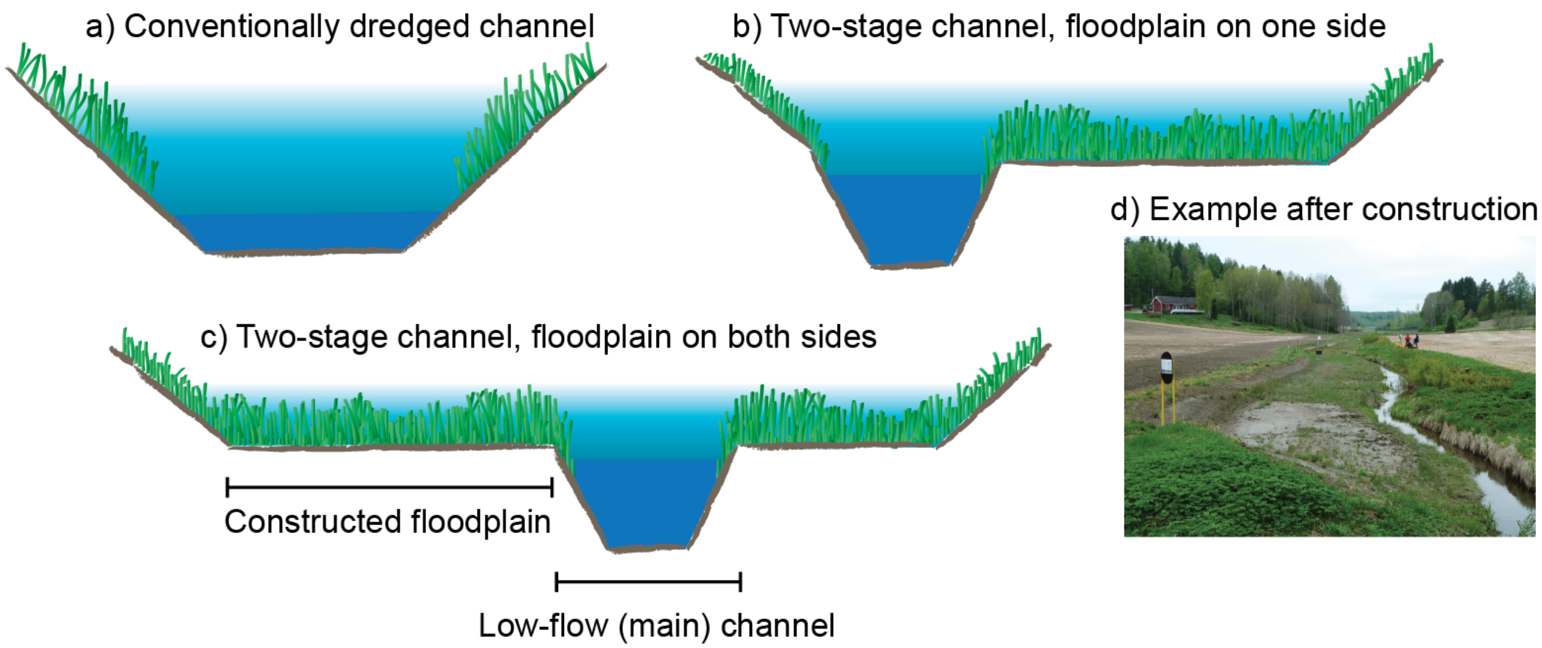
Two-stage channels for environmentally preferable drainage

DSc Kaisa Västilä (Aalto University, Finnish Environment Institute)

Sustainable drainage for food production workshop

15 November 2021

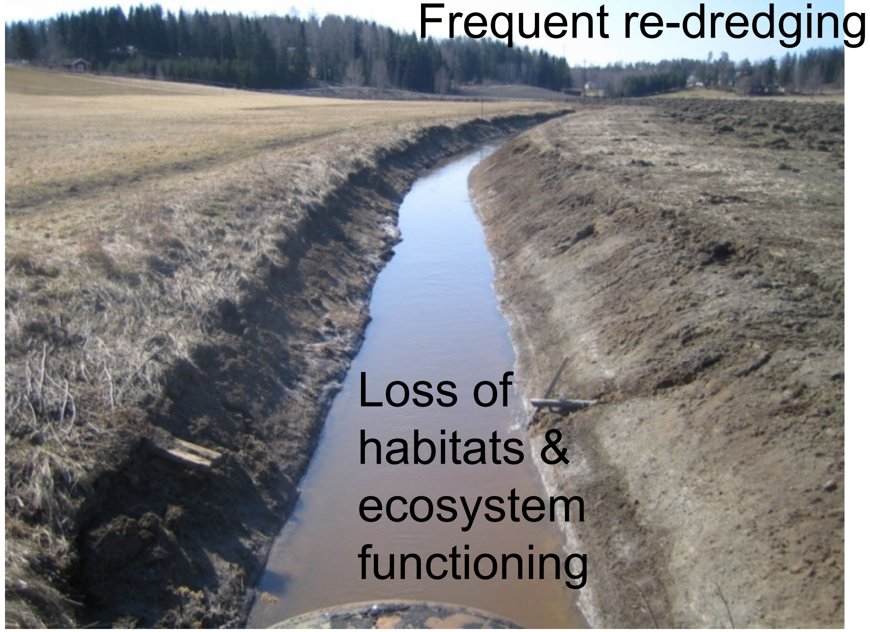


Agricultural streams & receiving water bodies largely under poor/moderate ecological status

Siltation,
overgrowi
ng

Climate change; need for water storage and irrigation

Loss of nutrient processing capacity



Factors to consider in sustainable agricultural channels

- Planform: avoid straightening, allow small-scale meandering
- Cross-sectional and longitudinal variation in width and depth
- Slope stability
- Vegetation (aquatic, riparian); maintenance
- Variable bed materials, stones, LWD
- Restoration of habitats

Nature-based solutions for engineered channels

Restoration of mires to cut highest discharges

Erosion protection: e.g. sowing grasses, fascines, erosion control blankets

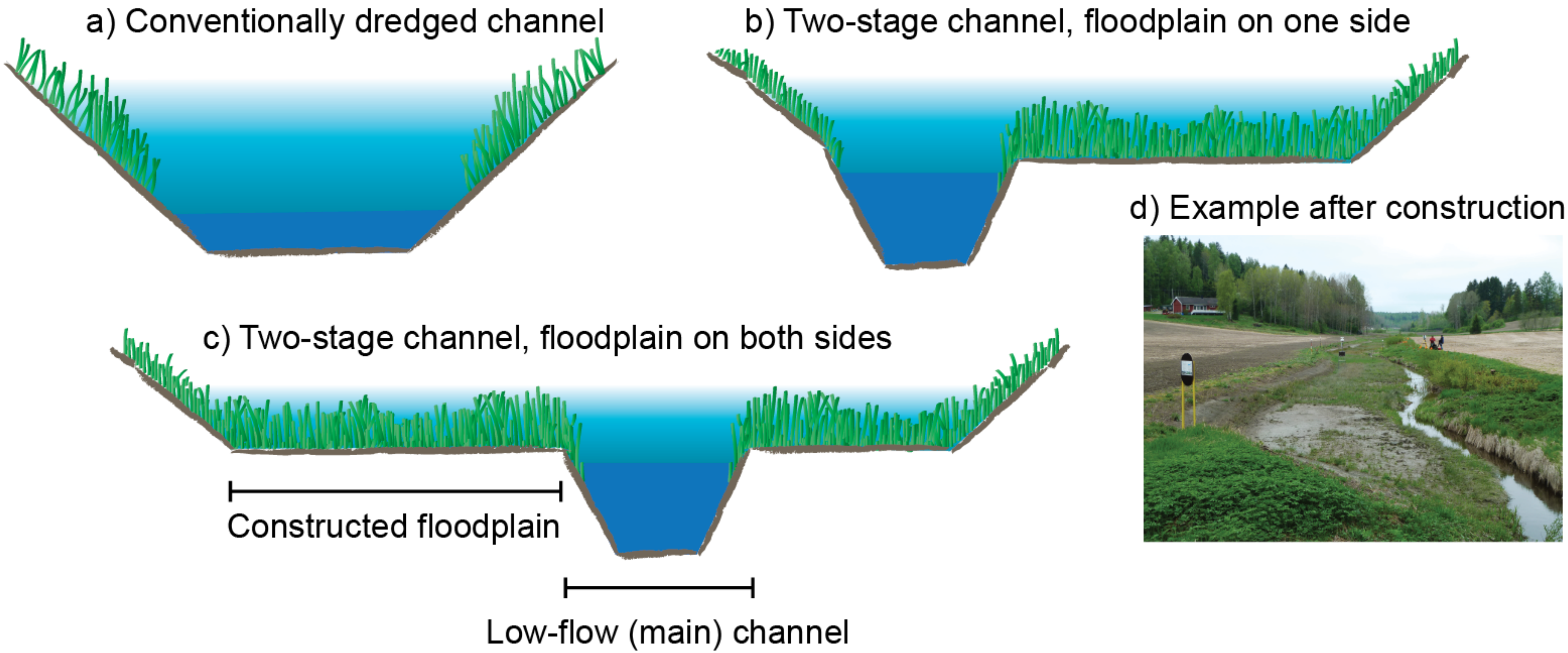
Natural-like bottom ramps or rocky sills for erosion protection, raising low water levels, diversifying habitats

Constructed wetlands for water quality and wildlife benefits, for retaining water

Two-stage channels for enhancing drainage and flood mitigation + environmental benefits

Habitat restoration

Two-stage channel (TSC) design as an environmentally preferable alternative to conventional dredging for agricultural drainage and flood mitigation



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

Some Finnish two-stage channels

Juottimenoja, Perniö (2 years after construction)

Leppioja, Tyrnävä

Uuhikonoja, Tammela (~4 months after construction)

Hardombäcken, Loviisa (<1v)

A review & case study examples on two-stage channels

sustainability Sustainability 13(16), 9349. https://doi.org/10.3390/su13169349) MDPI

Article

Agricultural Water Management Using Two-Stage Channels: Performance and Policy Recommendations Based on Northern European Experiences

Kaisa Västilä [1,2,*], Sari Väisänen [1], Jari Koskiaho [1], Virpi Lehtoranta [1], Krister Karttunen [1], Mikko Kuussaari [1], Juha Järvelä [2] and Kauko Koikkalainen [3]

Main benefits of TSCs compared to conventional dredging

- Longer-term functioning of drainage because of enhanced self-cleansing of the low-flow channel
- Retention of suspended sediment and phosphorus, and removal of nitrogen on the floodplain, which likely enhances water quality
- Larger plant and fish biodiversity, more habitat for pollinators
- More natural-like main channel geometry and flow conditions allow habitat restoration
- Other taxa (e.g. macroinvertebrates) may benefit from improved connectivity to floodplain and more diverse vegetation
- Landscape and recreational benefits through the more variable landscapes

Very limited studies on biodiversity impacts and medium-long-term physico-chemical performance. E.g. only few works provide an experimentally obtained over-annual-scale mass balance for suspended sediment or nutrients while the processes in the low-flow channel are not well taken into account.

(Västilä et al. 2021, Agricultural Water Management Using Two-Stage Channels: Performance and Policy Recommendations Based on Northern European Experiences. Sustainability 13(16), 9349. https://doi.org/10.3390/su13169349)

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 ~0.12 m3/s, 1/5-year discharge ~1.6 m3/s
- 10 km^2 catchment

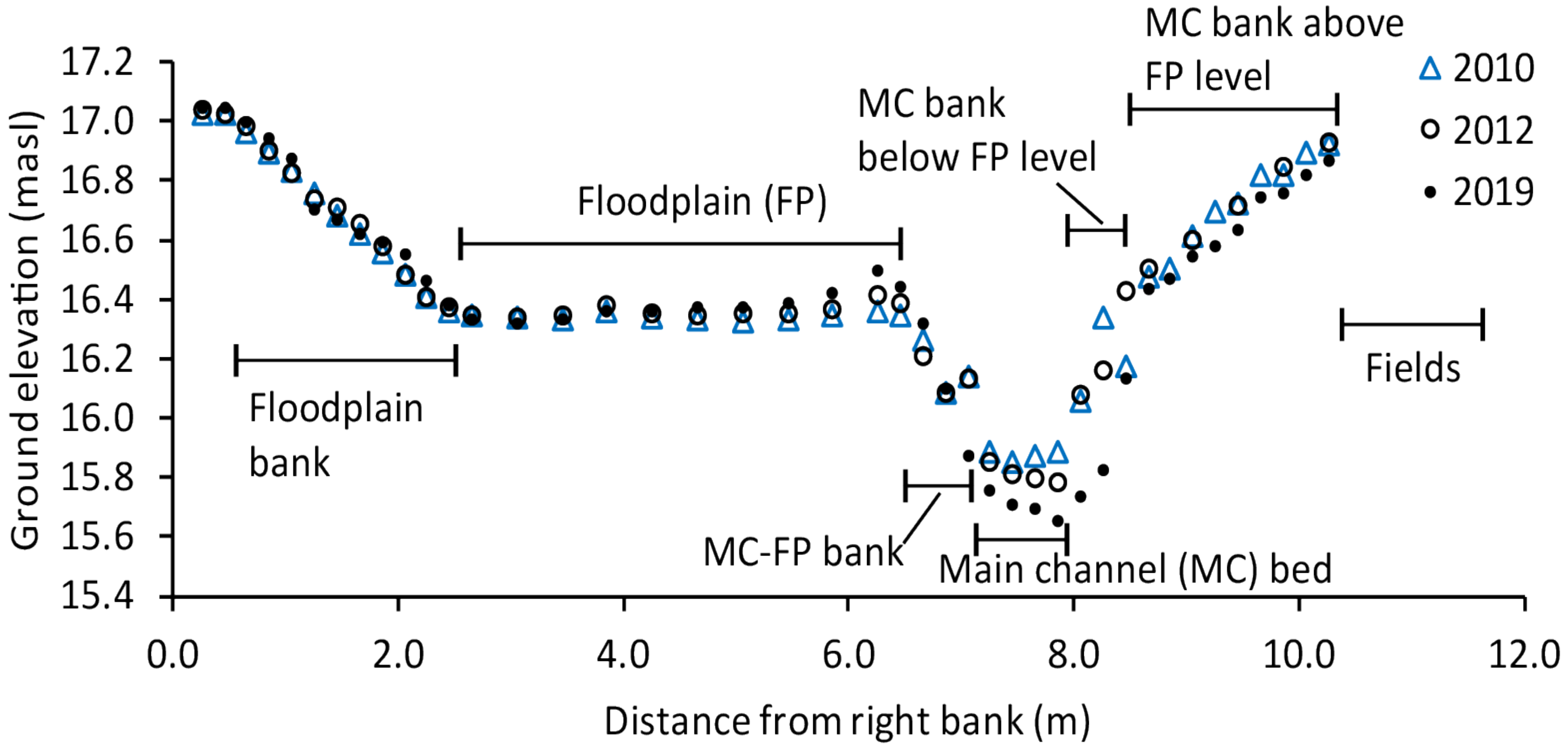
Västilä, K., Järvelä, J., 2011. Environmentally preferable two-stage drainage channels: considerations for cohesive sediments and conveyance. International Journal of River Basin Management 9(3-4): 171-180. DOI: 10.1080/15715124.2011.572888.

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

Ritobäcken TSC shows efficient self-cleansing capacity, even flushing old deposits



- TSC design maintained drainage depth and sufficient conveyance capacity
- Decrease in channel bed siltation likely supports stream biodiversity
- Continued monitoring to determine if there is erosion in main channel

SAMASSA VEDESSÄ

(Västilä & Jilbert, manuscript under prep.)

2-year retention of suspended sediment and phosphorus via floodplain deposition at Ritobäcken TSC

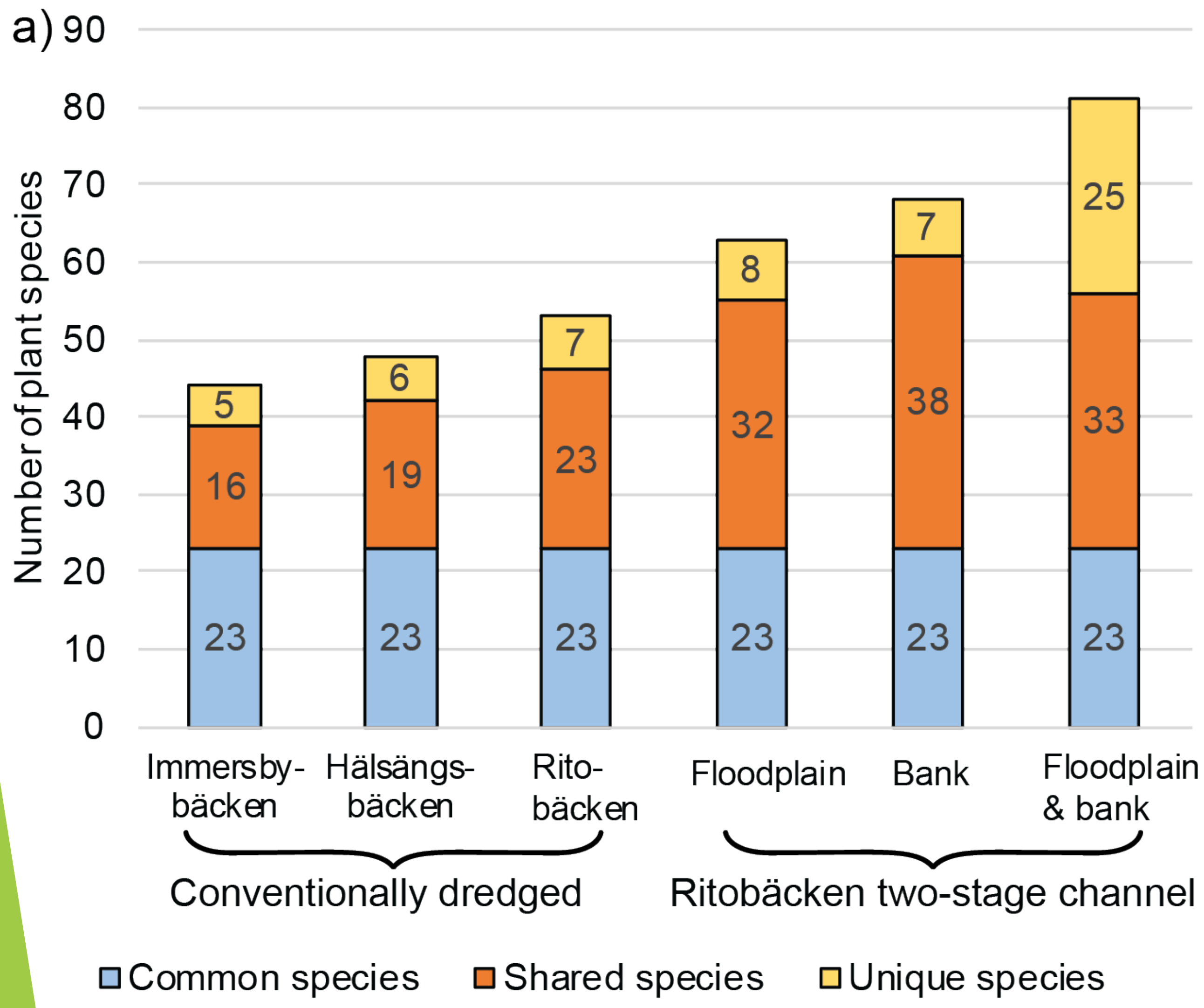
- Floodplain retained 14% of SS and 16% of P per 1 km of TSC (Västilä ym. 2021, Sustainability)
- Lower net retention of 2% of SS and 3.5% of P per 1 km of TSC because of flushing in the low-flow channel
- Retention likely higher if sub-surface drains discharge on floodplain and if vegetation is maintained

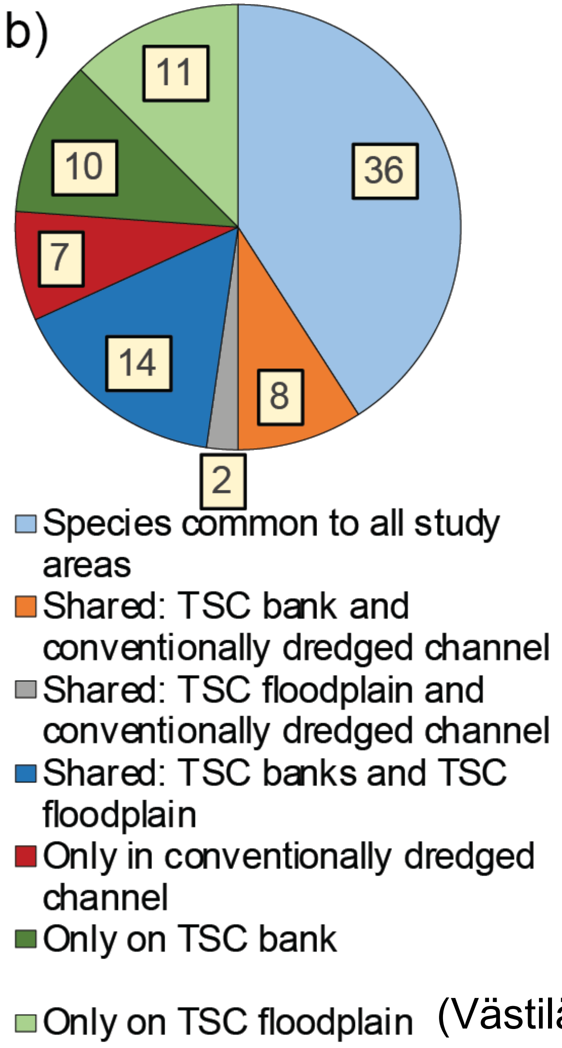
-> further investigations in collaboration with Valumavesi- and NBS-VEGE-NUTRI projects in 2021-2023

- Manuscript on 9-y mass balance under prep. (Västilä & Jilbert)

SAMASSA VEDESSÄ

Preliminary investigations show potentially higher plant species richness in Ritobäcken two-stage channel





- Plant biodiversity may be positively reflected on other taxa

(Västilä et al. 2021, https://doi.org/10.3390/su13169349)

Wider potential of two-stage channel design for decreasing the harmful hydro-environmental impacts of agriculture

- As an after-field type vegetated buffer, the design likely provides water quality improvements compared to edge-of-field buffers (especially in sub-surface drained areas) as it can treat both the lateral runoff and the loading from the upstream areas
- The excavated floodplains appeared to enhance the riparian plant biodiversity while edge-of-field buffer strips harbor a low amount of wetland species (e.g. Hille et al. 2018) and usual agri-environment schemes do not necessarily have positive effect on plant biodiversity
- Two-stage channels as a NBS address the emerging ecological paradigm proposing that ecosystems should be managed for adaptive and functional integrity rather than attempting to restore them to an idealized conception of the natural state (e.g. Barnosky et al. 2017), which is particularly true in the strongly modified drained agricultural landscapes (e.g. Rowinski et al. 2018)

(Västilä et al. 2021, https://doi.org/10.3390/su13169349)

Cost factors of TSCs

Pilot Site	Excavated soil volume (m^3)	Lost field area (ha)	Lost field area per channel length (m^2/m)	Unit construction cost per channel length (€/m)	Unit construction cost per excavated soil volume (€/m^3)	Construction cost ratio [1]	Value of lost field per channel length (€/m)	Value of lost crops per channel length (€/yr/m)	Sources of financing for construction[2]
Ritobäcken	2 000	0.33	4.0	18	7.5	3.7	3.8	0.28	ELY 100%
Kaukan-aronoja	2 600	0.26	3.8	11	3.0	2.3	4.3	0.26	no data
Luvalahden-oja	1 700	0.17	3.8	14	3.8	2.9	4.3	0.25	no data
Hardom-bäcken	1 400	0.08	2.6	23	4.8	4.6	2.4	0.17	Pr 90%, Ow 10%
Uuhikon-oja	9 800	0.94	4.0	35	8.4	4.3	3.6	0.27	ELY 48%, Pr 36%, Ow 16%
Leppioja	7 100	0.40	4.0	25	3.5	4.9	3.1	0.28	no data
Mean	4100	0.36	3.7	21	5.2	3.8	3.6	0.25	ELY 49%, Pr 42%, Ow 9%

[1] Depicts how many times more expensive the two-stage channel is to construct compared to one-time conventional maintenance dredging
[2] ELY = Regional State Authority, Pr = Externally funded project, Ow = Land owners

Västilä ym. 2021. Sustainability.
https://www.mdpi.com/2071-1050/13/16/9349

Total costs and monetary environmental benefits of TSCs scaled up to catchment level in a 60-y period in comparison to conventional dredging

Variable	Units/Unit cost	Conventional dredging	Two-stage channel design
Project life	years	60	
Channel length	km	14.8	
Maintenance interval	years	20	50
Maintenance costs	€5/€2.5 per meter	-222 000	-44 000
Construction costs	€0/€21.6 per meter	0	-314 000
Adjacent land price	€ 0/ €3.6 per m	0	-53 000
Lost crop value	€ 0/ € 268 per km	0	-223 000
Environmental benefits for biodiversity	€50 per *Unio crassus* mussel	0	594 000
Environmental benefits for water quality	€ 249 per phosphorus kg retained on the floodplain	0	951 000
Net costs in 60 years	€	-222 000	910 000
Equivalent annual cost (EAC)	€ per year	-1 200	7 400

Large initial contruction cost, but lower maintenance costs

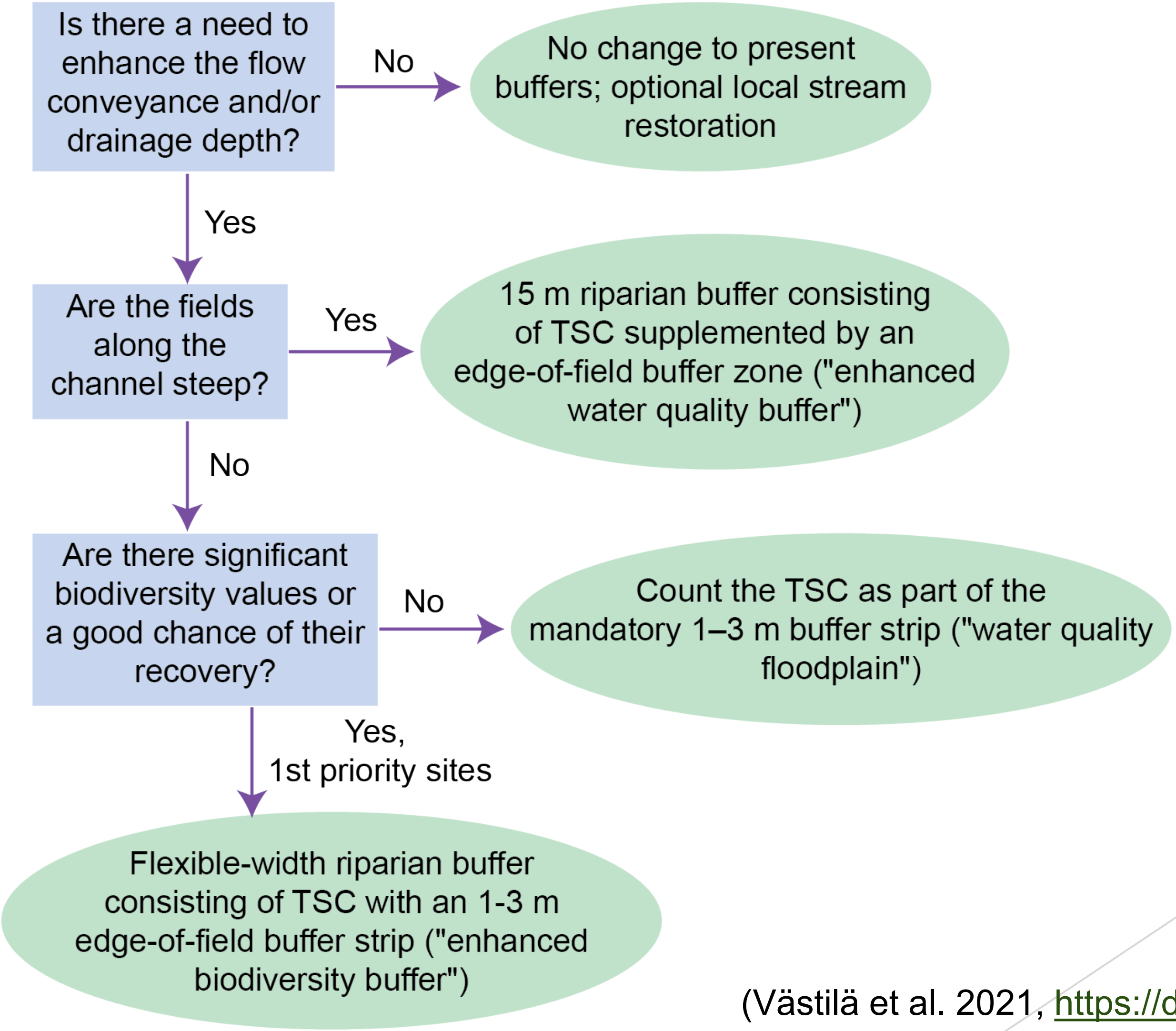
Costs related to lost field area because of non-integration into CAP-AES

Additional monetary environmental benefits related to water quality and biodiversity

Environmental benefits larger than the costs

(Västilä et al. 2021, https://doi.org/10.3390/su13169349)

Preliminary decision support tree for more efficient targeting of the various vegetated riparian buffers, including integration of two-stage channels into CAP-AES



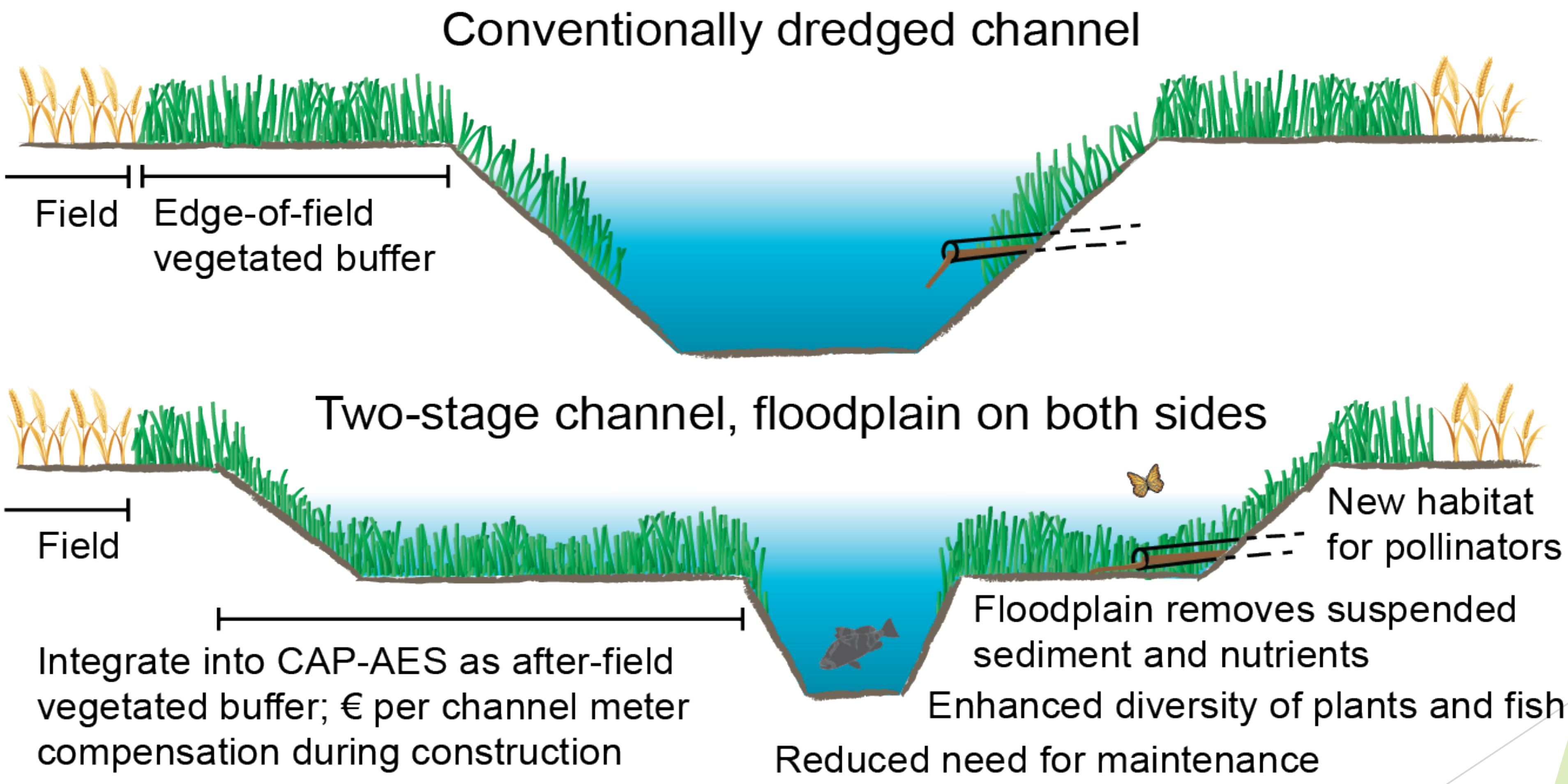
(Västilä et al. 2021, https://doi.org/10.3390/su13169349)

Applicability and generalizability of the two-stage channel design

- The design is widely applicable to small and medium-sized ditches, brooks and streams particularly under Boreal and Continental climates in areas requiring efficient flow conveyance
  - well suited to lowland and mildly sloping areas with clay to sand soils
  - favourable for channels having high biodiversity values, or where conventionally dredged channels are unstable or require frequent clean-outs
- Climate change increases the need for efficient drainage, flow conveyance and such new methods for controlling the agricultural loading because the amount and intensity of precipitation and the leaching of suspended sediment and nutrients from fields is expected to rise in the Boreal zone
- There are large needs to maintain the agricultural channel network in e.g. Central and Eastern Europe, which is a good opportunity to "*think about green before investing in grey*" (EEA 2015)

(Västilä et al. 2021, https://doi.org/10.3390/su13169349)

Conclusions



Note: Very limited knowledge on medium–long-term performance, including the processes in the low-flow channel.

Research has been supported since 2009 by the Academy of Finland, Maa- ja vesitekniikan tuki ry, Maj and Tor Nessling Foundation, Finnish Cultural Foundation, Ministry of the Environment, Ministry for Agriculture and Forestry, Salaojituksen tukisäätiö sr, Oskar Öflund Foundation, Emil Aaltonen Foundation, VALUE doctoral school, Tekniikan edistämissäätiö, and Sven Hallin Foundation.