Is browning of Finnish water bodies progressing? Long-term changes in streams, lakes and coastal waters

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Total organic carbon (TOC) and browning

- Browning is caused by increased leaching of humic matter (≈TOC) into water bodies

- To keep in mind: iron also affects browning

- Anyhow, in this presentation the focus is only in TOC

The River Kyrönjoki and its estuary 08.08.2022

Sisältää muokattua Copernicus-dataa, SYKE (8.8.2022)

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- Browning has been widely detected in northern Europe and North America.

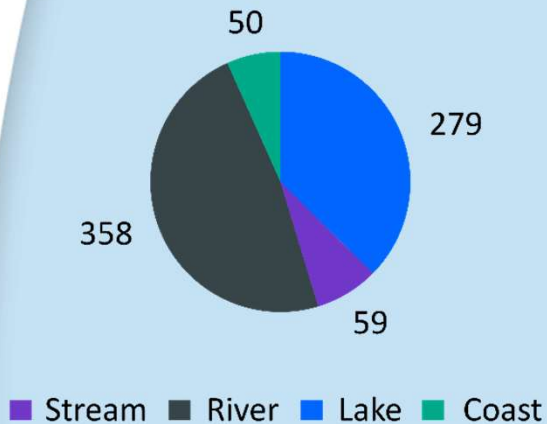- It has been intensively studied, also in Finland, but there are still many open questions.

Our aims were/are to answer three questions:

1. **Is browning still going on in Finland?**
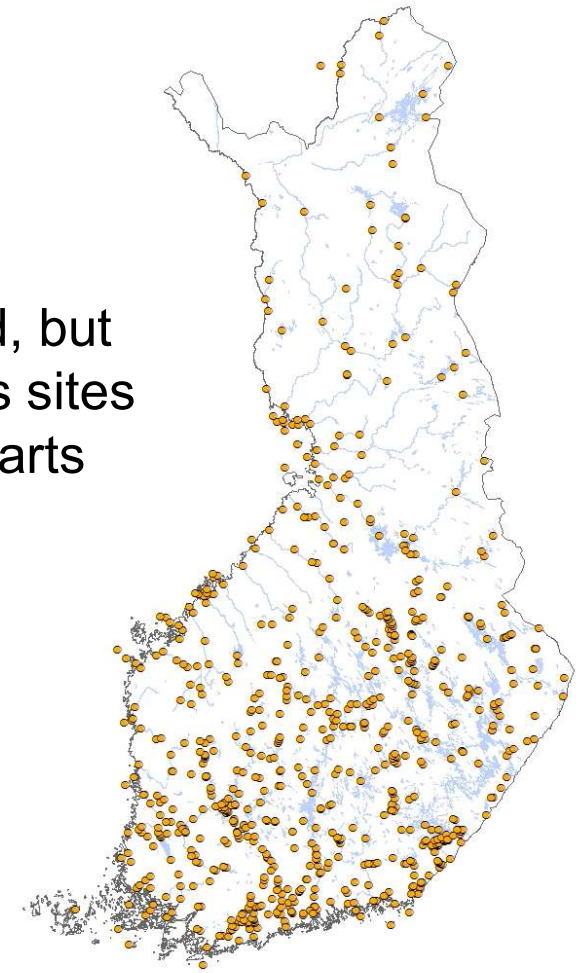2. **Does it occur in all types of water bodies?**
3. **What are the main drivers behind it?**

Water quality data

746 Monitoring stations

- Stream
- River
- Lake
- Coast

50
279
358
59

- Geographical coverage good, but in Lapland less sites than in other parts of the country.

- Major part (55%) of the monitoring sites were in fluvial waters

- If gaps in TOC data, CODMN was used as a proxy of TOC
  - Linear mixed model in which TOC was explained with CODMN
- Monitoring stations with more than 50 TOC/COD-observations during the study period 1990−2020 were included

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TOC changes in different types of waterbodies

- Same kind of TOC increase in different waterbodies
- Concentrations decrease from streams to rivers and lakes and are lowest in coastal waters
- Beside concentrations also interannual variation decreases with increasing water volume

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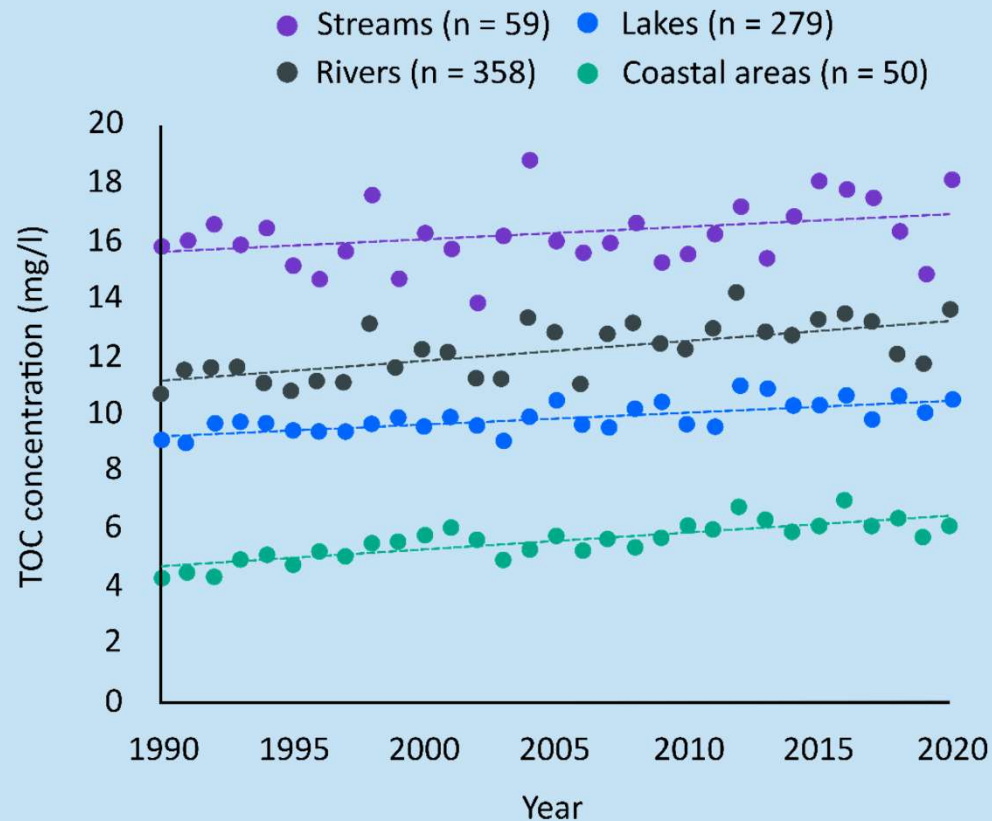
Trends in TOC concentrations

- Changes, mainly increases, were detected all around Finland, but very few in Lapland

- Proportionally (%) more increases in lakes and coastal waters compared to streams and rivers

- This slide shows linear trends, but trends are not often linear…

TOC trend
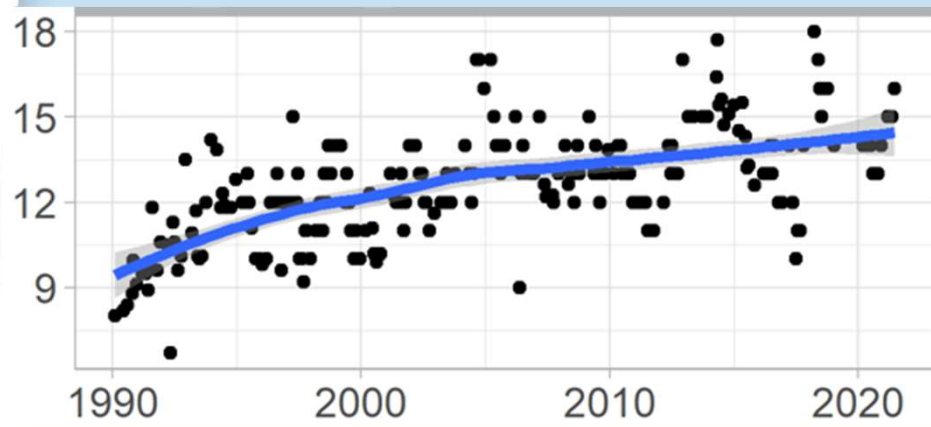
- Downward
- No trend
- Upward
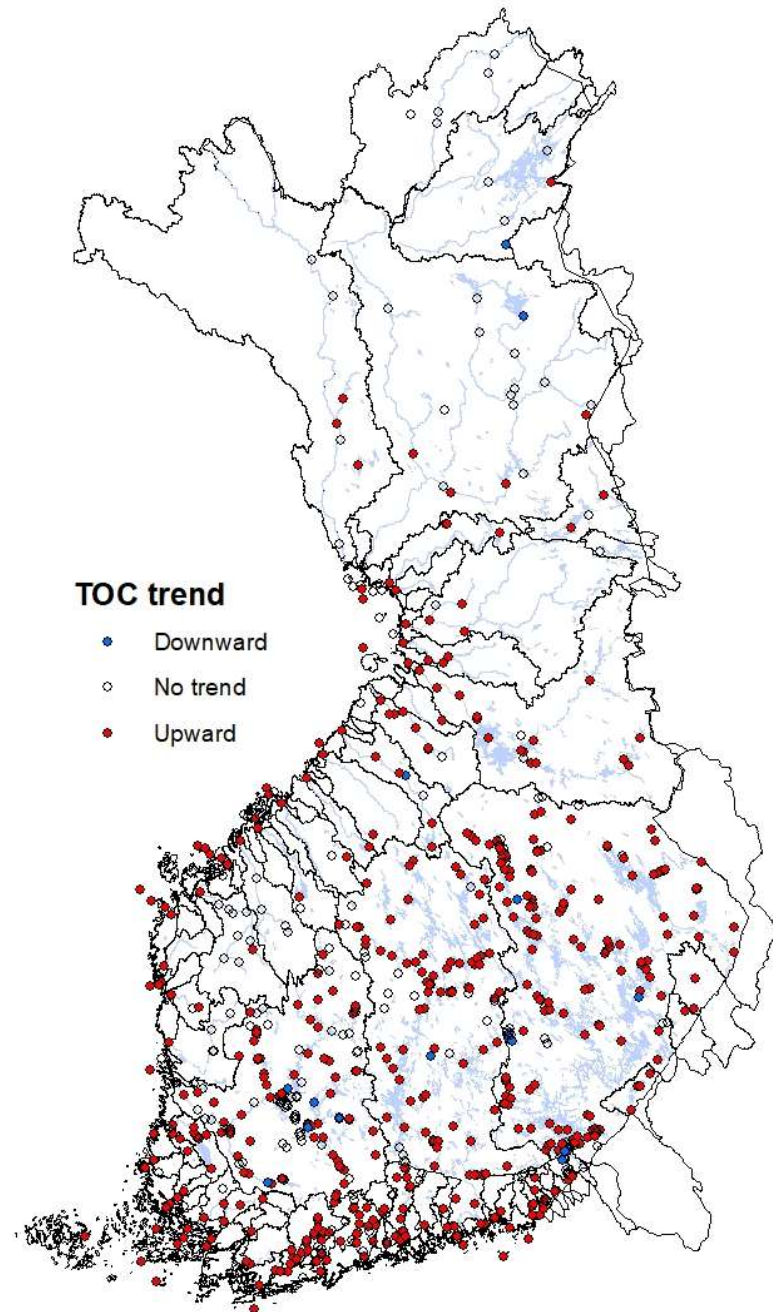
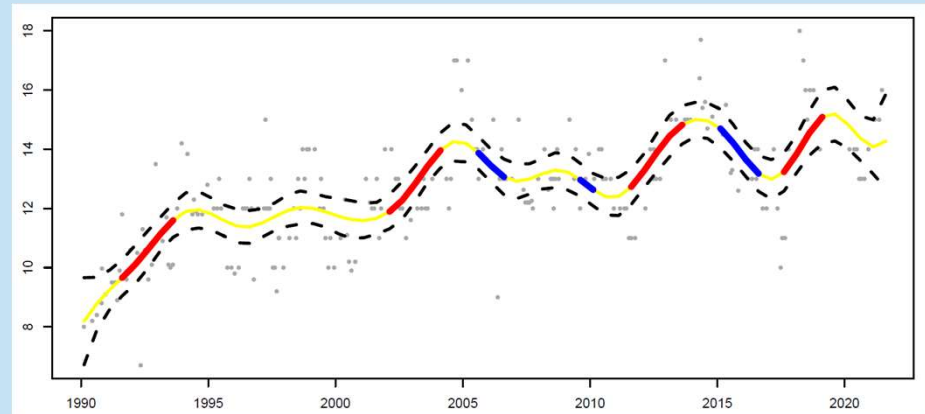# What to use: Linear model or Generalized Additive Model (GAM)?

Would it be enough to know if there has been a trend over the whole period or is more detailed information needed?

Lake Valkea-Kotinen
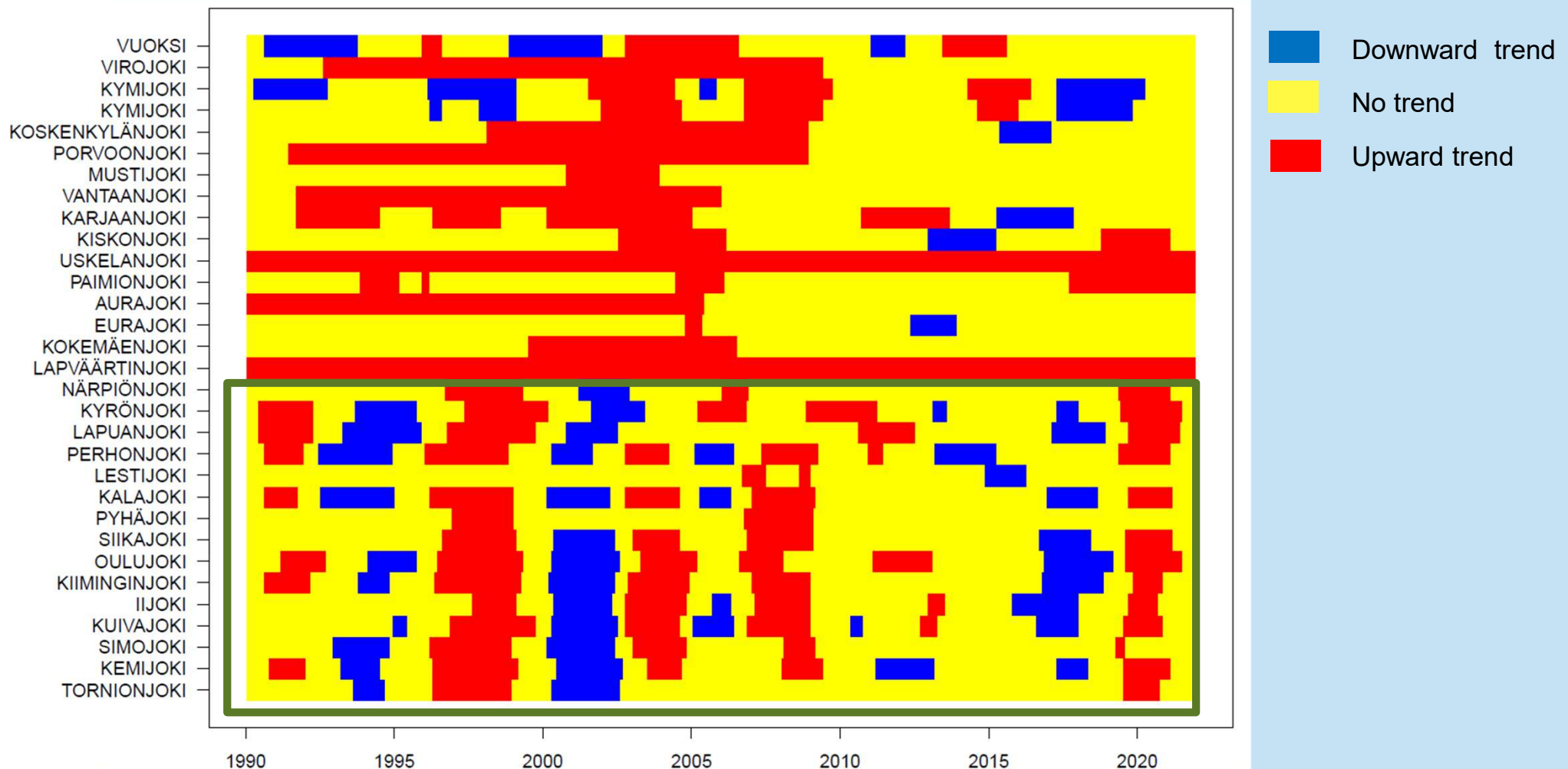
Mann-Kendall test: slope 0.136, p <0.0001

GAM: ▬ Decrease ▬ No change ▬ Increase

- GAM produces a lot of information
  - The problem might be how to utilize/summarize that information, especially if you have a lot of stations in your dataset…

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# An example how to summarize GAM results: Annual TOC-trends in big rivers

- In rivers draining into the Bothnian Bay (inside the green box) changes often happen simultaneously
  - Relationship between TOC and flow is stronger there than in other areas

Work in progress: link TOC-trends to drivers

- We selected 103 fluvial and 64 lake catchments

- Selected catchments included both stations with no TOC trends and upward trends

- Around 30 different types of drivers are tested etc. soil type, land use, tree species, precipitation, air temperature…

- Point source loading was also taken into account

- What is already evident: Difficult task and there are multiple drivers behind the changes

Fluvial catchments

No trend
Upward trend

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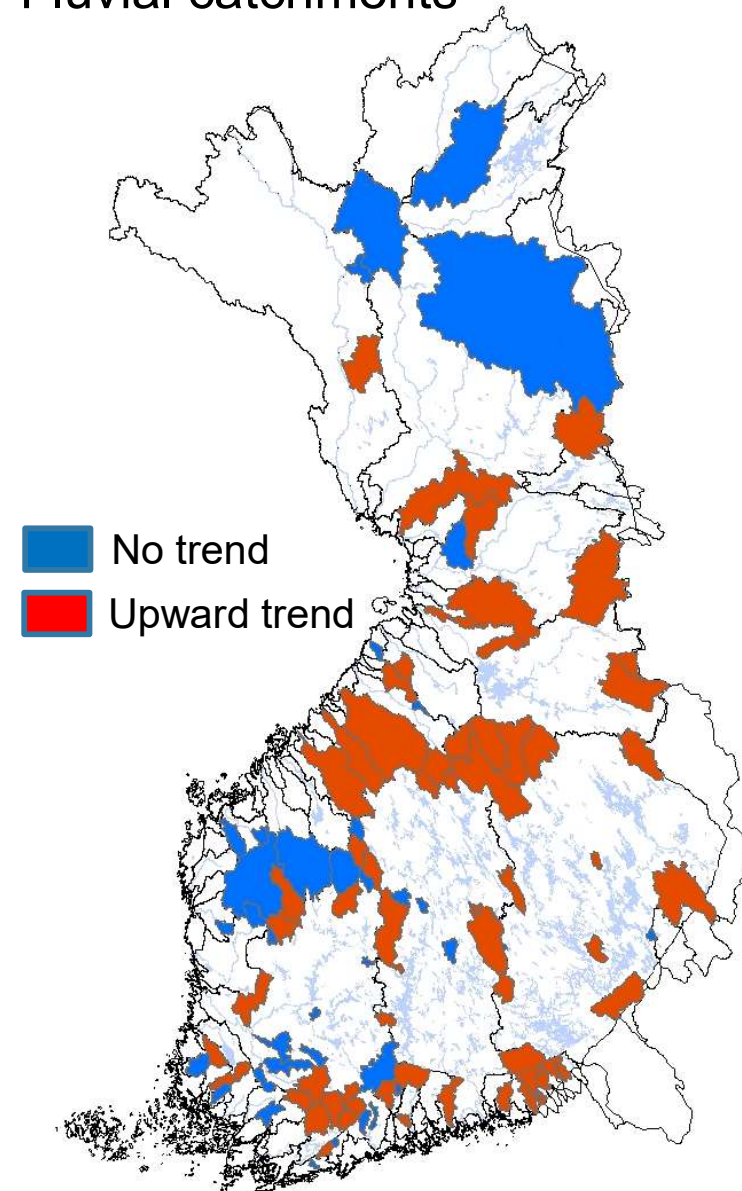
Factors behind browning

- ## Decrease of acidic deposition
  - Solubility of soil organic carbon increases to compensate decreased acidity in soil water

- ## Climate change
  - Warming accelerates mineralization processes in soils
  - Decrease of soil frost and snow cover
  - Changes in precipitations, autumn floods…

- ## Land use
  - In Finland especially forestry and ditching of peatlands

- ## Point sources
  - OC loading from point sources has remarkably decreased
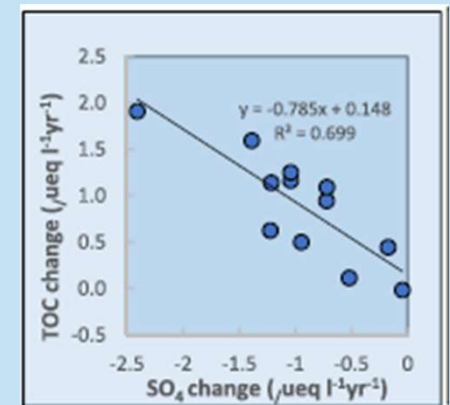
Source: Lepistö et al. 2021
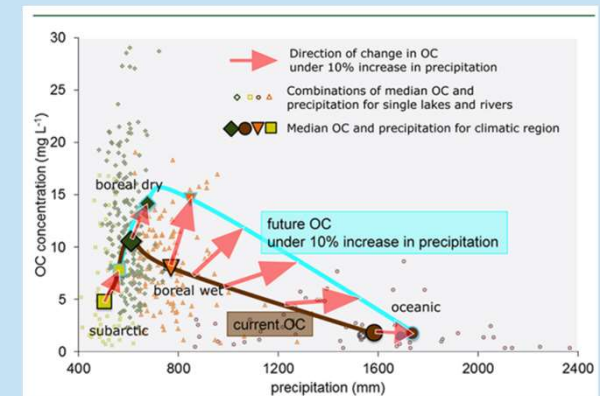
Source: de Wit et al. 2017
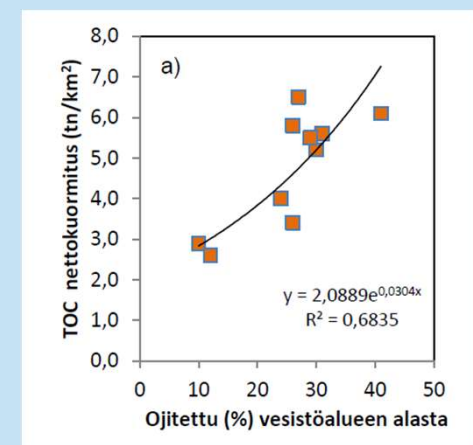
Source: Finér et al. 2020

Conclusions

- Browning of different types of water bodies continues in Finland
- Multiple drivers are detected behind changes and their importance vary geographically
  - Quantification needs further work
- With ongoing climate change TOC concentrations are expected to further increase
  - A big challenge for mitigation measures
- The role of land use, especially forestry, as a driving force behind browning is remarkable and effects are long lasting
- In Finland we need systematic changes in forestry practices and further strengthening of water protection measures

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Thank you!