Using NutSpaFHy model to assess nature-based solutions for mitigating nutrient and sediment loading under changing forest management and climate scenarios

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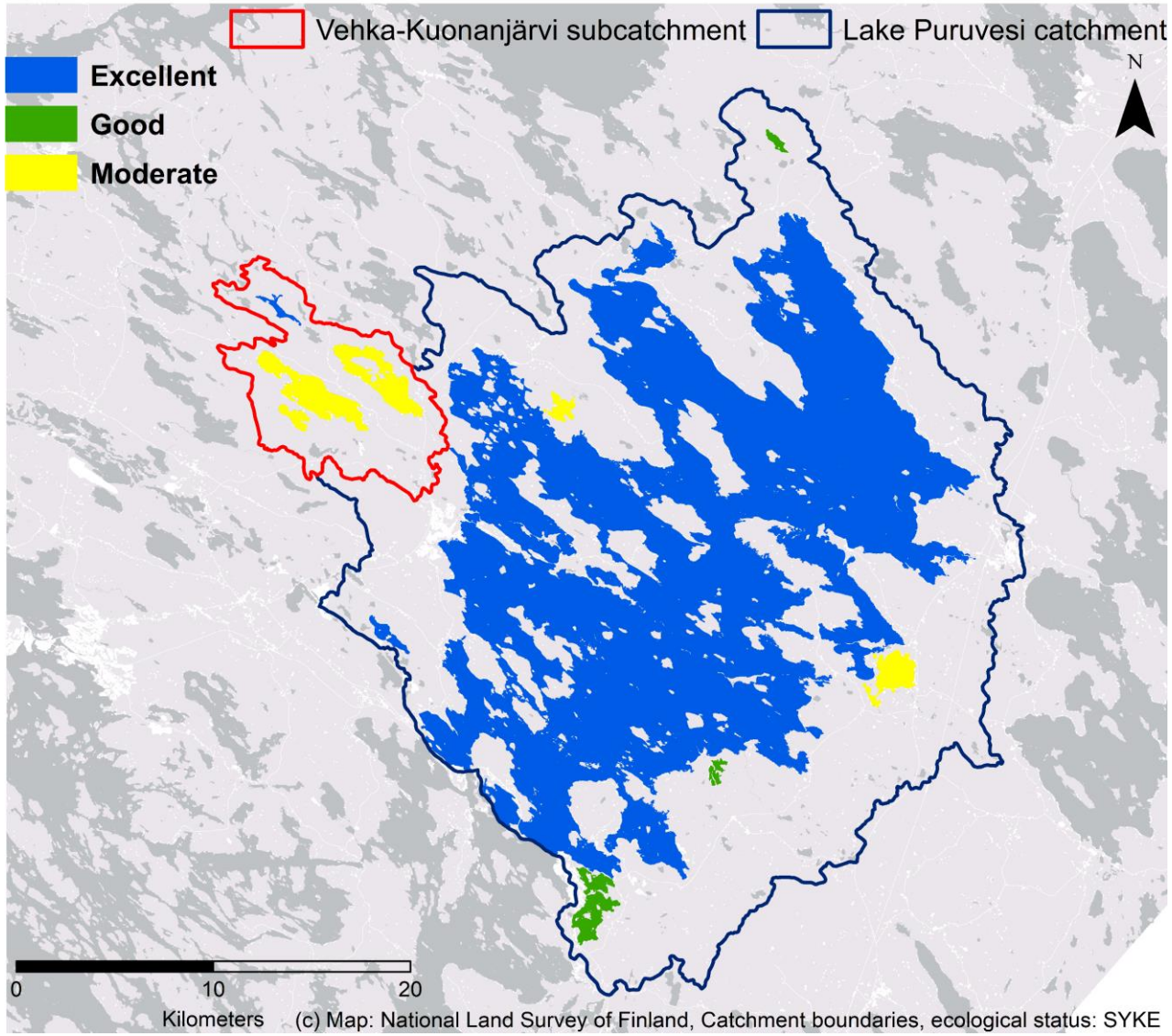
Figure: Kosti Keistinen Pixabay

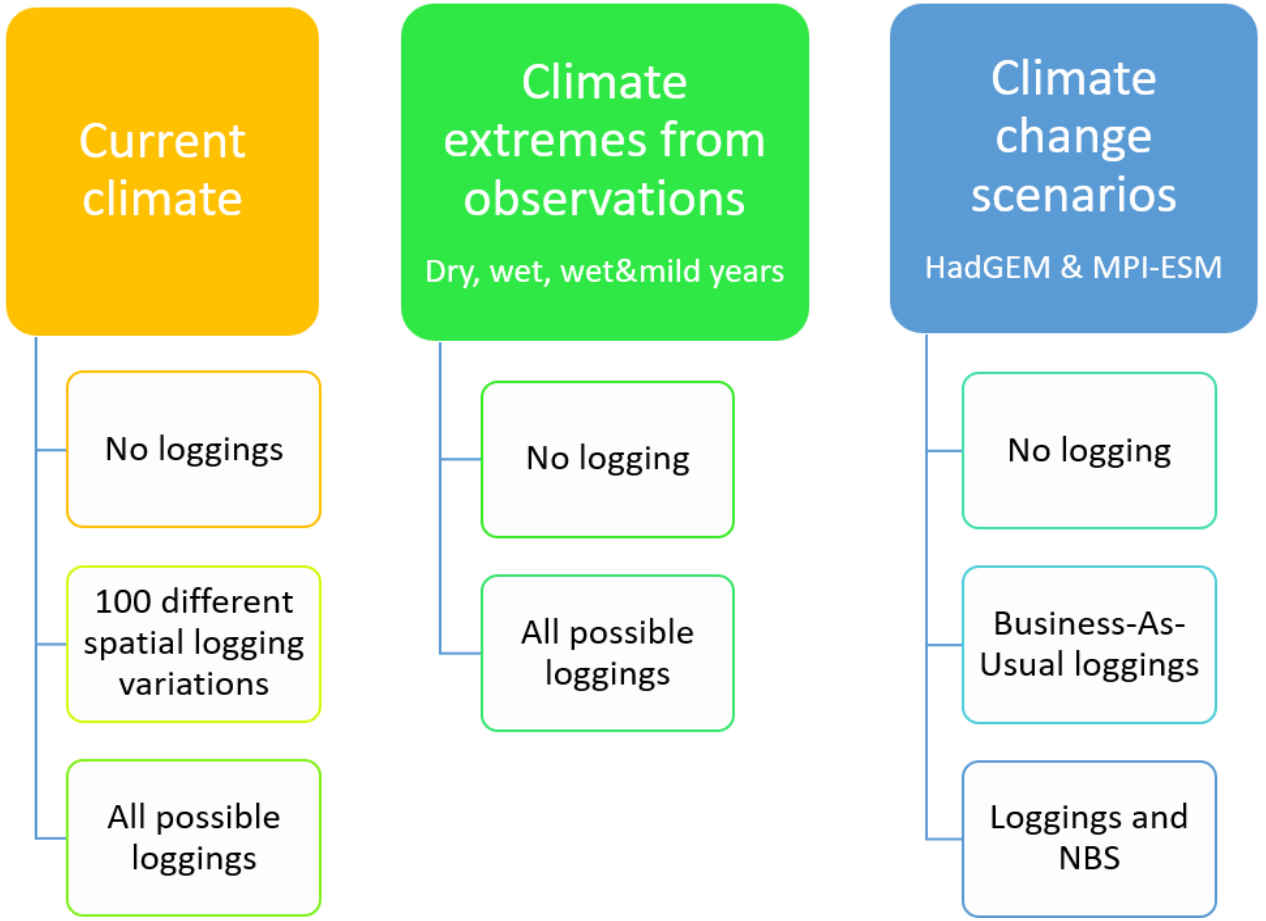
- Study site (and Open-Air Laboratory Finland of OPERANDUM) is located in the Lake Puruvesi catchment (1017 km^2), in the eastern part of Finland. The Lake Puruvesi area is about 416 km^2 and it is unexceptionally oligotrophic, clear water and low humic lake and has an excellent water quality. The 77% of the lake area belongs to the Nature 2000 network presenting oligotrophic habitat type.
- **Hazard: Forest harvesting and extreme weather events may increase suspended solid and nutrient load to Lake Puruvesi**
- **Risk: Euthrofication of Lake Puruvesi --> threaten recreation, fishing (professional and recreational) and biodiversity of the area.**
- **Main objective: To reduce the load and maintain the excellent water quality**
- The main land use in the Lake Puruvesi catchment is forestry, as 92% of the catchment land area is covered with forest (share of peatland forest is 18% of the forest area), 7% with agriculture, 1% with built area and < 1% with wetlands. Activities related to these land-uses, forestry and agriculture, and infrequently occurring high runoff peaks due to heavy rain or snowmelt impose suspended solid load, nutrient leach and further risk for eutrophication.
- Lake Puruvesi is known for its pure water and has uniquely excellent underwater visibility that reaches up to 12 meters. However, recent observations have shown that eutrophication and spread of vegetation has increased around the large and shallow basins.

Location of Puruvesi catchment and its ecological status. Vehka-Kuonanjärvi subcatchment on the north-western part of Puruvesi is focus area for nutrient modelling.

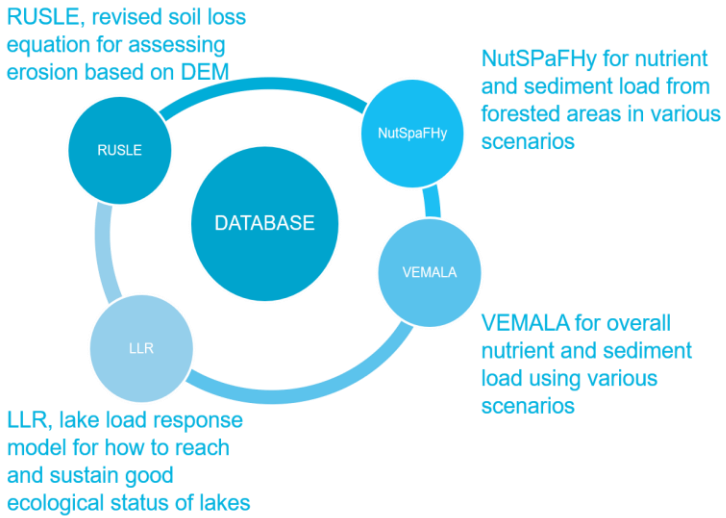
The ecological status of Lake Puruvesi



- Aim is to explore the effect of forestry and climate for the nutrient loading in current and future conditions
- Nutrient and sediment loading emerges as a result of complex processes that have spatial and temporal variability. In order to be able to assess the current and future status of nutrient and sediment loading, the factors influencing those and possible management actions to mitigate negative impacts, we need a systemic approach based on modelling tools.
- Decision support protocol is used for producing catchment scale nutrient and sediment load scenarios including different NBS and their combinations to involve the local land owners and other stakeholders in co-designing the sustainable future for Lake Puruvesi.
- The decision support protocol (NIM) considers the loading of nutrients and sediment from the terrestrial part of the catchment with each land use separately and combines this with the ecological status of the receiving water body.

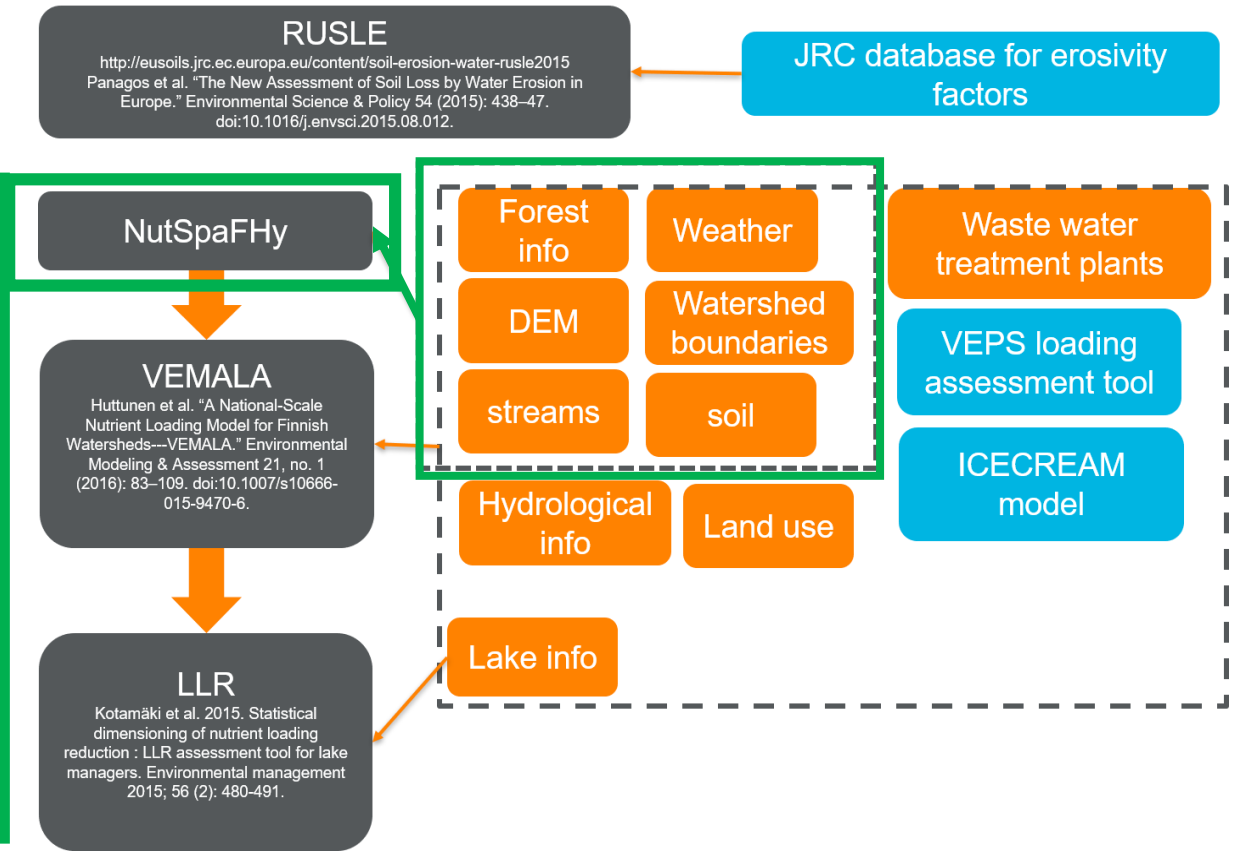


**Logging here means clear cut*

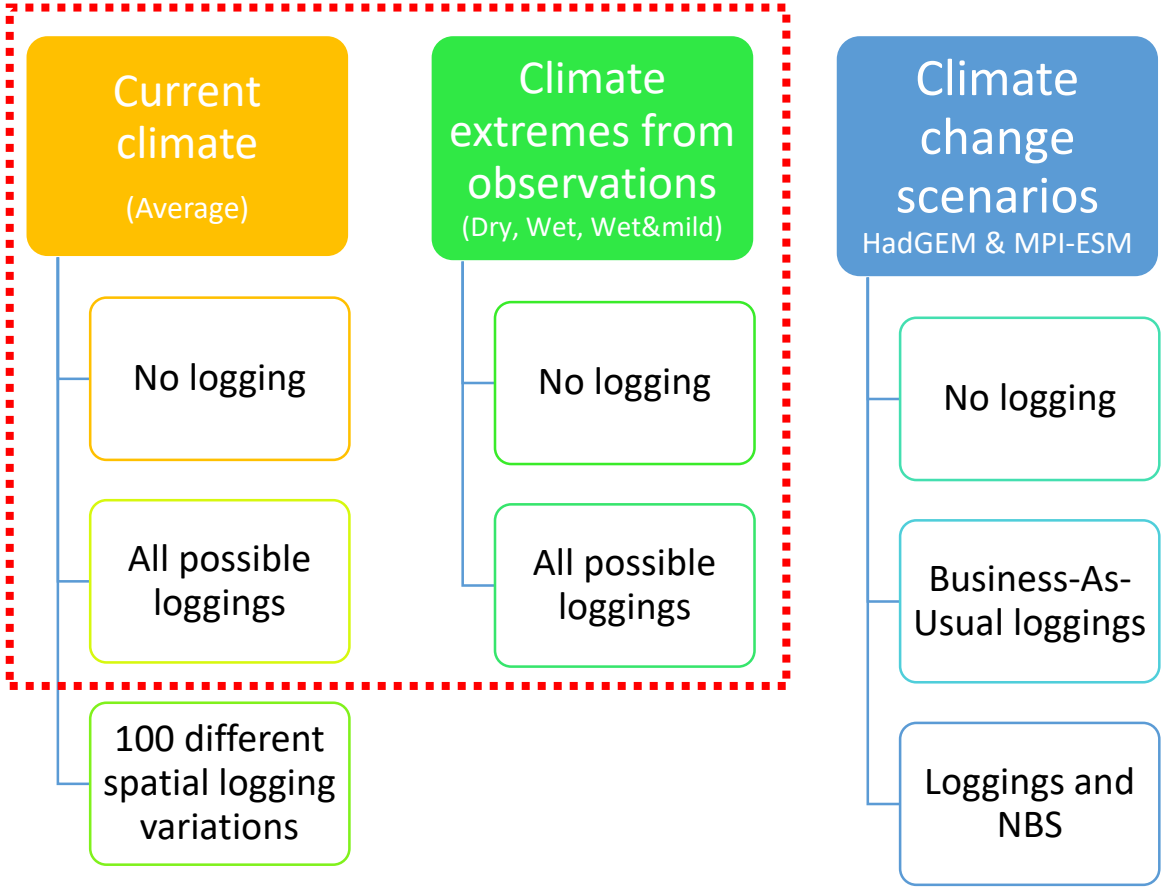


- National Integrated Modelling framework
- Here we focus on preliminary results from NutSpaFHy

NutSpaFHy is a grid-based catchment-scale distributed model based on a simplified and computationally efficient hydrological model SpaFHy. It includes a nutrient balance component where nutrient uptake, release and storage are quantified grid by grid (16m resolution) at monthly scale based on meteorological drivers and spatial data from national forest inventory and soil and topography. After calculating nutrient balance, the export loading component is used, and it includes an exponential delay function which is built upon the hydrological simulation and nutrient balance quantification.



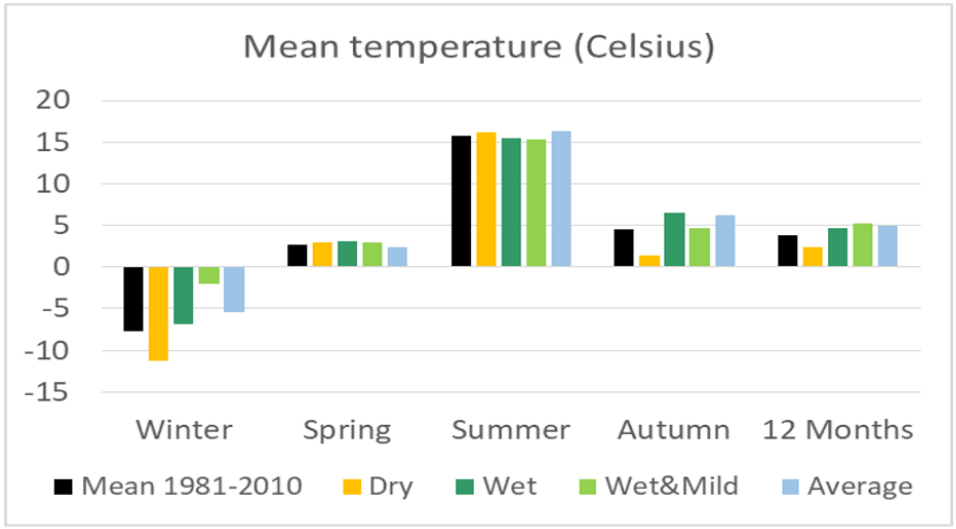
Focus in this presentation:

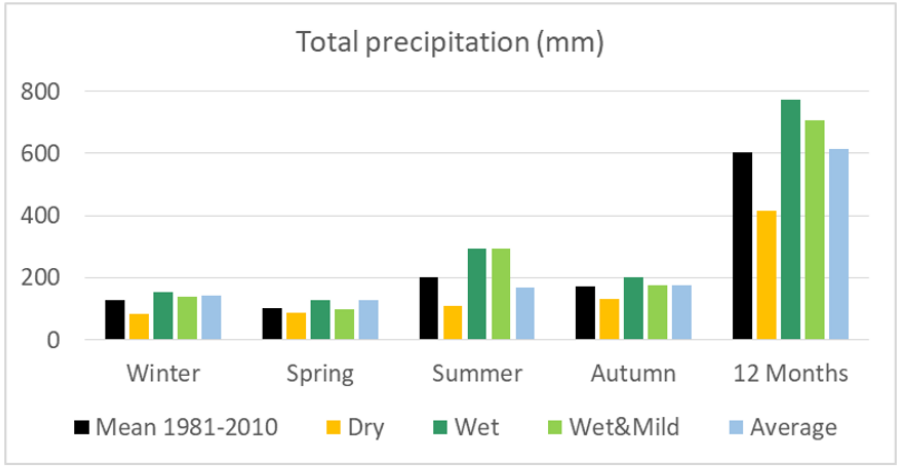


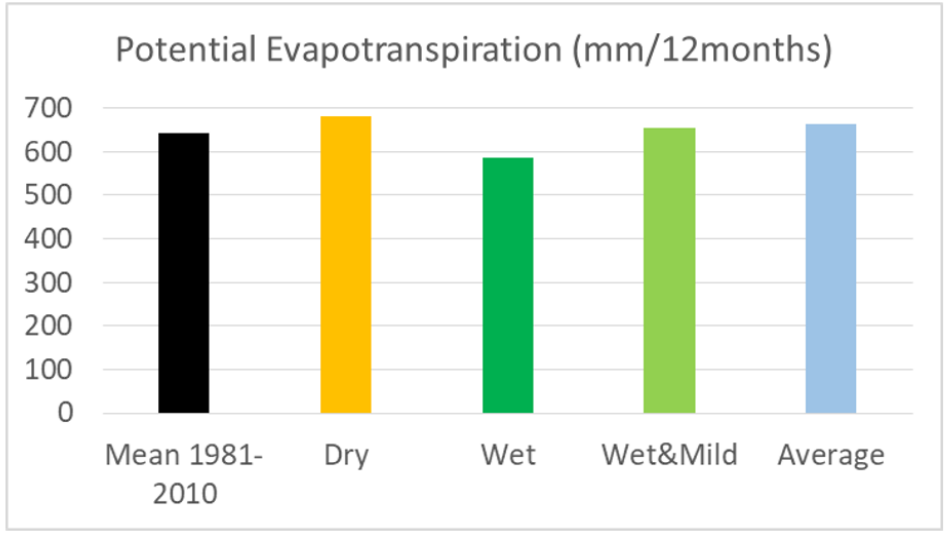
- NutSpaFHy model is under constant development
- For development purposes the model was ran with extreme scenarios both for logging (clear cut) and climate to examine the variation range and ensure correct functioning of the model
  - Focus in this presentation, results will inform us about the role of climate and enable identifying hotspots and discussing NBS potential in mitigating nutrient load in these areas
- Each model run was for 10 year period
- Average yearly nutrient load was calculated
- Specific nutrient load caused by logging was calculated by subtracting nutrient load in “logging” scenario from nutrient load in “no logging” scenario

Climate extremes data used for model development:

- Mean 1981-2010
- Dry: 1.8.2002 – 31.7.2003
- Wet: 1.8.2011 - 31.7.2012
- Wet&Mild: 1.8.2007 - 31.7.2008
- Average: 1.8.2012 – 31.7.2013

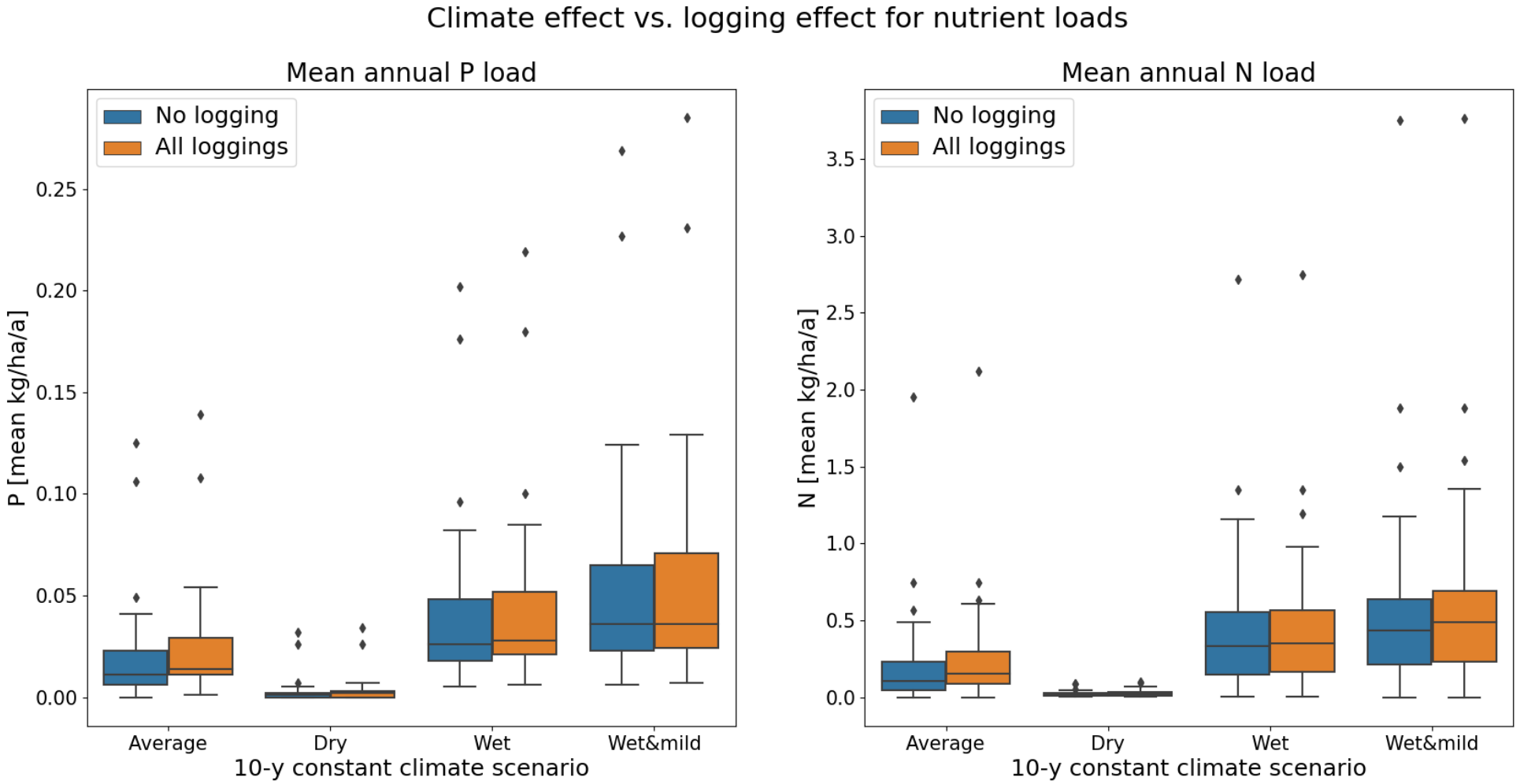






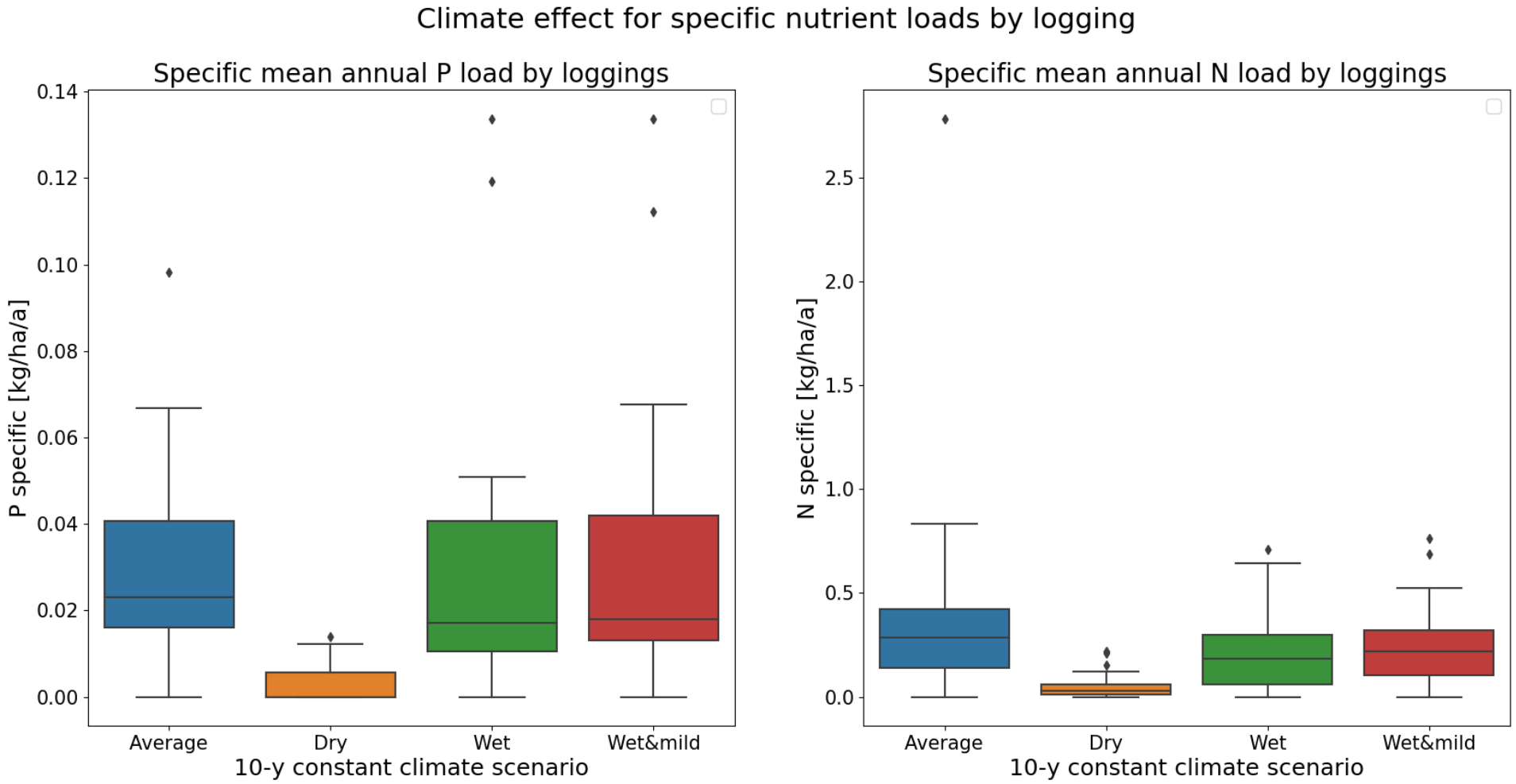
Mean annual P and N loads with no loggings and all loggings (n=33 catchments incl. Lake Vehkajärvi & Kuonanjärvi):

The role of extreme climate is significant



Specific mean annual P and N export load by loggings (n=33 catchments incl. Lake Vehkajärvi & Kuonanjärvi):

The role of nutrient loading by logging decreases when climate is more wet and mild compared with average climate

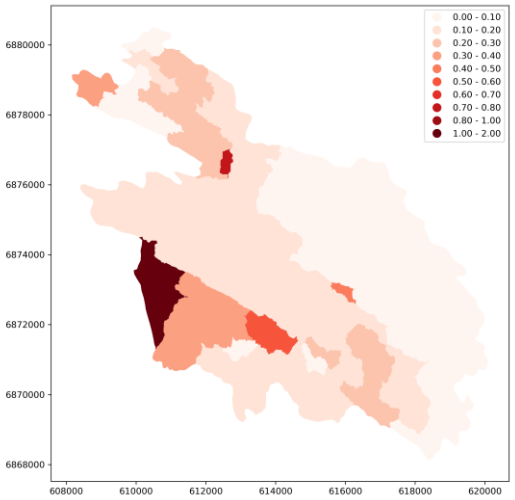


These utopistic scenarios help us to put the nutrient load model results ran with climate change scenario into perspective as we know the range for variation.
Nutrient loads and residence time of nutrient within the catchment before reaching the water body can take from tens of days to years. Now we understand the role of weather better and its potential to increase nutrient loads even though the forestry operations would be in minimum.
However, these are unpredictable issues and therefore it is important to identify the hotspots, where we assume nature-based solutions (NBS) could mitigate export of nutrients and suspended solids.
The efficiency of most of the NBSs is based on their ability to reduce flow velocity and ability to capture eroded suspended solids and nutrients before they enter to the receiving water body. Such NBS include e.g. sedimentation ponds and pits, as well as peak flow control structures, constructed wetlands and overland flow areas. Furthermore, certain forest management practices such as continuous cover forestry and buffer zoning are assumed to decrease leaching of nutrients and suspended solids.

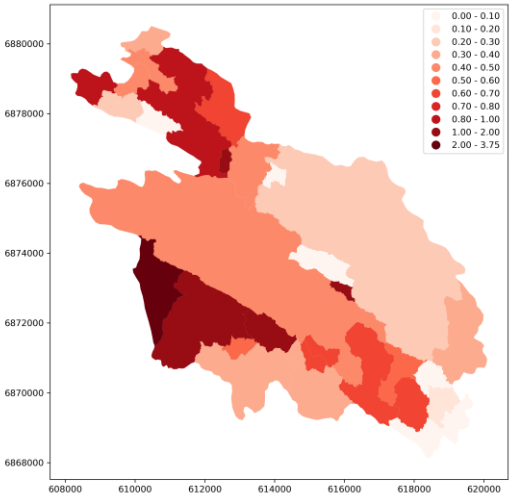




N [mean kg/ha/a], Average climate, no logging

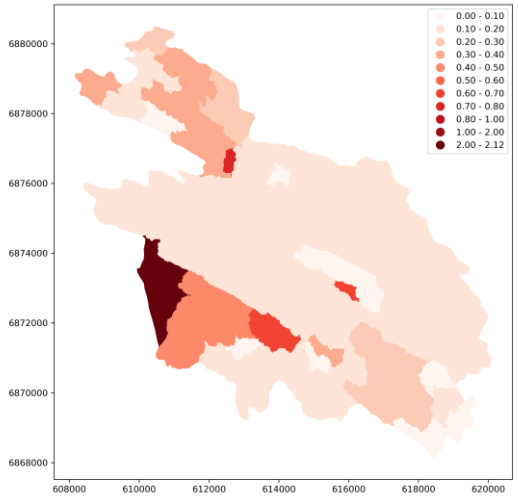


N [mean kg/ha/a], Wet&mild climate, no logging

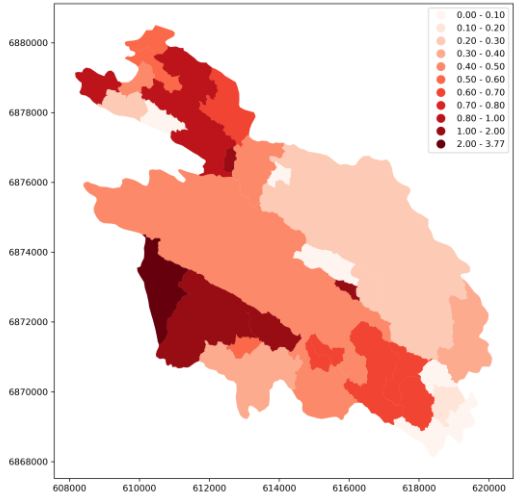


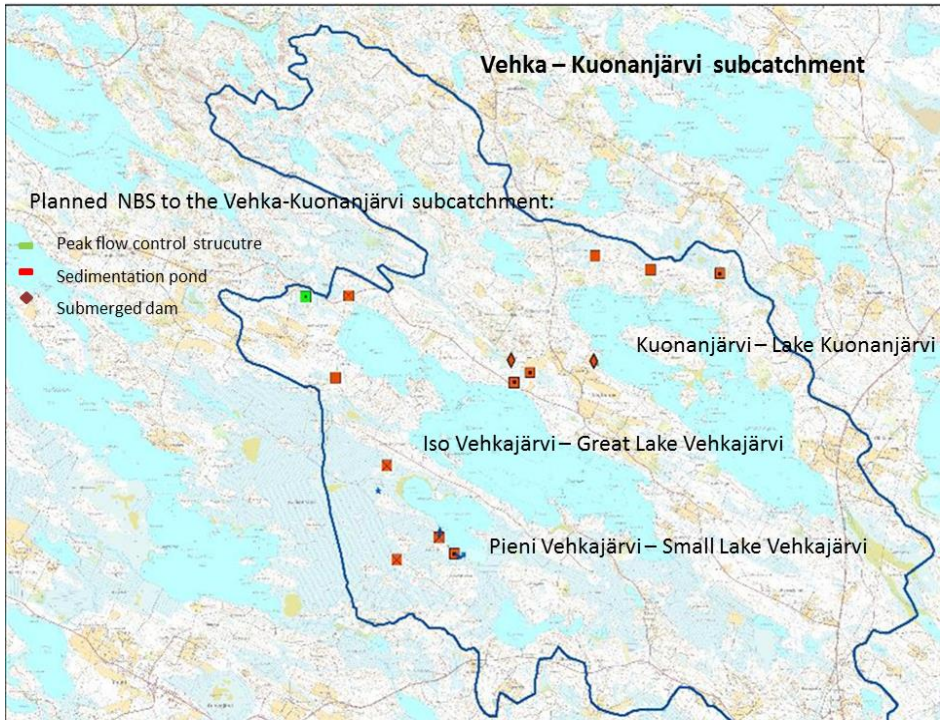
0.00 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 0.60
0.60 - 0.70
0.70 - 0.80
0.80 - 1.00
1.00 - 2.00
2.00 - 3.77

N [mean kg/ha/a], Average climate, all loggings



N [mean kg/ha/a], Wet&mild climate, all loggings





Planned NBS to the Vehka-Kuonajärvi subcatchment (Seppo Ollikainen, Forest Centre)

Hotspot areas can be clearly spotted and require actions independent of weather or logging scenario, even though differences between climate scenarios are very clear and also to some extent between logging scenarios

Next steps:

- Final adjustments to the model
- Model runs with climate scenario data MPI & HadGEM, two time periods, three logging scenarios
- National integrate model framework utilization for final results