



Growing  
**ideas**  
through  
**networks**

# UAS MONITORING OF STREAM RESTORATIONS

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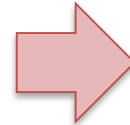
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# UAS and stream restoration monitoring



- *Dated question, but still topical...*
- High variability of approaches and methods
- Methods vary according to the aim of monitoring - hydromorphology, flood protection, water quality, hydrobiology, riparian vegetation...
- Lack of objective data sources for post-project assessment
- No standards in data acquisition and processing



## Potential for UAS

- Very high resolution and spatial accuracy
  - Level of detail adequate for fluvial geomorphology even at small streams
- Repeatability
  - Building time series of observations
- Reproducibility
  - Framework, enabling monitoring using different platforms/sensors
- Quantitative assessment
  - Stream geometry, areal and volumetric changes
- Qualitative assessment
  - Classification, spectral indices



# Protocol for UAS monitoring of stream restorations

## Key aspects of restoration success in a long-term perspective detectable from UAS

### I. Fit to the plan

- Fit of stream planform to the approved plan

### II. Magnitude of change

- Change of stream length
- Change of stream sinuosity
- Number of meander bends

### III. Sustainability of restoration

#### A. Hydromorphology

- Channel headcuts
- Bank erosion
- Fluvial accumulations

#### B. Hydrology

- Flood protection
- Stream connectivity
- Floodplain connectivity

- Eutrophication

#### C. Riparian zone

- Riparian vegetation
- Riparian shading

#### Quantitative aspects

*Change of geometric properties of the stream for the prior-, planned and post-restoration state*

#### Qualitative aspects

*Detection of elements, affecting sustainability of restorations*

# Study area

Metropolitan region of Prague  
Czech Republic

Protocol tested on 3 recently  
restored streams:

- Rokytká (ROK)
  - 1 km long stream segment
  - Restored 2014-15
- Hostavický brook (HOS)
  - 1 km long stream segment
  - Restored 2015-16
- Lipanský brook (LIP)
  - 2 km long stream segment
  - Restored 2018-19.



2014



2015



2016

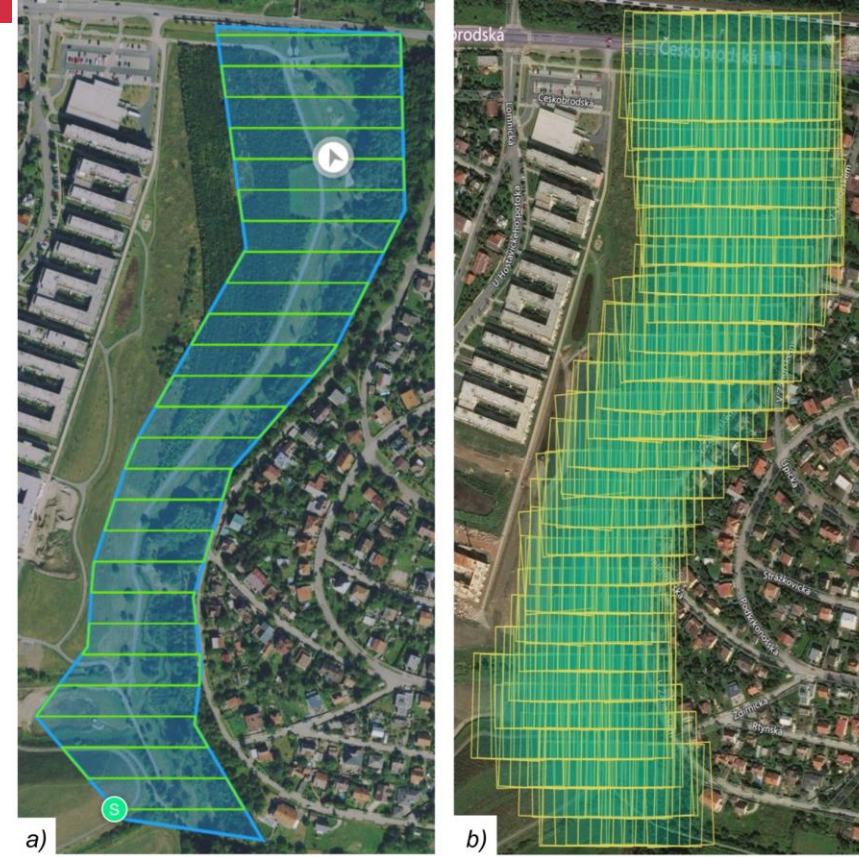


2018



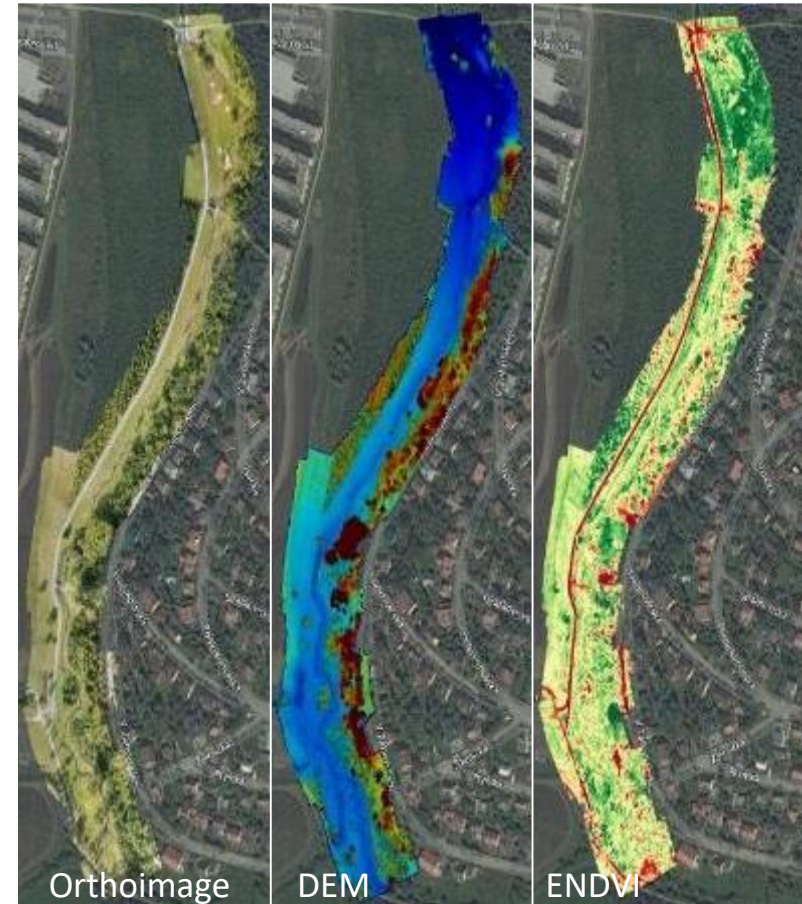
# UAS monitoring setup

- **Monitoring campaigns**
  - Start – HOS 2015/09, ROK 2016/09, LIP 2018/09
  - Monitoring of restored stream segments
  - Frequency - 4 campaigns per year + after flood events
  - Segment length 1-2 km, width 200-400 m
- **Imaging platforms**
  - DJI Inspire 1 Pro
    - Zenmuse X5 16 MPx, lens Zuiko Digital 12 mm
  - Mavic 2 Pro
    - Hasselblad L1D-20c, 20 MPx
- **Image acquisition**
  - Altitude 60 m
  - Resolution GSD = 2 cm
  - 80% frontlap/sidelap
  - Pre-planned routes
  - 200-400 images per campaign

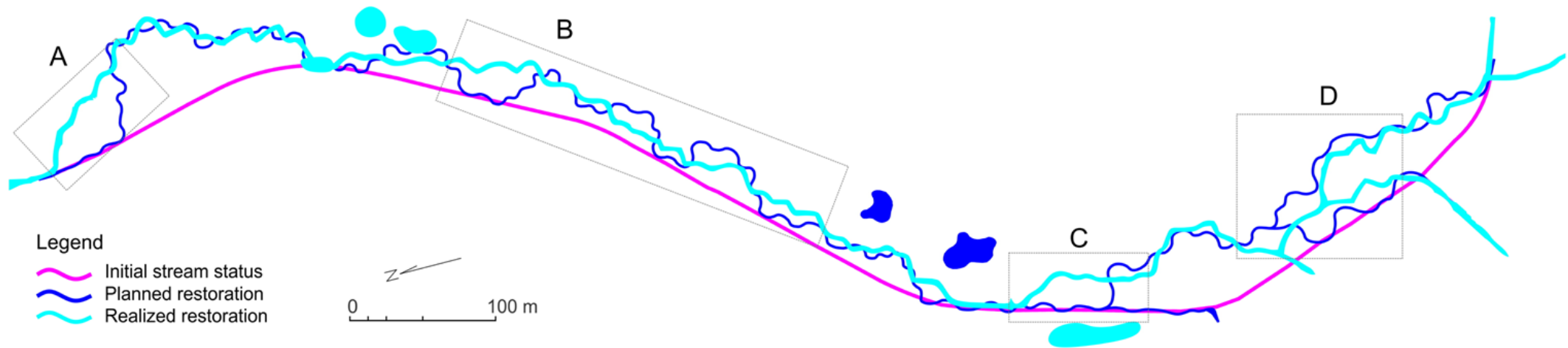


# Image processing and analysis

- **Photogrammetric processing**
  - DroneDeploy
    - After-flight quick data quality check
  - Agisoft Metashape
    - Full processing
    - GCPs
    - Orthoimage - 2cm/px
    - DSM – 5cm/px
- **Vectorization**  
(linear features)
  - Vextractor
  - SAGA GIS
- **Analysis of stream geometry**
  - River Metrics
  - QGIS
- **Image segmentation**
  - flooded area, riparian vegetation
  - Google EarthEngine
  - SAGA GIS
- **Spectral indices calculation**
  - Eutrophication
  - SAGA GIS



# Results I - Fit of the restoration to the plan

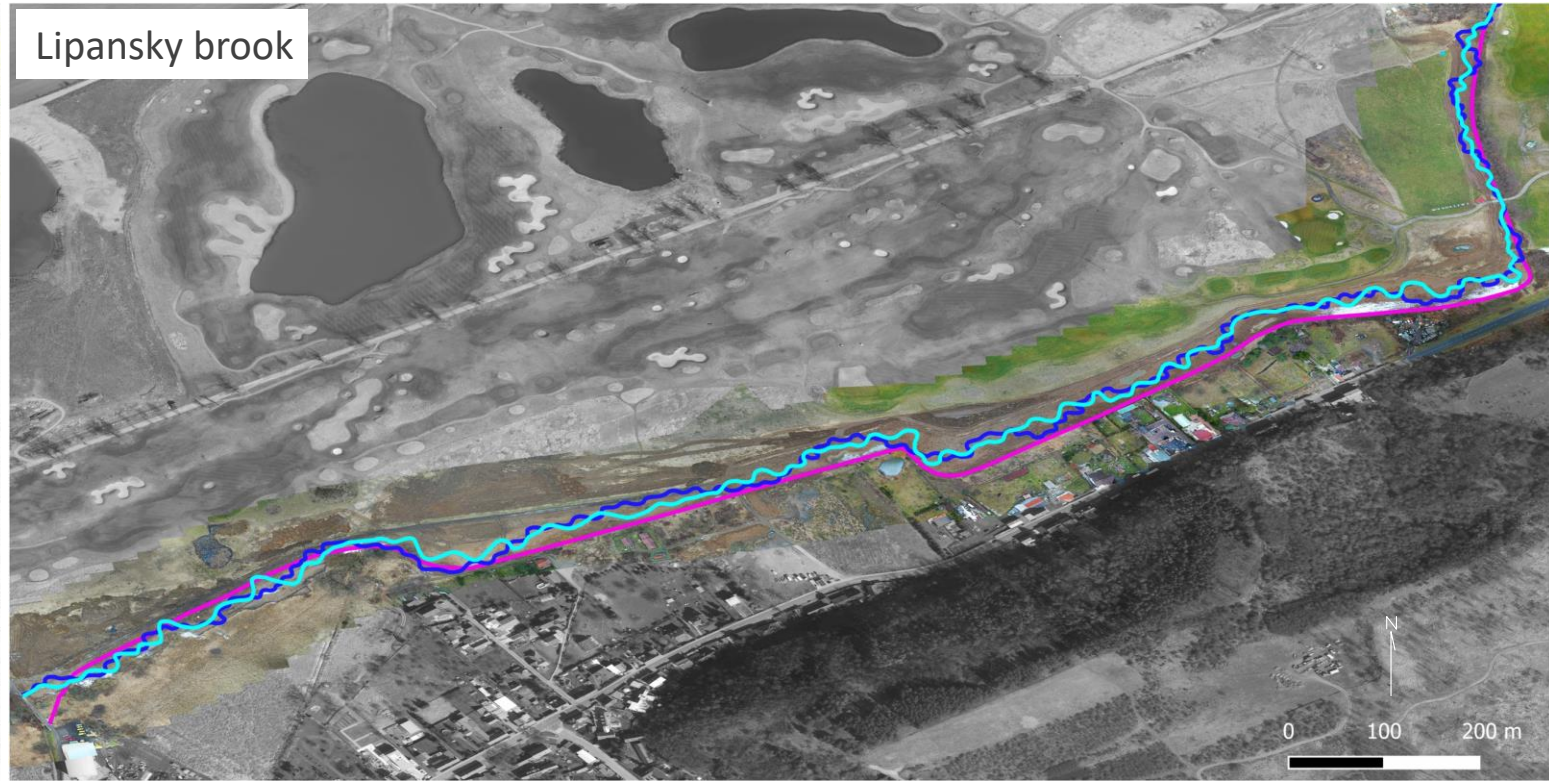
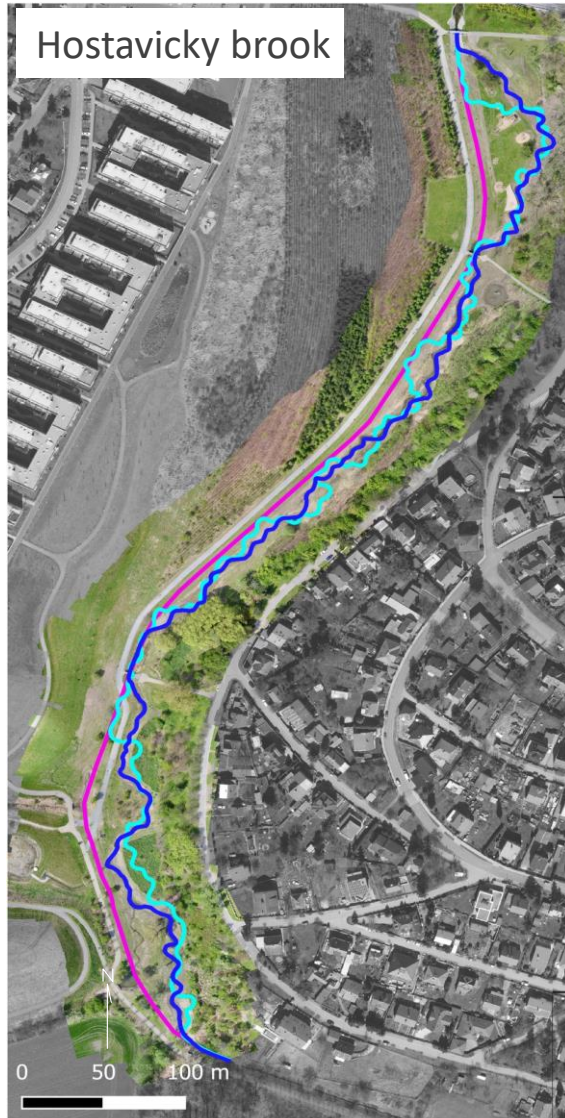


- ... Substantial improvement from the initial status
- ... Significant discrepancy of the restoration from the approved plans



# Discrepancy from the plan

- isolated or common problem?

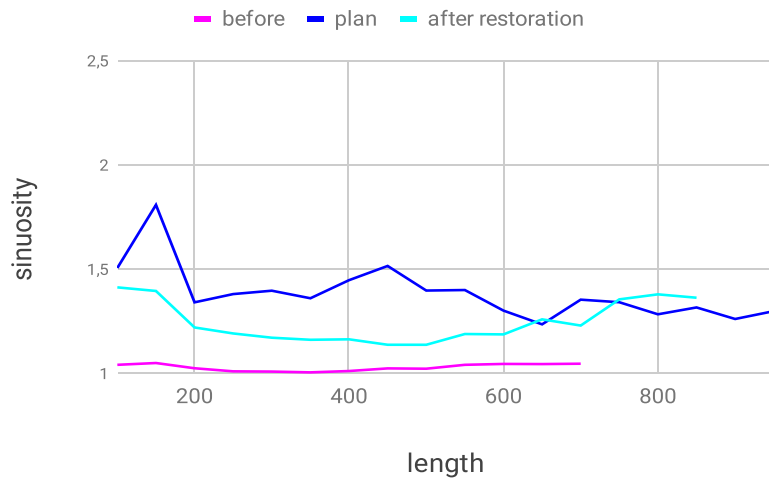


# Results II - Magnitude of change

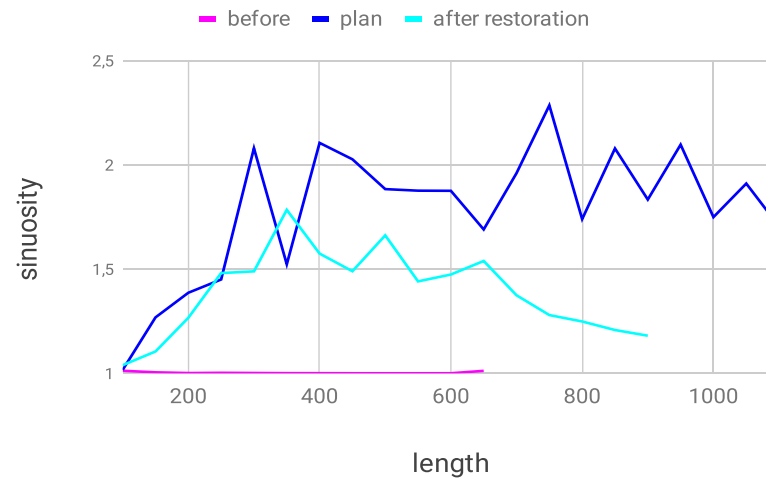
## River Metrics

- Differences in stream sinuosity
- Calculation in 50 m long segments
- HOS, ROK – almost straight prior restoration
- LIP – straight segments with large bends
- ROK – largest discrepancies between the plan and realized restoration
- LIP – closest match but lowest change in stream length

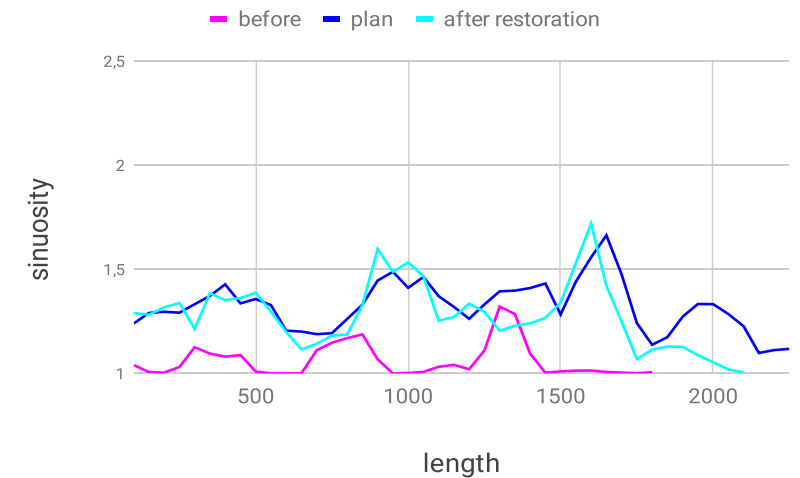
Hostavicky brook



Rokytká



Lipansky brook



# II. Magnitude of change

- **Effects of restoration**

- Stream length increased by 15-32%
- Sinuosity increased by 21-38%

- **Discrepancy from the plan**

- Stream length lower by 5 to 19%
- Sinuosity lower by 2 to 22%

	Hostavicky (HOS)		Rokytká (ROK)		Lipansky (LIP)	
	stream length [m]	mean sinuosity	stream length [m]	mean sinuosity	stream length [m]	mean sinuosity
Initial	845,0	1,028	760,7	1,003	1 917,0	1,061
Plan	1 076,0	1,385	1 246,8	1,787	2 366,0	1,321
Restored	979,0	1,246	1 004,4	1,390	2 248,0	1,278
<b>Absolute change</b>						
Restored - Initial [m]	134,0	0,218	243,7	0,387	331,0	0,218
Restored - Plan [m]	-97,0	-0,139	-242,4	-0,397	-118,0	-0,043
<b>Relative change</b>						
Restored / Initial [%]	15,9	21,2	<b>32,0</b>	<b>38,6</b>	17,3	20,5
Restored / Planned [%]	-9,0	-10,0	<b>-19,4</b>	<b>-22,2</b>	-5,0	-3,2

Can the alterations, made to the restorations affect their sustainability?



# Results III - Elements of restoration sustainability

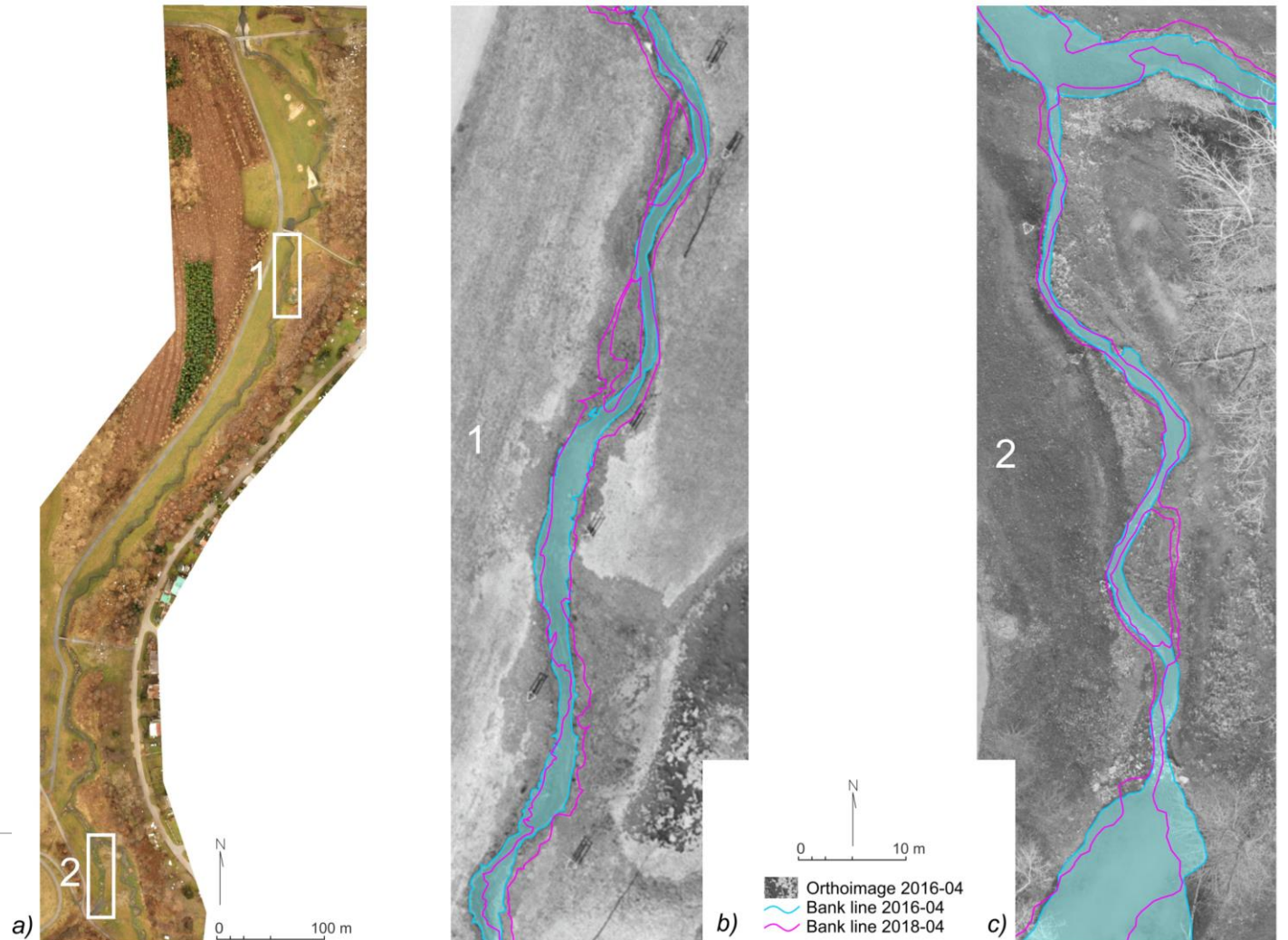
Assessed features	Indices of sustainability	UAS detected features
<b>A. Hydromorphology</b>		
• <b>Channel headcuts</b>	<i>No channel headcuts</i>	<i>Evolution of channel headcuts, stream wandering</i>
• <b>Bank erosion</b>	<i>Bank erosion corresponding to the steam type</i>	<i>Extent of bank erosion</i>
• <b>Fluvial accumulations</b>	<i>Fluvial accumulations corresponding to the steam type</i>	<i>Extent of fluvial accumulations</i>
<b>B. Hydrology</b>		
• <b>Flood protection</b>	<i>Flood protection corresponding to the plan</i>	<i>Extent of flooding</i>
• <b>Stream connectivity</b>	<i>No steps/weirs in restored segments, no flow interruptions in dry periods</i>	<i>Steps and weirs in stream segment, dry segments</i>
• <b>Floodplain connectivity</b>	<i>Unobstructed flow in the floodplain, hydrologically connected objects in riparian zone</i>	<i>Lack of direct hydrological connection, flood plain cross sections</i>
• <b>Eutrophication</b>	<i>No extensive eutrophication in stream or objects in floodplain</i>	<i>Spectral indices</i>
<b>C. Riparian vegetation</b>		
• <b>Riparian vegetation</b>	<i>Abundant and diverse riparian vegetation</i>	<i>Extent and diversity of riparian vegetation</i>
• <b>Riparian shading</b>	<i>Efficient riparian shading</i>	<i>Extent of stream shading per segment</i>

Selected examples

# Hydromorphology - Channel headcuts

- **Hostavický brook**

- Initiation of headcuts after minor peak flows
- Two segments with continuous stream wandering
- Small headcuts inside the riparian zone
- Minor impact
- No extensive bank erosion
- No extensive fluvial accumulations

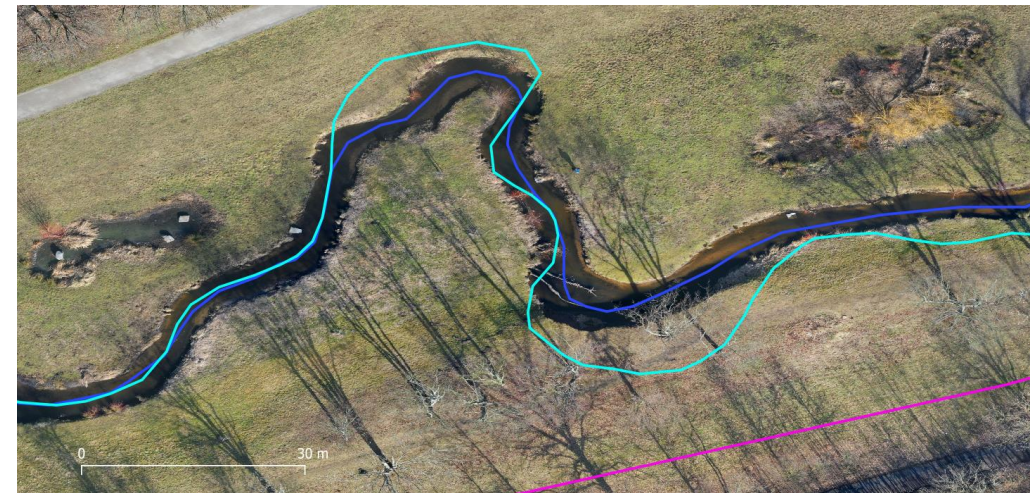


# Hydromorphology

## - Bank erosion

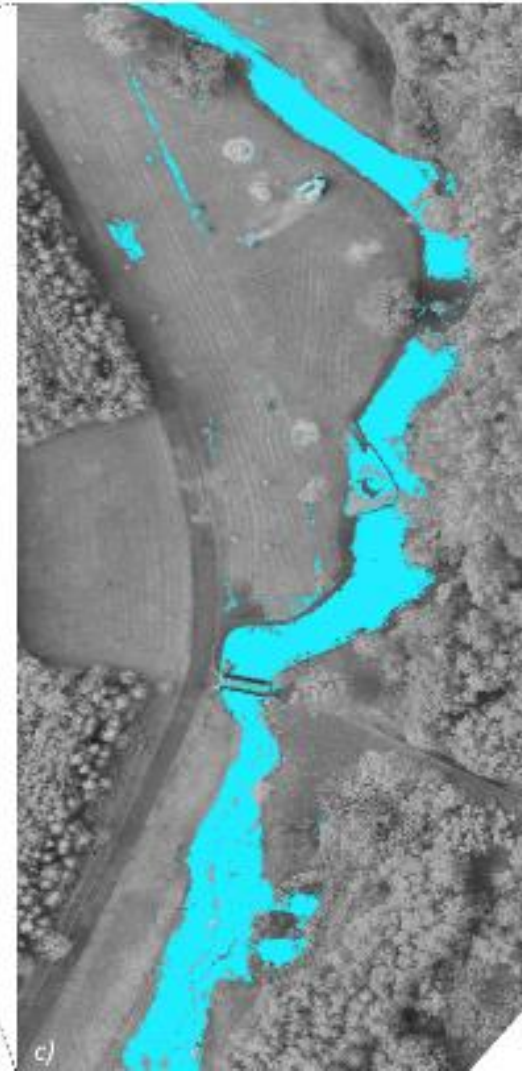
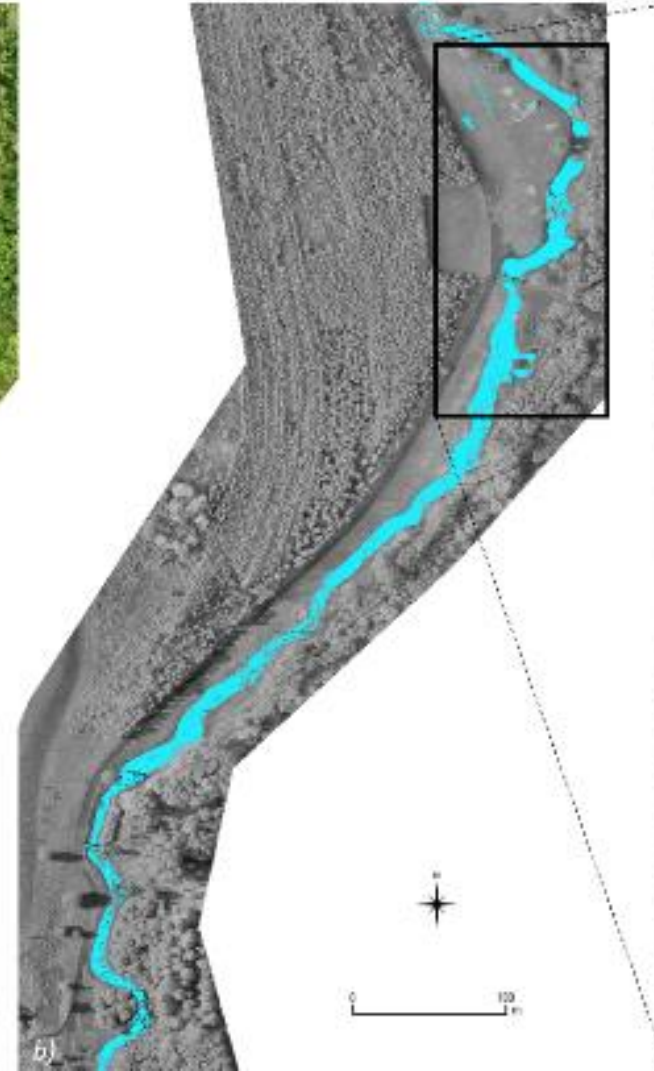
- **Rokytká brook**

- Extensive bank erosion
- Erosion initiated in meander, built with different parameters than planned
- Unstabilized bank
- Continuous cutbank
- No substantial flood events
- Rapid progress
- 2 years
  - 2,4 m height
  - 2,5 meters depth
  - 8 meters width



# Hydrology - Flood protection

- Finding the balance between the needs of flood protection in urban area and stream restoration
  - Detection of flood spill during a summer storm flood
  - Hostavický brook
    - 2018-06-30
    - Approx 5 year flood
  - Google EarthEngine Random Forests classification
- Flood spill is not constrained by artificial barriers or dikes
- Flood spill not exceeding the riparian zone



# Hydrology - Eutrophication

## Urban streams

- Extensive pollution by nutrients (N, P)
- Extensive water abstraction
- Improperly set designed low flow values (environmental flow)
- Improper design of restoration elements

## In-stream eutrophication

- Extensive supply of nutrients
- Water abstraction, extreme low flows

## Eutrophication in ponds and cut-off meanders

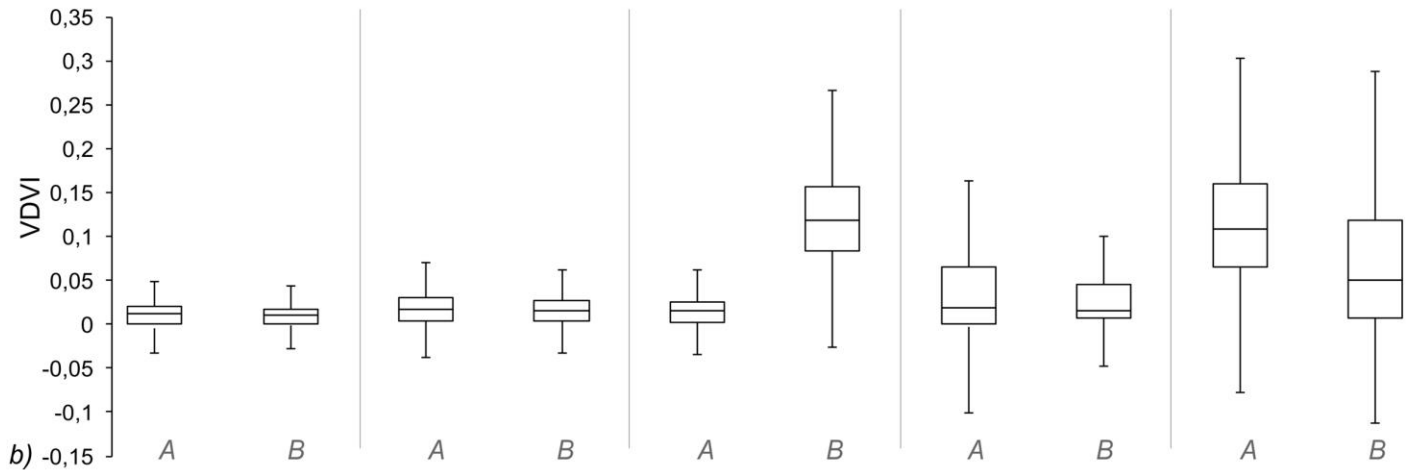
- Insufficient drainage



# Detection of eutrophication



a)



b)

## VDVI index

Testing of sensitivity of different spectral indices, applicable on RGB imagery

$$VDVI = (2 \times G - R - B) / (2 \times G + R + B)$$

*VDVI index calculated under the mask of ponds – Correctly reflecting intensity of eutrophication*

*- Quantitative measure of the dynamics of eutrophication processes*

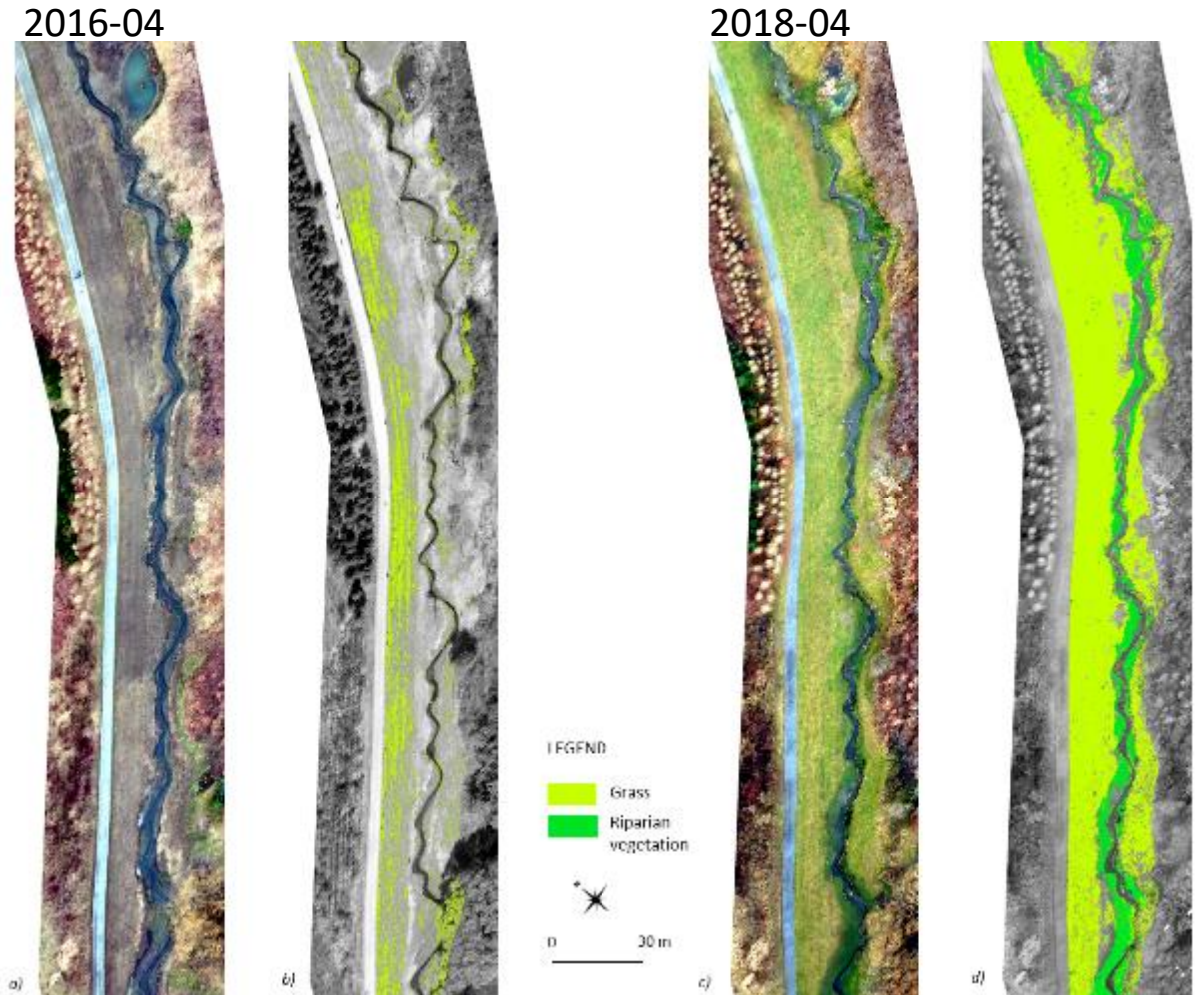
**Hostavický brook**

eutrophication in newly built ponds



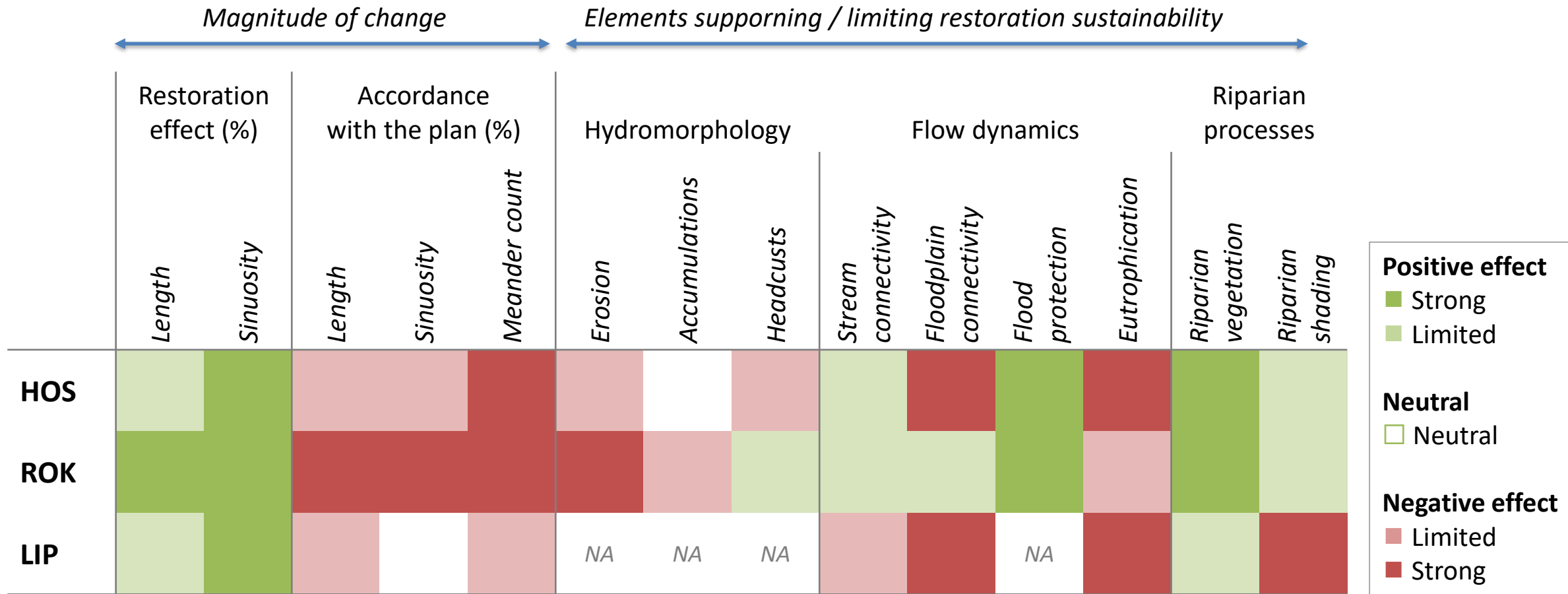
# Riparian vegetation

- Vegetation succession
- Bank stabilization
- Stream habitat development
  - Extent of grassing
  - Diversity of riparian vegetation
- Google EarthEngine Random Forests classification under mask of riparian zone
- ... same technique used for detection of riparian shading



# Results

Regardless the selected threshold for classification, assessment should be type specific...



# Conclusions

Back to the initial question:

- Is anyone monitoring?
- If not, UAS now provide reliable and affordable tool
- The proposed protocol enables to identify critical aspects of restoration success / failures
- Analysis on three streams proved systematic discrepancies between realized and planned restorations
- The detected extent of deviations deteriorates the effect of restorations
- Scope of changes limits sustainability of restorations
- Similar or different experience? Let's cooperate 😊





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# THANK YOU FOR YOUR ATTENTION!

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