic curiosity
for sustainable use of boreal ecosystems”

- Samuli Launiainen, Antti-Jussi Kieloaho, Kersti Haahti, Mingfu Guan, Aura Salmivaara

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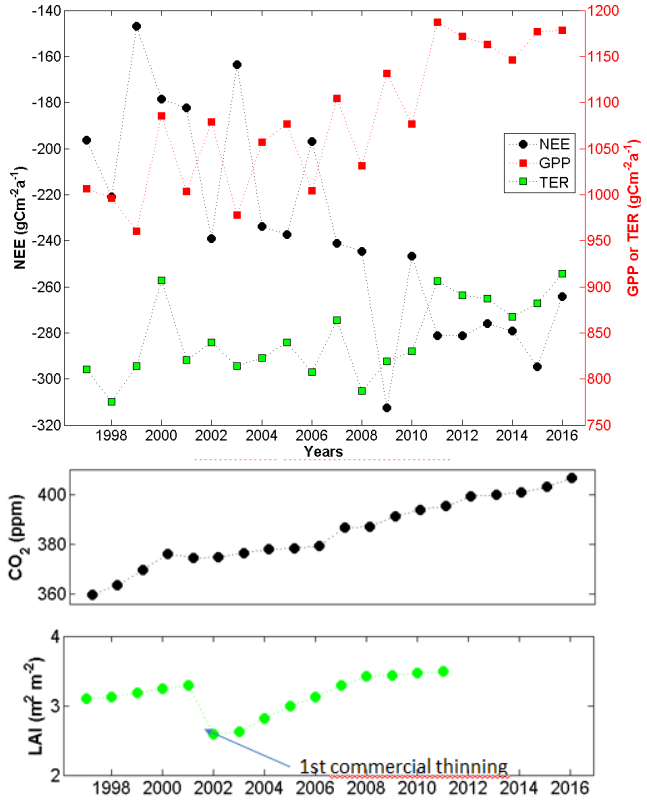
Why carbon sink increases at Hyytiälä Fluxnet site?

- Two decades of eddy-covariance data at Hyytiälä SMEAR II –site
- Increasing annual CO2 sink that is mostly due to enhanced productivity
  - NEE: from -180 to ~-200 g C m-2 a-1 (+53%)
  - GPP: from ~1000 to 1200 g C m-2 a-1 (+19%)
- Also annual ecosystem ET has increased (+22%)

- Plausible explanations for increased productivity?
  - CO2 fertilization
  - Increasing T & longer growing season
  - Stand development
  - Footprint changes



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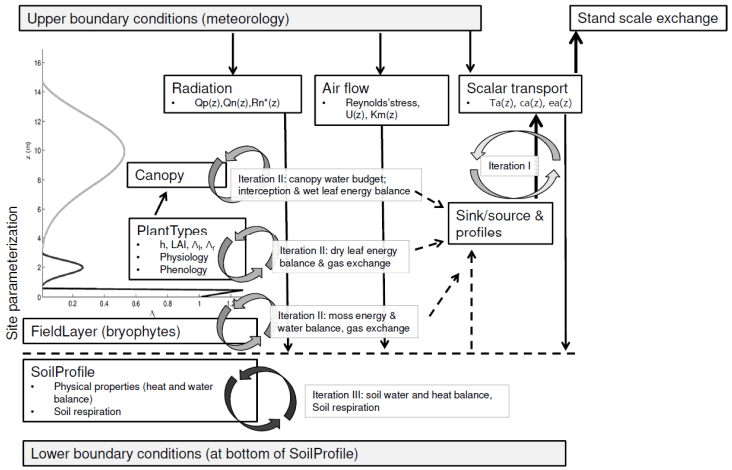
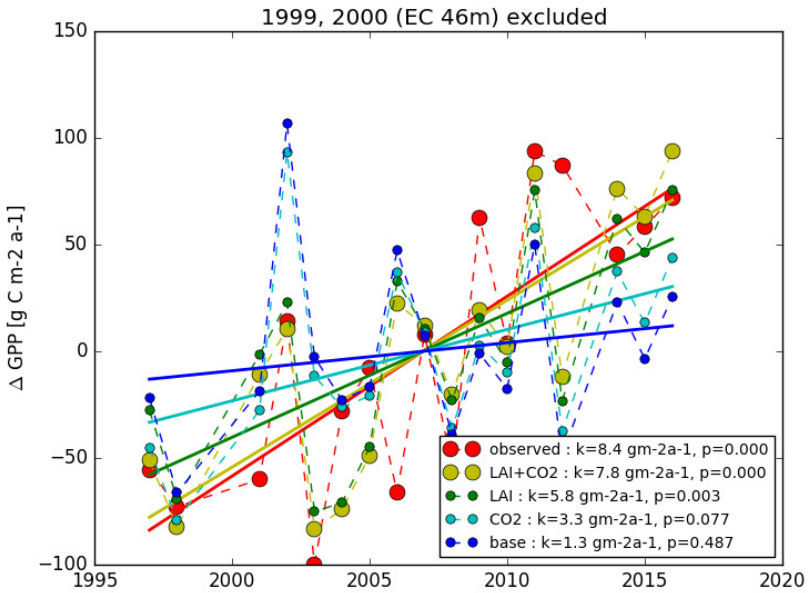
APES: Atmosphere-Plant Exchange simulator



GPP



APES:

- Multi-layer, multi-species SVAT-model
- CO2-H2O-energy
- Sub-daily forcing
- Scenarios: base, CO2+, LAI+, CO2 & LAI+

Launiainen et al. 2015. Ecol. Mod; 2016 Global Change Biol.

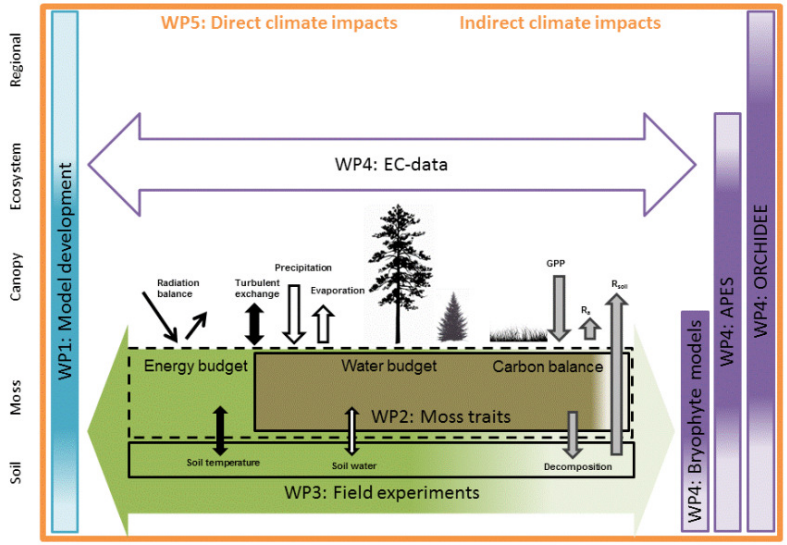
Geophysical Research Abstracts
Vol. 20, EGU2018-18561, 2018
EGU General Assembly 2018

Does atmospheric CO_2 explain increased carbon sink at a boreal coniferous forest flux site?

Tiia Grönholm (1), Samuli Launiainen (2), Gabriel Katul (3), Pasi Kolari (1), Toprak Aslan (1), Ivan Mammarella (1), Timo Vesala (1), and Pertti Hari (1)

(1) University of Helsinki, Institute for Atmosphere and Earth System Research, Finland (tiia.gronholm@helsinki.fi), (2) Natural Resources Institute Finland, Finland, (3) Nicholas School of the Environment, Duke University, Durham, NC, USA

Climate impacts of bryophytes: from functional traits to global models



CLIMOSS (2016-2021, Acad. Finland)

- Pinpoint the most important functional traits of the bryophyte layer?
  - Hydrological properties
  - Optical and thermal properties
  - Carbon usage
- Start with APES + develop description further bryophyte layer
  - Energy and water balance
  - Photosynthesis, respiration, growth
- Put mosses into a climate model
  - Orchidee?
  - Regional climate impacts

Antti-Jussi Kieloaho

Response of drained peatland forest to management alternatives?

Kersti Haahti

Lettosuo Fluxnet site (FMI)

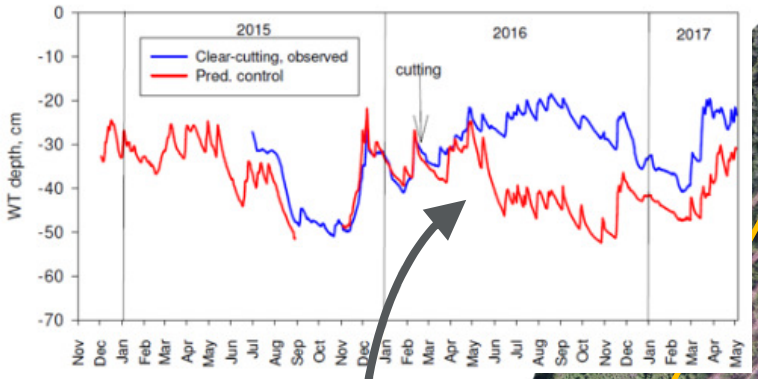
EC, chambers , WT depth, biomass

Coupled APES, 1-D Richards + Hooghoud drainage equation

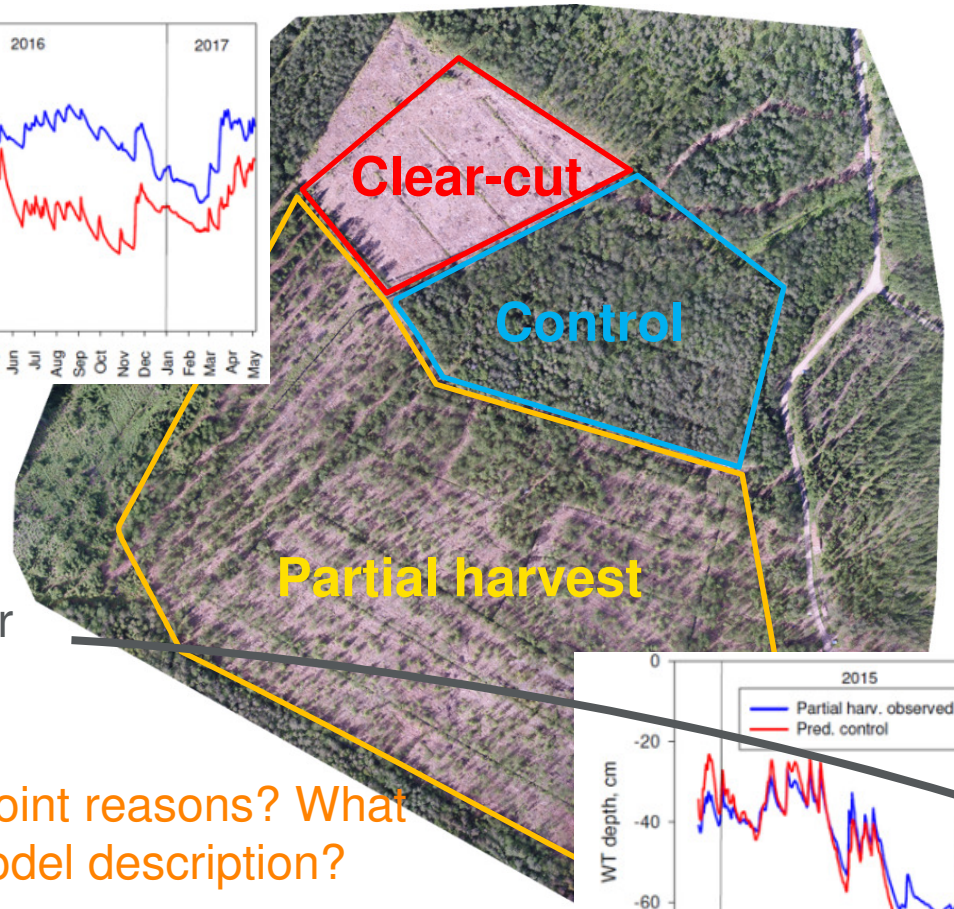
Validate for 5-year control, perturb system to replicate experiment

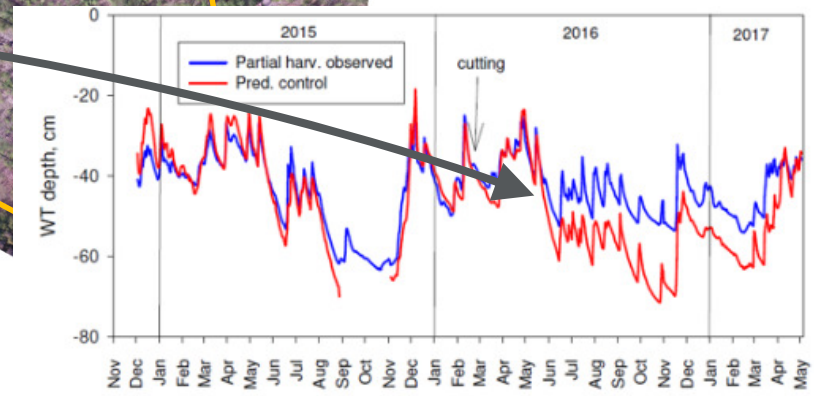
→ Pinpoint reasons why changes took place

→ Inter/extrapolate to other conditions



Measurements show water table level increase after treatments





Can modeling pinpoint reasons? What is a sufficient model description?

CCFpeat (2018-2020, SOMPA 2018-2024, Acad. Finland)

Why water table, ET and CO2 balance change?

Kersti Haahti

Approach:

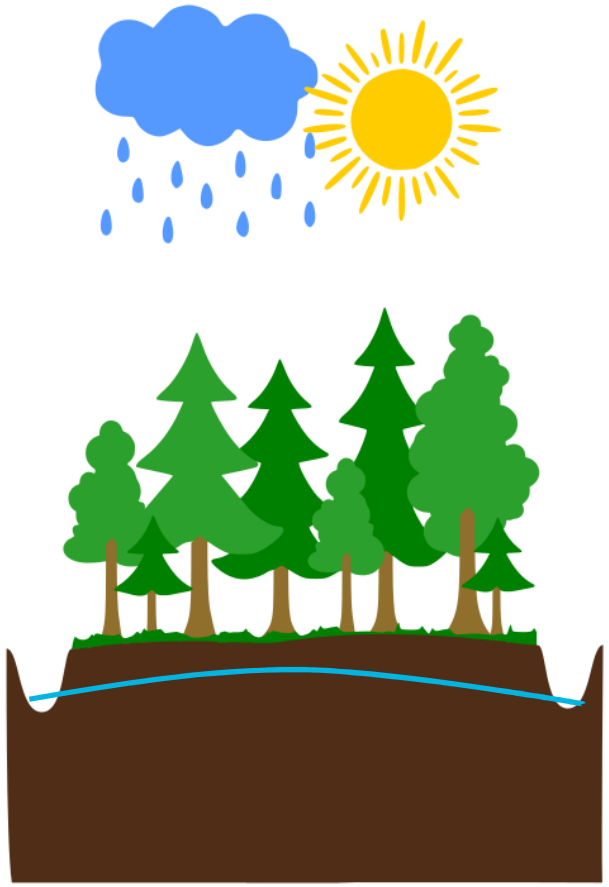
Couple APES, 1-D Richards + Hooghoud drainage equation

Validate for 5-year control data (WT, ET from EC)

Alter stand structure to replicate experiment

→ Pinpoint reasons why changes took place

→ … and perform model-based inter/extrapolation for other conditions



Meteorological conditions

LAI, species composition, vertical distribution, stress response, recovery

Peat characteristics and drainage design

CCFpeat (2018-2020, SOMPA 2018-2024, Acad. Finland)

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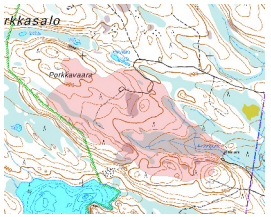
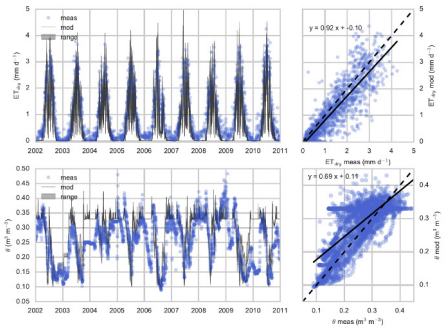
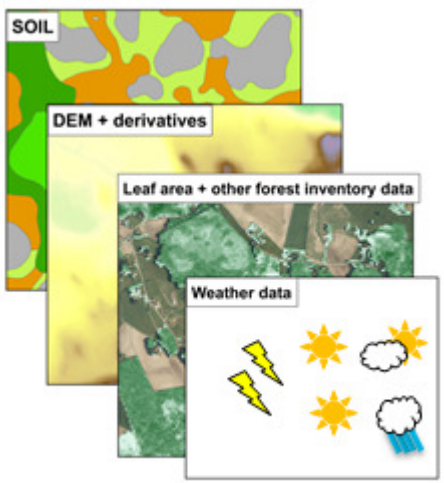
Can we upscale from point to landscape?



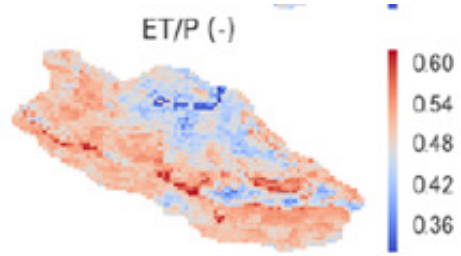


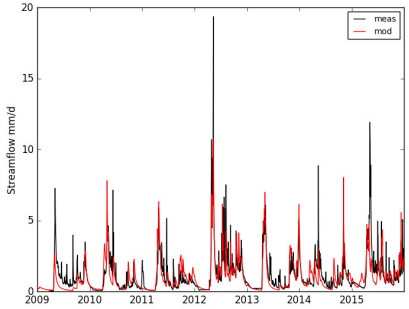
Working point scale model

”simplifications where possible”



Open GIS-data
meteorologic data
streamflow data





Distributed ET,
snow & soil water
predictions,
streamflow

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SpatHy: (semi)distributed catchment model

INPUT:

- Multi-NFI: conifer vs. deciduous LAI
- Soil maps, peatland mask
- DEM
  - Catchment mask
  - Topografic wetness index TWI
  - For TOPMODEL – water budget
- Forcing by daily weather data
  - Precip, Rglob, Tair, RH

GRID-OUTPUTS:

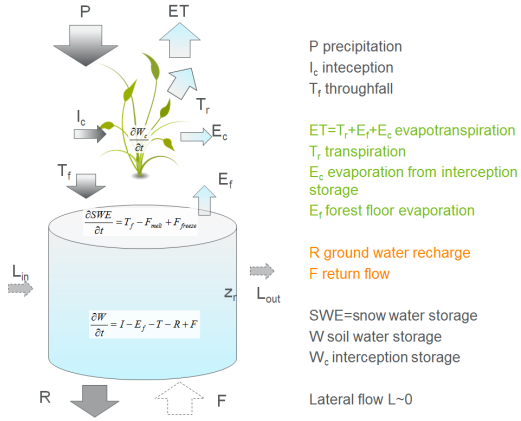
- ET components
- Root zone moisture
- Snow water equivalent
- Drainage to ground water
- Saturation deficit (→ WT)
- saturated gridcells, returnflow

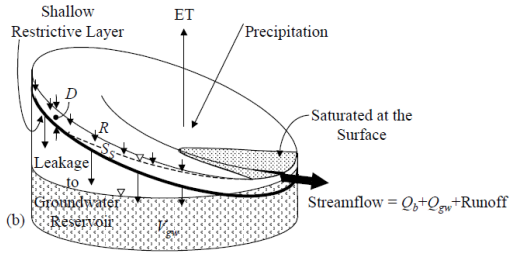
CATCHMENT LEVEL

- Streamflow

Launiainen et al. 2018 GMD, in prep.

Catchment → (n x m) grid of buckets





+ TOPMODEL for streamflow generation & saturated area

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Upscaling of ET (P-M –based)

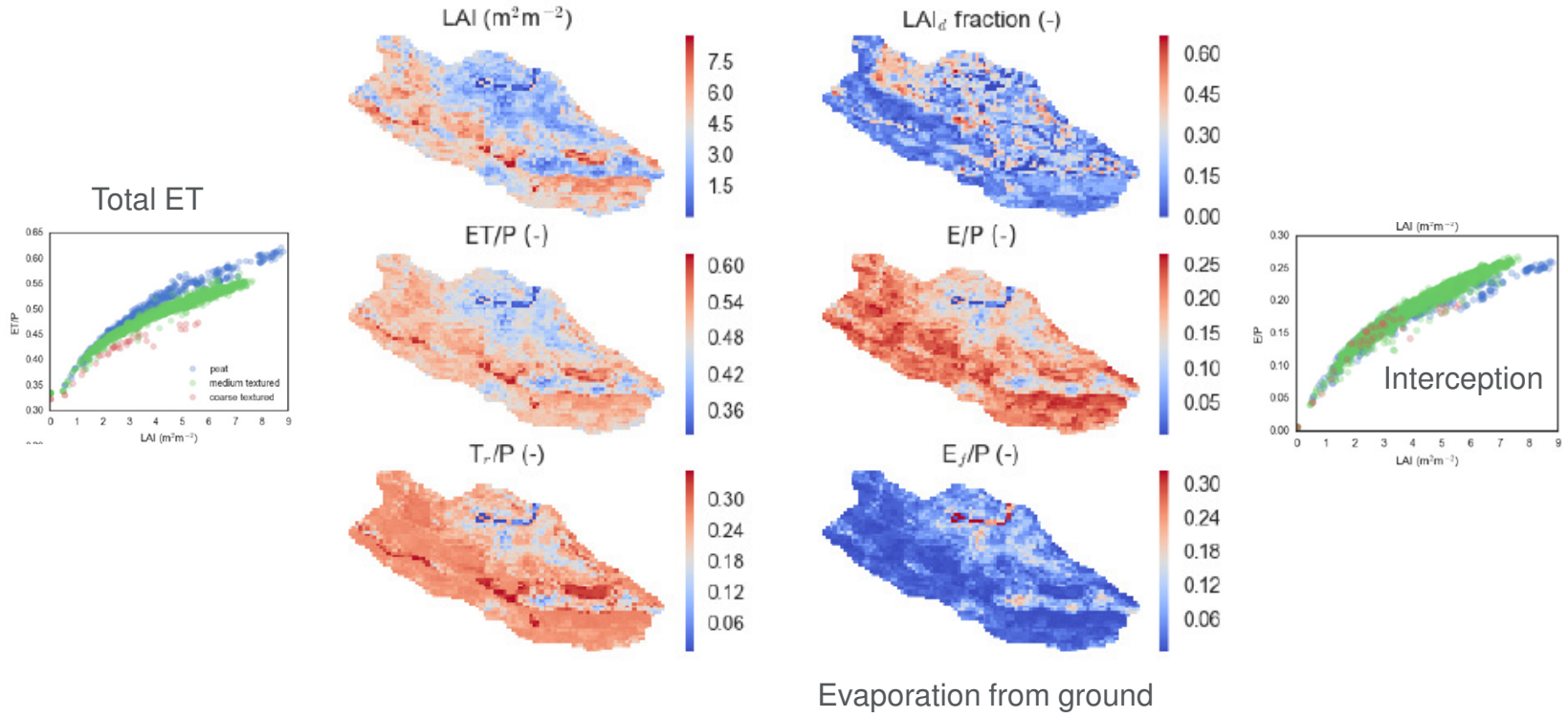
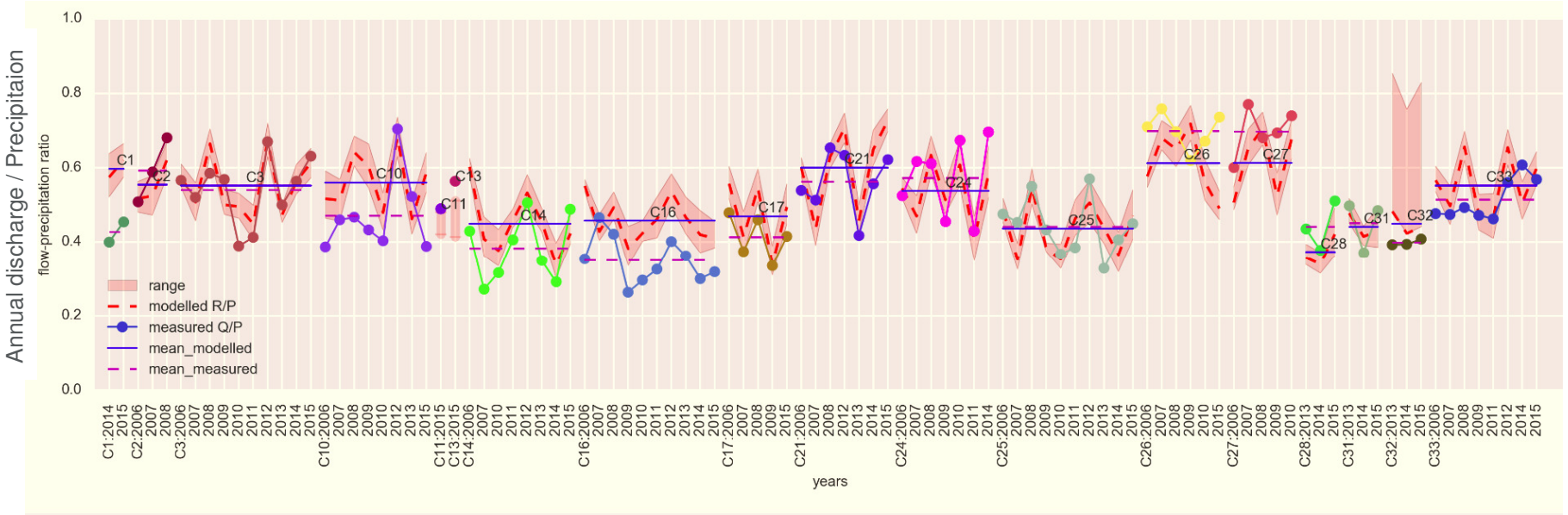


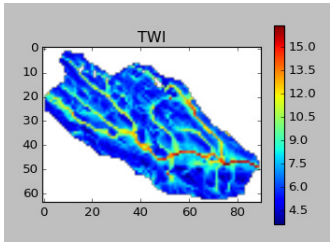
Figure 9. Annual total ET and its components: transpiration Tr, interception evaporation E and soil/ forest floor evaporation Ef as a fraction of annual P. Top row shows maximum annual LAI and the relative share of deciduous LAI / total LAI

Can we predict partitioning of annual water budgets without calibration?

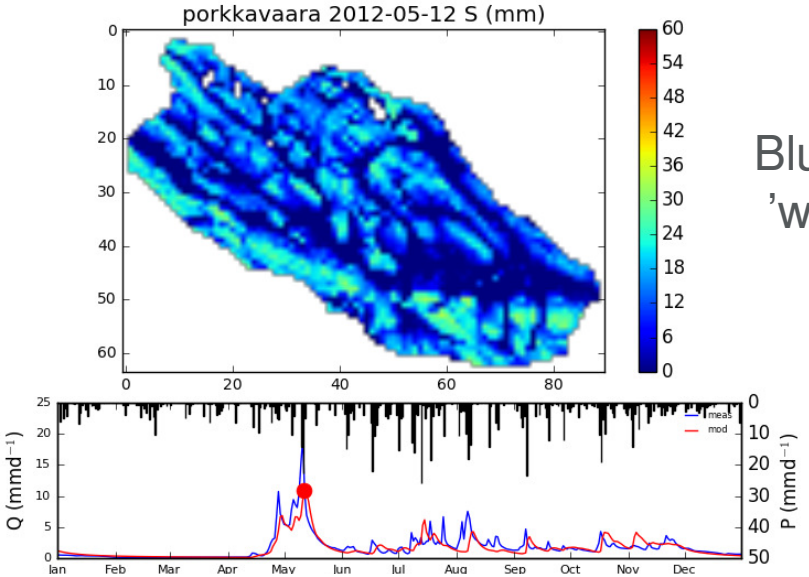


- Points → from measurements
- Red line + region = model + parameter uncertainty
- Model uncertainties: vegetation type, plant water use efficiency, interception efficiency, snow, peatland evaporation, open fjells, …
- Measurement uncertainties:
  - Boundaries
  - Discharge
  - Precipitation from 10x10km FMI grid data

Example results

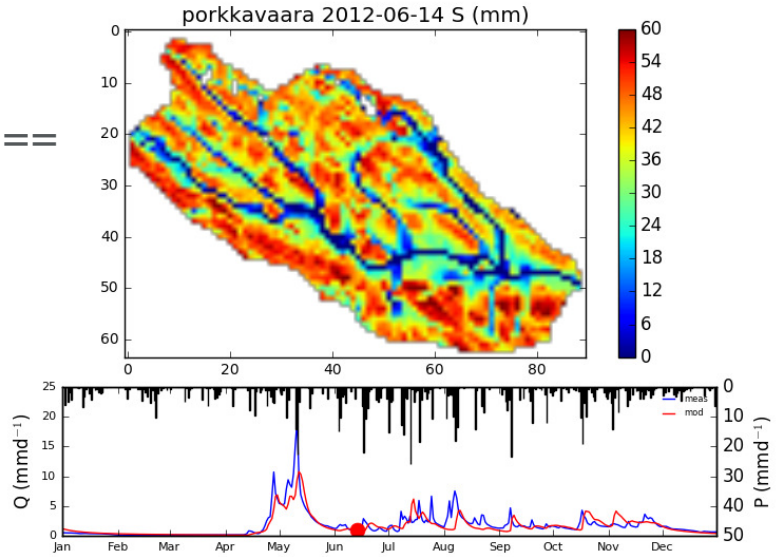


Saturation deficit during snowmelt

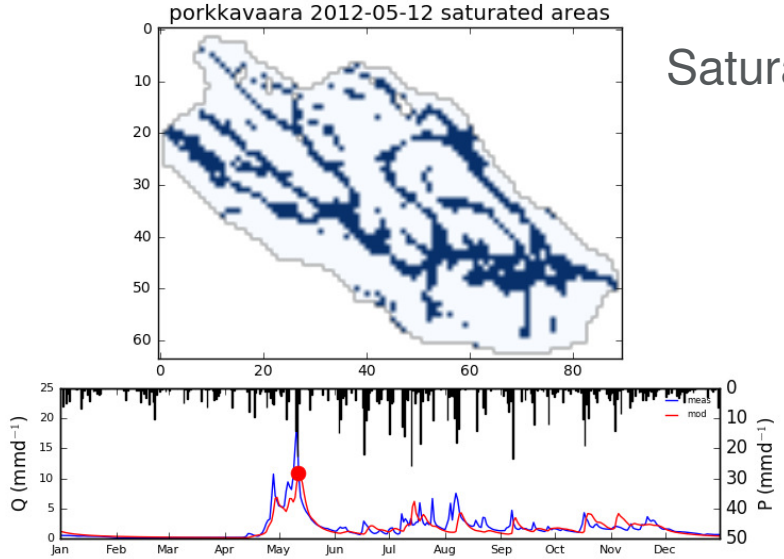


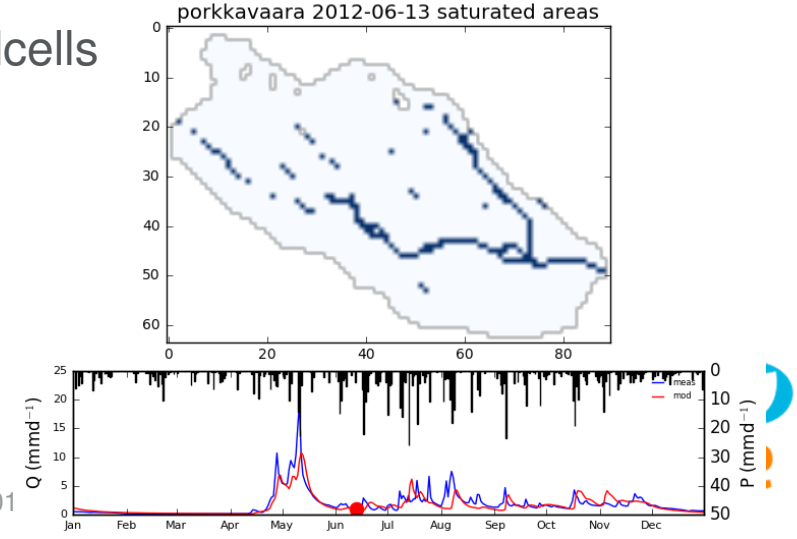
Blue == 'wet'

During dry period



Saturated gridcells



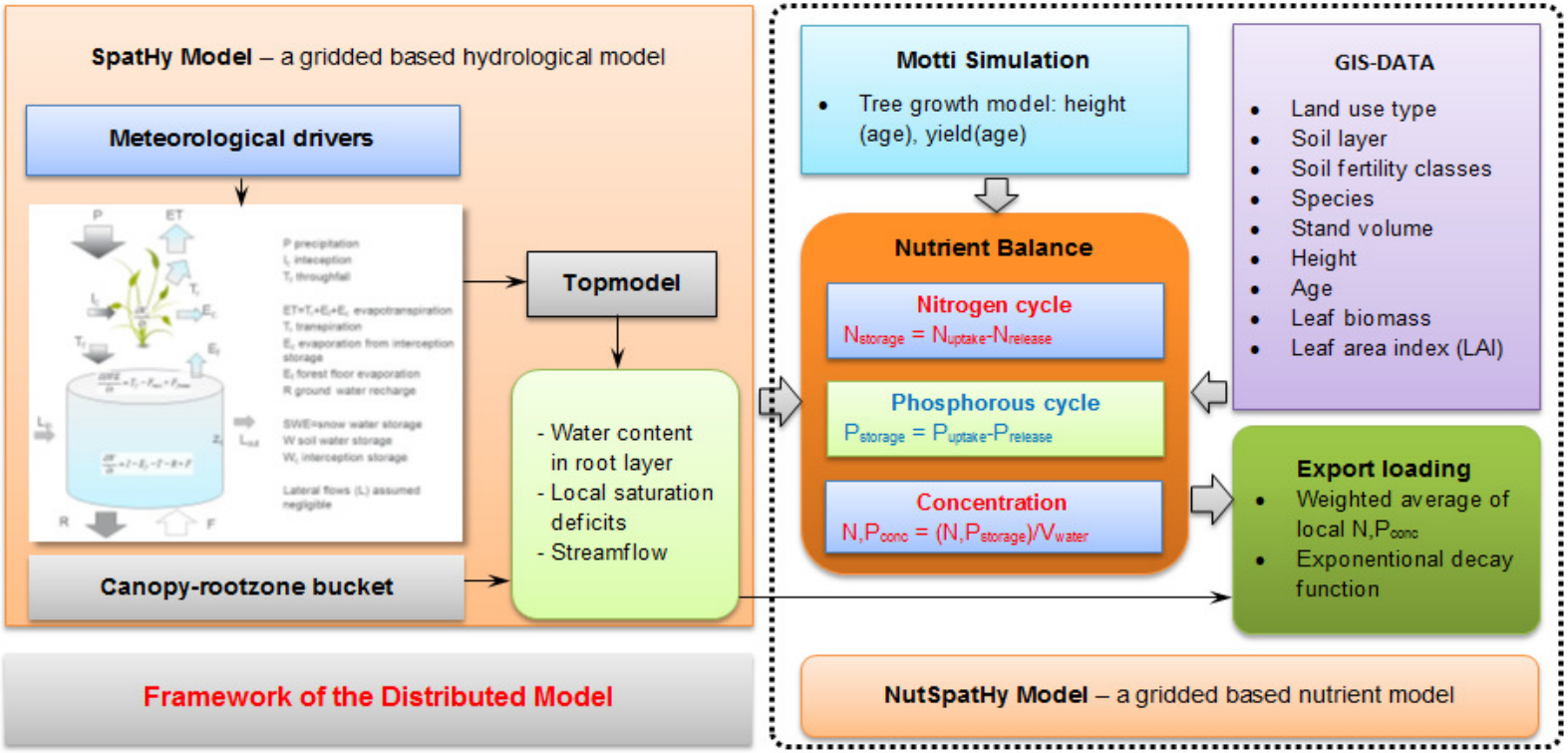


NutSpatHy

Mingfu Guan

Ari Lauren

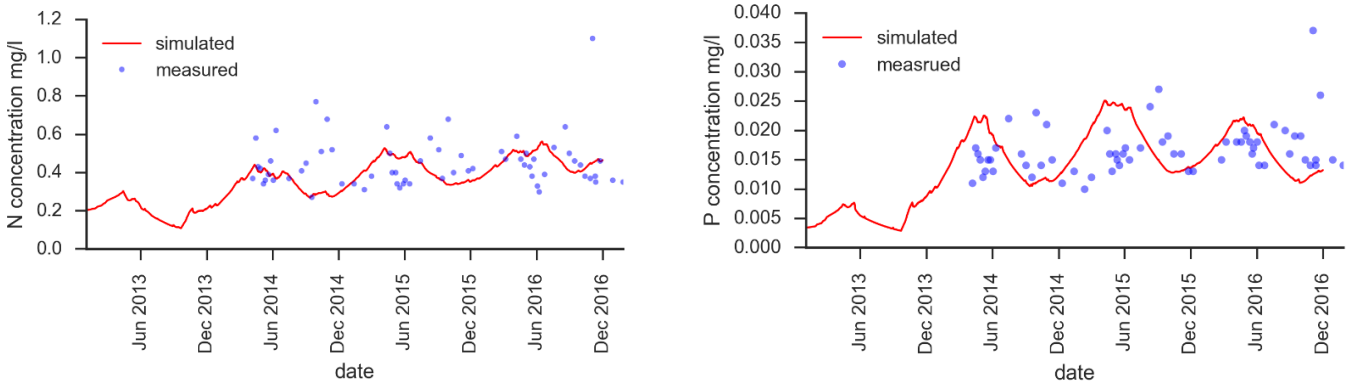
- **A grid-based distributed nutrient model for predicting nitrogen (N) and phosphorous (P) leaching in forested catchments**
- **Model key features:**
  - Grid-based nutrient balance (Δstorage = release - uptake)
  - Nutrient concentration prediction (conc = storage/water_volume)
  - Export loading simulation based on SpatHy runoff prediction
  - Spatiotemporal modelling of nutrient dynamics



FRESHHABIT (2016-2022, EU LIFE+)

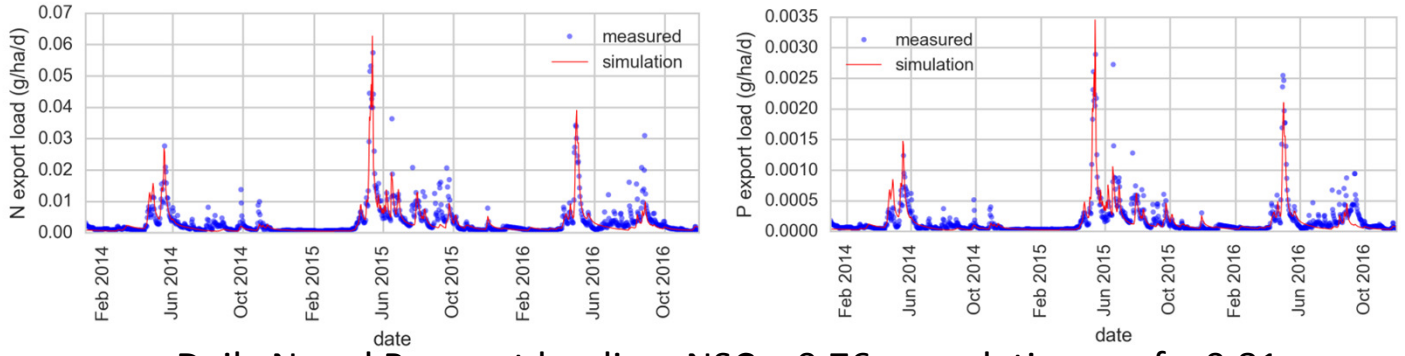
- **N and P concentration**

Nutrient concentration is reasonably predicted considering the complex chemical process and a series of uncertainties of parameters and input data.



- **Daily and monthly N and P export loading**

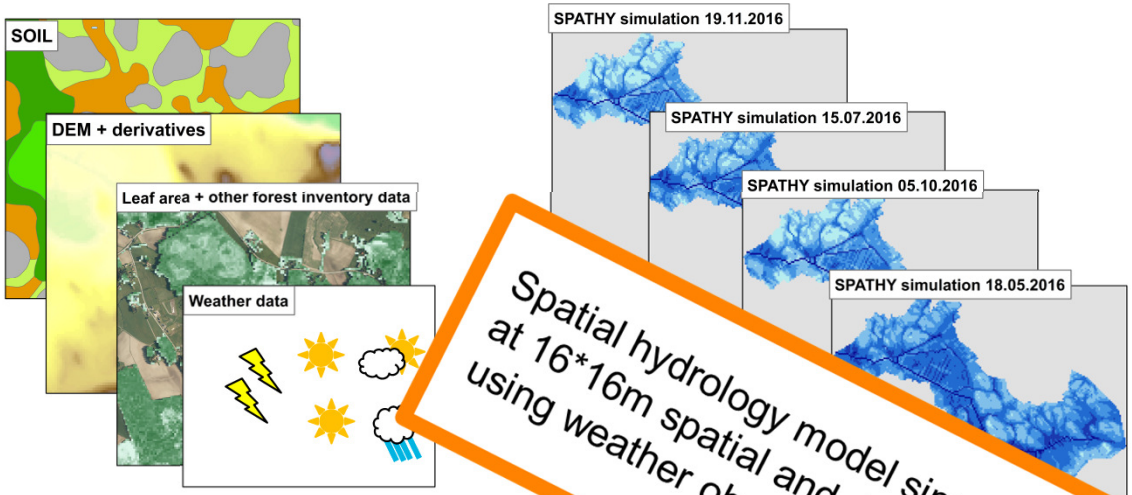
Good performance in the prediction of export loading verifies the controlling role of hydrology on nutrient transport processes.



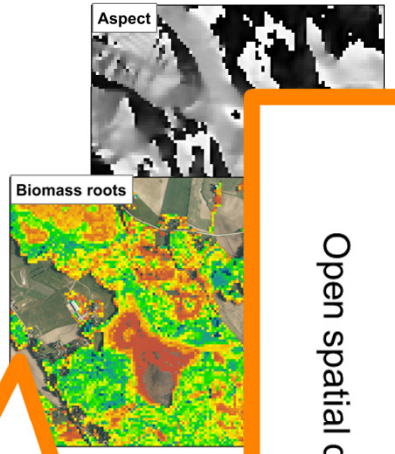
Daily N and P export loading: NSC = 0.76, correlation coef.= 0.81

Dynamic forest trafficability prediction by fusion of open data, hydrologic forecasts and harvester-measured data

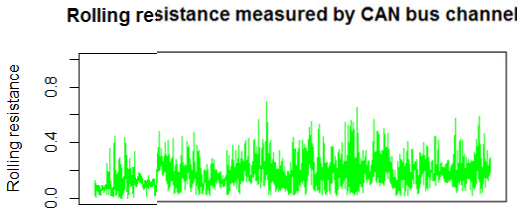
Aura Salmivaara



Spatial hydrology model simulations at 16*16m spatial and daily temporal resolution using weather observations and forecasts



Open spatial data

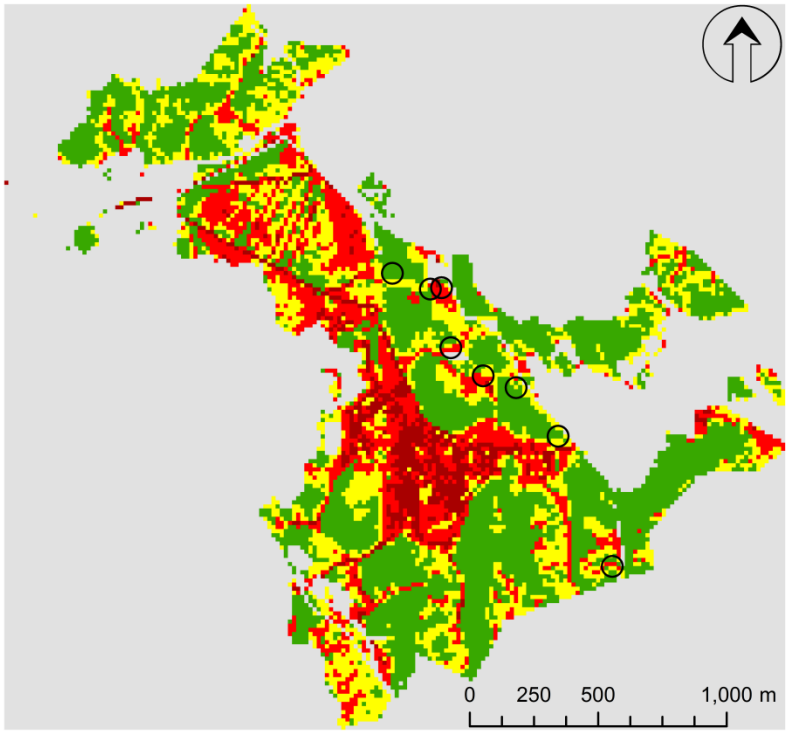


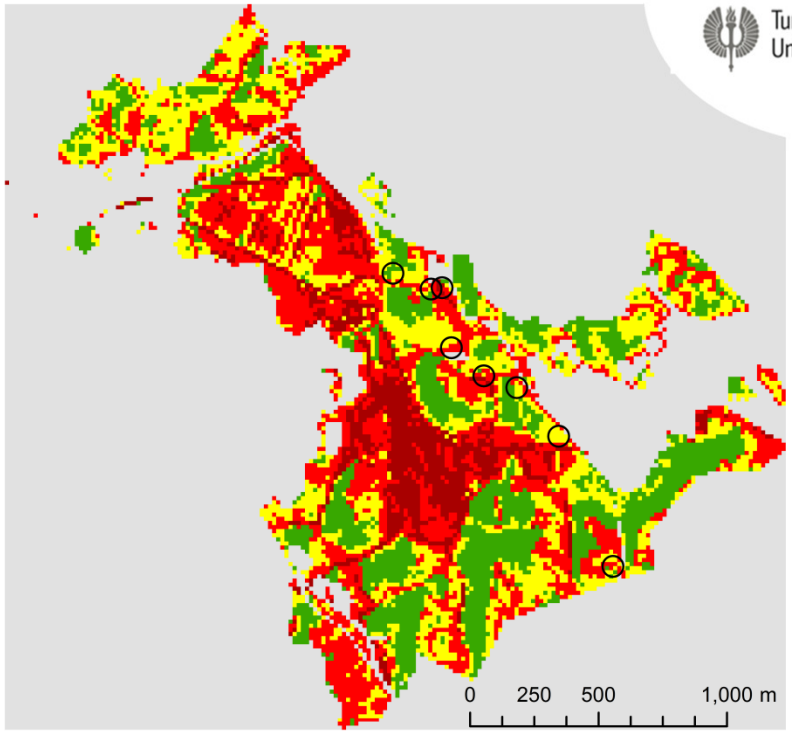
Forest machine measured data for improving prediction models

Rut depth prediction f(t, x, y)

Salmivaara, A., Launiainen, S., Ala-Ilomäki, J., Kulju, S., Laurén, A., Sirén, M., Tuominen, S., Finér, L., Uusitalo, J., Nevalainen, P., Pahikkala, T., and Heikkonen, J. 2017. *Dynamic forest trafficability prediction by fusion of open data, hydrologic forecasts and harvester-measured data. Poster.*

Dynamic forest trafficability prediction by fusion of open data, hydrologic forecasts and harvester-measured data





Predicted rut depth in "dry" conditions (19.11.2016) [cm]

- < 5
- 5 - 10
- 10 - 20
- 20 - 40

Predicted rut depth in "moist" conditions (18.5.2016) [cm]

- < 5
- 5 - 10
- 10 - 20
- 20 - 40

In ”moist” conditions the area with ruts >10 cm covers 45% of the total area, while in ”dry” conditions this proportion is 26%.

FOTETRAF (2016-2017, Acad. Finland): Advanced computational methodologies on open big data for forest terrain trafficability monitoring and forecasting

Summary

- We try to use mechanistic models to:
  1) Explain observations
  2) Offer ways to simplify problems
  3) Stimulate thinking
  4) Benefit practitioners?
  5) Find unpleasent truths (from data …and models)
- We:
  1) Do ecohydrology – link water, carbon and energy, in future also biogeochemistry
  2) Aim to go spatial by merging GIS and mechanistic models
  3) Need to strengthen landscape approach (all interesting happens between local and global scale… which is often ignored)
  4) **Want to work with you and Krycklan data!**

- **Tandem Forest values call (DL end of March)**

Thank you!

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