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Modelling the Role of Weather and Forest Management on Nutrient Export in Boreal Forested Catchments

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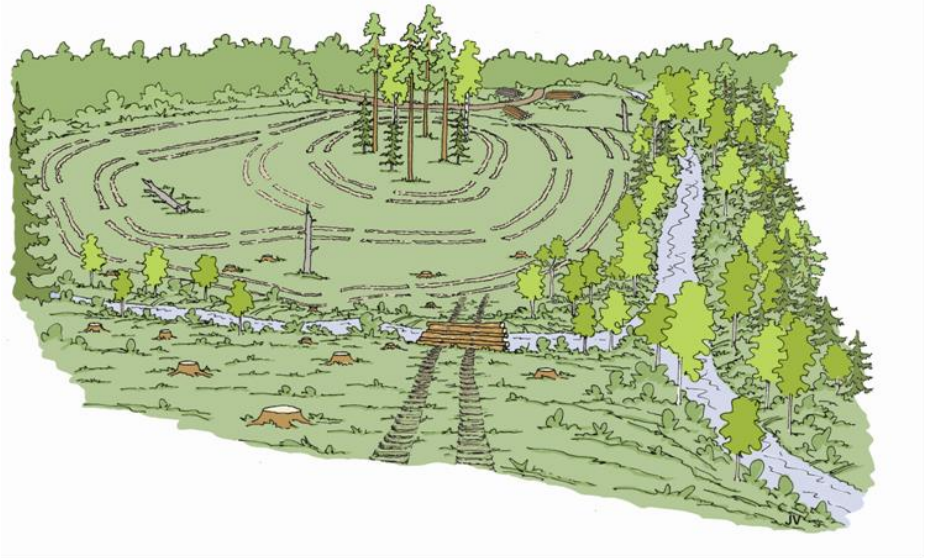
Why we need modelling?

Nutrient leaching from forested areas is influenced by various spatially and temporally changing factors:

- the operations: intensity and surface area and type
- site topography and position in relation to receiving water body
- soil type and structure
- groundwater table depth
- weather conditions and impact of climate change



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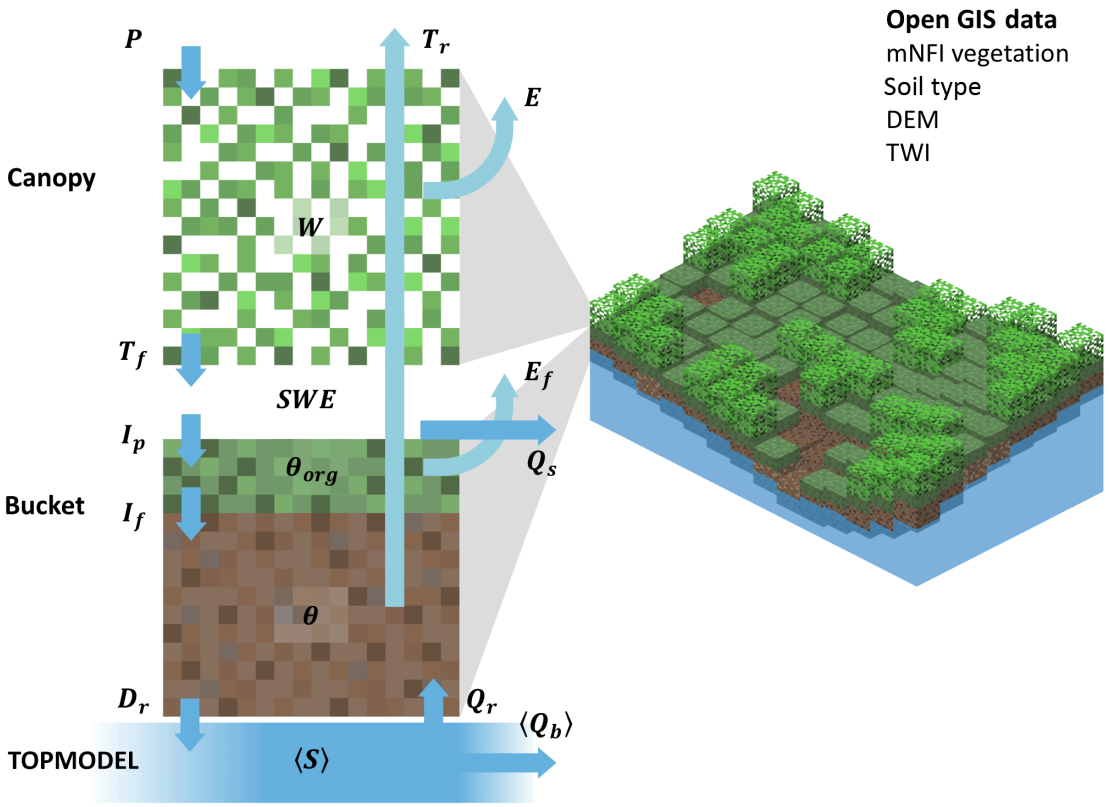
Modelling hydrology

Distributed spatial hydrological model developed by Launiainen et al. 2019 calculates the daily hydrology in a catchment using open spatial data on forest resources, topography and soil as well as weather data

The base unit if 16m X 16m grid cell for which the water balance is solved. The computation is relatively light as the water flow is not modelled considering linkages between neighbouring grid cells but topmodel and topograhic wetness index is utilised in modelling the catchment scale grid per grid variation in daily hydrology

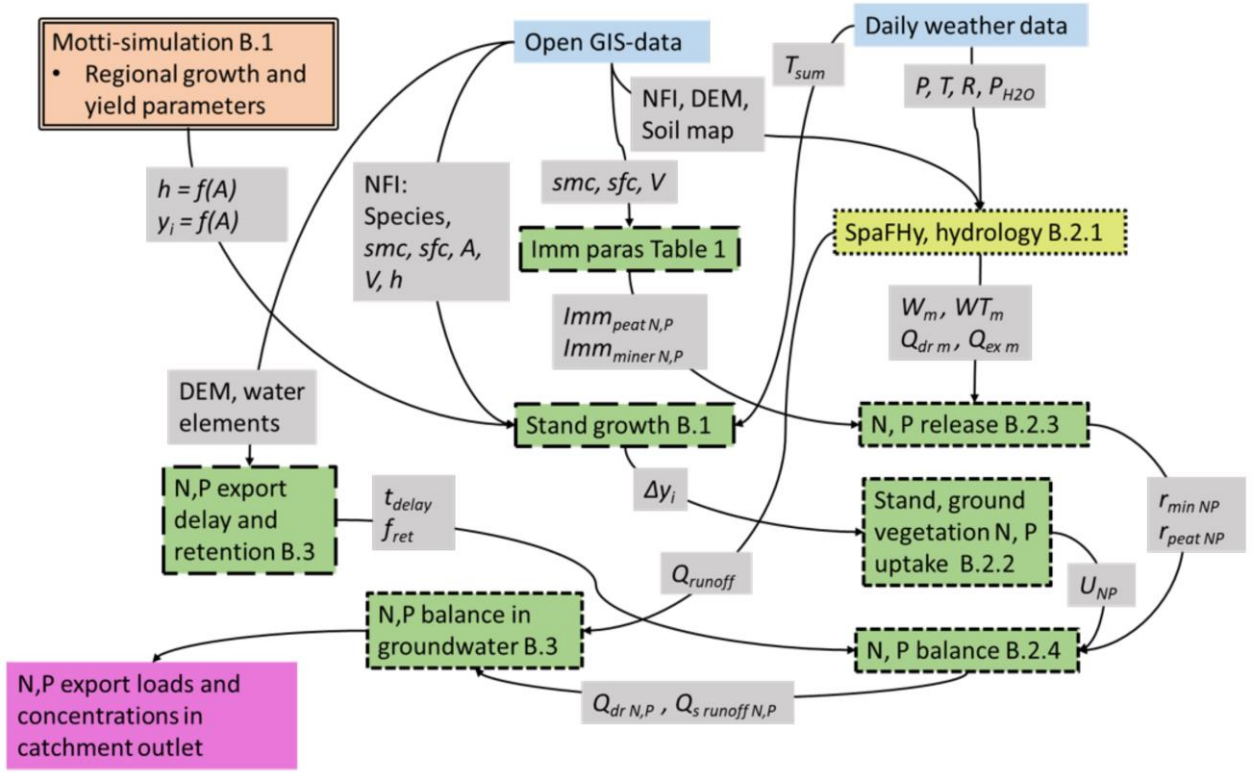


Launiainen, S., Guan, M., Salmivaara, A., and Kieloaho, A.-J.: Modeling boreal forest evapotranspiration and water balance at stand and catchment scales: a spatial approach, Hydrol. Earth Syst. Sci., 23, 3457–3480, https://doi.org/10.5194/hess-23-3457-2019, 2019.

Modelling nutrient export

Nutrient export modelling developed by Annamari Laurén (currently in University of Helsinki) has been built upon SpaFHy-model by adding module for calculating nutrient balance in monthly time step in a grid cell and then utilising distance to catchment outlet in another module which considers the delay and retention of nutrients on the way to the outlet.

The model considers if a clear-cut or CCF-type thinning occurs and updates the grid cell hydrology, and the nutrient uptake by trees and ground vegetation accordingly

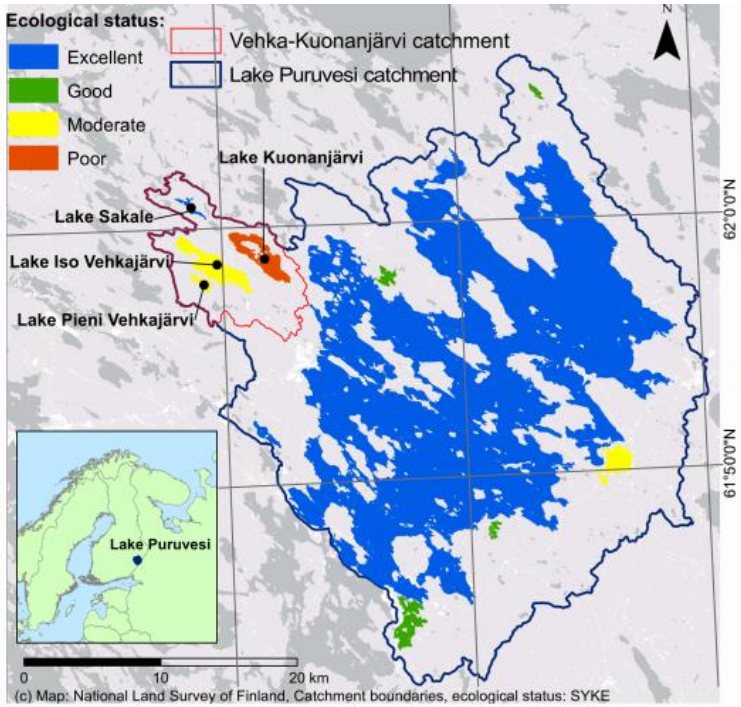


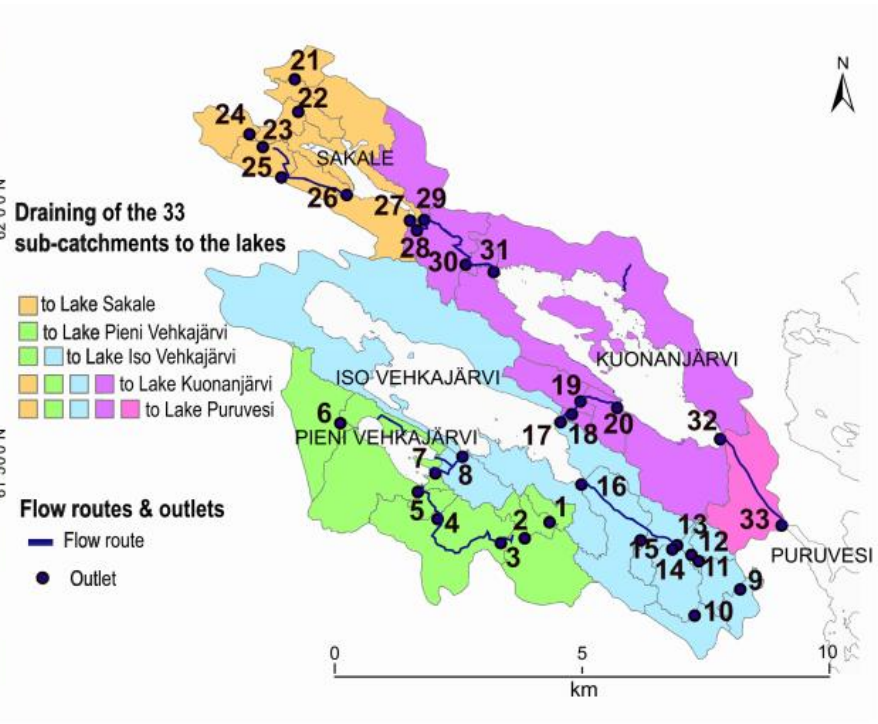
Lauren, A.; Guan, M.; Salmivaara, A.; Leinonen, A.; Palviainen, M.; Launiainen, S. NutSpaFHy—A Distributed Nutrient Balance Model to Predict Nutrient Export from Managed Boreal Headwater Catchments. *Forests* **2021**, *12*, 808. https://doi.org/10.3390/f12060808

Case studies from a boreal forested catchment in Puruvesi region

Using nutspafhy model to estimate phophorus (P) and nitrogen (N) export load and exploring:

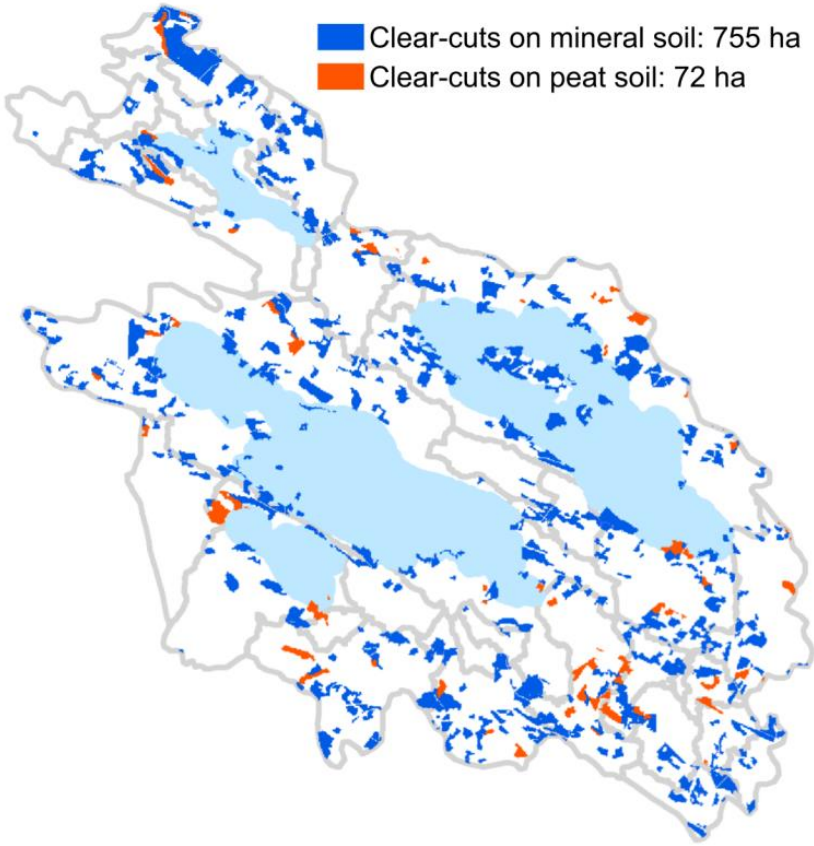
- Role of extreme weather for nutrient export compared to role of clear-cuts
- Role of location of clear-cuts
- Role of intensity of cutting: comparison between clear-cut and continuous cover forestry related thinning

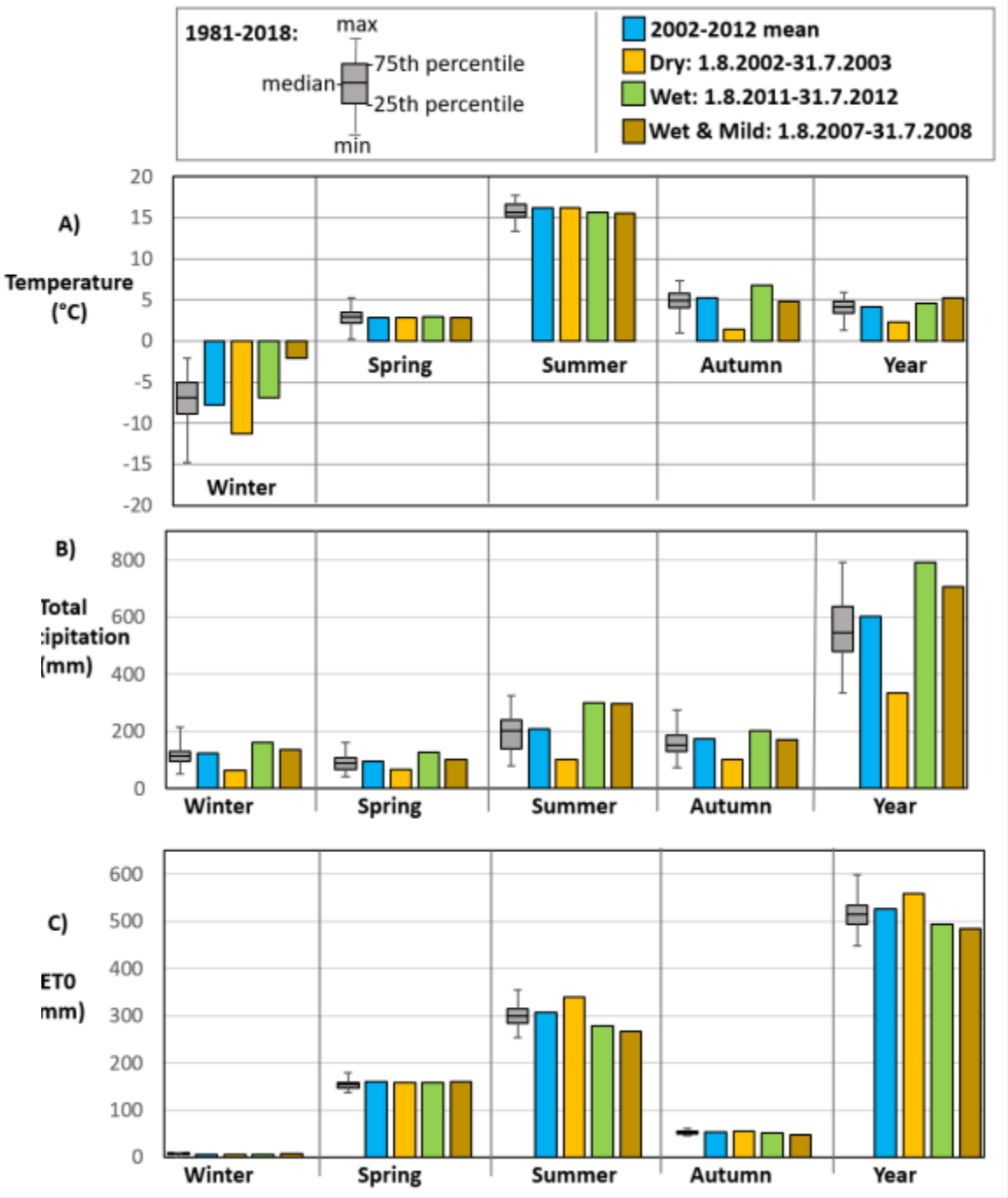




Role of extreme weather

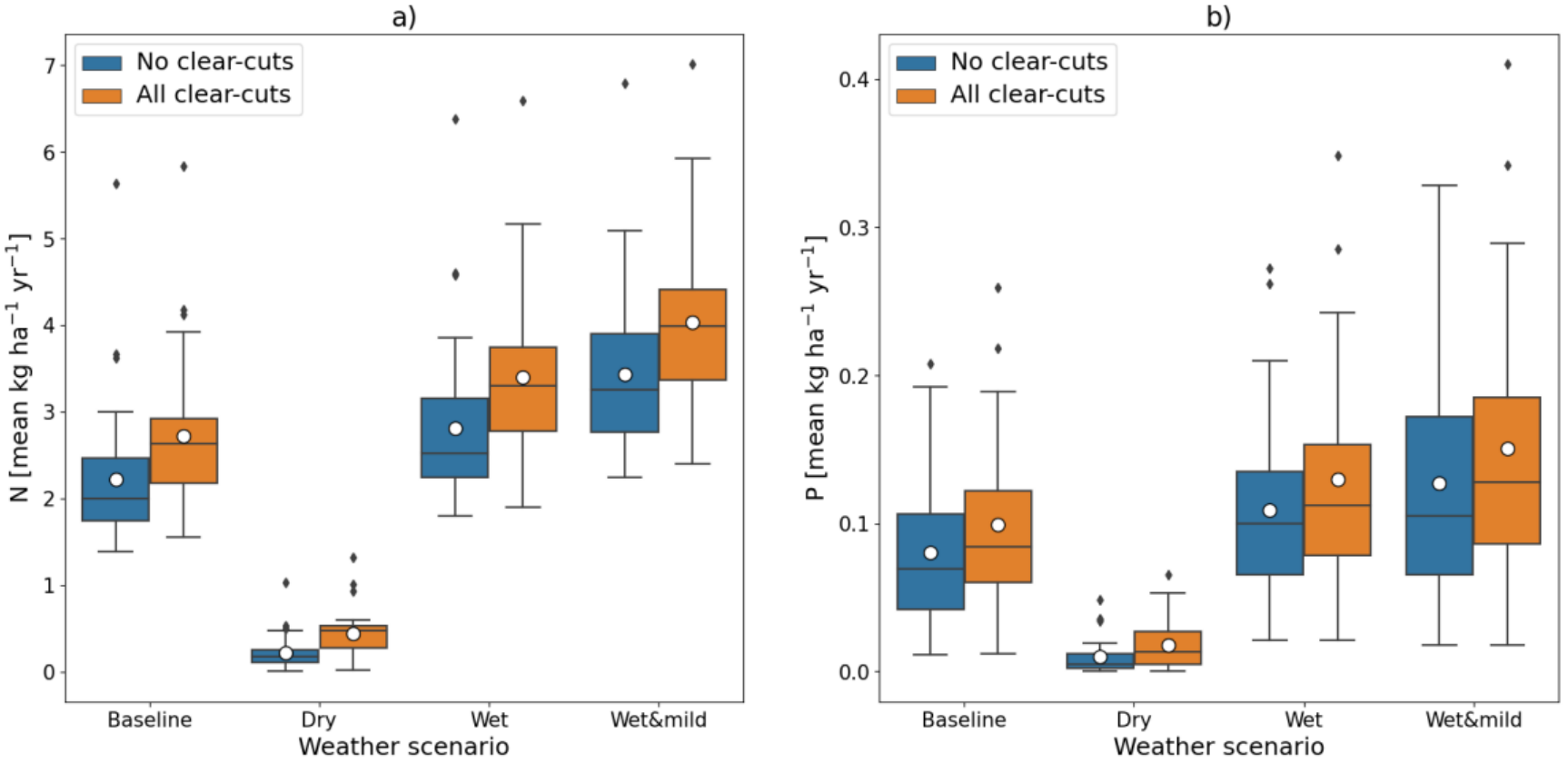
Extreme weather scenarios and extreme clear-cut scenarios: Extreme but still possible as based on observations or areas that mature for cutting





Role of extreme weather

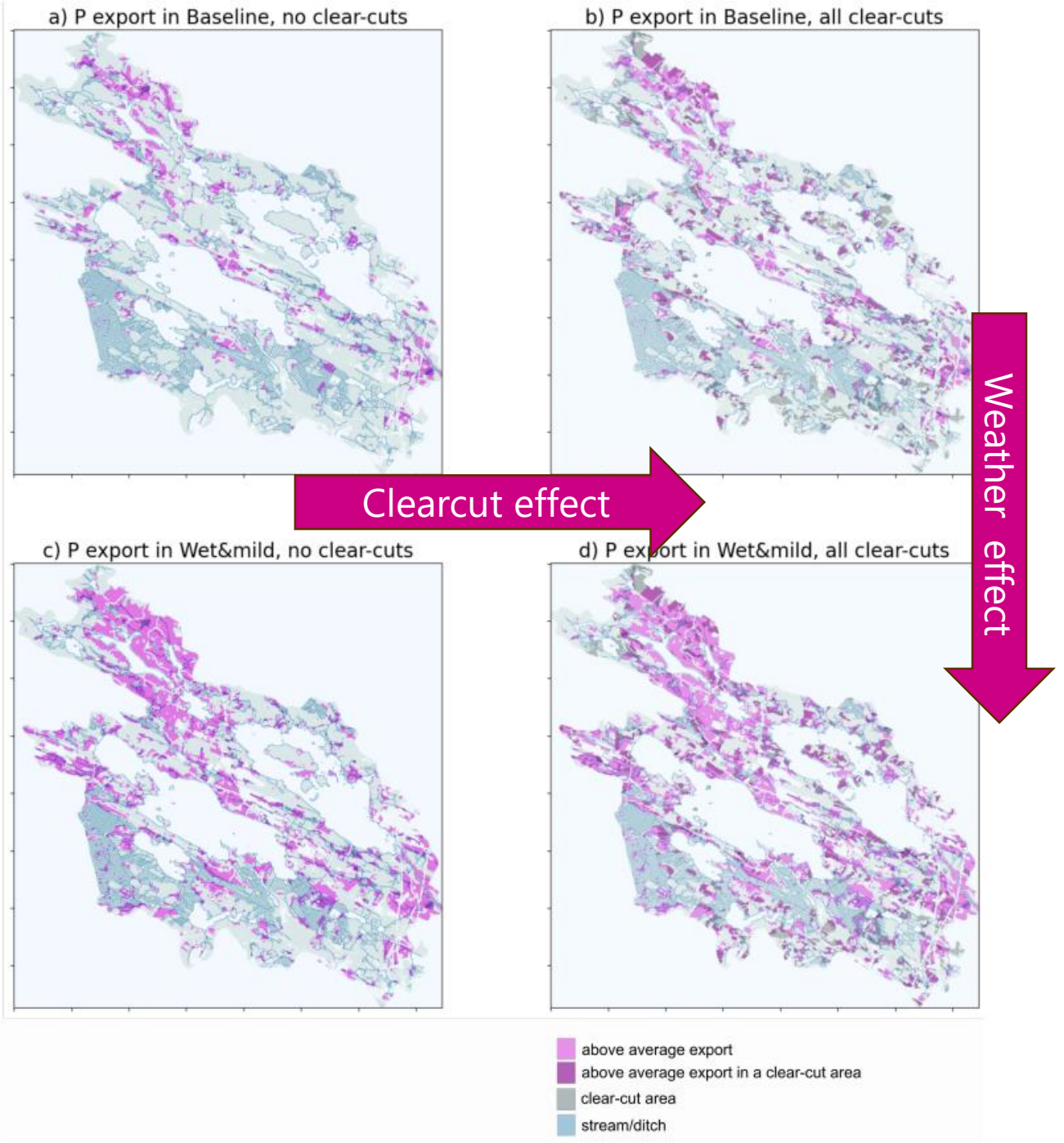
Salmivaara, A.; Leinonen, A.; Palviainen, M.; Korhonen, N.; Launiainen, S.; Tuomenvirta, H.; Ukonmaanaho, L.; Finér, L.; Laurén, A. Exploring the Role of Weather and Forest Management on Nutrient Export in Boreal Forested Catchments Using Spatially Distributed Model. *Forests* **2023**, *14*, 89. https://doi.org/10.3390/f14010089



The increase in nutrient export by wet & mild weather (over 55%) exceed the increase caused by the clear-cutting scenario (23 %) when compared to baseline.

Role of extreme weather

Increase in runoff, particularly in the winter time with less frost cause nutrient export to increase, and much more than an extreme clear-cut scenario



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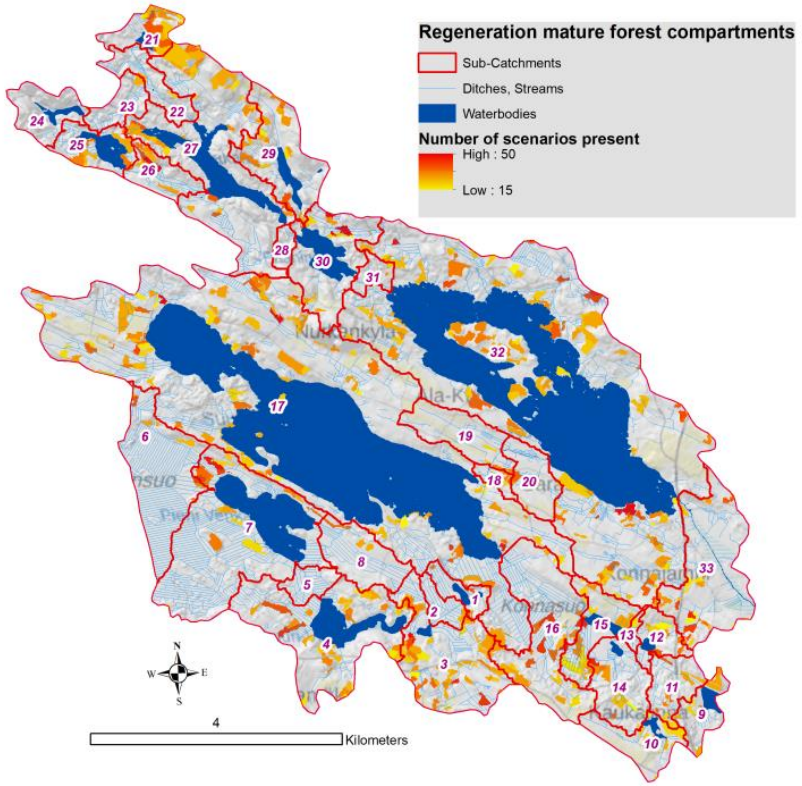
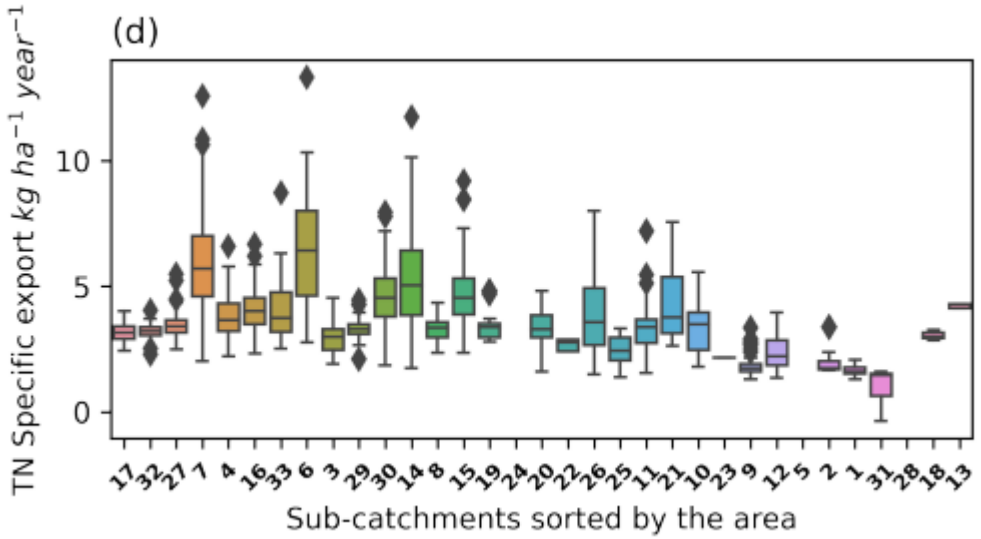
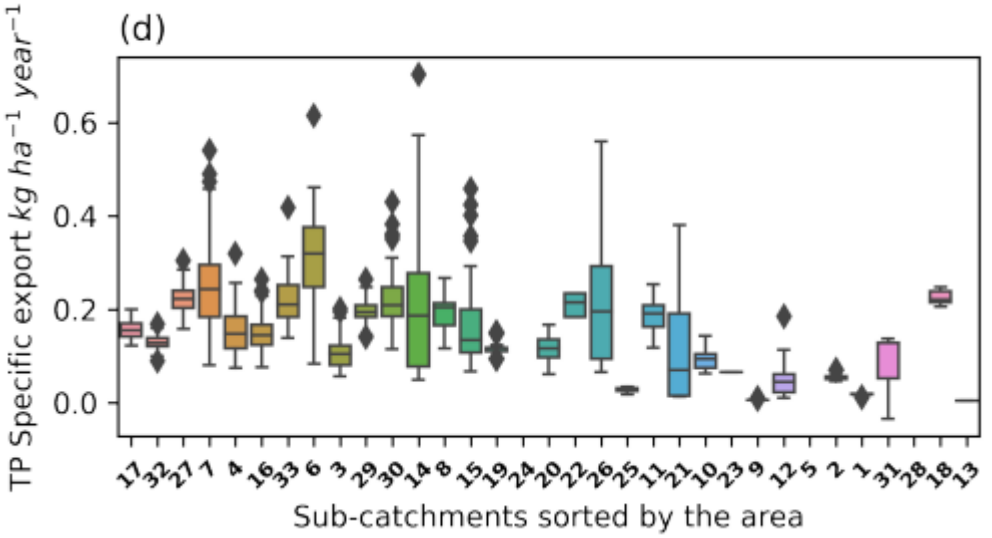
Role of location of forest operations



Exploring a 100 equally probable logging scenarios and their influence on nutrient export with NutSpaFHy model

The clear-cut-induced excess nutrient exports varied overall by 4-7% between scenarios. There was very large variation within the sub-catchments.





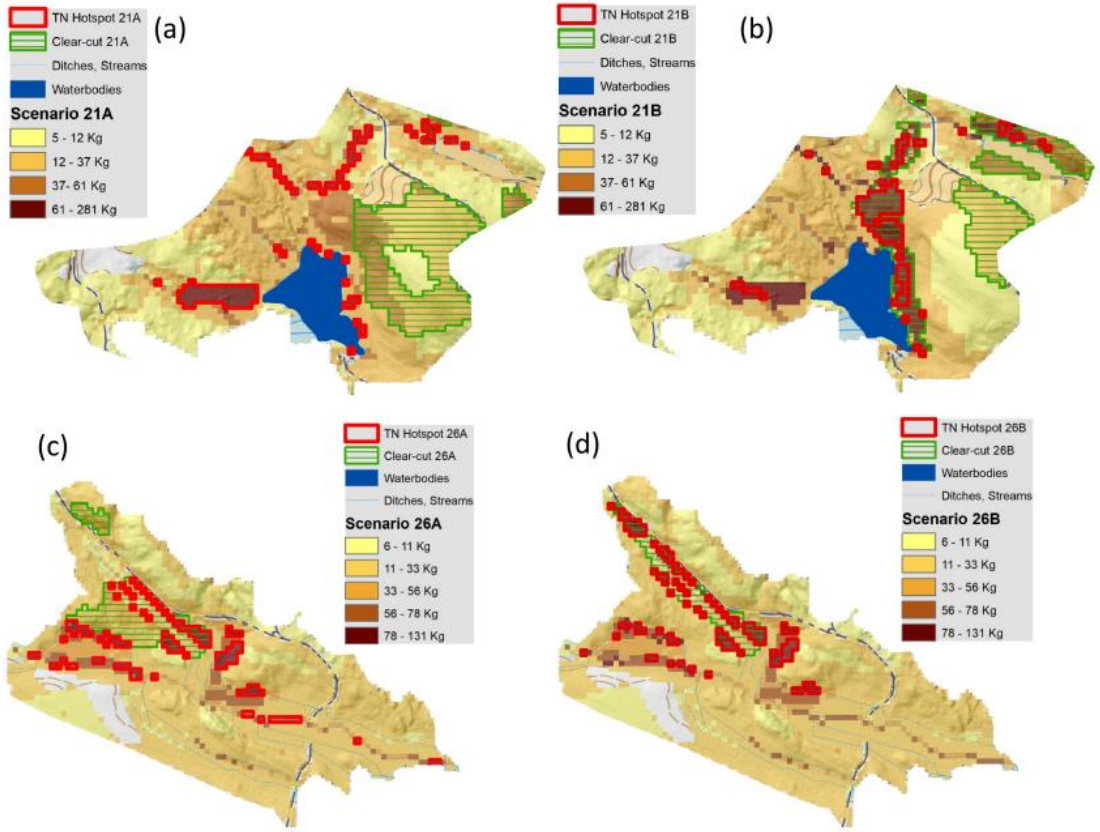
Leinonen, A.; Salmivaara, A.; Palviainen, M.; Finér, L.; Peltola, H.; Laurén, A. Identifying Nutrient Export Hotspots Using a Spatially Distributed Model in Boreal-Forested Catchments. *Forests* **2023**, *14*, 612. https://doi.org/10.3390/f14030612

Role of location of forest operations

By locating clear-cuts to less risky areas and decreasing the intensity of cuttings, the magnitude of the nutrient export can be reduced

Scenario	Clear-Cut%	$TN_{kg\ catch.}$	$TN_{kg\ hotspot}$	TN%
Background 21	0	41,236	10,304	25
Clear-cut 21A	17	51,820	11,222	22
Clear-cut 21B	17	62,404	14,810	24
Background 26	0	45,830	11,540	25
Clear-cut 26A	4	51,940	10,556	21
Clear-cut 26B	2	51,864	11,089	21

Scenario	Clear-Cut%	$TP_{kg\ catch.}$	$TP_{kg\ hotspot}$	TP%
Background 21	0	756	433	57
Clear-cut 21A	17	803	461	57
Clear-cut 21B	17	1574	674	43
Background 26	0	2391	671	28
Clear-cut 26A	4	2738	739	27
Clear-cut 26B	2	2811	770	27



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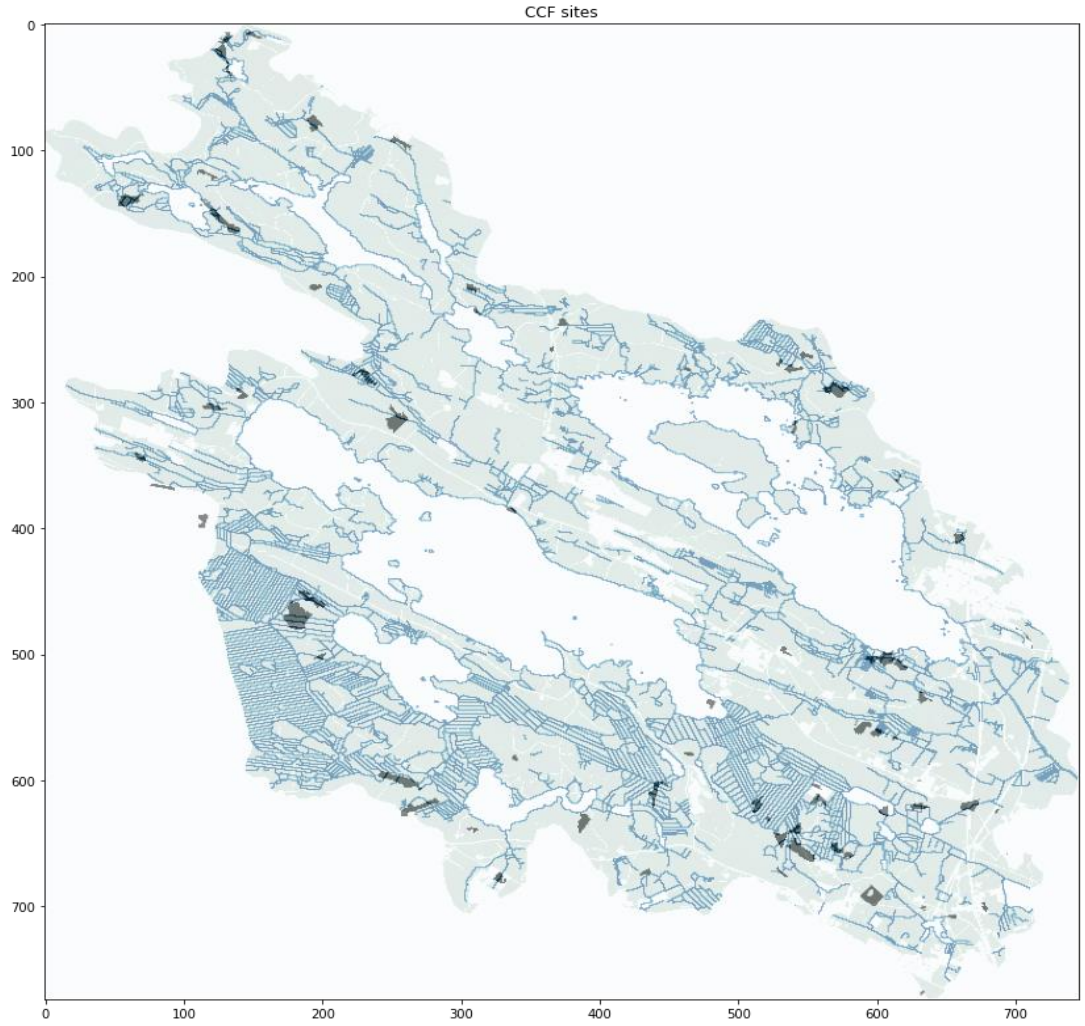
Role of the intensity of cutting

NutSpaFHy was used to study the effect of less intense cutting for peatland stands that are suitable for continuous cover forestry:

soil type peat,
fertility class herb-rich heath forest or mesic heath forest,
stand was mature for harvesting,
and the remaining tree volume was possible to be ≥75m^3.



Jaakko Juvonen, Tuija Lankia, Aura Salmivaara, Vesa-Pekka Parkatti, Eija Pouta, Heini Ahtiainen, Eeva Kuntsi-Reunanen, Annika Tienhaara, Annamari Laurén, Marjo Palviainen, Sakari Sarkkola, Liisa Ukonmaanaho (under review). Evaluating Costs and Benefits of Continuous Cover Forestry in Boreal Peatlands: A case study from Lake Puruvesi

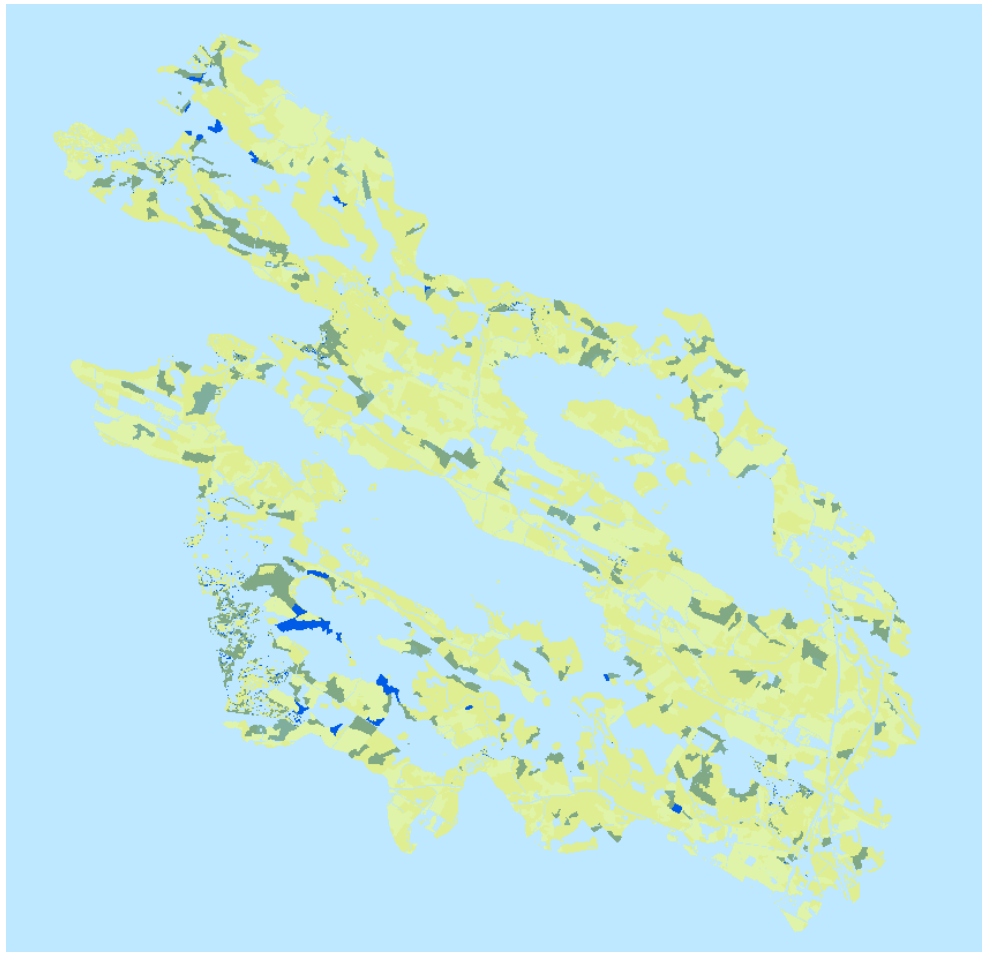
Role of the intensity of forest management

	2006-2016 TN kg/year Savonlahti
No (additional) clear-cuts	13900
CCF sites (76ha),	14100 / +1.7 kg/ha/yr
clear-cuts on the CCF sites (76 ha)	14250 / +3.4 kg/ha/yr
Business-as-usual (203 ha)	14300

	2006-2016 TP kg/year Savonlahti
No (additional) clear-cuts	506
CCF sites (76ha),	509 / +0.027 kg/ha/yr
clear-cuts on the CCF sites (76 ha)	510 / +0.042 kg/ha/yr
Business-as-usual (203 ha)	520

For N CCF-> ~50% less export load per ha

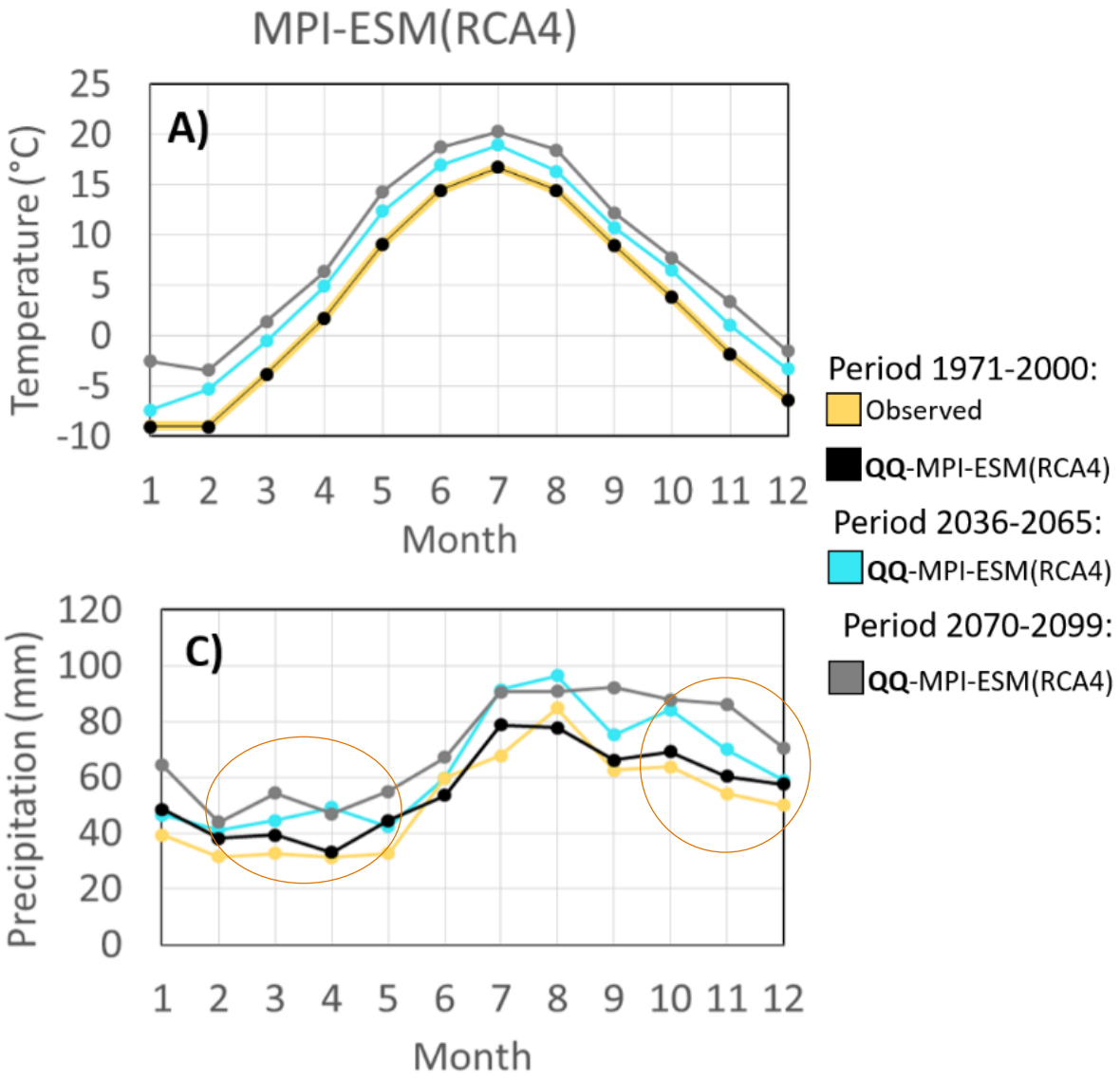
For P CCF -> ~35% less export load per ha



In near future 130 ha of potential CCF sites

Conclusions

- Extreme weather can make reducing nutrient export from forest areas difficult - especially if runoff increases outside the growing season
- Forest management alternatives differ in their nutrient export contribution, and there are potential actions that can be cost-effective and economically viable to be committed in near future that can decrease the nutrient export load to the receiving water body when targeted wisely
- Modelling tools simplify complex ecosystem functions but offer important tools for considering multiple changing factors
- Open source models and open data enables developing the tools further



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