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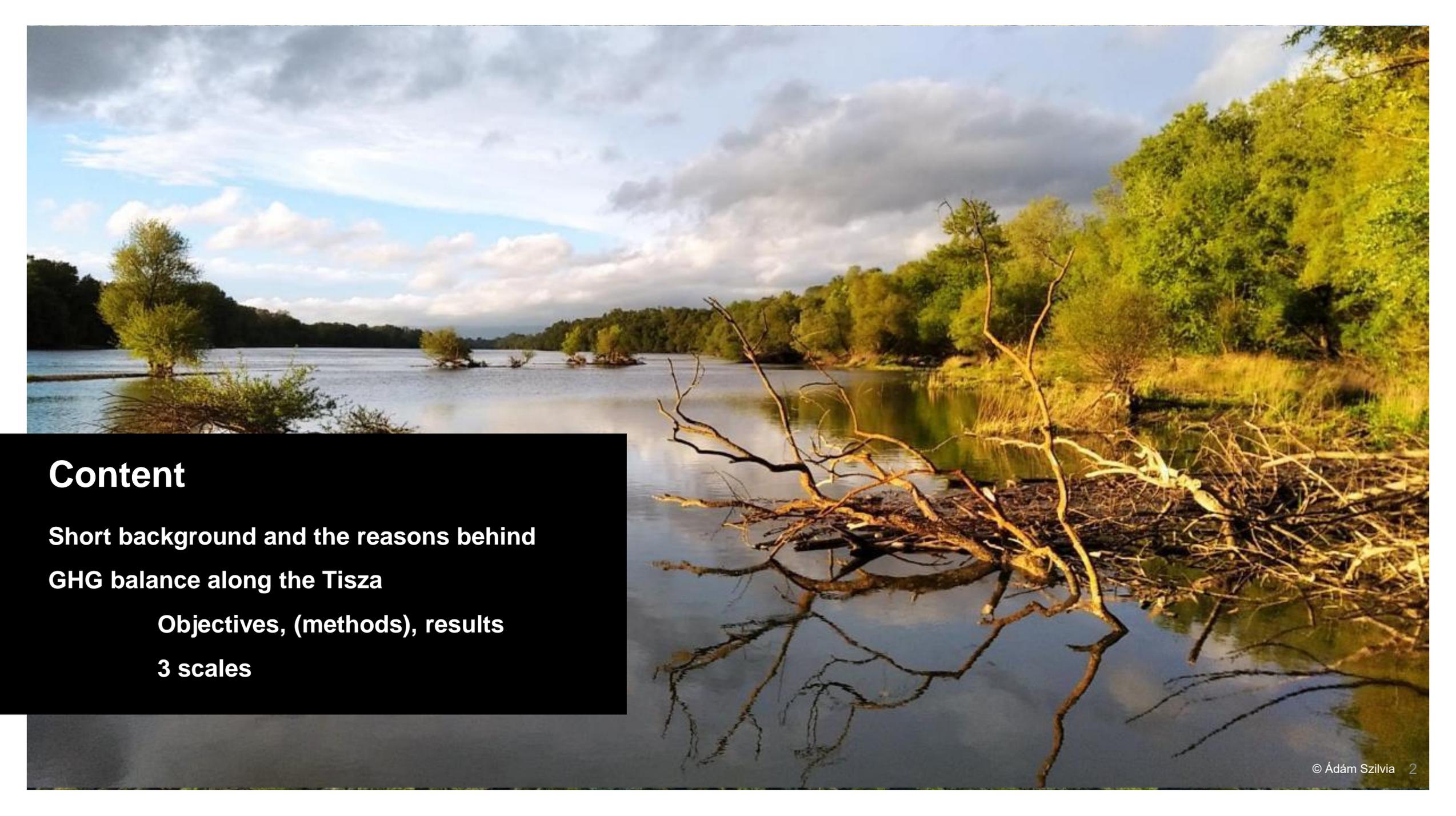
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# Greenhouse Gas (GHG) balance of floodplain restoration – Tisza river NBS case

LDP Bridge Project – Pilot research – 2022-2023 (2024)

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## Content

Short background and the reasons behind  
GHG balance along the Tisza

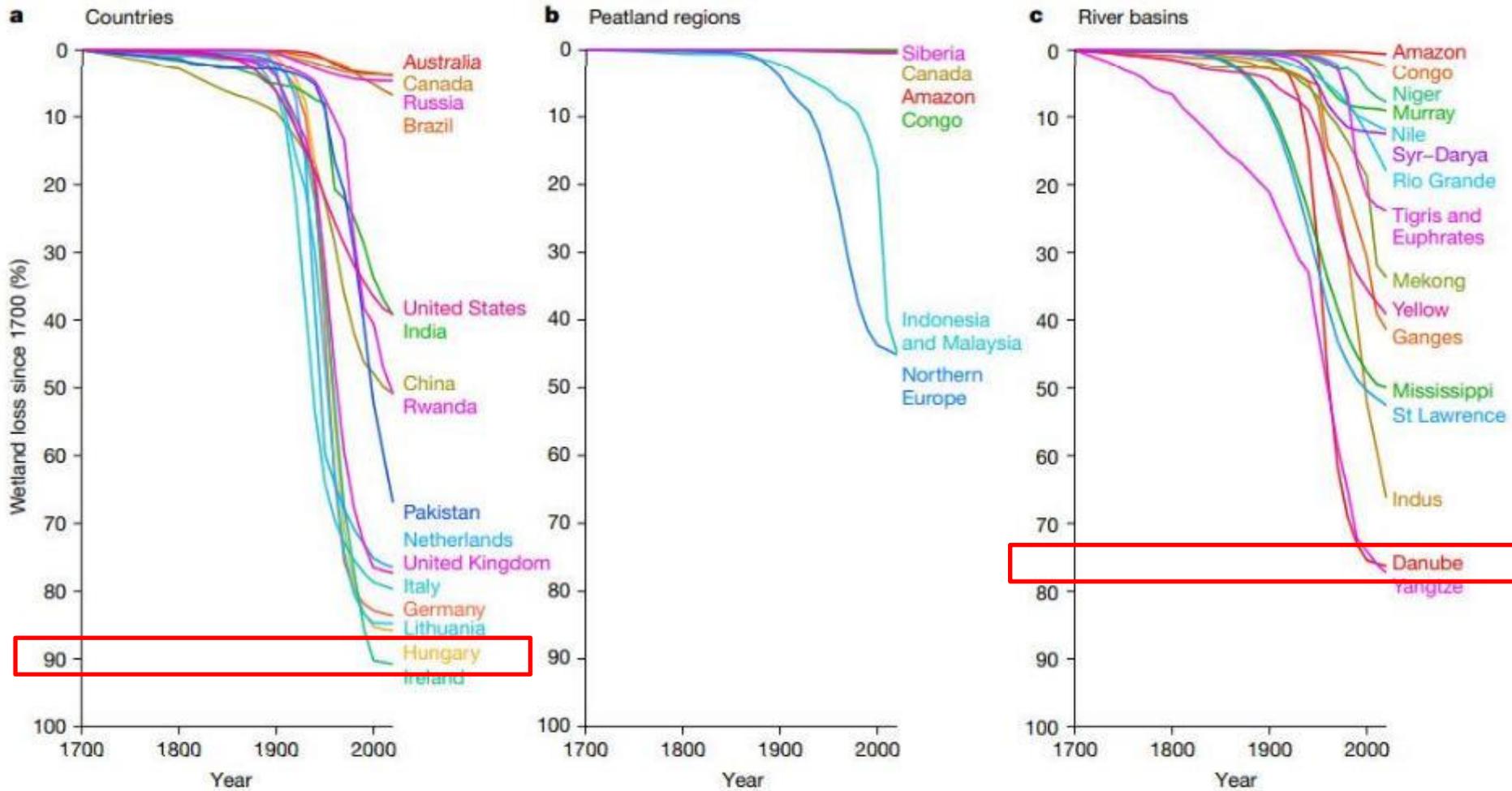
Objectives, (methods), results

3 scales

# Background: NbS, large-scale, NWRM



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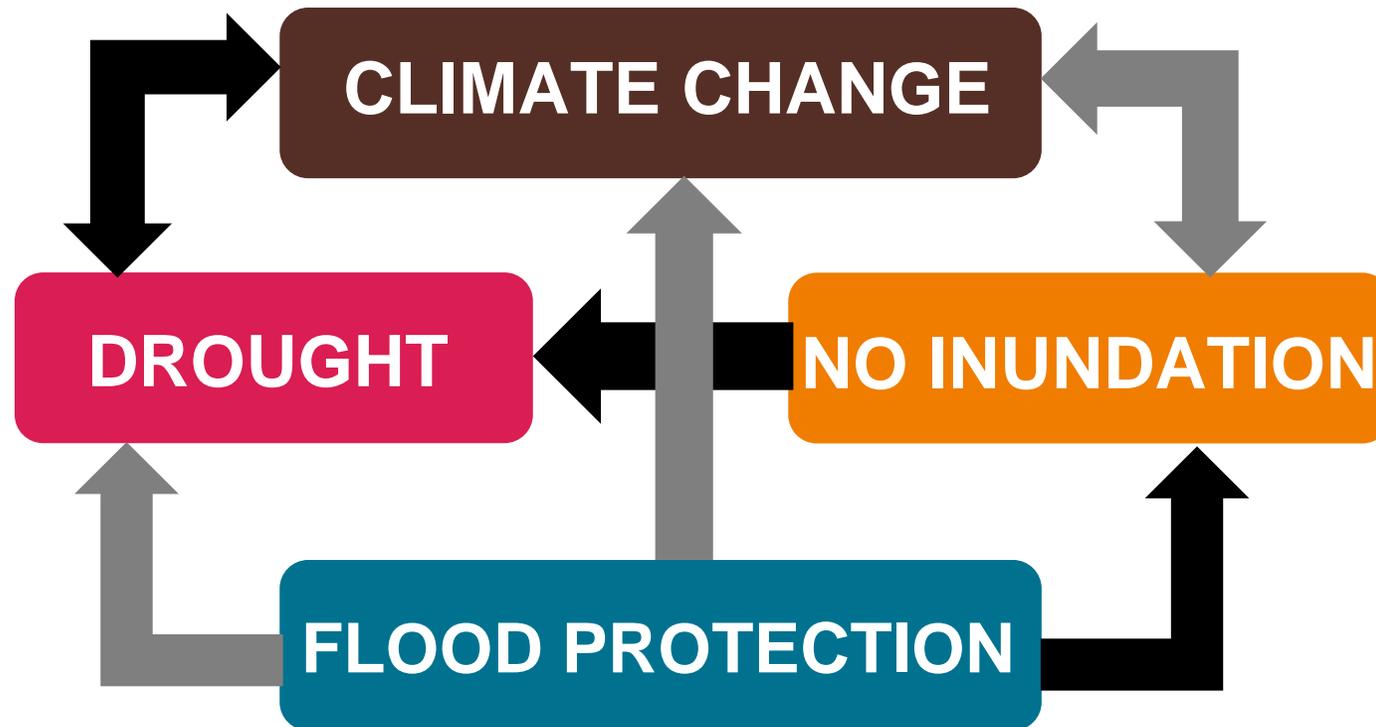


**Severe wetland loss in the Danube basin**

**Hungary in the middle of the Danube basin is in the TOP 3 in wetland loss in the world since 1700 (history)**

**Fig. 2 | Heterogeneous wetland loss across countries, peatland regions and river basins of the world. a–c.** Percentage of wetland loss since the 1700 baseline within selected countries (a), peatland-dense regions (b; see peatland

regions in Supplementary Fig. 7) and major river basins (c) (Regional summary of wetland loss).



## Floodplain restoration benefits:

- Climate adaptation
- Flood risk mitigation
- **Drought mitigation**
- Microclimate benefits
- Heatwaves mitigation
- Sustainable landuse
- Nature conservation benefits
- Ecosystem services
- Green infrastructure

# Carbon stock (+GHG balance)



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## Soil carbon stock of ecosystem (t C/ha):

Soil organic C content (SOC)  
+ biomass (BGB, AGB)

**Wetlands:  $61 \pm 9$  t C/ha<sup>2</sup>**

**Grasslands:  $56 \pm 11$  t C/ha<sup>2</sup>**

**Arable lands:  $55 \pm 11$  t C/ha<sup>2</sup>**

**Forests:  $49 \pm 13$  t C/ha<sup>2</sup>**

Significant regional differences!

## WETLANDS:

High **biomass** productivity!

Their **soil organic carbon** is the highest!

Global carbon sequestration of wetlands:

**830 Tg/year<sup>3</sup>**

**~20-25% of global soil carbon**

**~5-8% landcover of inland wetlands**

# Carbon stock (+GHG balance)



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## National Greenhouse Gas Inventory<sup>4</sup> (IPCC)

Water supply increases biomass  
production  
= carbon sequestration in wetlands' soil

**20 t C / ha / 20 year**

**BUT**

**for wetlands CO<sub>2</sub> / carbon sequestration  
calculation is not enough, can be  
misleading!**

**Because wetlands can be both sinks or  
emitters of the 3 main GHGs! (depending on  
the conditions)**

# (Carbon stock +) GHG balance



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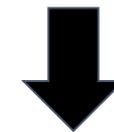
**GHG = CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O**

**Global Warming Potential<sup>5</sup>**

**CH<sub>4</sub> = 34x CO<sub>2</sub>**

**N<sub>2</sub>O = 298x CO<sub>2</sub>**

**...over 100-year time horizon**



**We had to estimate the full GHG balance with all 3 main GHGs.**

**GHG balance: CO<sub>2</sub>equiv./year/ha**

# (Carbon stock +) GHG balance



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*(70+ national and international literature)*

## GHG balance of ecosystem<sup>2</sup>

*positive: sequestration (sink)*

*negative: emission (source)*

**Forests:** 2–4 t CO<sub>2</sub>equiv./year/ha

**Grasslands:** -0.35 – +0.15 t CO<sub>2</sub>equiv./year/ha

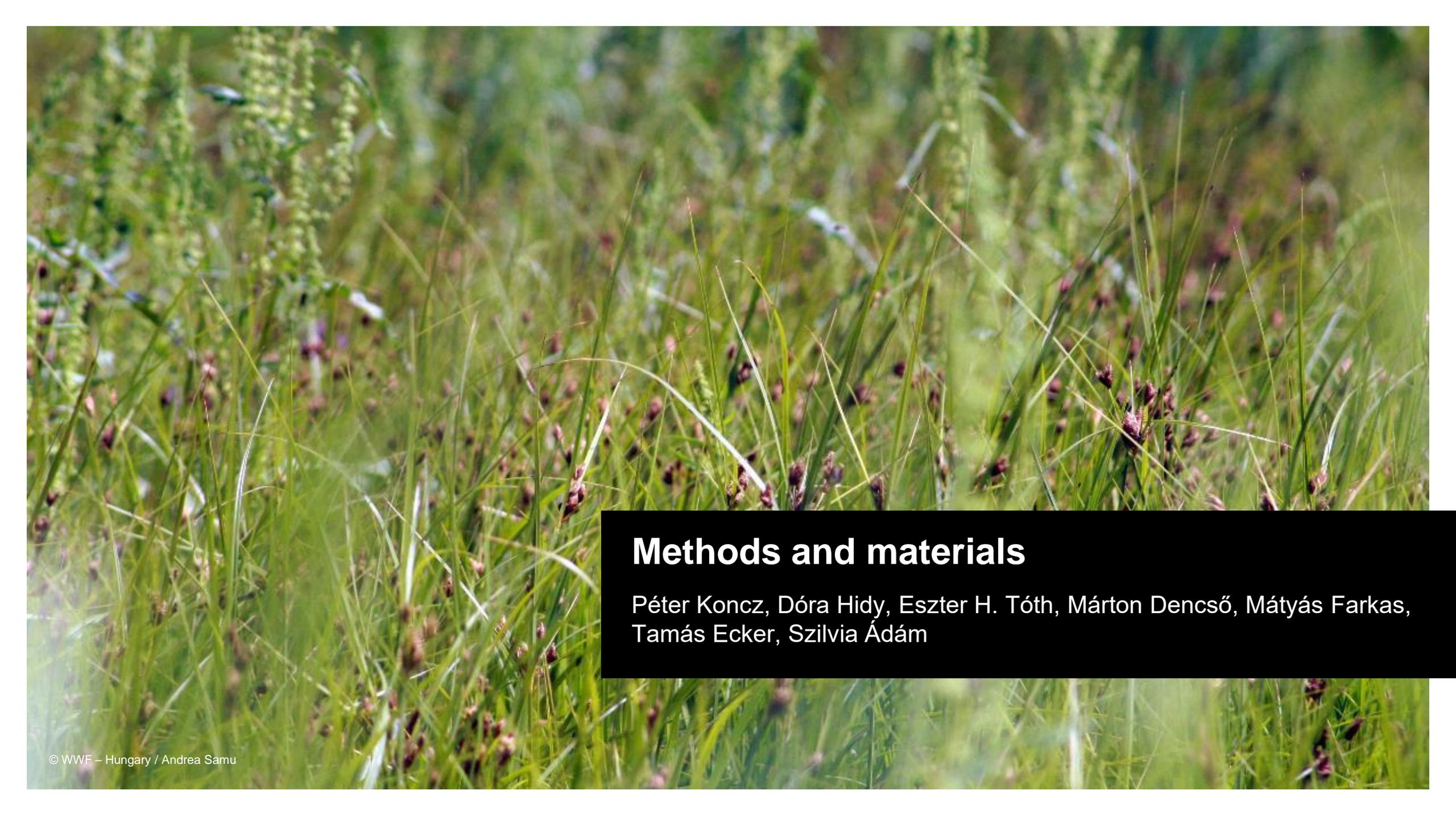
**Arable lands:** -0.7 – -4.6 t CO<sub>2</sub>equiv./year/ha

**Wetlands:** sporadic data -5.4 t ... (???)

Wetlands are very diverse,  
so their services are very variable.

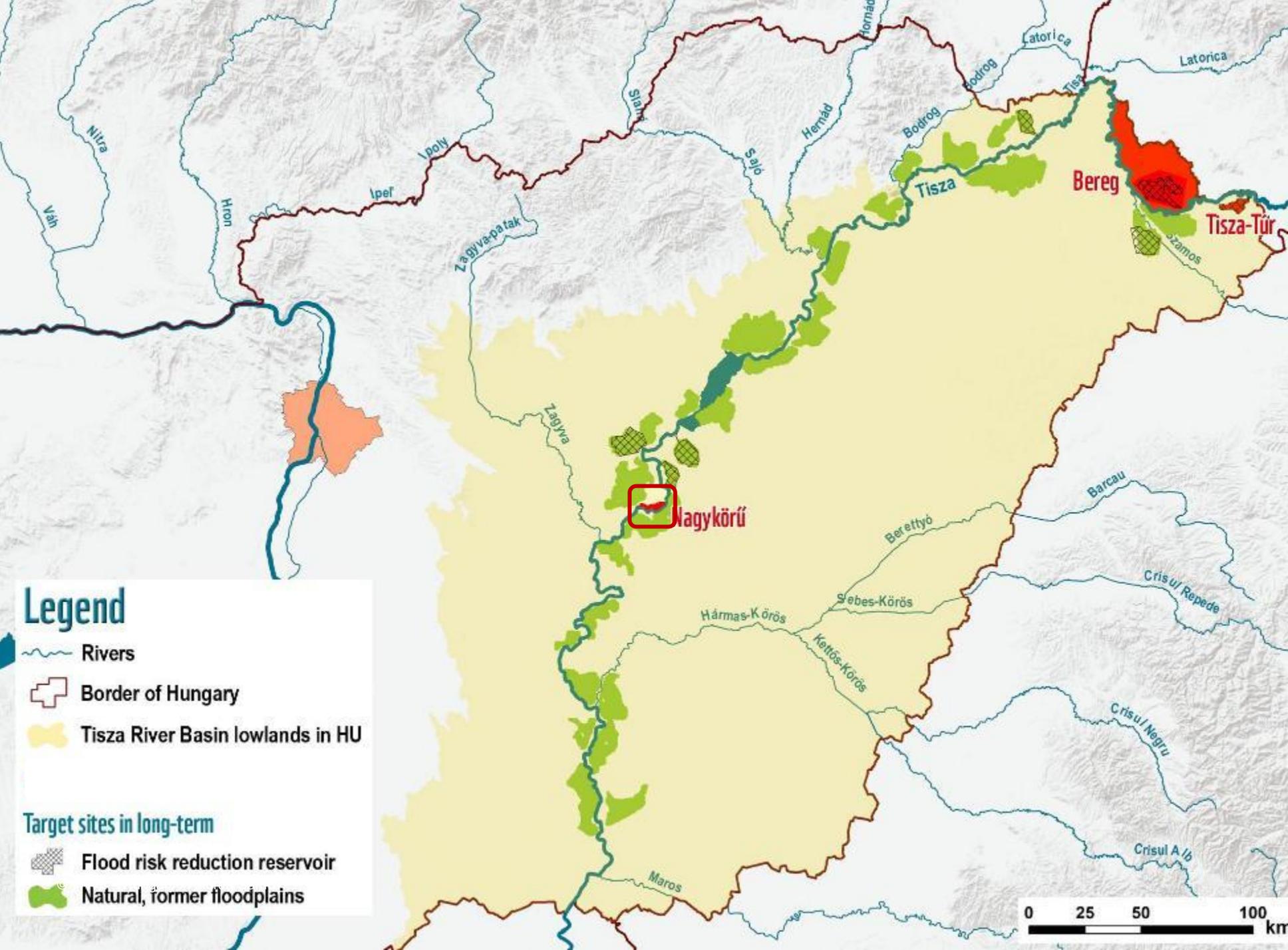
Lack of information.

Floodplain = mosaic of ecosystems.



## Methods and materials

Péter Koncz, Dóra Hidy, Eszter H. Tóth, Márton Dencső, Mátyás Farkas,  
Tamás Ecker, Szilvia Ádám



## 3 levels or scales:

1. local  
**20-30 ha**

2. regional  
**4500 ha**

3. landscape  
**150 000 ha**



Visited area: sodic grassland

Selected control pilot site (flood protected area)

G

G = Gulyagyep  
Flood  
protected site

Selected pilot site (floodplain)

T

T = Tóalja  
Active  
floodplain site

Visited area: lake Anyita

Visited area: water inlet structure

# Tóalja - active floodplain



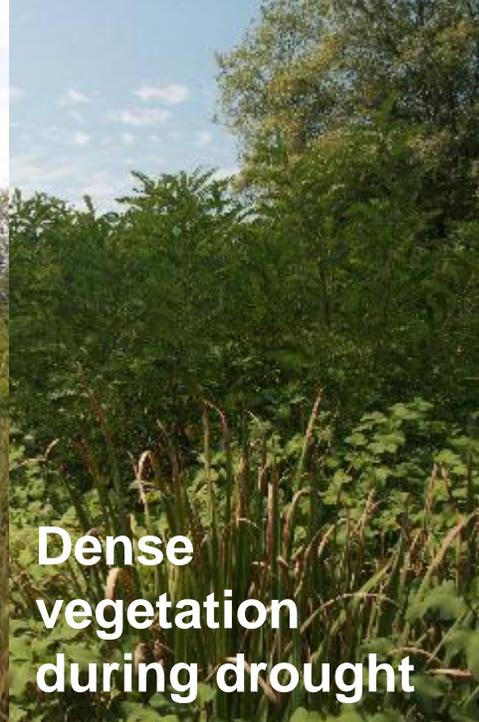
# Tóalja - active floodplain



**17 June 2022**



**Active floodplain site**



**Dense  
vegetation  
during drought**

**28 July 2022**



**Grazing animals**

**17 June 2022**



**Flood protected site**



**Dried  
vegetation  
during drought**

**28 July 2022**



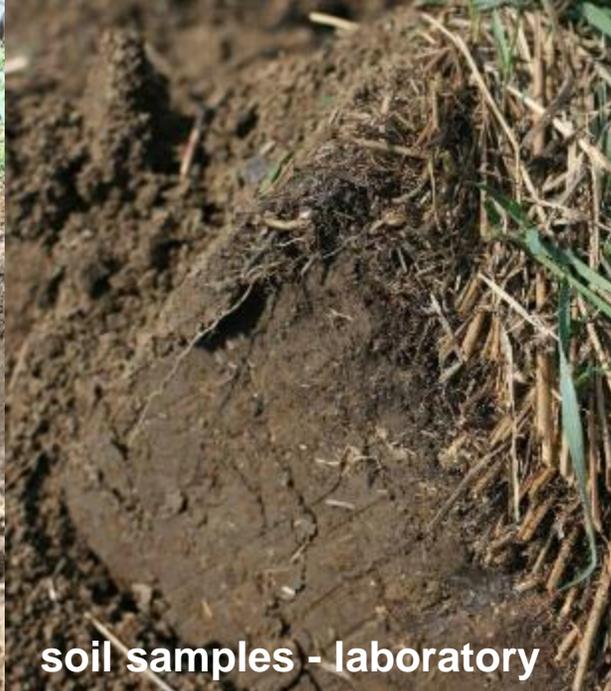
**Cracked soil due to drought**



soil temperature



soil water content



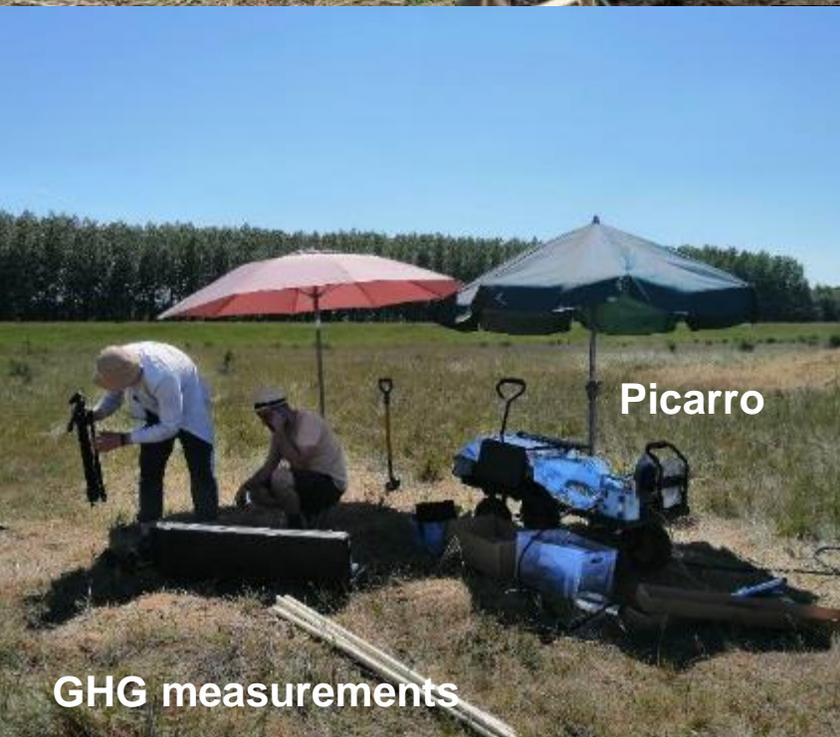
soil samples - laboratory



soil profile

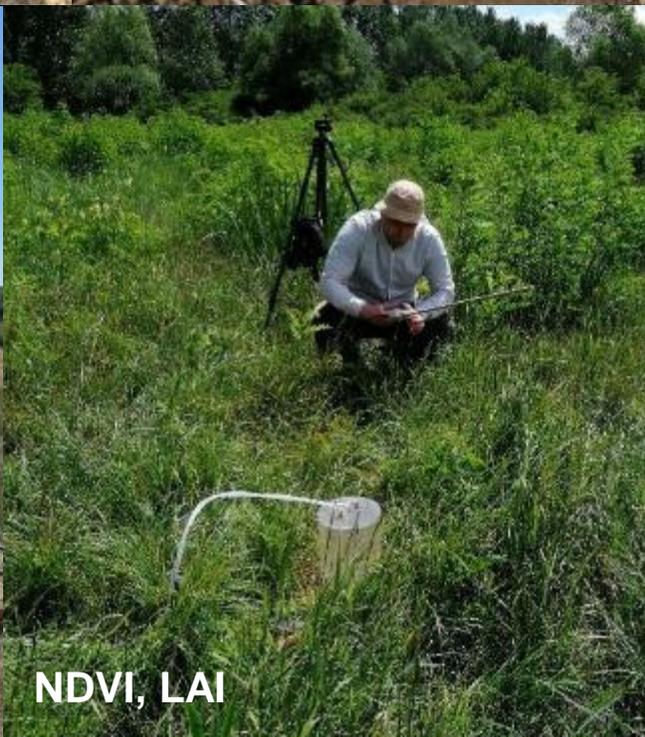


local meteorology



GHG measurements

Picarro



NDVI, LAI



Biomass



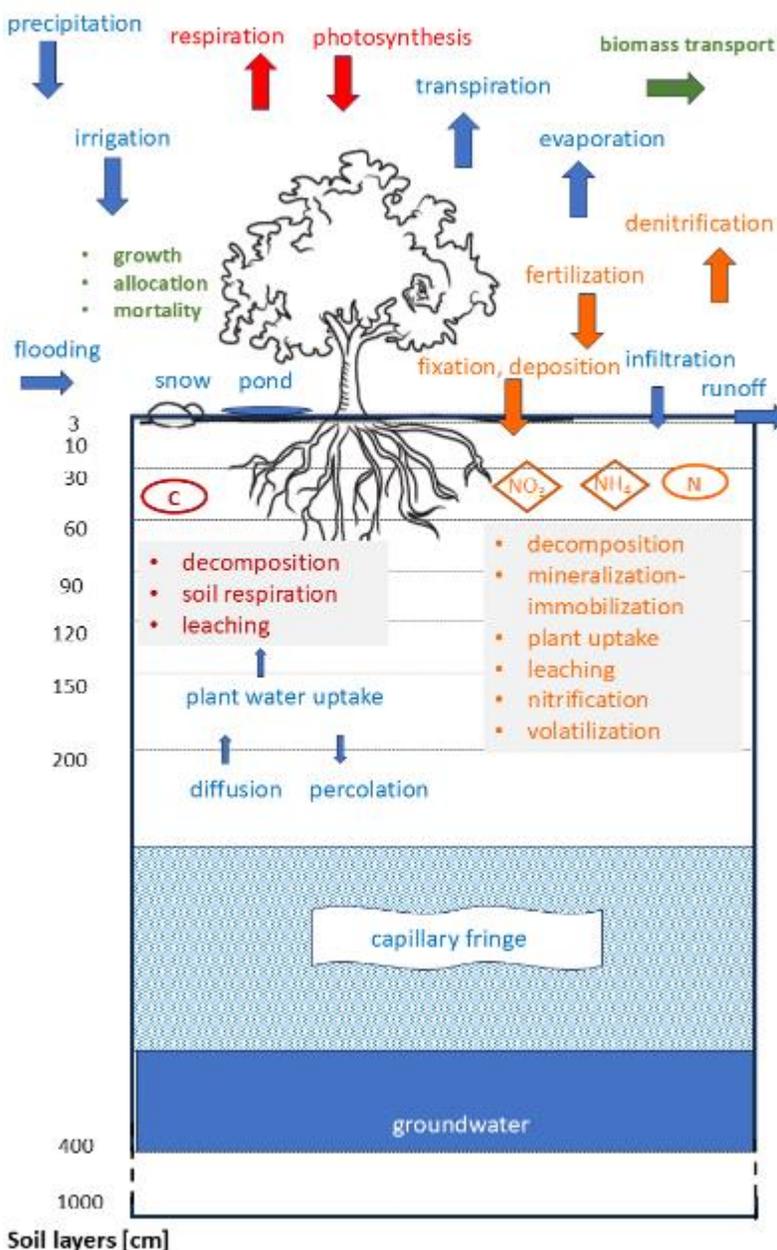
Coenology



## Results 1. Model runs – local level – 20-30 ha

Dóra Hidy, Eszter H. Tóth, Márton Dencső, Péter Koncz, Szilvia Ádám

# Model runs: Biome-BGCMuso<sup>6</sup>



1. **Past and present phase:** simulation of grazing and flooding based on historical data (2012-2023)
2. **Pre-defined scenarios:** (2024-2052)  
**2 reality +10 potential!!!**
  - Present GHG budget with or without flood at both sites?
  - Pasture or arable land?
  - Arable land (maize) with or without flood?
  - Arable land (maize) with or without fertilizers?

## Parametrization and calibration:

former project experiences for arable lands  
field measurements (SWC, TS, assimilation)

GHG measurement only for **validation!**

# Net GreenHouse Gas Balance (NGB)\* of the active floodplain site\*\*

*POSITIVE = sequestration*

*NEGATIVE = emission*

Pasture without flood is and will be GHG emitter.

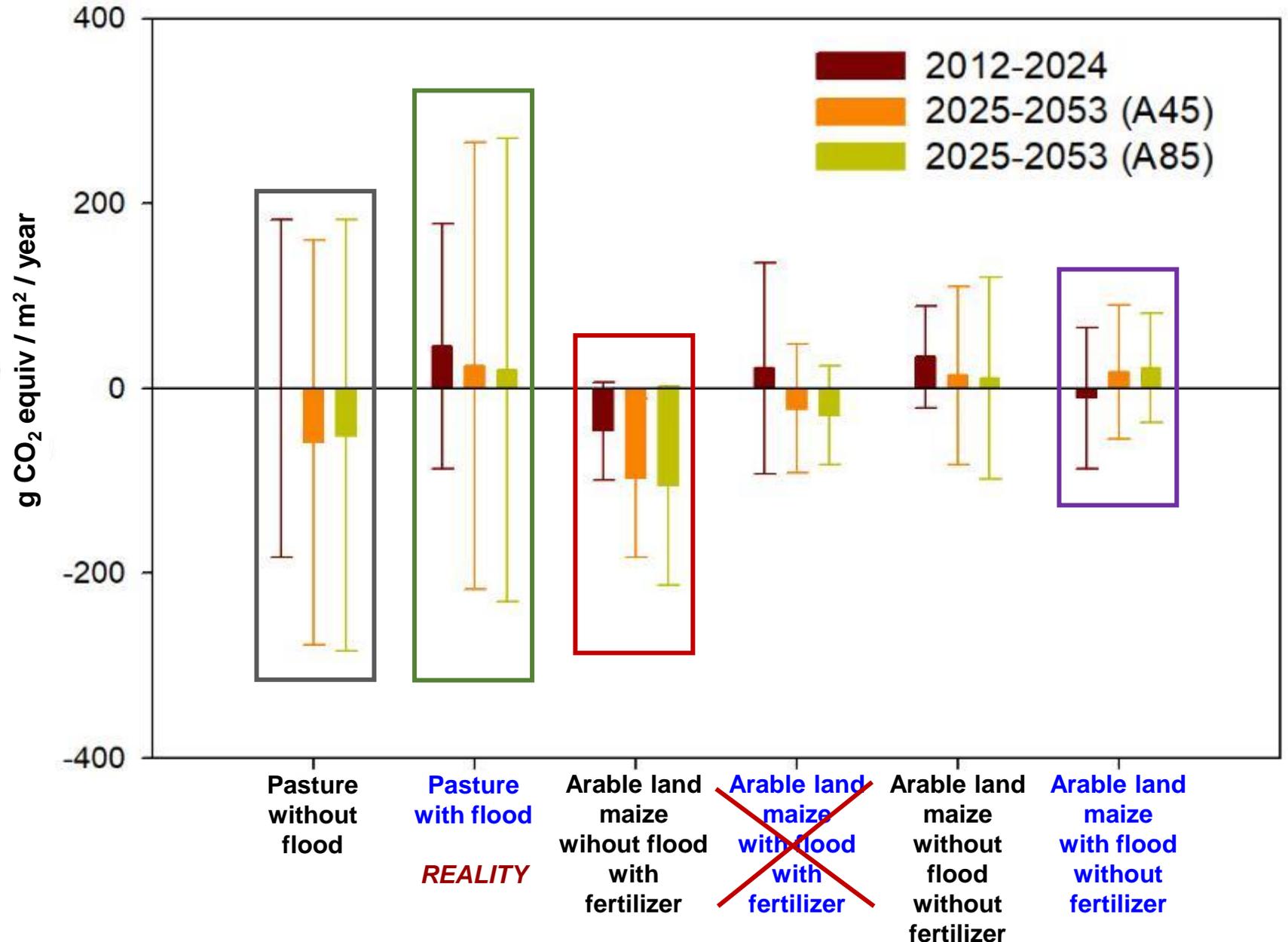
Pasture with flood is/will be the best in GHG sequestration.

From GHG point of view the intensive arable land is the worst choice.

Arable land with flood and without fertilizer could work.

\* Net amount of the 3 GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) accumulating or lost in ecosystems at the regional scale

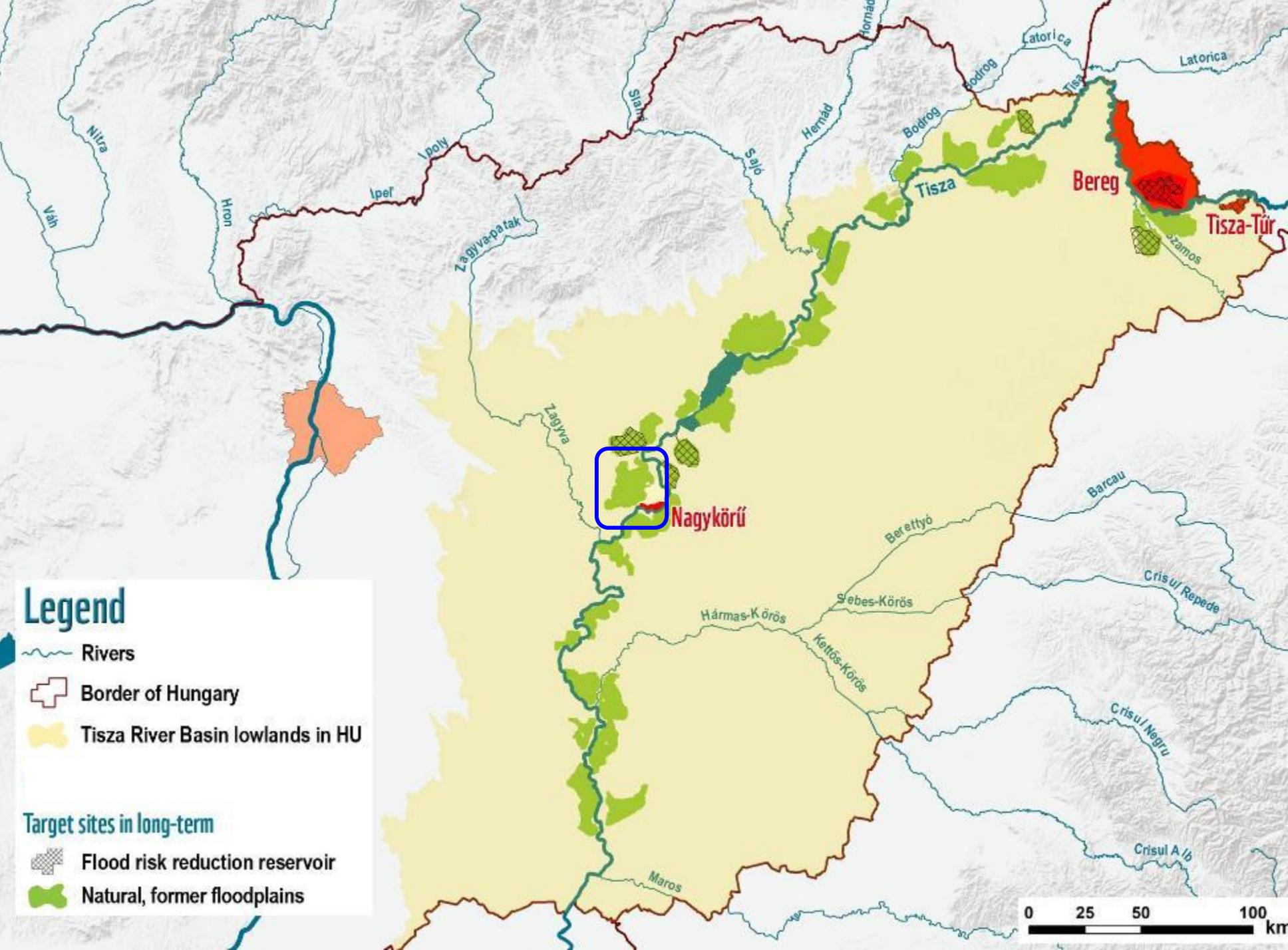
\*\* Average of the cumulative fluxes based on process oriented biogeochemical model runs - Biome-BGCMuSo, Hidy (2024)





## Results 2. – medium level – 4500 ha

Péter Koncz, Szilvia Ádám



## 3 levels or scales:

1. local  
**20-30 ha**

2. regional<sup>10,11</sup>  
**4500 ha**

3. landscape  
**150 000 ha**

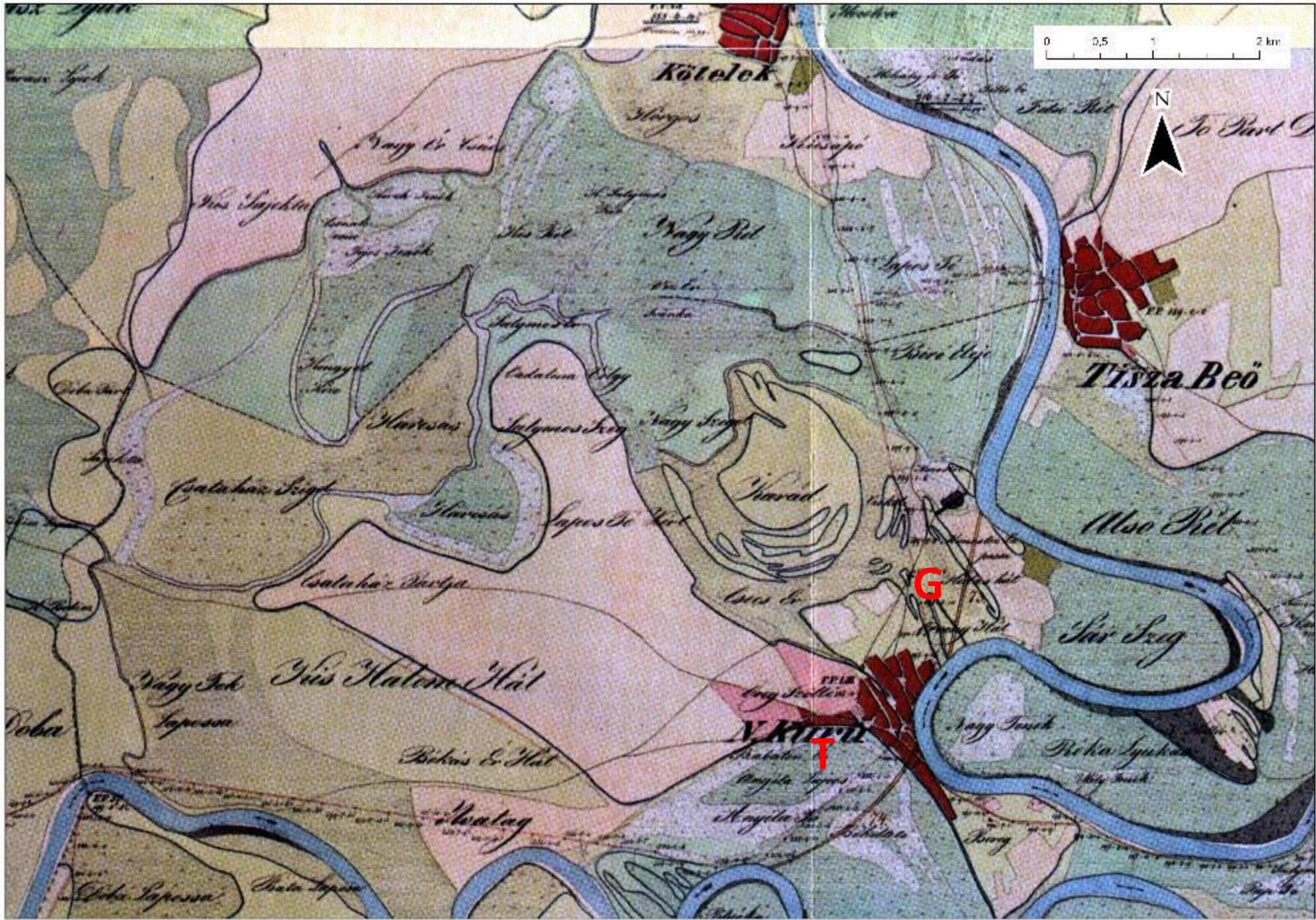
Ecosystem  
basemap  
**2016**  
(AM<sup>7</sup>)



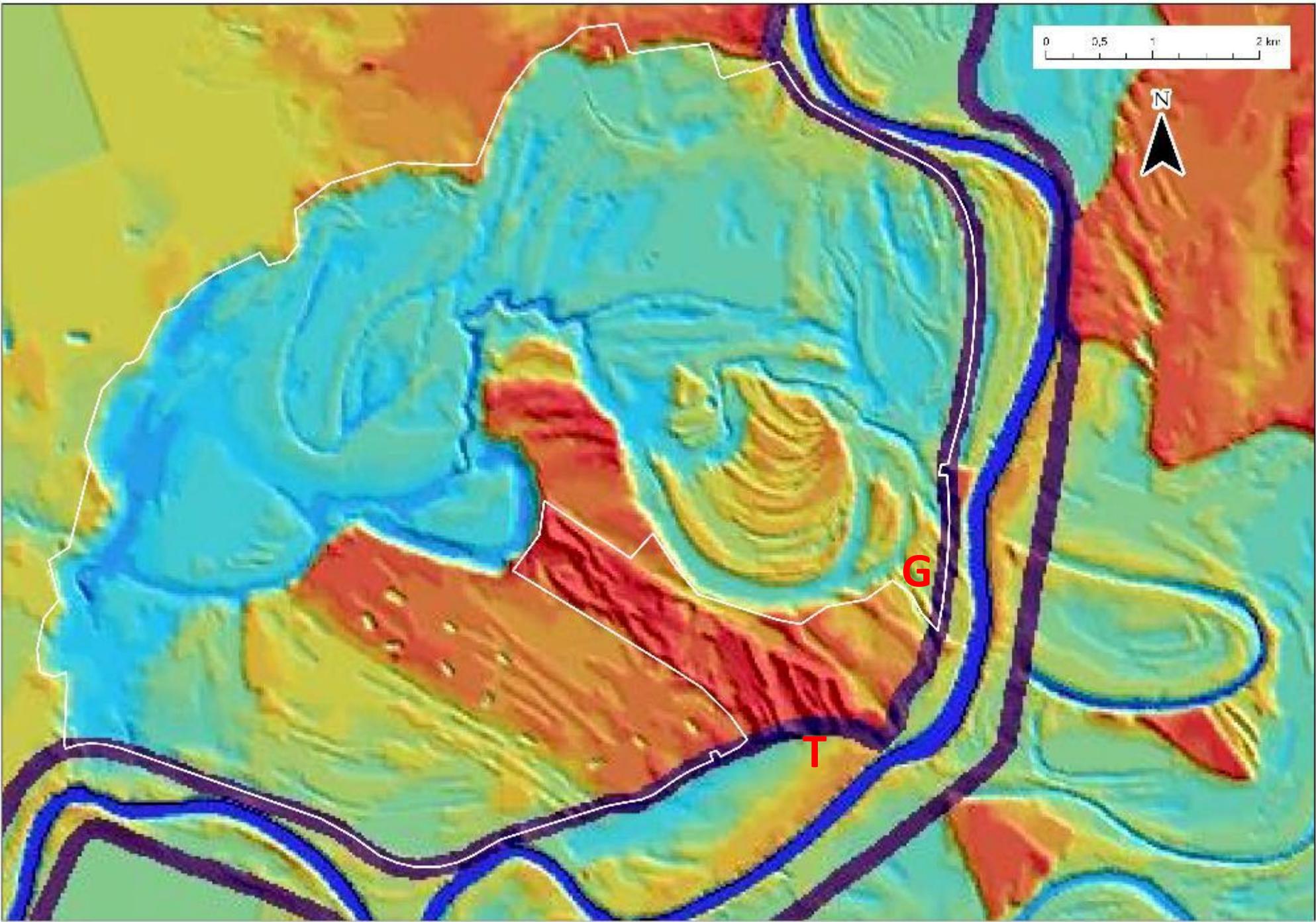
Lányi

# 1845

(Dobó István  
Muesum<sup>8</sup>)



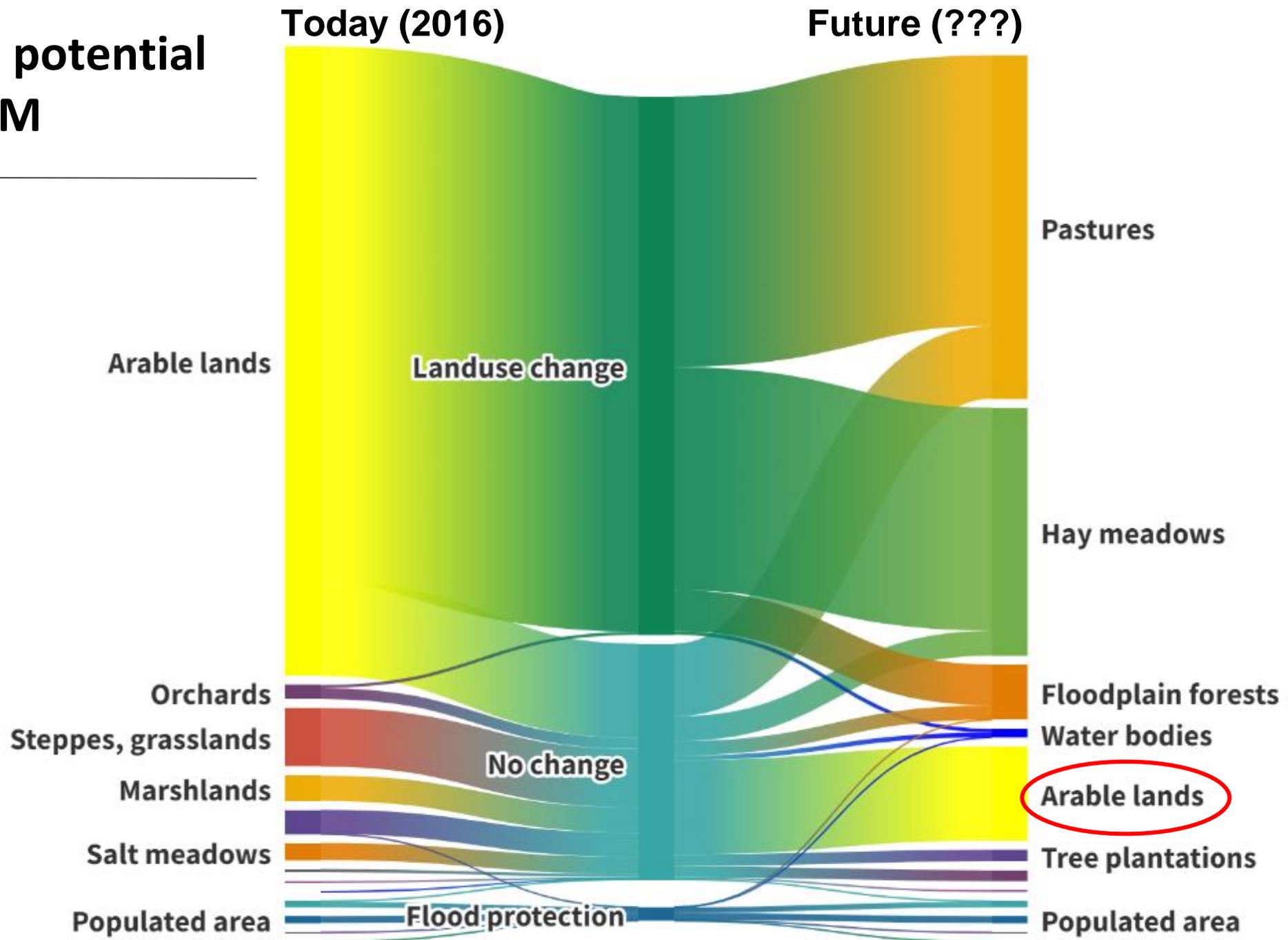
**Relief**  
(Tímár and Rácz 2001<sup>9</sup>)



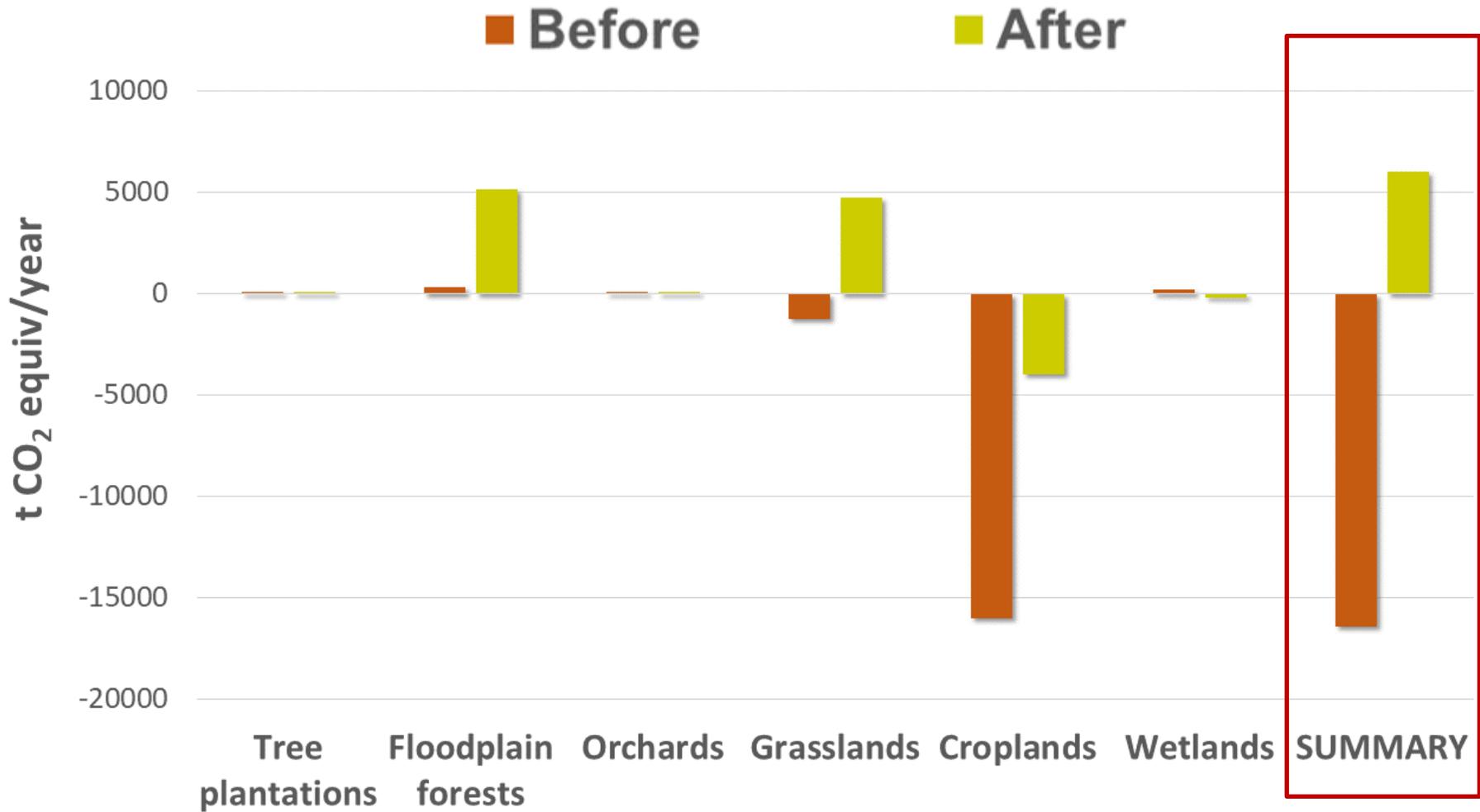
# Actual landuse and potential landuse after NWRM

Grouped by the need for landuse change, intervention

1/3 landuse may remain as usual



# GHG balance of 4500 ha floodplain before (2023) and after (2053) landuse change



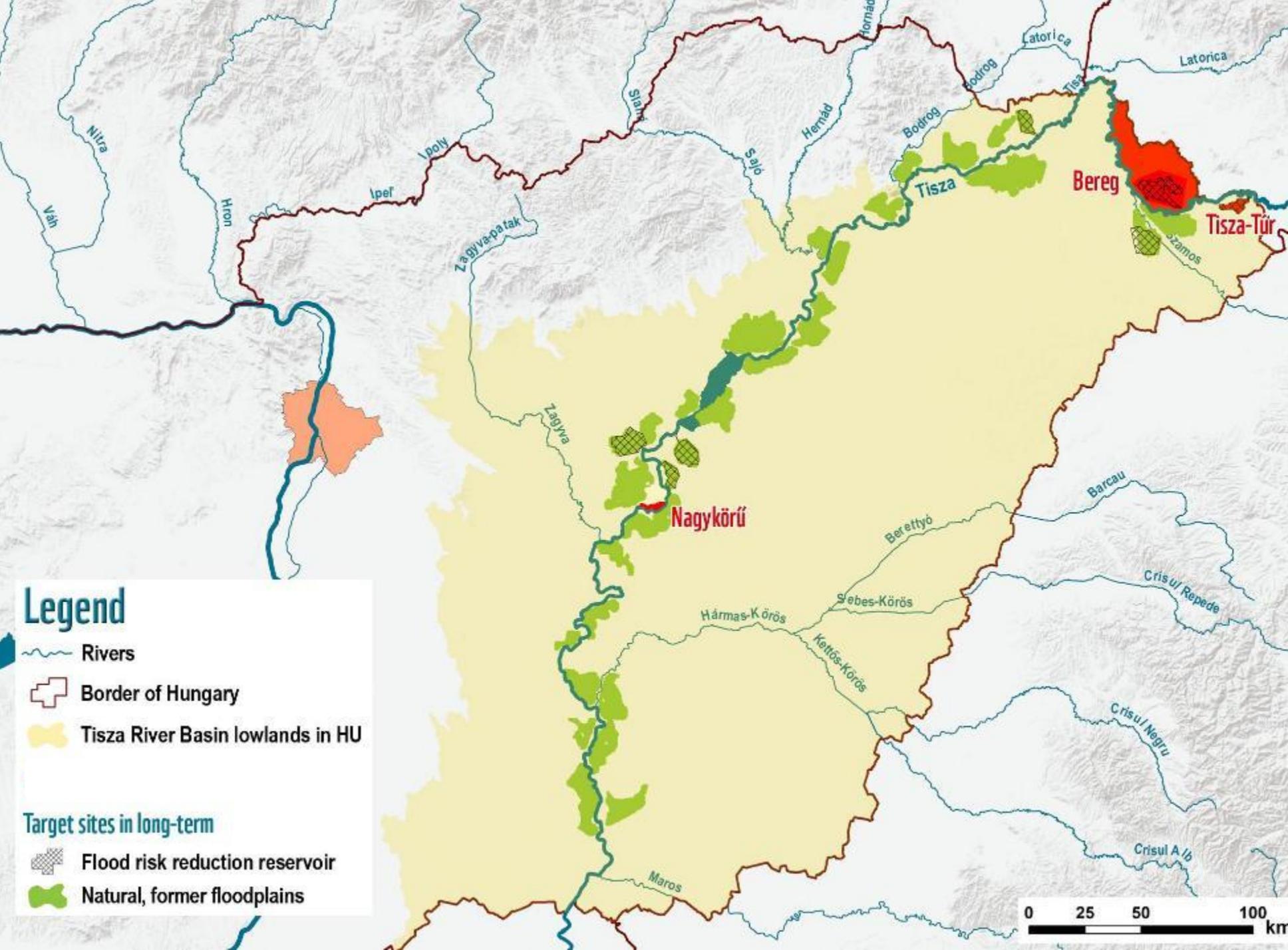
**Before the restoration (2012-2024) the ~4500 ha was severe emitter of GHG**

**After the restoration, due to periodic floods (2025-2053) the ~4500 ha would become GHG sink**



## Results 3. – landscape level – 150.000 ha

Koncz, P., Hidy, D., Ádám, Sz.



### 3 levels or scales:

1. local  
**20-30 ha**
2. regional  
**4500 ha**
3. landscape<sup>10,11</sup>  
**150 000 ha**

# Landuse conversion

Arable lands  
100% → 0 %

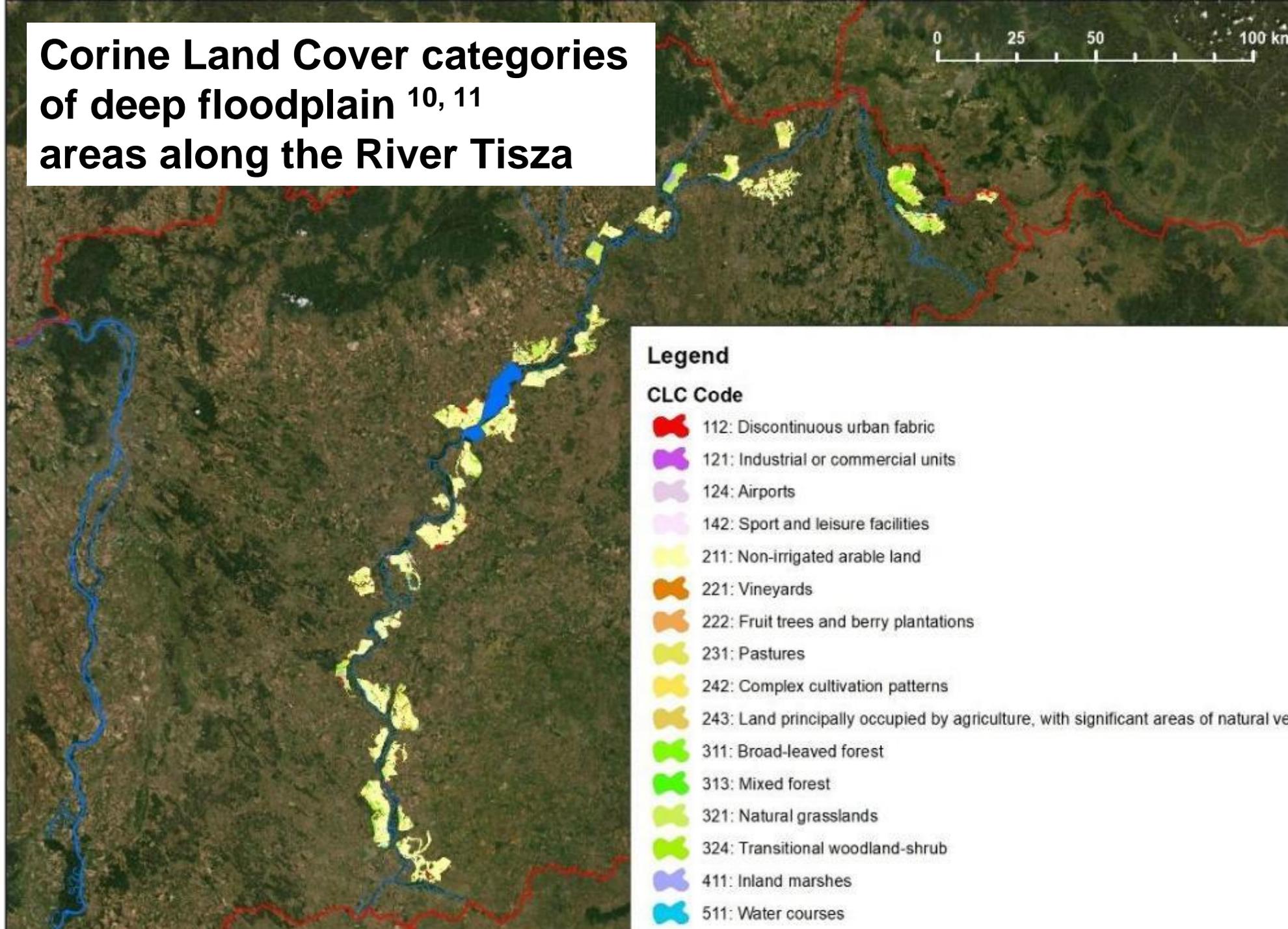
Mowed meadows  
11% → 35%

Grazed meadows  
6% → 20%

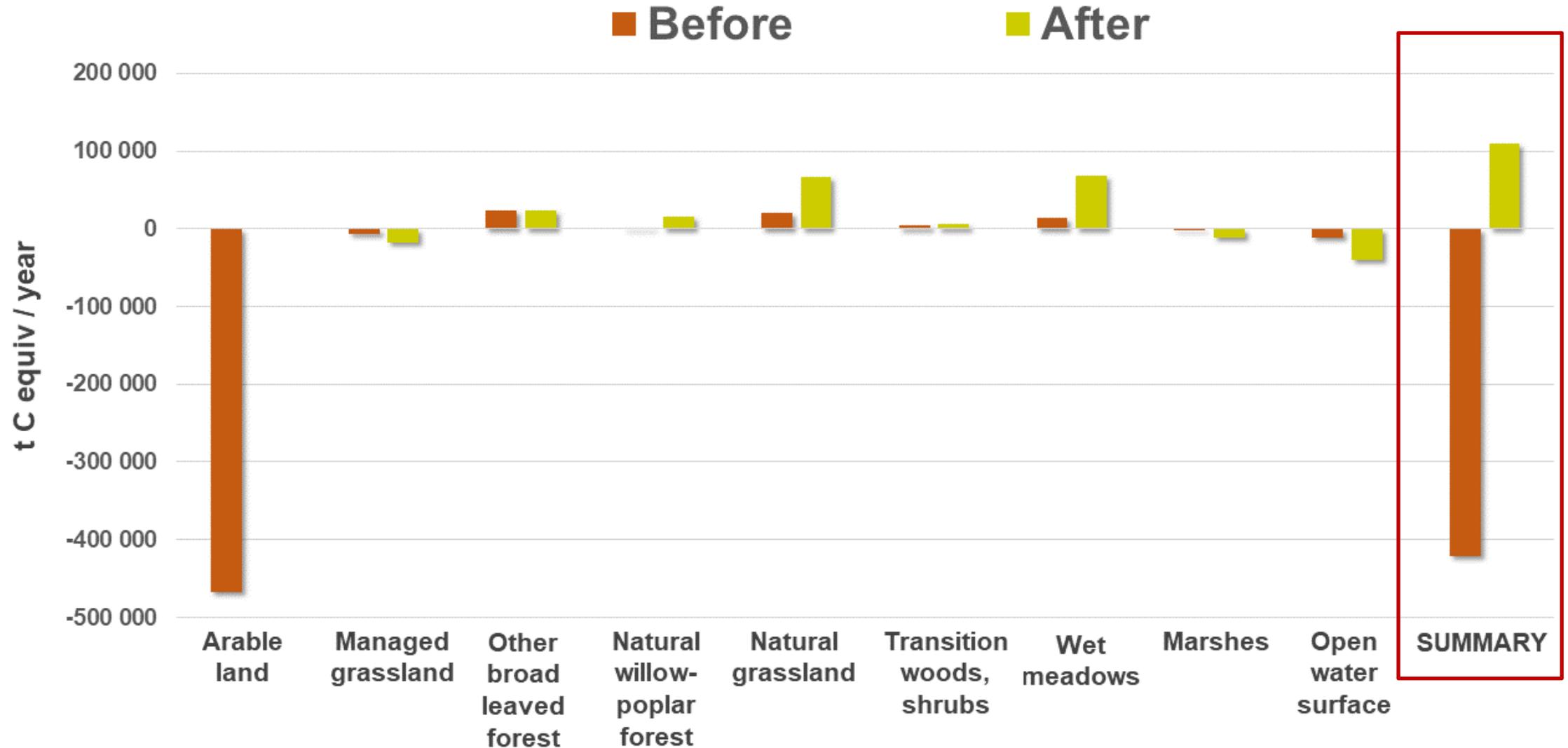
Floodplain forests  
5% → 5%

Wetlands  
0,2% → 20%

Corine Land Cover categories  
of deep floodplain<sup>10, 11</sup>  
areas along the River Tisza



# The GHG balance of deep floodplain areas (144 000 ha) along the River Tisza before and after the FUTURE landuse change





# Conclusion

1. **Periodical floods** increase the **carbon sequestration ability** due to the enhanced biomass production, which may **offset** the net methane and nitrous oxide **emission**.
2. Floodplain restoration-induced **land use change** can **transform the landscape from a net greenhouse gas emitter into a net greenhouse gas sink**.
3. **Drought** reduces the carbon sequestration potential, so the **future emission** without floods **will increase**.
4. Shifting from arable land to **sustainable land** use in floodplain areas **supports both climate and biodiversity goals**.
5. **Not all arable lands have to be converted into grasslands or wetlands**. Arable lands with periodical floods and without fertilisers may also sink carbon with acceptable yield averages.

## ***GENERAL CONCLUSION***

***Floodplain restorations,  
as a nature-based solution (NbS),  
can also be interpreted as a  
climate adaptation measure with mitigation benefits,  
which can reduce vulnerability to weather extremes  
and increase resilience.***

[Press release about the study  
and its summary in Hungarian](https://wwf.hu)  
<https://wwf.hu>

[Press release about the study  
and its summary in English](https://wwfcee.org)  
<https://wwfcee.org>

**Thank you for your  
attention!**

More information: [sadam@wwfcee.org](mailto:sadam@wwfcee.org)

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