Aalto University
School of Engineering

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Nature-based solutions for flood management and drainage

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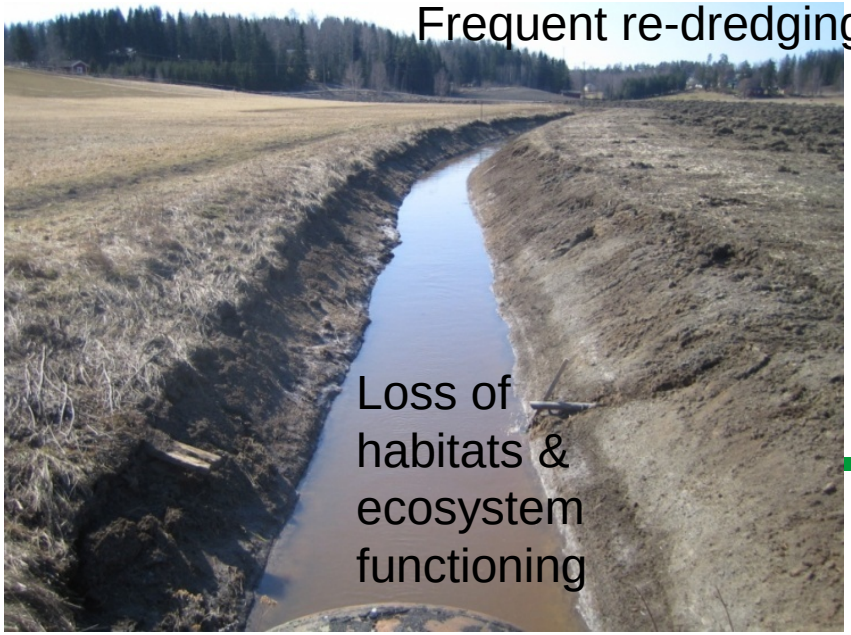
Aalto-yliopisto
Insinööritieteiden korkeakoulu

Coastal streams & Baltic Sea largely under poor/moderate ecological status: perspective from heavily impacted rivers & channels

Siltation, nutrient leaching

Loss of nutrient processing capacity in streams

Frequent re-dredging



Loss of habitats & ecosystem functioning

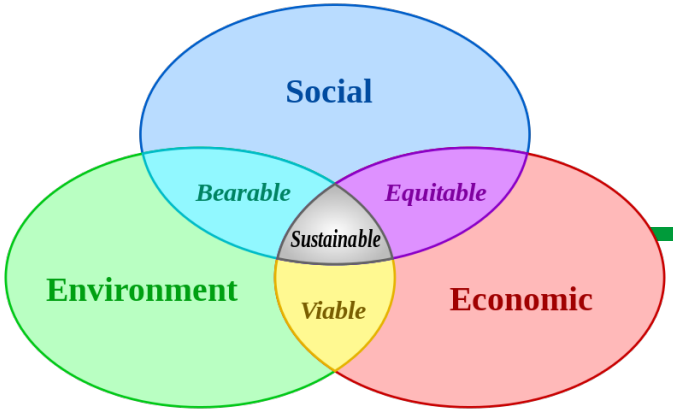
Channel erosion

Focus on small streams & rivers

- Need new cost-effective measures to enhance the status of the water bodies
- In Southern Finland, only 2-7% of streams are under natural or natural-like condition
- Agricultural streams most impacted but can show good ecological potential
- Measures in small streams most cost-effective -> influence the downstream water quality

At Aalto University, we develop environmentally, economically and socially sustainable solutions for flood management and drainage

- Using laboratory and field-scale experiments and numerical models
- Investigating dynamics and processes of water, sediment, vegetation, nutrients, and harmful substances in the hydro-environment
- Focusing on both natural and built environments: e.g. rivers, streams, wetlands, and urban water features
- **Working in close collaboration with consultancies, authorities, advisory bodies, cities and other landowners**



Recent research-based advice on stream/river management in heavily modified catchments

- Buffer strips may not be effective for sub-surface drained areas
  - Sub-surface drains transport ~10 times more suspended sediment than overland flow (e.g. Turunen 2017)
- Improvement of stream ecology requires improvements in habitats, ecosystem functions and water quality (e.g. Blann et al. 2009; Pierce et al. 2012; Turunen et al. 2017)
- Ecosystems should be managed for adaptive and functional integrity (e.g. Barnosky et al. 2017).

References: Barnosky, A.D., Hadly E.A., Gonzalez P. et al., 2017. Merging paleobiology with conservation biology to guide the future of terrestrial ecosystems. Science 355(6325), eaah4787. DOI: 10.1126/science.aah4787.

Blann, K.L., Anderson, J.L., Sands, G.R., Vondracek, B., 2009. Effects of agricultural drainage on aquatic ecosystems: a review. Crit. Rev. Env. Sci. Tech., 39(11), 909–1001. DOI: 10.1080/10643380801977966.

Pierce, S.C., Kröger, R., Pezeshki, R., 2012. Managing artificially drained low-gradient agricultural headwaters for enhanced ecosystem functions. Biol., 1(3), 794-856. DOI: 10.3390/biology1030794.

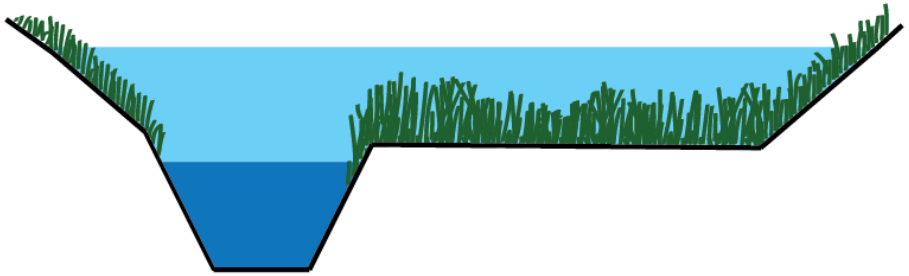
Turunen, M. 2017. Assessing water and sediment balances in clayey agricultural fields in high-latitude conditions. Doctoral thesis, Aalto University. http://urn.fi/URN:ISBN:978-952-60-7378-1

Turunen et al. 2017 Differential responses by stream and riparian biodiversity to in-stream restoration of forestry-impacted streams. Journal of Applied Ecology 54, 1505–1514. doi: 10.1111/1365-2664.12897

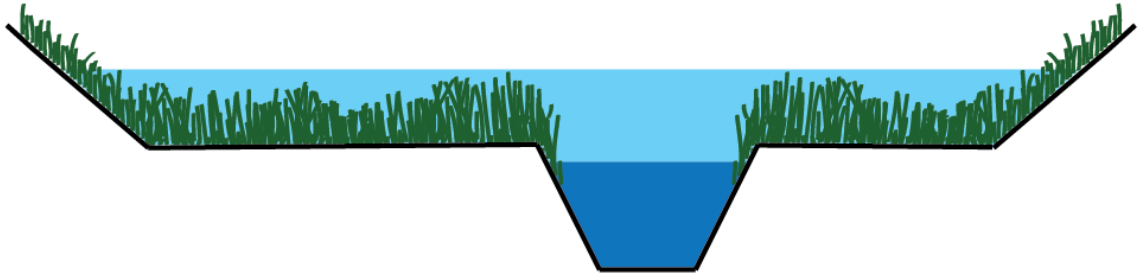
Two-stage channels as a Nature-based Solution (NbS) – combining technical, environmental and ecological aspects in flood management & drainage

Conventional trapezoidal-shaped channel

Two-stage channel with a floodplain on one side



Two-stage channel with a floodplain on both sides



+controlled vegetation growth
+large geochemically active surface area
+increased hydraulic retention

Ritobäcken Brook: a two-stage agricultural channel in Sipoo (southern Finland)

- Floodplain excavated at the level of mean discharge in February 2010
- Clayey-silty soil
- Mean discharge: 115 l/s, maximum ~ 1400 l/s
- 10 km^2 catchment

Västilä, K., Järvelä, J., 2011. Environmentally preferable two-stage drainage channels: considerations for cohesive sediments and conveyance. International Journal of River Basin Management 9(3-4): 171-180. DOI: 10.1080/15715124.2011.572888.

Västilä, K., Järvelä, J., Koivusalo, H., 2016. Flow–Vegetation–Sediment Interaction in a Cohesive Compound Channel. Journal of Hydraulic Engineering 142(1): 04015034. DOI: 10.1061/(ASCE)HY.1943-7900.0001058

Before excavation

After excavation

Two-stage channels: scientific findings from Ritobäcken and US sites

- Function from low to high flows: efficient drainage/flood management
- Stable under varying soil types
- More diverse habitats, enhance water quality, limited floodplain connectivity
- More self-sustaining -> up to 3 times longer design life
- Allow habitat restoration in the main channel

Reference: Rówinski et al. 2018. HOW VEGETATION CAN AID TO COPING WITH RIVER MANAGEMENT CHALLENGES. SUBMITTED TO Ecohydrology & Hydrobiology, under revision.

Some Finnish two-stage channels

Juottimenoja, Perniö (2 years after construction)

Leppioja, Tyrnävä

Ritobäcken, Sipoo (4 months after construction)

Water quality improvement in two-stage channels in USA

Compared to conventional channels, concentrations/loads in two-stage channels (n=6-15) found to be

- **~10-20% lower for soluble reactive and total phosphorus (P)**
- **slightly higher for ammonium**
- **~equal for nitrate (but enhanced denitrification)**

-> can be notably improved with optimal channel design

Need more information on nutrient retention and processing at overbank flows. Planned investigations at Finnish field sites.

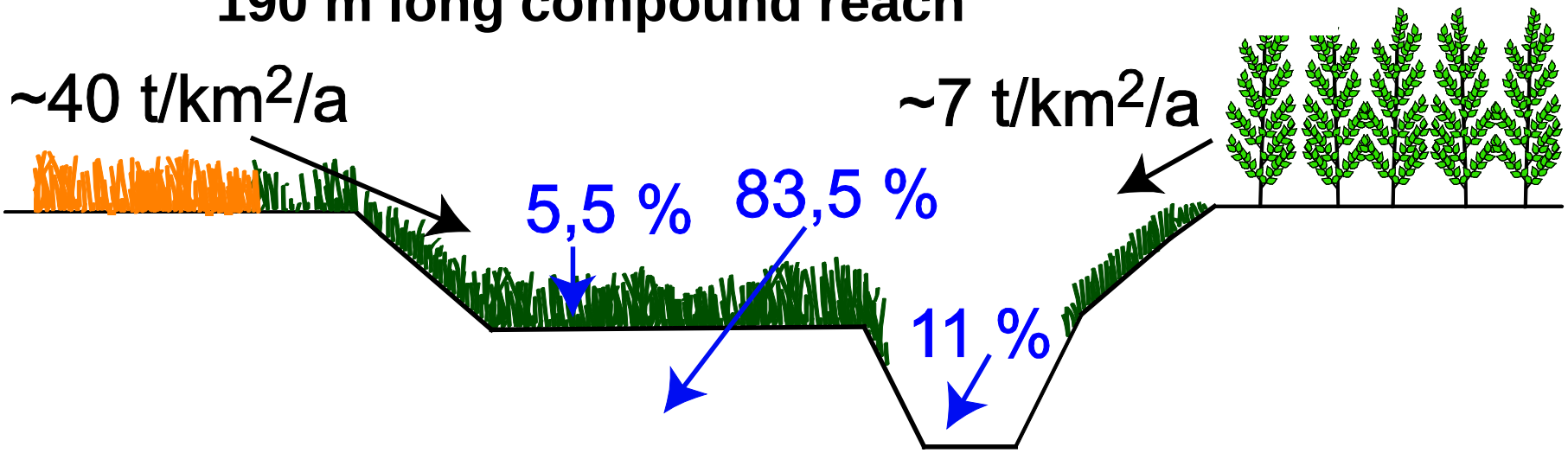
References: Davis, R.T., Tank, J.L., Mahl, U.H., Winikoff, S.G., Roley, S.S., 2015. The influence of two-stage ditches with constructed floodplains on water column nutrients and sediments in agricultural streams. J Am Water Resour Assoc. (JAWRA), 51(4), 941-955. DOI: 10.1111/1752-1688.12341.

Faust, D.R., Kröger, R., Moore, M.T., Rush, S.A., 2017. Management practices used in agricultural drainage ditches to reduce Gulf of Mexico hypoxia. Bull Environ Contam Toxicol., 100(1), 32-40. DOI: 10.1007/s00128-017-2231-2.

Mahl UH, Tank JL, Roley SS, Davis RT (2015) Two-stage ditch floodplains enhance N-removal capacity and reduce turbidity and dissolved P in agricultural streams. J Am Water Resour Assoc 51:923–940

Ritobäcken: deposition on the floodplain improved water quality

Suspended sediment balance in the 190 m long compound reach



+Deposition likely **removes P** from water column

~2-3% of total P&N taken up into floodplain vegetation biomass

Västilä, K., Järvelä, J., Jalonen, J., 2015. Effect of floodplain vegetation on flow and transport of cohesive particles in an environmental two-stage channel, 36th IAHR World Congress, 28 June–3 July 2015, Delft – The Hague, the Netherlands

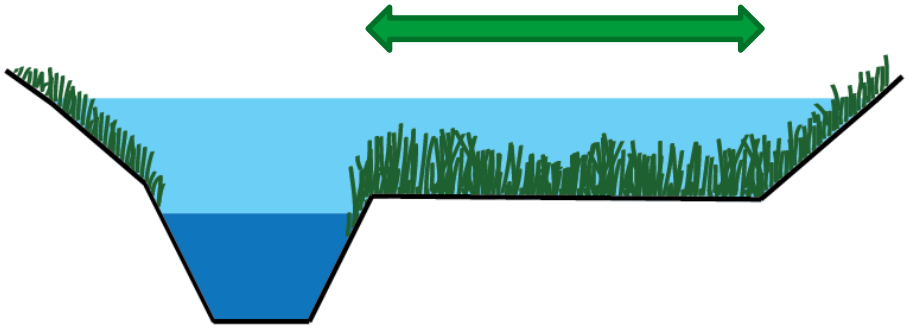
Västilä, K. & Järvelä, J. 2017 Characterizing natural riparian vegetation for modeling of flow and suspended sediment transport. Journal of Soils and Sediments, doi: 10.1007/s11368-017-1776-3.

Economics of two-stage channels (Finnish and US sites)

- Compared to conventional dredging, two-stage channels have
  - on average ~2-4 times higher construction costs per linear channel meter
  - lower construction costs per excavated soil volume
  - up to 3 times longer estimated life cycle (larger cross-sectional area, less siltation in main channel) (e.g. Paradis & Biron 2016)
- Besides construction costs
  - landowners need to consider the return on investment
  - society needs to consider the external costs/value-added benefits (e.g. water quality, biodiversity, landscape, recreation)

Cost-share possibilities & disincentives

Count as buffer strip/wetland



If productive land taken out of production, some states in US pay an annual rental rate for the land & cost + maintenance of the two-stage channel (BMP in US)

Disincentive for two-stage channels: narrow channels considered as subsidized field area

Ongoing/planned investigations at Aalto to develop nature-based flood management & drainage

- Nutrient retention & processing in two-stage vs conventional channels
- Channel maintenance, including vegetation management
- Including habitat restoration in two-stage channels in rural & urban areas
- Tools for channel design, including the estimation of the influence of vegetation on flow and water quality

Conclusions

- Nature-based solutions successfully used in agricultural & urban channels
- Two-stage channels improve flood management & drainage while decreasing harmful environmental impacts
- Large-scale benefits improve with optimal channel design & maintenance

- More information at
  - http://builtenv.aalto.fi/en/research/water_and_environmental_engineering/water_resources_management/environmental_hydraulics/
  - https://people.aalto.fi/kaisa_vastila