Solutions for surface water quality protection in forest lands

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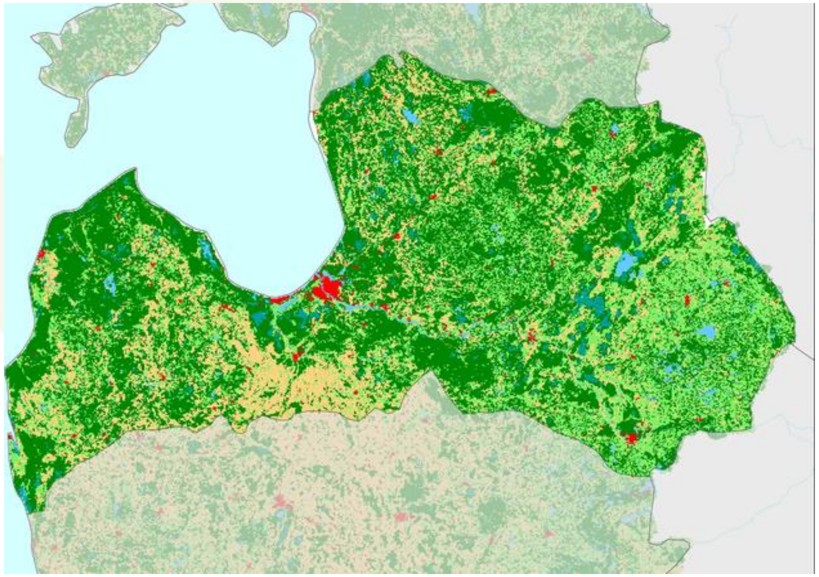
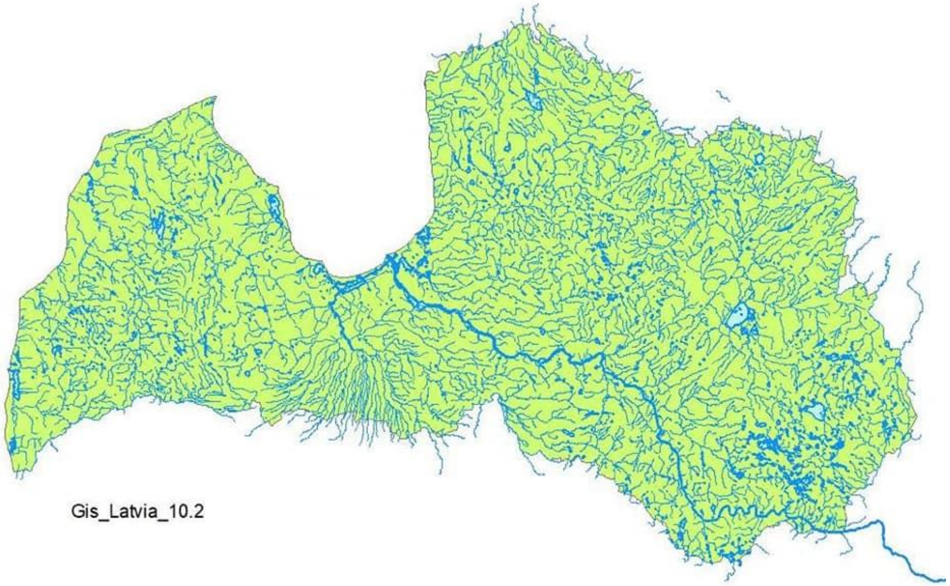
Final Conference
Project “Daily Allowable Maximum Loads to decrease nutrient load to the Gulf of Riga” (DAML)
13.05.2022.

Forests and water

- 53% forest cover
- More than 12 000 rivers and streams
- More than 2000 lakes

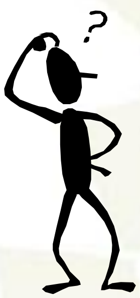
➔ interaction of forest and water is inevitable



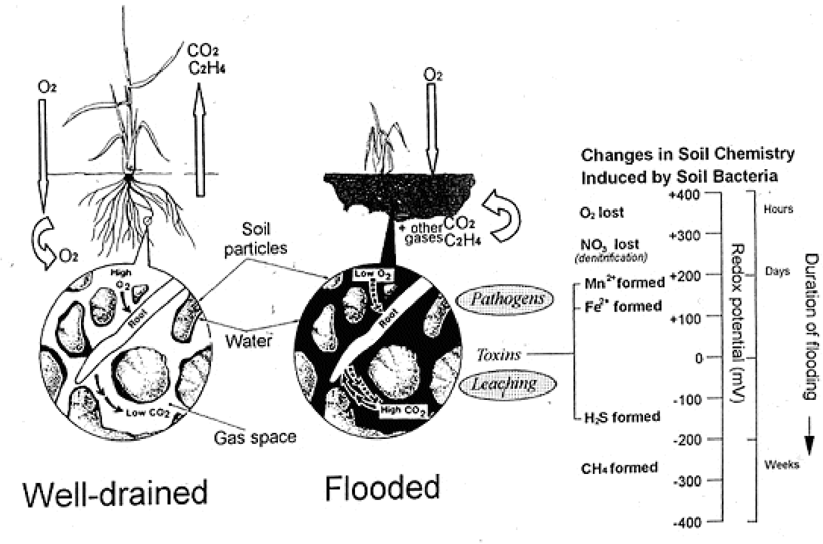


What disturbs forest growth in wet conditions?

Too much water?



No! Too little oxygen!



In the pores of well-aerated soils, the oxygen content is 10-30%.

What disturbs forest growth in wet conditions?

Impact of flooding (6 weeks) on the oak root system.
A – optimal soil moisture;
B – flooded root system and lower part of the stem;
C – flooded root system.

Copini et al. 2016

Why is forest drainage needed?

The volume increment after drainage in pine and spruce forests increases 3-4 times, in birch forests - 2-3 times and in black alder forests - up to 1.5 times.

Also aspen and sometimes ash can form high-yielding forest stands in drained forests.

Since 1938 each hectare of Latvia's forests has become more productive by average 100 m^3.

Drainage system maintenance (DNM)

In Latvia, an **open network of ditches** is used for forest drainage.

In Latvia, **more than 0.8 million ha of forest land is drained so far**. These forest drainage systems were mostly constructed in the 1960s and 1980s.

Drainage systems require **constant maintenance and periodic renovation** including a set of activities such as cleaning existing ditches and the establishment of supplementary ditches.

The primary aim of DNM in already drained forest stands is **to sustain or increase tree growth** by maintaining favourable moisture conditions for trees in the upper soil layer.

Photos by Zane Lībiete

Ditch network maintenance impact on water quality

During and after DNM in forest land, transport of suspended solids (SS), nitrogen (N) and phosphorus (P) to downstream watercourses may increase.

Immediately after the excavation or cleaning of ditches, the risk of erosion of the ditch banks becomes topical which is particularly pronounced in fine-textured soils and main ditches.

To reduce the transport of SS and nutrients to watercourses during and after DNM in forest land, the water protection structures are recommended.

Photos by Zane Lībiete

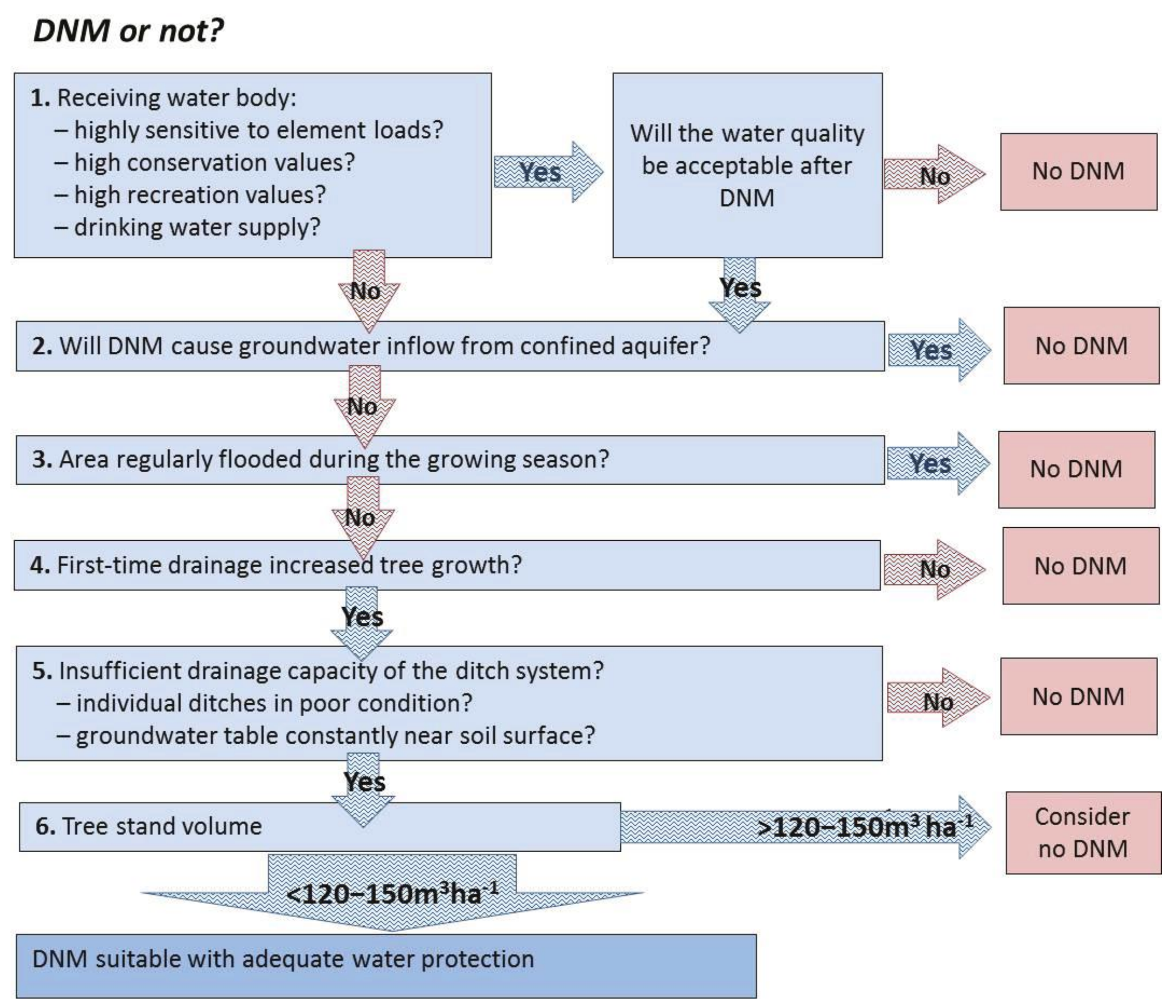
Water protection structures in a DNM area

Water protection structures in a DNM area:

- Uncleaned ditches and

ditch stretches;

- Sedimentation pits and ponds;
- Wetland buffers;
- Peak flow control structures;
- Bottom dams.



Finer et al., 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region.

Uncleaned ditches and ditch stretches

To avoid erosion and transport of SS to receiving waters, **it is essential to critically evaluate the actual need of DNM for every ditch separately.**

To achieve efficient drainage with minimum ditch cleaning **an option is to leave some uncleaned ditches and ditch breaks within the DNM area.**

The function of such uncleaned ditches and ditch stretches is to reduce water velocity and hence also the transport of SS from a DNM area.

Examples of a drainage ditch on sites where first-time ditching has promoted forest growth in Sweden. Some stretches of the ditches have been left uncleaned, and sedimentation pits have been dug every 100 to 200 m along the ditches. Photos by Bo Leijon

Finer et al., 2020. WAMBAF (Water Management in Baltic Forests) Tool Box project.

Sedimentation pits and ponds

The purpose of the sedimentation pits and ponds is to capture sediment and particulate nutrients released from the active forest management area before they enter the receiving water bodies.

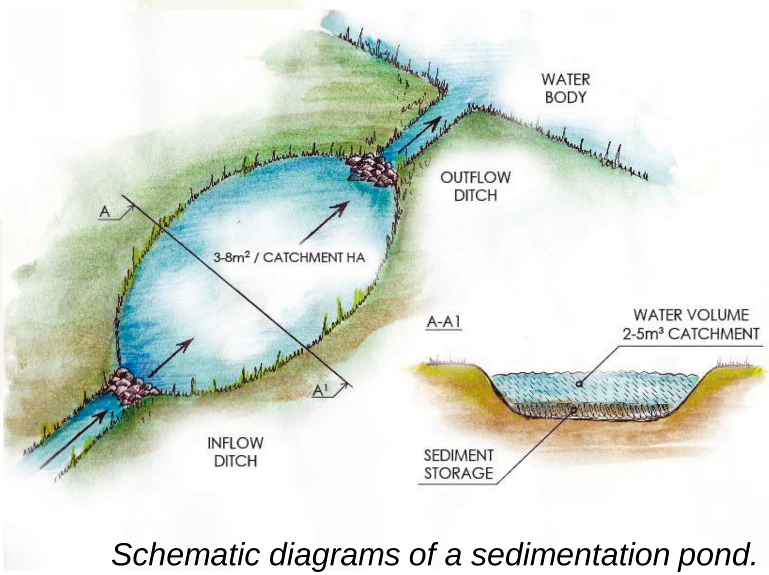
In Finland, usually sedimentation pits are up to 1 m deep and are installed every 100 m along the ditches.

Sedimentation pits in DNM area in Finland
Photo: Z. Lībiete

Sedimentation pits and ponds

Traditionally, **sedimentation ponds are a deepened and widened section of a ditch**, in which water has a wider flow area and a reduced flow rate (i.e. down to 0.2 m s^{-1} at least), which facilitates the deposition of SS to the bottom.

Usually, sedimentation ponds are constructed at the outlet ditches.



Schematic diagrams of a sedimentation pond. Figure Ilze Paulina.

A sedimentation pond in eastern central Sweden. Constructed in February 2013, about two years before the photo was taken. Photo Ulf Sikström.

Finer et al., 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region.

Sedimentation pits and ponds

In general, the sedimentation ponds are efficient for capturing particles with diameters greater than 0.05 mm, whereas smaller particles can be captured by the wetland buffers (Kasak et al. 2016).

Efficiency of sedimentation ponds to mitigate SS transport **depends on their design**, especially on the pond volume and water retention time.

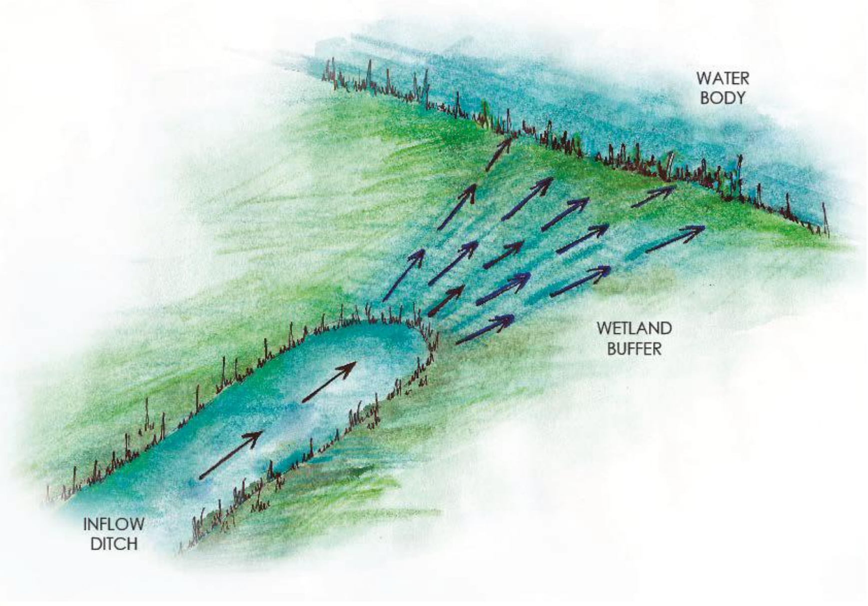
Water retention time reduces as the pond is filled by sediment, thus regular removal of the deposited sediments is needed to maintain efficient sediment retention.

In Finland, surface area of sedimentation ponds is 3-8 m^2 per one ha catchment area (catchments up to 40 ha) and deep – 2 m.

In Latvia, sedimentation ponds are used in state owned forests in ditch networks longer than 0.8 km. The depth of this sedimentations pond is 0.5 m below the mark of the bottom of the ditch and length is 30-50 m depending on the length of the system.

Wetland buffers

Natural, restored or constructed wetland buffers, also known as overland flow areas, are the most effective of the different water protection structures at retaining SS and nutrients in drainage areas (Nieminen et al. 2015). Highly efficient SS retention has been reported, particularly where the SS inputs to buffer areas were large and the size of the buffer area was at least 0.5–1.0% of the size of the whole upstream catchment area (Nieminen et al. 2005).



A schematic diagram of a wetland buffer
Figure Ilze Paulina.

Wetland buffer in northern Finland
Photo Antti Leinonen.

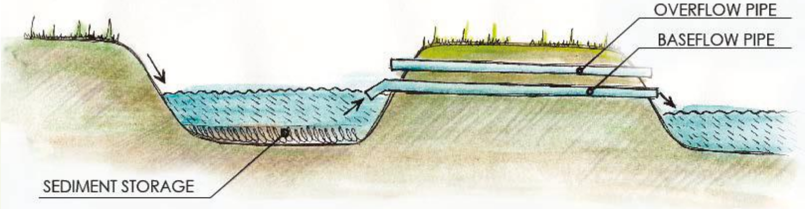
Finer et al., 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region.

Peak flow control (PFC) structures

PFC structures with runoff regulating pipes have been shown to reduce the transport of SS and particulate nutrients in DNM areas efficiently (Marttila and Klöve 2010, Marttila et al. 2010).

The correct functioning of the PFC structure is dependent on correctly dimensioned pipes, which stop high flow rates while allowing through water at lower rates.

A combined PFC/pond structure is recommended for maximum efficiency. PFC is ineffective in retaining SS immediately after DNM when flow rates are low and SS concentrations are high (Haahti et al. 2017).



A schematic drawing of a peak flow control structure Figure Ilze Paulina.

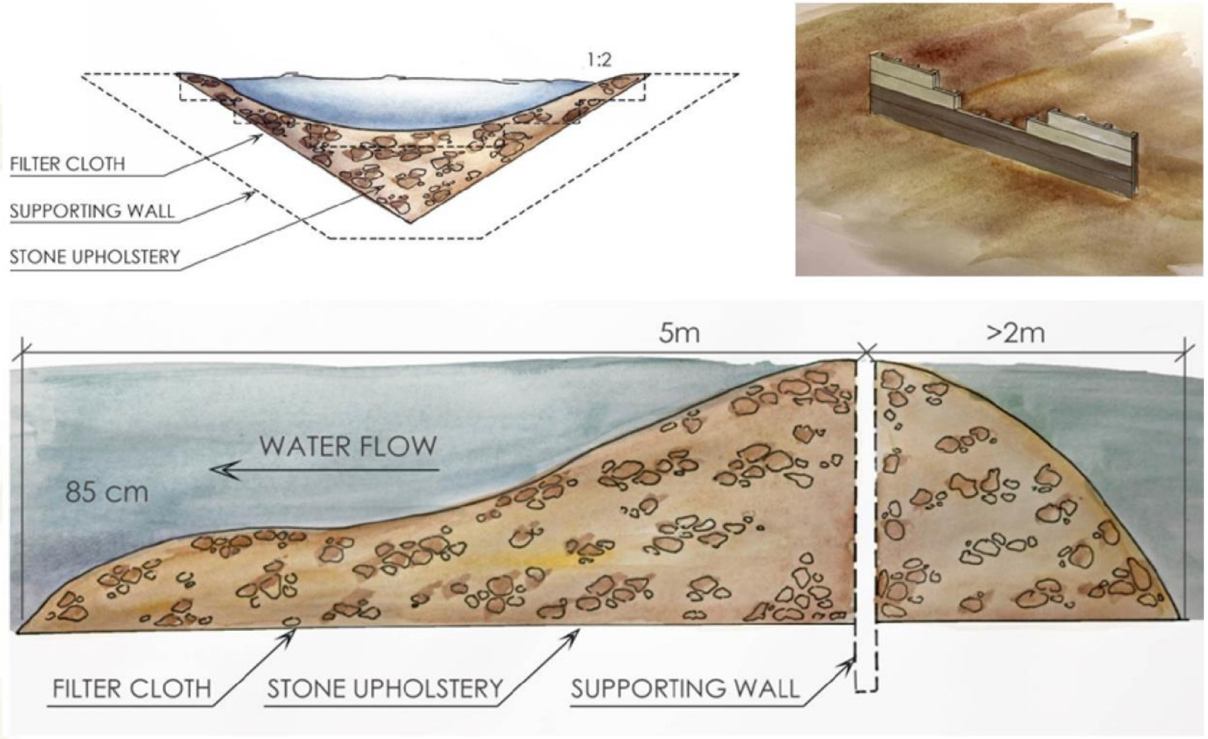
Outlet of a peak flow control structure with two pipes in a drained area located in Finland. A sedimentation pond has been constructed upstream of the peak flow control structure. Photo Leena Finér.

Finer et al., 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region.

Bottom dams

The aim of installing a bottom dam is to reduce the slope of the ditch, consequently reducing the water velocity.

This entails reduced risk of erosion and enhanced probability of sedimentation of eroded material, preventing its further transport.

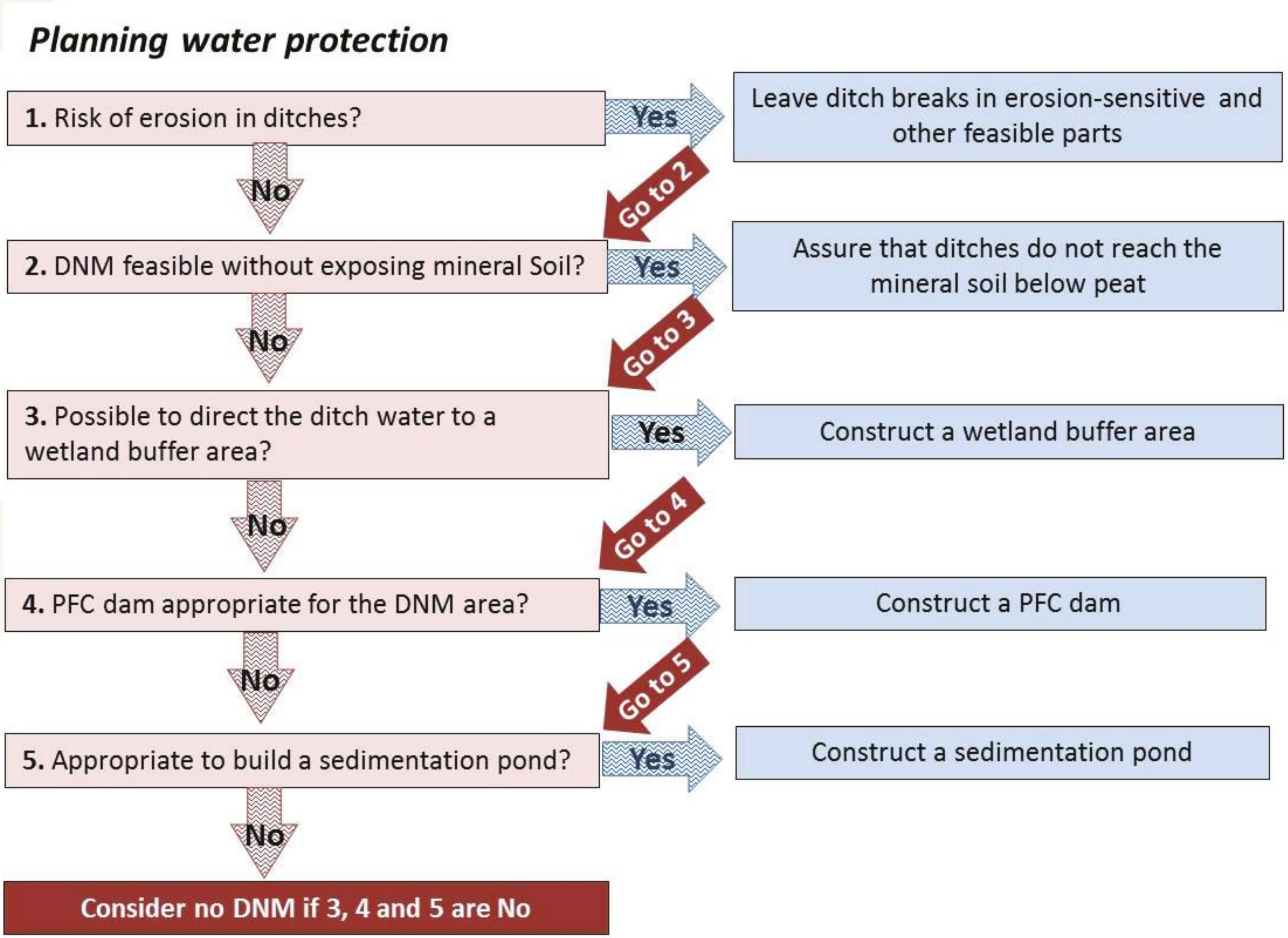


A cross-section in scale 1:2 (above, left) and longitudinal cross-section (below) of a bottom dam and the supporting wall before the stone upholstery is piled around it (above, right). Figures by Ilze Pauliņa.

A supporting wall under construction: it is placed in the middle of the bottom dam across the ditch where the water velocity is expected to be high. Photo by Matti Seppälä.

Finer et al., 2020. WAMBAF (Water Management in Baltic Forests) Tool Box project.

Logical order of planning different water protection structures in DNM

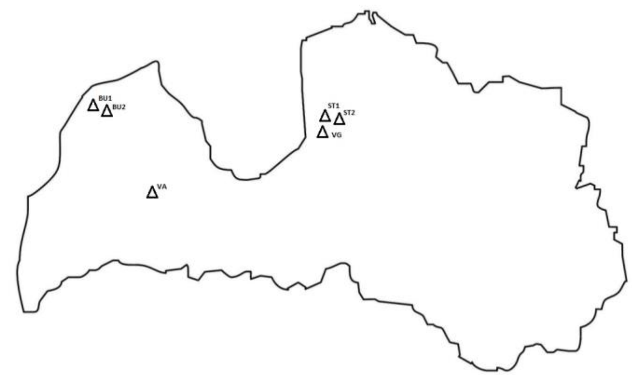


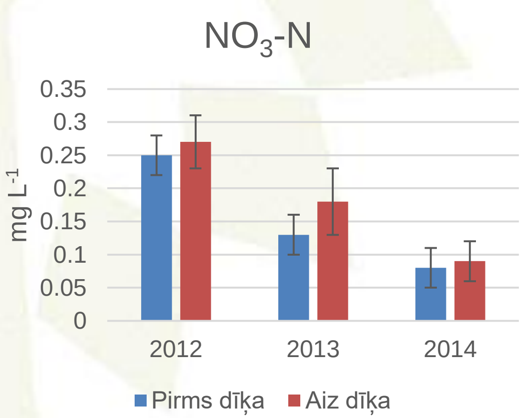
Finer et al., 2018. WAMBAF – Good Practices for Ditch Network Maintenance to Protect Water Quality in the Baltic Sea Region.

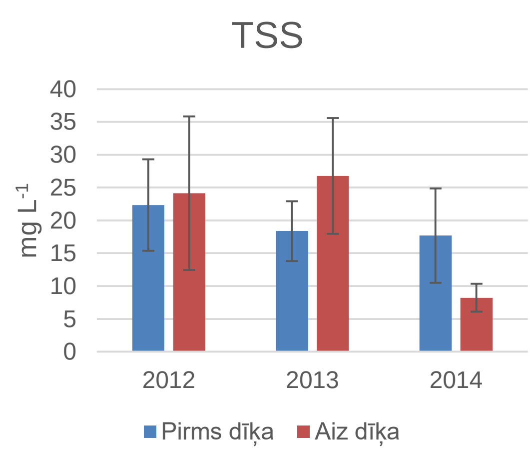
What is practically tested in forest land in Latvia?

Efficiency of standard sedimentation ponds

- 6 objects in state owned forests in Latvia
- Renovation of drainage ditch network in spring/summer 2012, establishing sedimentation ponds of standard size
- Water sampling before and after sedimentation ponds as well as in ponds until 2014, ditch profile and current velocity measurements
- Water chemical analysis







Kalvīte et al. 2019. The efficiency of forest drainage system sedimentation ponds in the context of water quality.

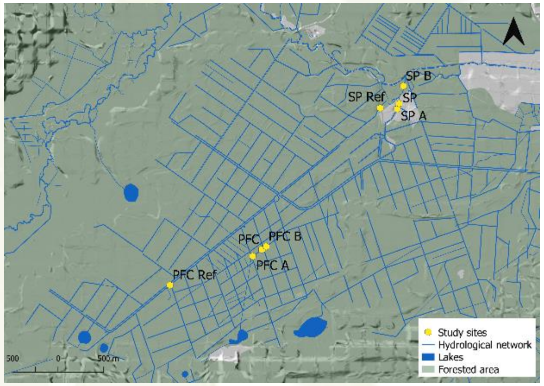
Conclusions

We could want better efficiency.

Concentrations of nutrients and SS below the pond sometimes tend to exceed concentrations above it.

SS are of major concern, as their concentrations tend to be quite high and exceed water quality criteria.

What is practically tested in forest land in Latvia?



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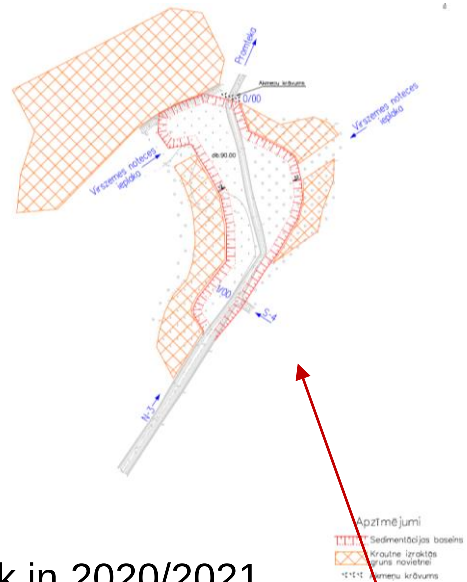
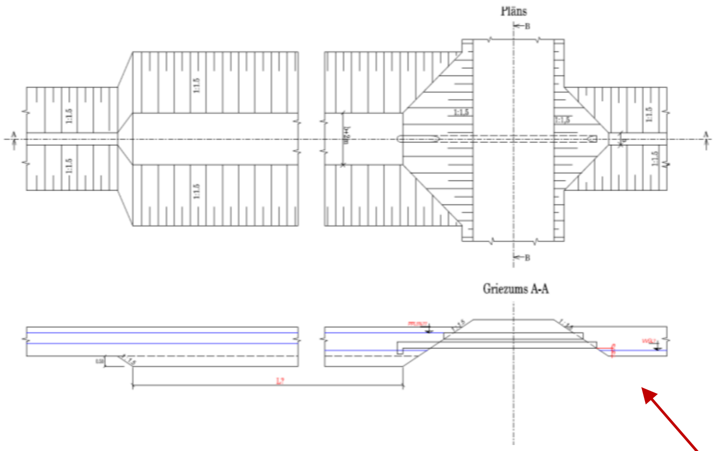
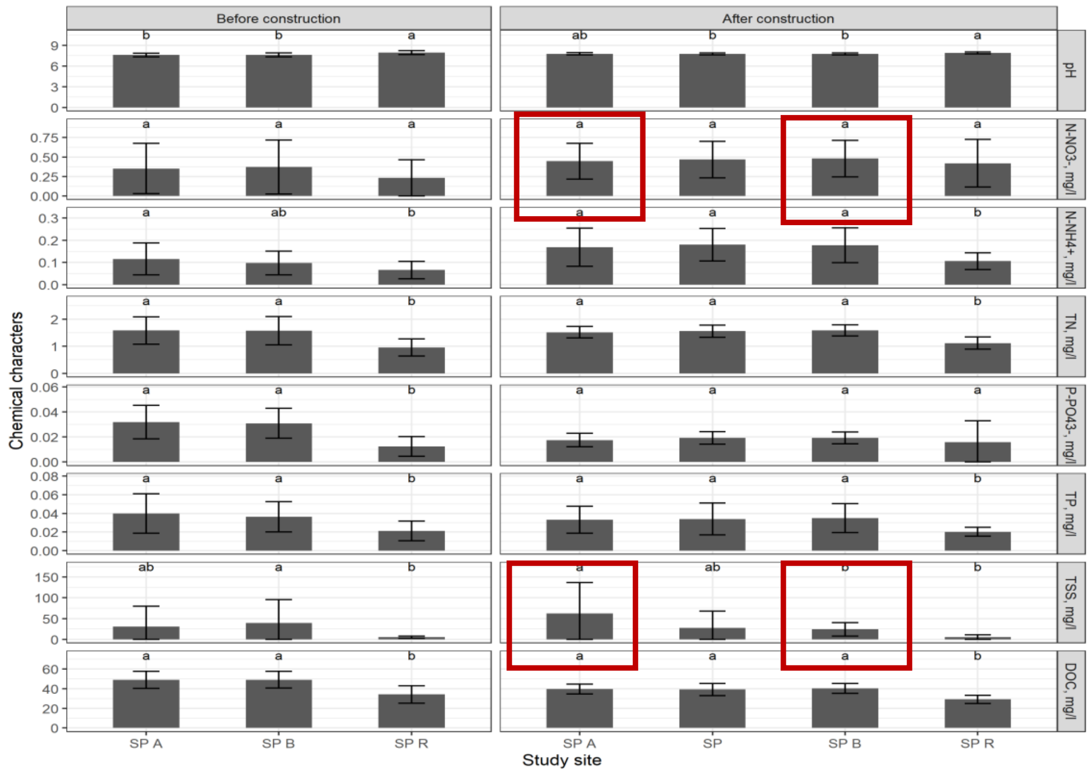
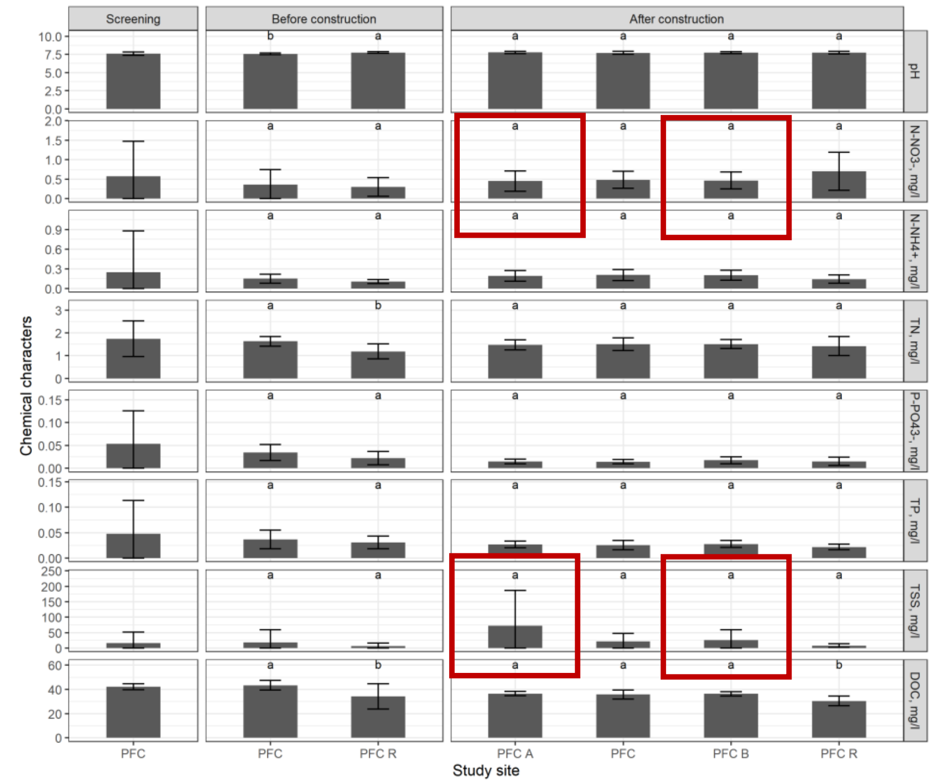




2 research objects in Latvia
Renovation of drainage ditch network in 2020/2021
Establishment of **sedimentation ponds with irregular shape adapted to the area of catchment** and **peak flow control structure**.
Water sampling at the installation site before, during and after the establishment.

What is practically tested in forest land in Latvia?





Kļaviņa et al. 2021. Solutions and effectiveness of water protection structures in forest drainage system maintenance: examples from Latvia

Conclusions

The initial results are promising.

Water protection structures reduce SS concentrations and discharges to water bodies.

Work needs to continue on refining the dimensions and technical parameters.

Green infrastructure to improve water quality in forest land

Riparian zone functions:

- protects aquatic and terrestrial habitats;
- provides aquatic organisms with food (e.g., fallen leaves, insects);
- provides shading;
- provides large-scale woody debris (dead wood) in watercourses;
- protects the soil in the coastal zone;
- stabilizes the banks.

Photo by Toms Štāls

Green infrastructure to improve water quality in forest land

Activities in the river Aģe basin (tributary Tora):

Adjustment of the composition of tree species, promoting species diversity, in particular:

- increasing the proportion of deciduous trees;
- reducing the proportion of spruce close to the watercourse;
- creating a mosaic structure of the stand for the development of diverse vegetation.

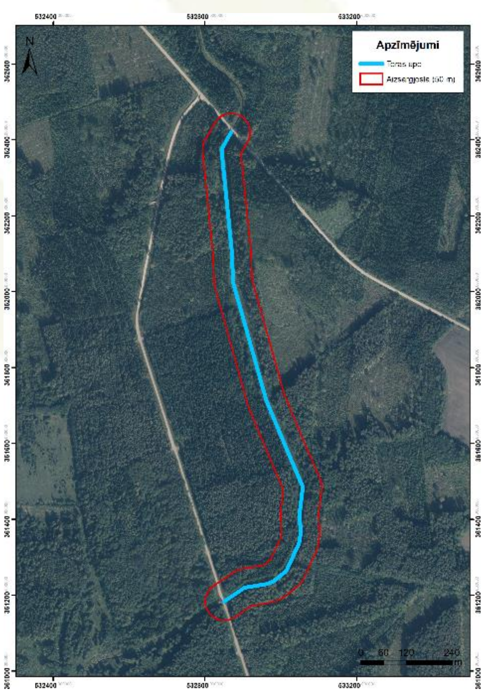
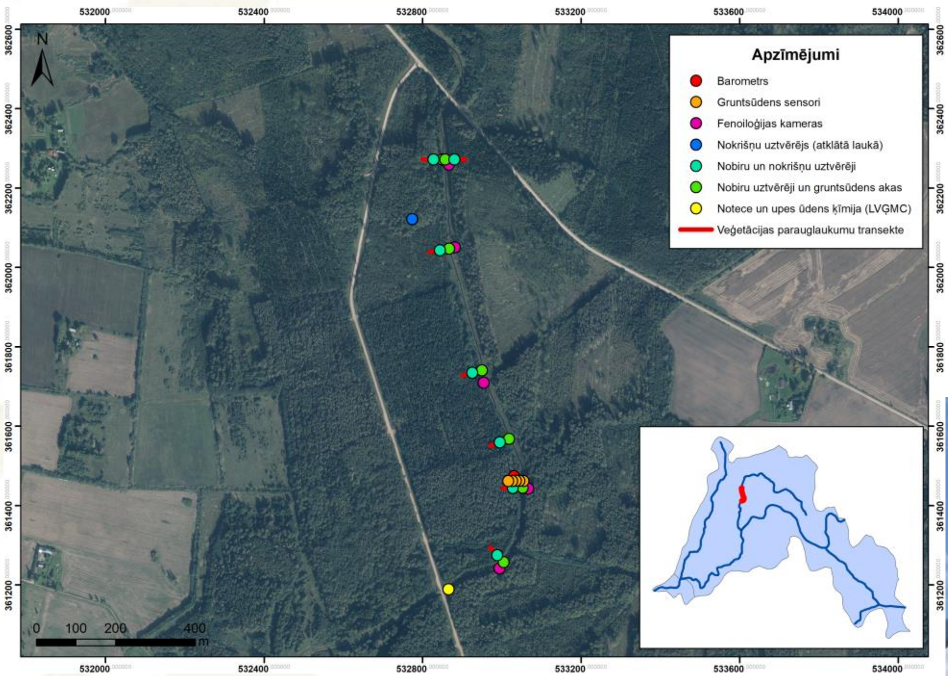


Photo by Toms Štāls

Green infrastructure to improve water quality in forest land



Photos by Toms Štāls

Effects of different intensity regeneration fellings on soil solution in riparian zones

Three typical forest site types in Latvia:
Oxalidosa turf. mel. (euthrophic; drained peatland)
Hylocomiosa (mesothrophic; mineral soil)
Myrtillosa (oligotrophic; mineral soil)

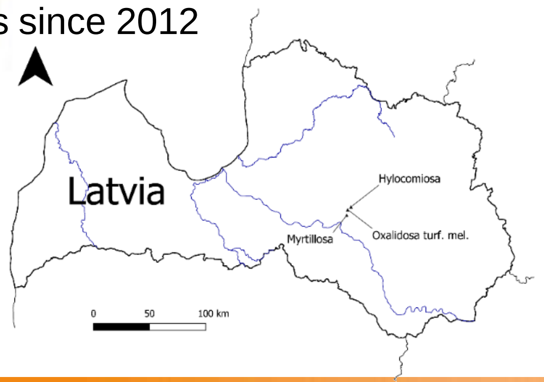
Six plots in each site
C – Control
SOH – Stem Only Harvesting
WTH – Whole-Tree Harvesting

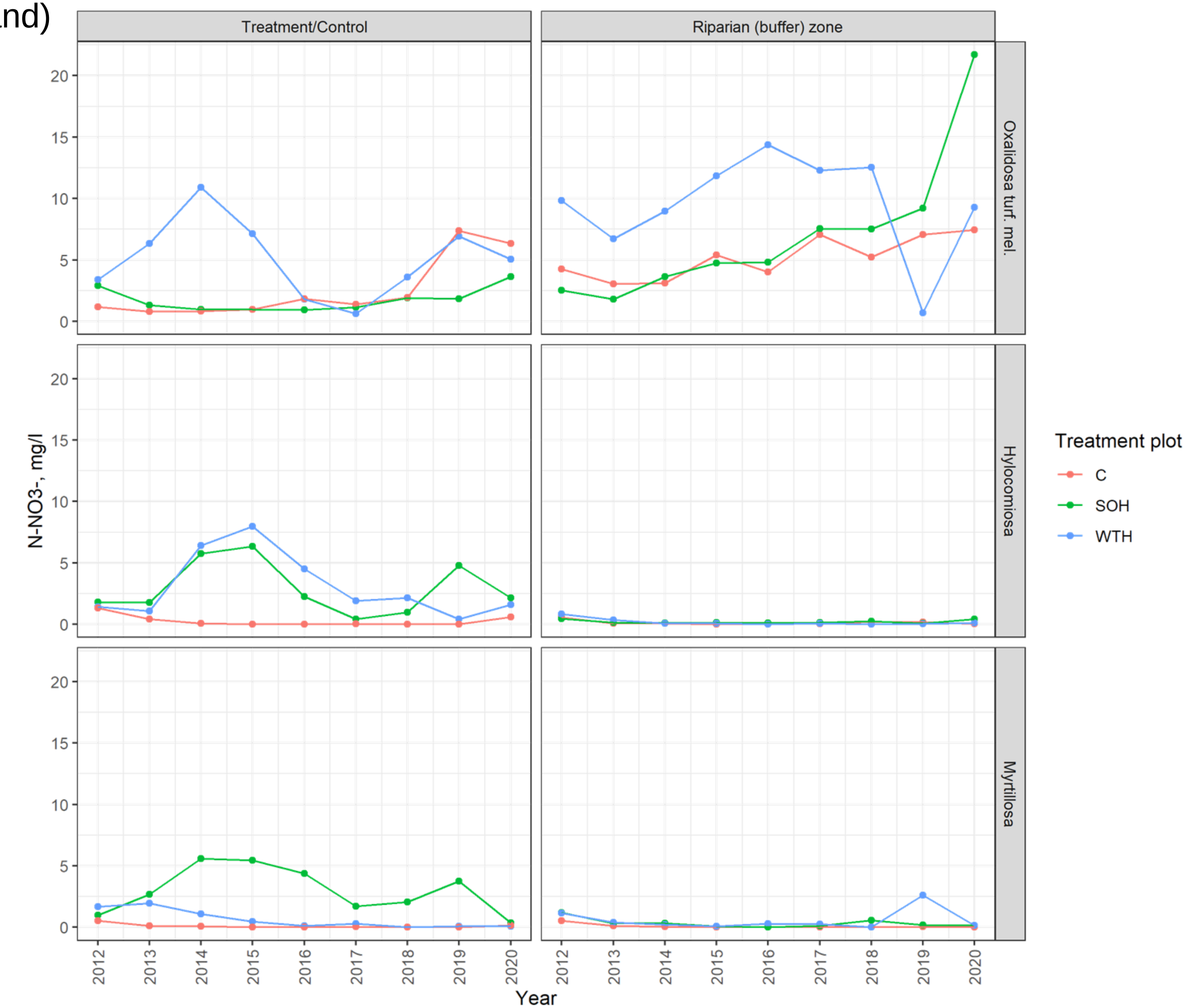
Riparian zones down the slope of every treatment plot

Treatment plots felled in spring 2013

Seedlings planted in spring 2015
Hylocomiosa: Scots pine
Oxalidosa turf. mel.: Norway spruce
Myrtillosa: Scots pine

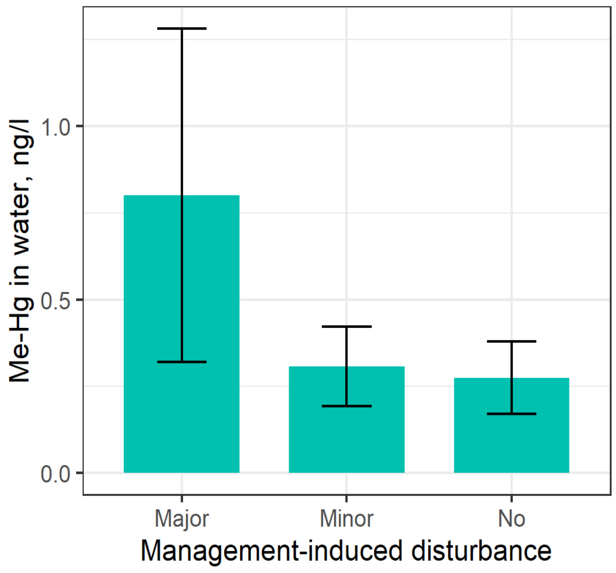
Observations since 2012

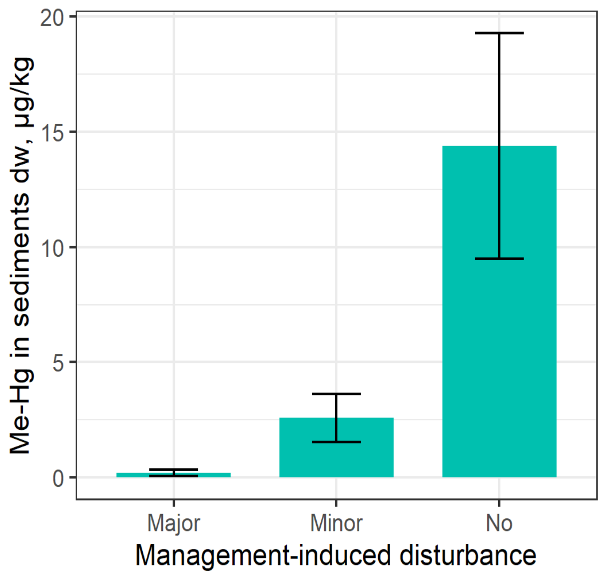


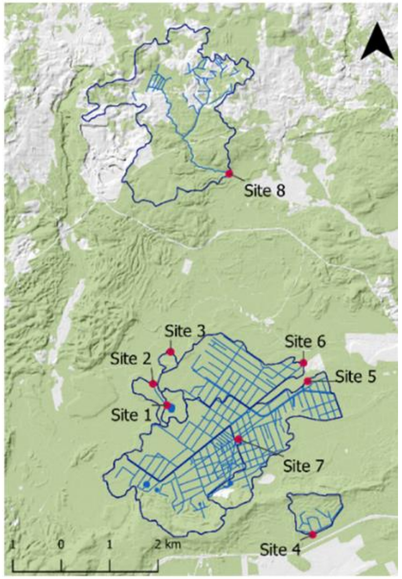


Kļaviņš et al., 2022 (in preparation)

MeHg concentration in water and sediments







The study (2019-2022) was conducted in the eastern part of Latvia, in experimental forests of the Kalsnava Forest district

- No statistically significant differences in MeHg concentration in water between disturbed and undisturbed sites were detected.
- MeHg concentration in sediments was statistically higher in undisturbed sites (14.4 ± 4.9 µg kg^{-1} dw) characterized by high content of organic matter and nutrients if compared to disturbed sites.

Kļaviņa et al., 2021. Forests 2021, 12(9), 1278.

The research is funded by the Latvian Council of Science, project "Interaction of microbial diversity with methane turnover and mercury methylation in organic soils", project No. lzp-2018/1-0434

Thank you for your attention!

Ditch cleaning in the Baltic sea region:
https://www.youtube.com/watch?v=rPJo_Osnvas