Unmanned aircraft for detection and monitoring of invasive plant species

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Why plant invasions?

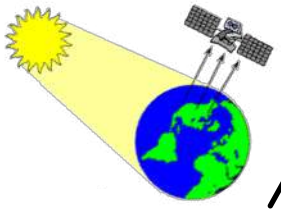
- threat to biodiversity, ecosystem functioning, traditional landscapes
- impact grows despite the worldwide efforts to control and eradicate
- once fully established - hard to permanently eliminate

fast and precise monitoring crucial

Why remote sensing?

- improving early detection of invading plants
- fast, repeatable and efficient computer-assisted methods of timely monitoring
- reducing the costs of field campaigns → more efficient and less expensive management and eradication
- information on spatial structure of invasions

Which data are available?



long time series

satellite

Landsat (30m), Sentinel

FREE (10m)

costly

VHR

- optimal timing of the campaign (phenology)
- targeted monitoring
- DSM as a by-product

flexible

UAV

RGB-NIR

long time series

aerial

MSS

color

PAN

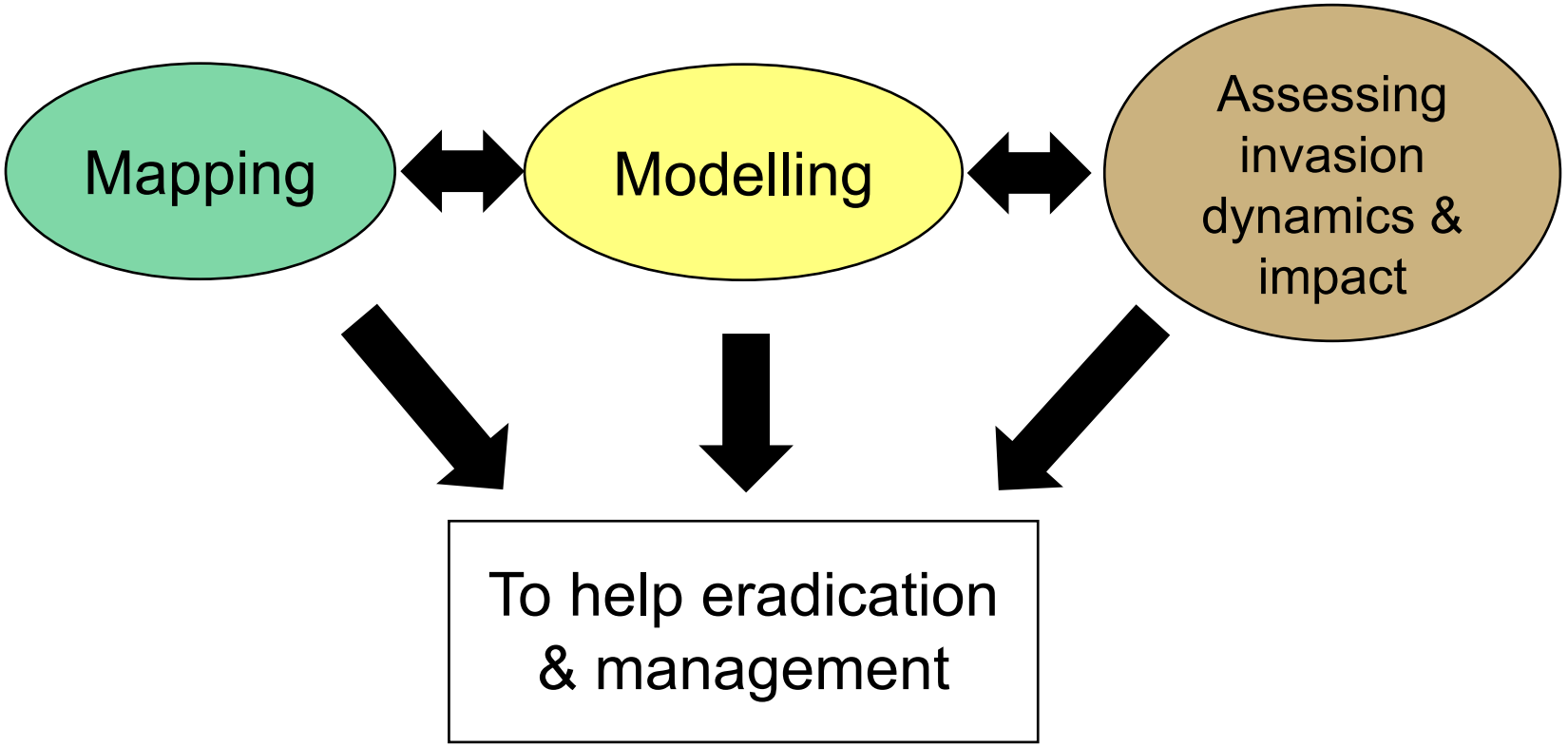
(historical)

- not standardized
- complex
- constrains

spectral

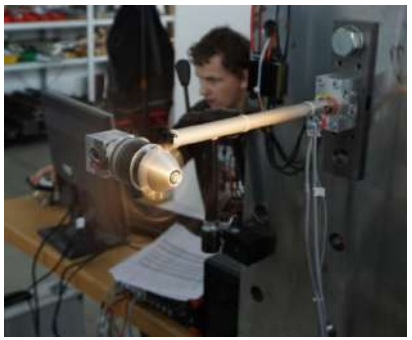
spatial resolution

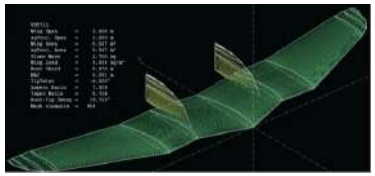
How can we use RS to tackle invasions?

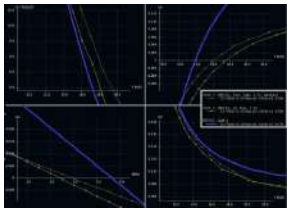


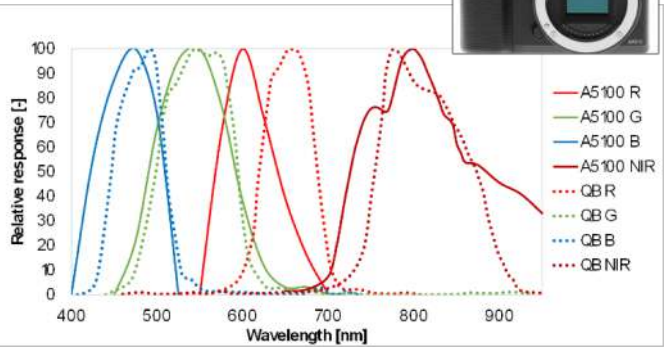
What unmanned aircraft?

Our goal – inexpensive approach for nature conservation



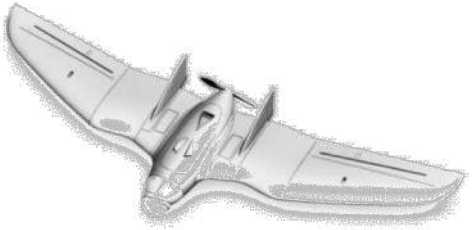


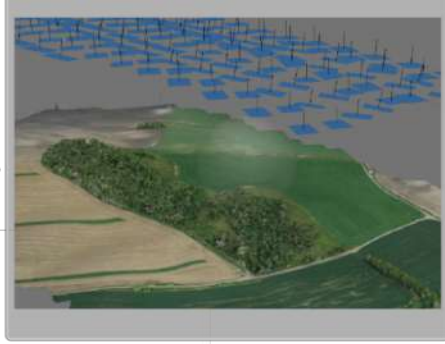


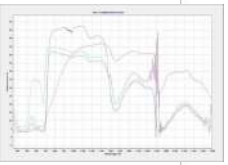


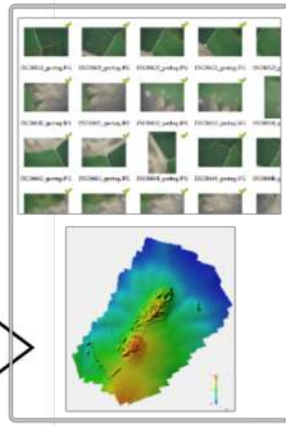
	VUT 720	VUT 712	VUT 713
Span	2.6 m	2.1 m	2.0m
Length	1.3 m	0.9 m	0.7m
m_{TOW}	2.2 kg	3.1 kg	3kg
v_C	15 m/s	17 m/s	18m/s
Endurance	1 hr	0.9 hr	0.8hr
Power	360 W	800 W	600 W
Payload	0.3 kg	0.8 kg	0.9 kg
Autopilot	APM2.5+ autopilot	Pixhawk autopilot	Pixhawk autopilot
Camera	1x Canon S100+ 1x GoPro	2x Canon S100 stabilized	2x Sony A5100 + E20/2.8
Based on	Multiplex Cularis	SkyWalker X8	RVJET

Camera setup	Stabilization	Georeferencing	Triggering	Comments
2x Canon S100 (VIS + NIR)	External mechanical	Internal GPS / Precise shutter time	Intervalometer ~0.5Hz (CHDK scripting)	Light solution, can be customized by CHDK, prone to dust
2x Sony A5100 (VIS+NIR)	No need	Autopilot DGPS – trigger log	Distance based – from autopilot system	Sensor size, fixed lens, stabilization not needed, better precision
Sony A6000 (VIS) Sony A5100 (NIR)	No need	Autopilot DGPS – trigger log	Distance based – from autopilot system	Sensor size, fixed lens, X-contact synchro, best orthomosaic









UAV flight

GPS Data processing & geotagging

DSM and Orthoimage (SfM approach)

Delineation of the area of interest

GCPs collected in the field

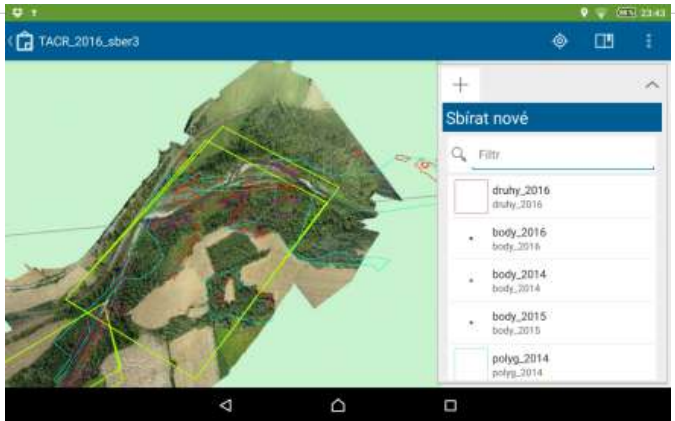
Signature creation

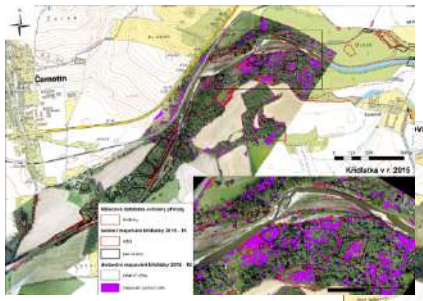
Classification

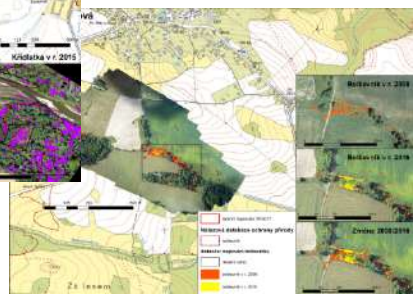
Ground truth data

Accuracy

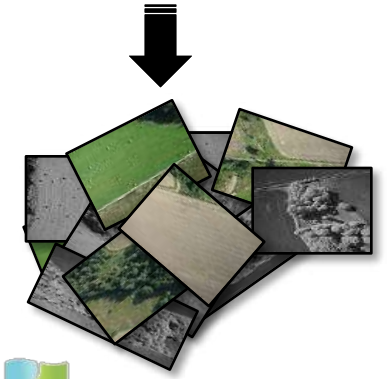
Map of the invasive species



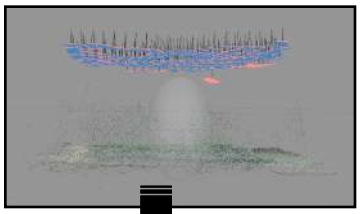




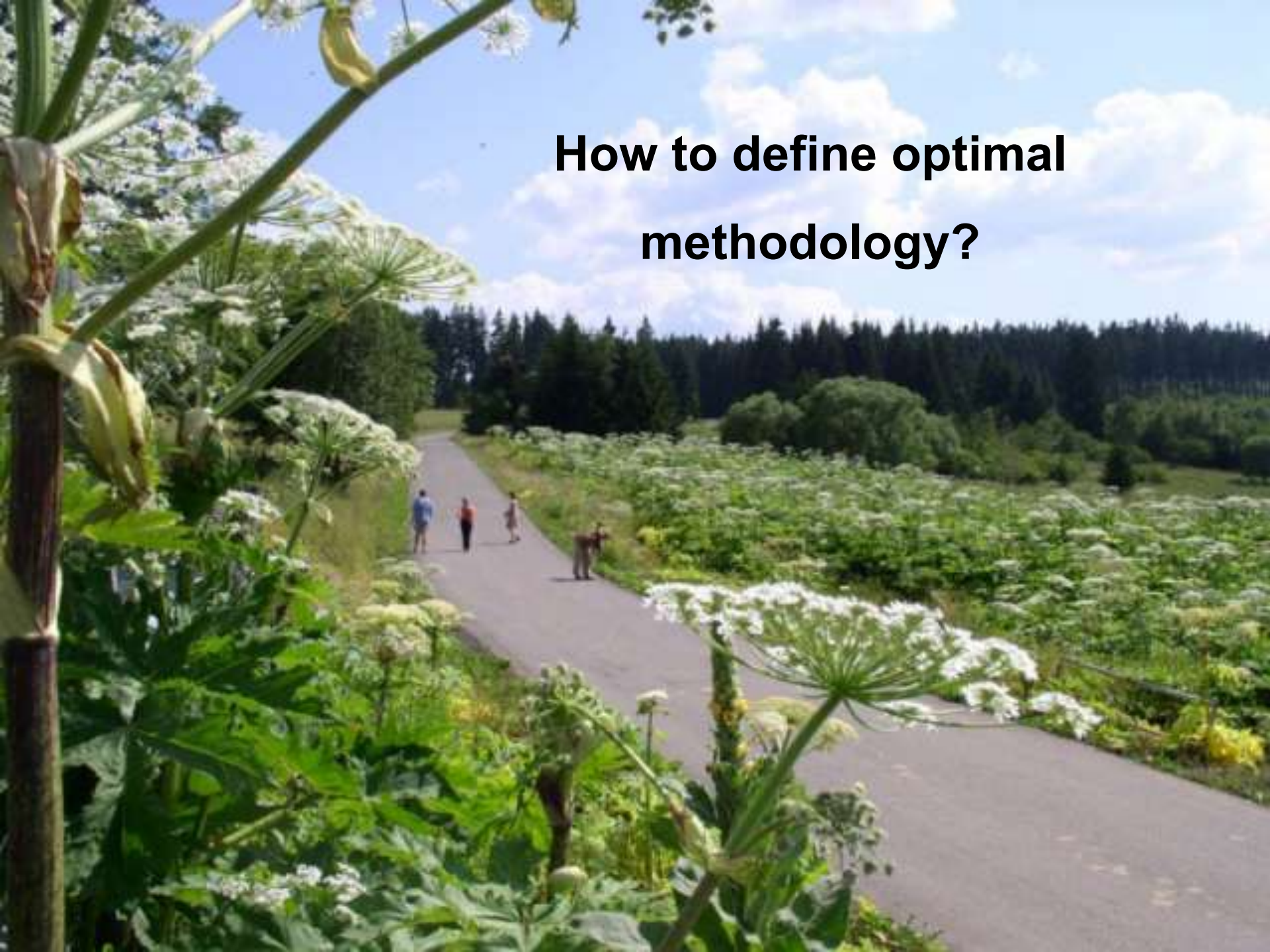
Pre-processing



PhotoScan



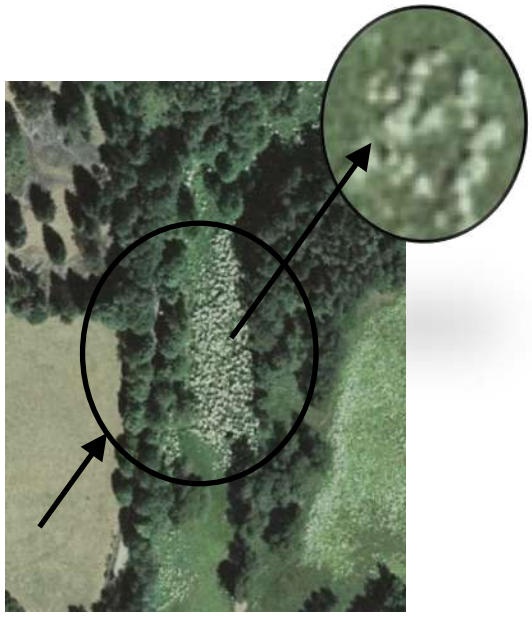
	Point cloud	3D model	DEM	Mosaic
Only VIS data	SPC clean and well defined	clean and realistic		
VIS+NIR data coprocessed	SPC "noisy"	unrealistic artifacts		
VIS+NIR data coprocessed + aggresive depth filtering for dense point cloud	DPC clean	clean		


How to define optimal
methodology?

1. Role of spatial resolution

Giant hogweed

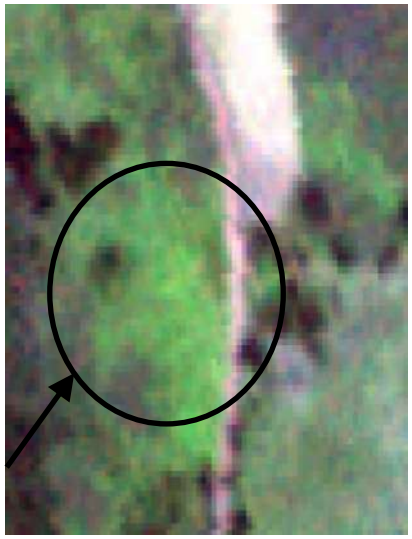
Aerial PAN (1962, 0.5m)



Aerial color (2006, 0.5m)

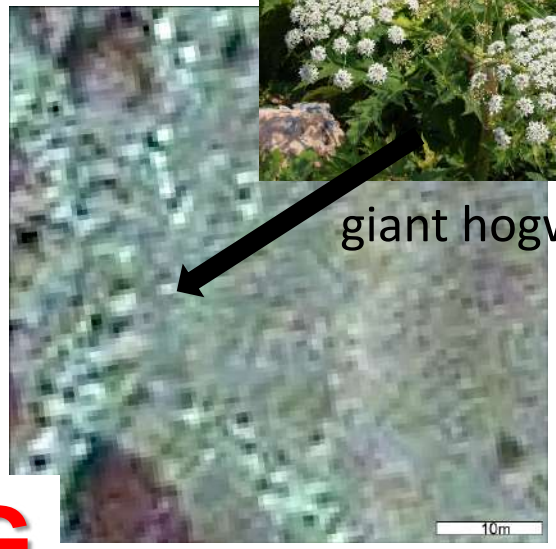
UAV (2015, 5cm)

Pleiades (2013, 2.8m)



RapidEye (2010, 6.5m)

2. Role of temporal resolution

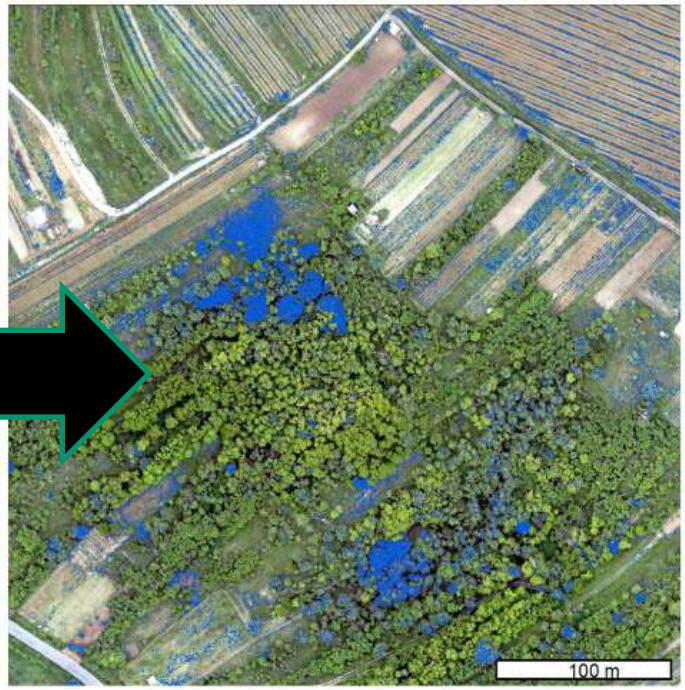


giant hogweed

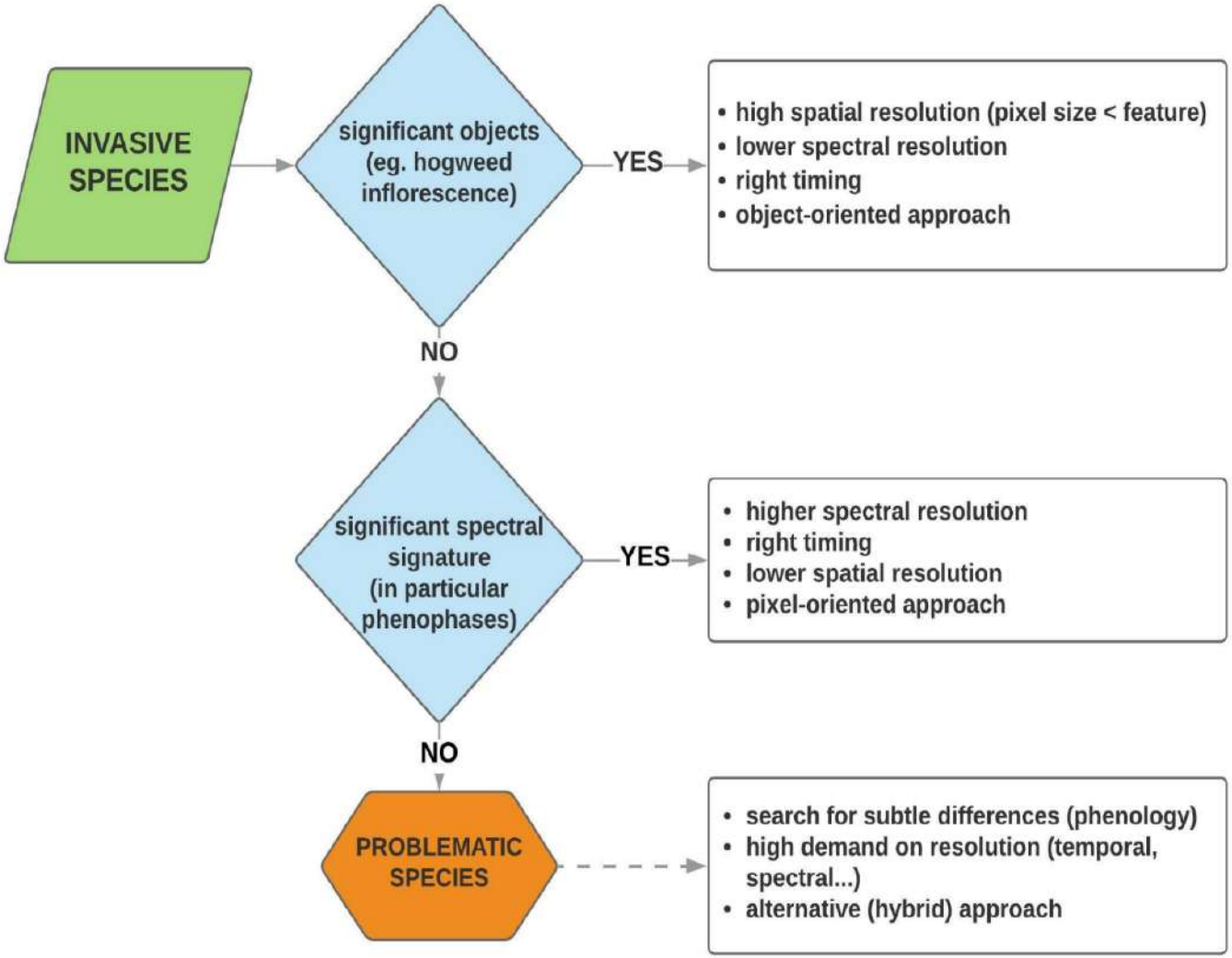
RIGHT TIMING

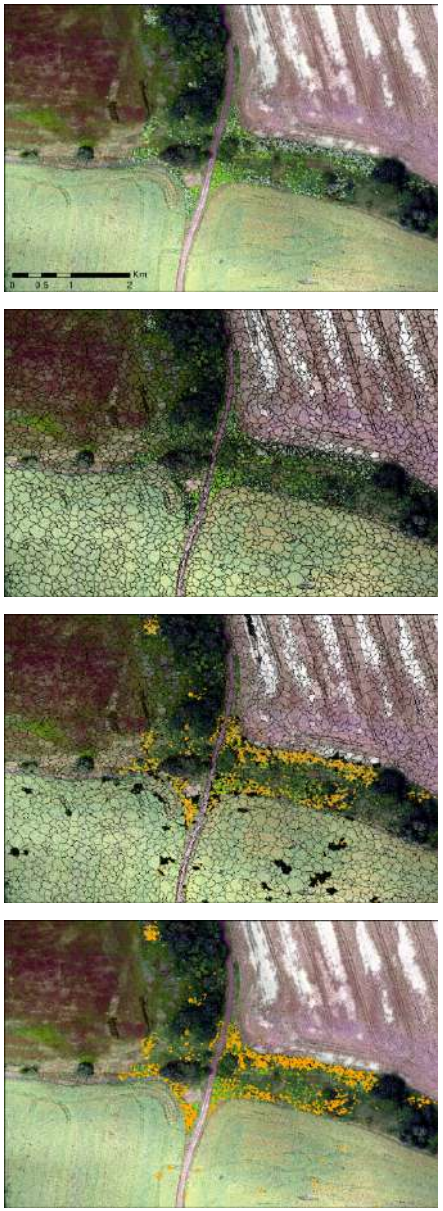
knotweeds

Ailanthus altissima



3. Choice of classification approach





Accuracy – giant hogweed

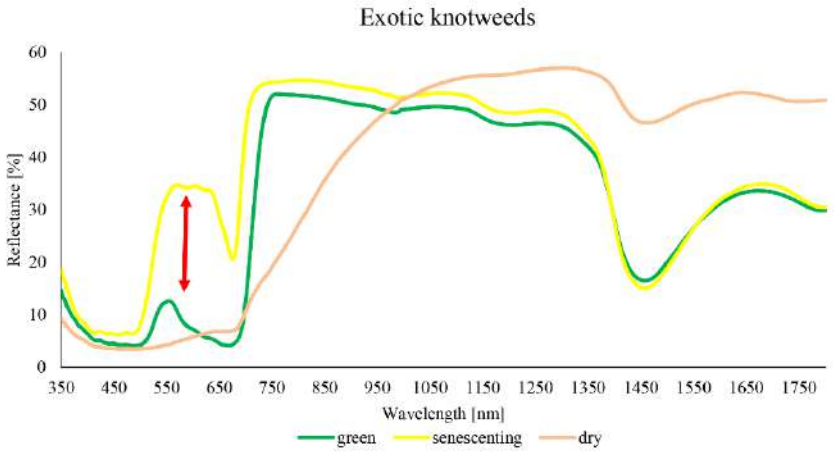
Data	Resolution	Phenology	Method	User´s accuracy	Producer´s accuracy
RapidEye	6.5 m	early flowering	pixel (MaxLike) / OBIA	65 / 44%	76 / 65%
Pleiades	2.8 m	middle flowering	pixel / OBIA (RF)	86 / 70%	94 / 99%
aerial PAN	0.5 m	middle flowering	OBIA	89.0%	80.5%
aerial color	0.5 m	middle flowering	OBIA	57.4%	94.3%
UAV RGB/NIR	0.05 m	middle flowering	OBIA	99.0%	99.8%
aerial PAN	0.5 m	final-size/ripe fruiting	OBIA	86.4%	68.9%
aerial MSS	0.5 m	ripe fruiting	OBIA	51.6%	74.2%
			pixel-based (MaxLike)	42.0%	28.5%

Phenology, method and resolution matters

Accuracy – Asian knotweeds

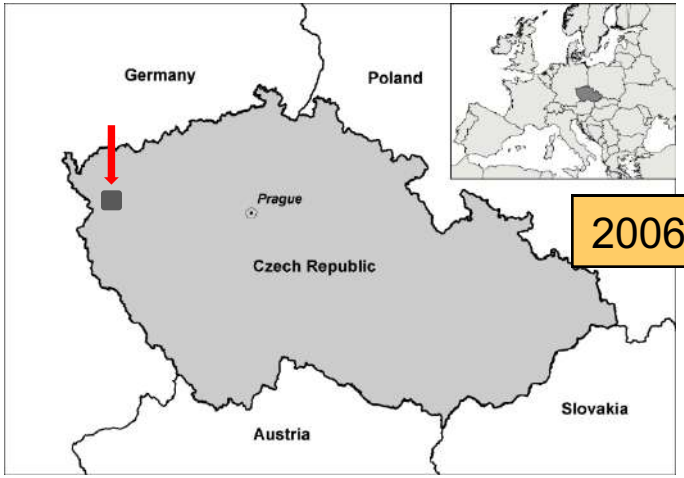
Data	Resolution	Phenology	Method	User´s accuracy	Producer´s accuracy
Pleiades 1B	0.5 / 2m	green	pixel (RF)	44%	95%
UAV RGB/NIR	0.05m	green	pixel (SVM)	60%	92%
		senescence	pixel (MaxLike/SVM)	80 / 54%	78 / 95%
UAV RGB/NIR + BTBR / Canopy Height Model	0.05m	green	OBIA (RF)	80 / 78%	83 / 86%

$$\mathrm{BTBRmod} = \frac{(NIR_{off} / R_{on}) - (G_{off} / G_{on})}{(NIR_{off} / R_{on}) + (G_{off} / G_{on})}$$

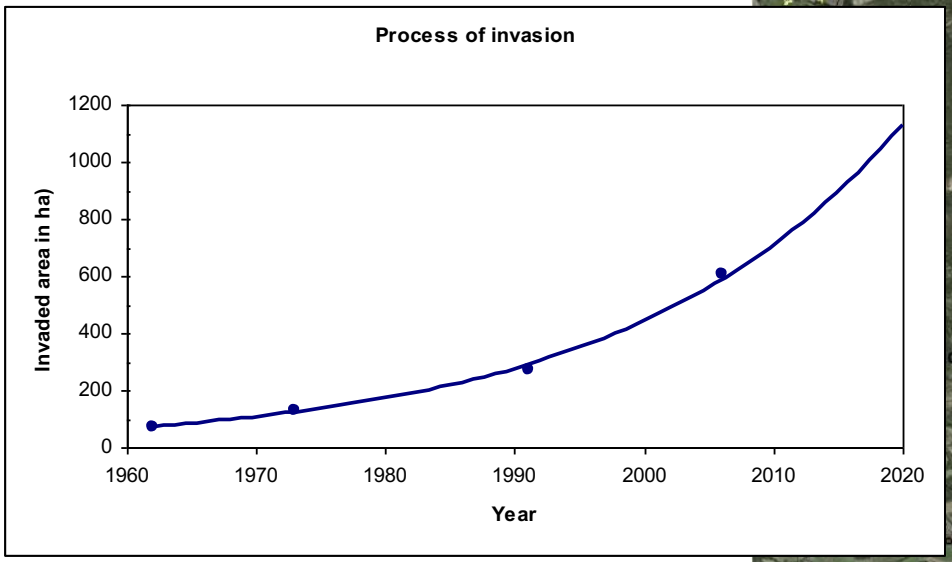


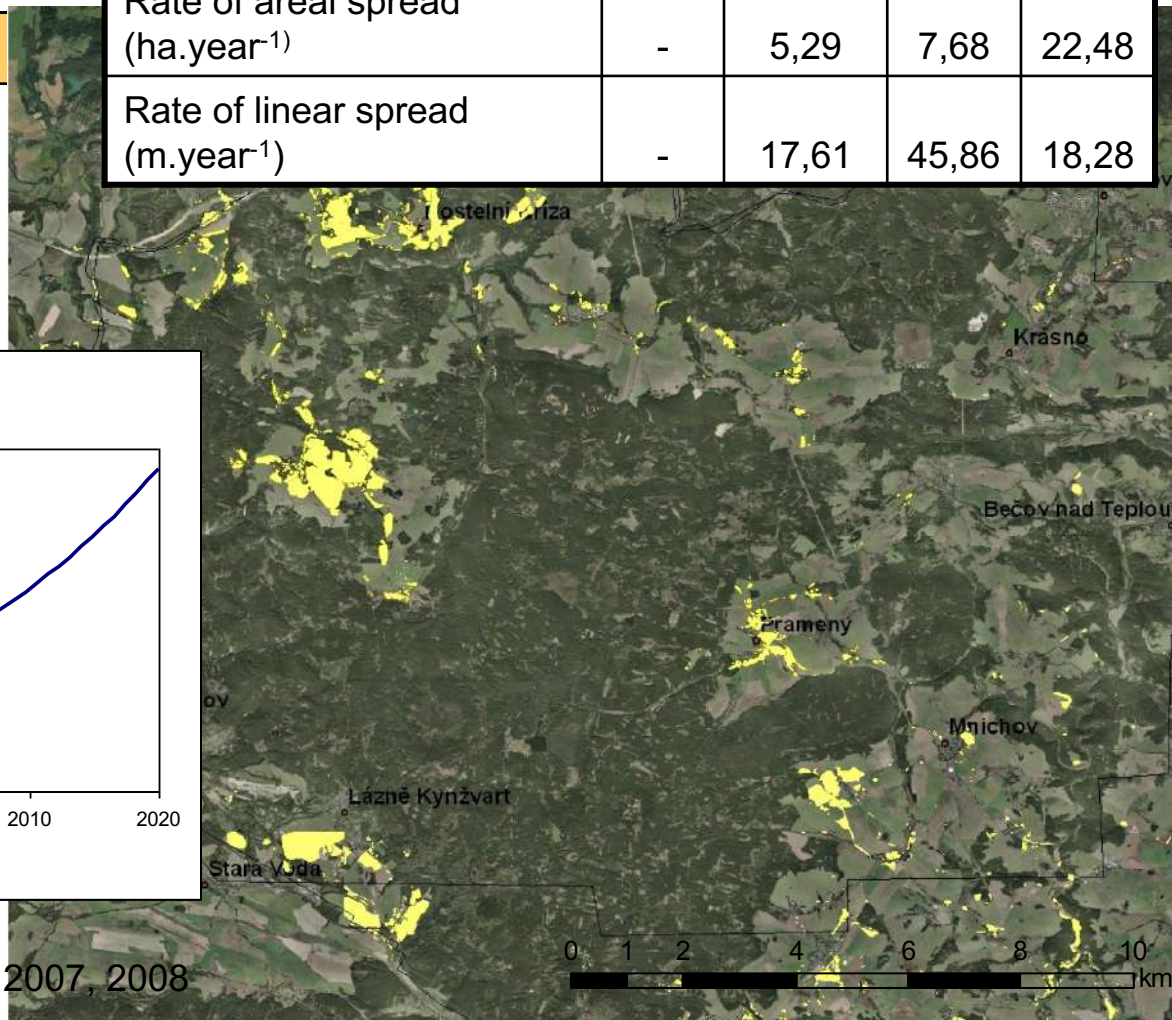
Müllerová et al. (2017) Frontiers in Plant Science; Martin et al. (2018)

Invasion at the landscape scale

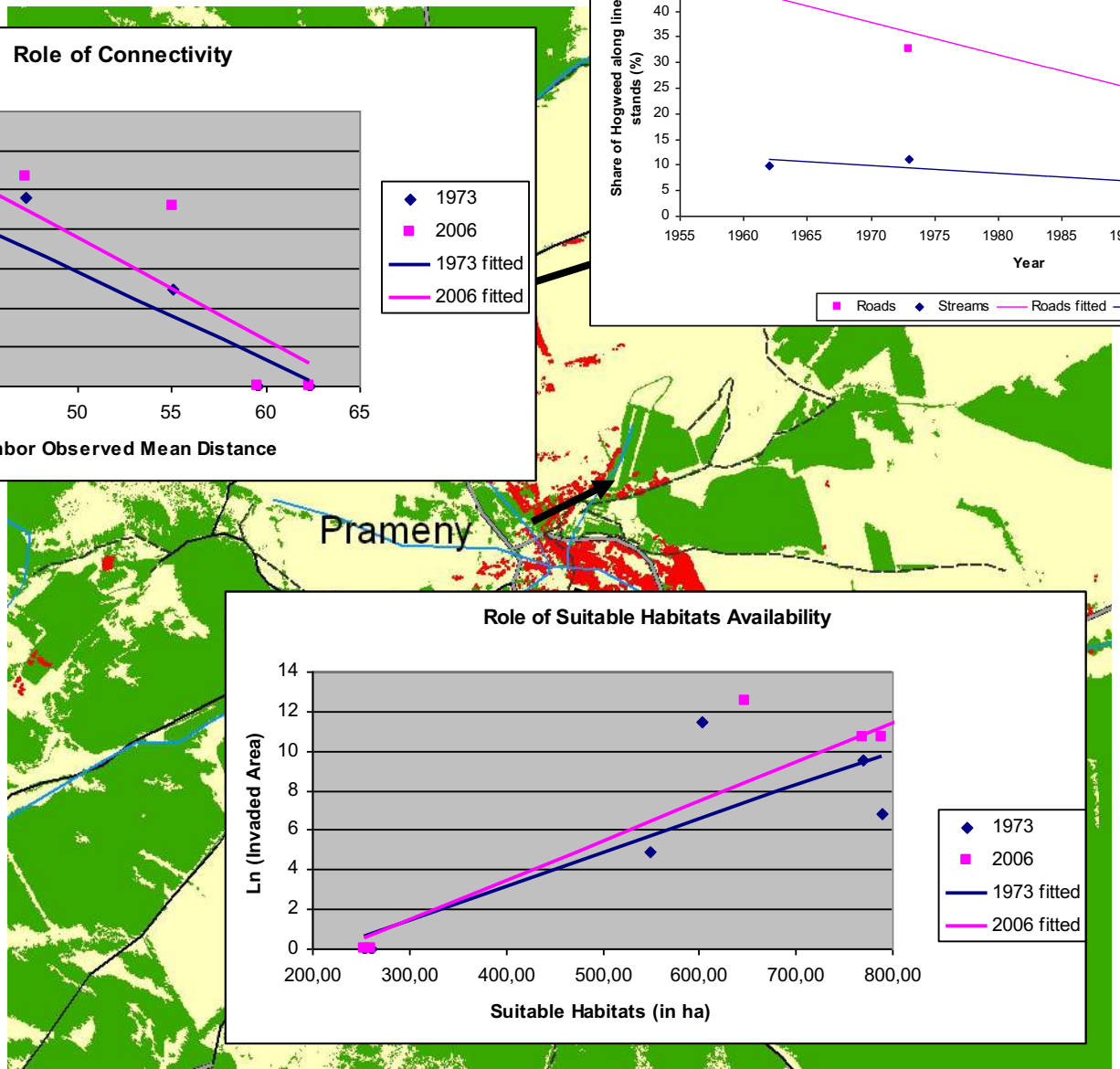


	1962	1973	1991	2006
Invaded area (ha)	73	131,2	269.5	606.7
Rate of areal spread (ha.year^{-1})	-	5,29	7,68	22,48
Rate of linear spread (m.year^{-1})	-	17,61	45,86	18,28



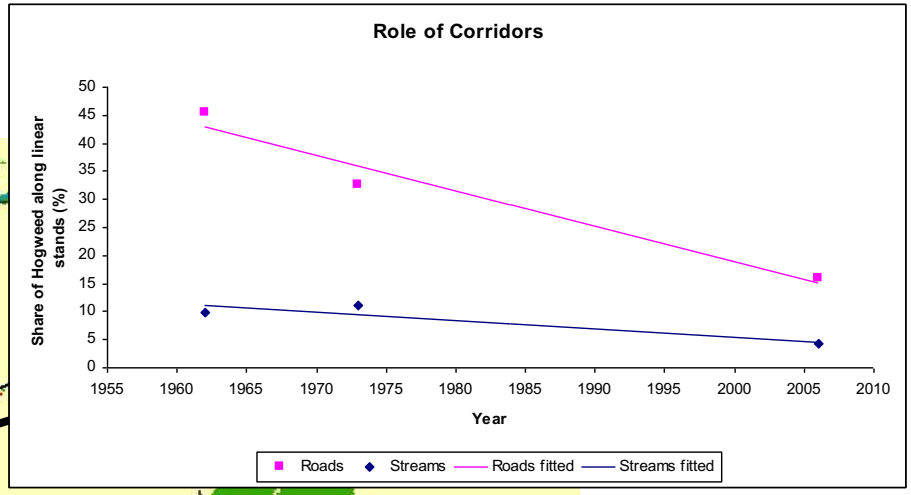


Müllerová et al. 2005, 2017; Pyšek et al. 2007, 2008

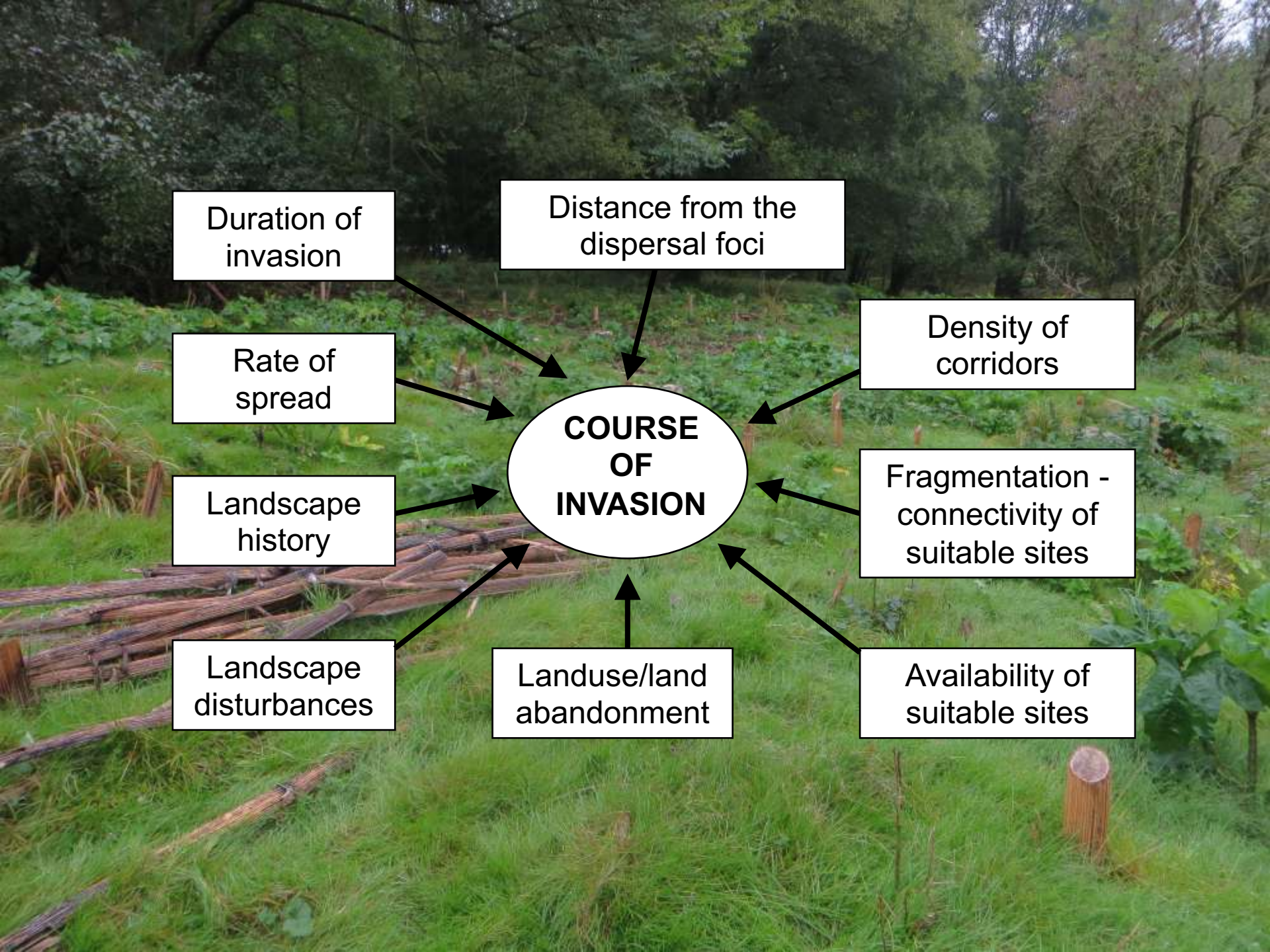


Role of Connectivity

Role of Corridors

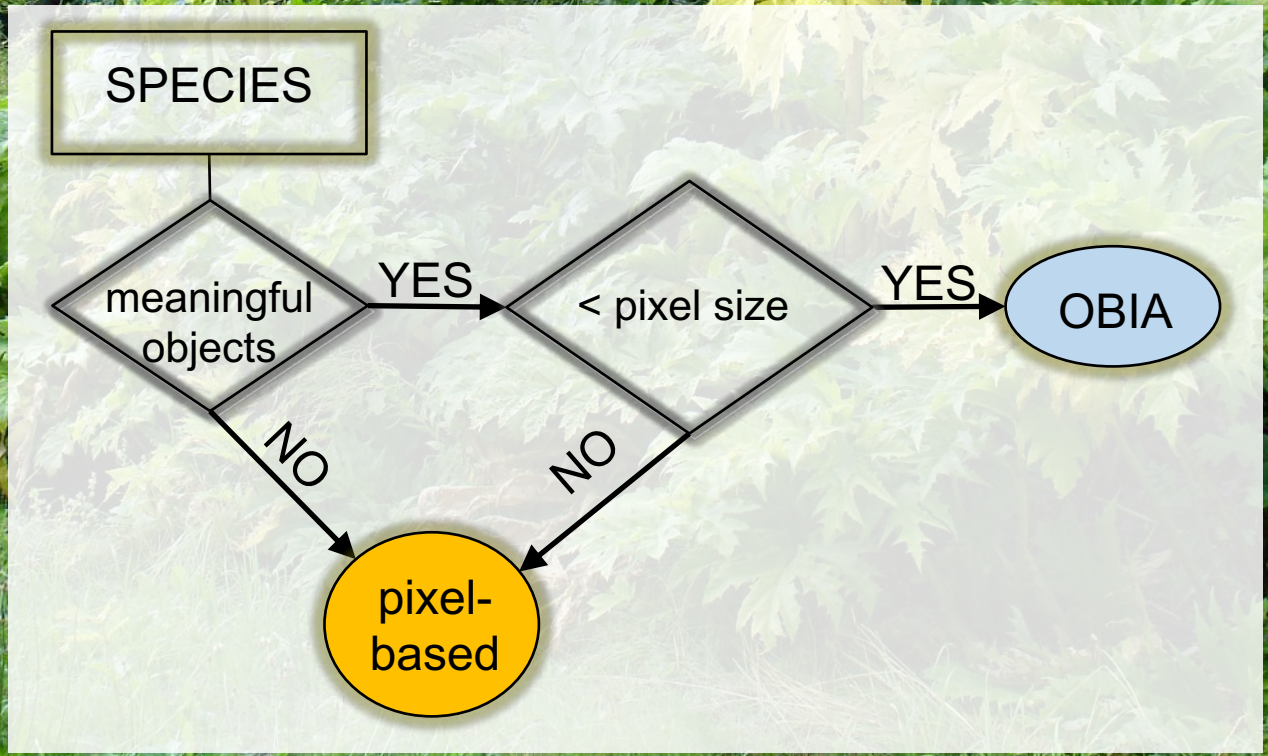


Role of Suitable Habitats Availability


Duration of invasion
Distance from the dispersal foci
Density of corridors
Rate of spread
COURSE OF INVASION
Fragmentation - connectivity of suitable sites
Landscape history
Landscape disturbances
Landuse/land abandonment
Availability of suitable sites

Lessons learned, practical implications

1. RS advantages x limits
2. Methodology must reflect phenology, morphology and structure of the target plant

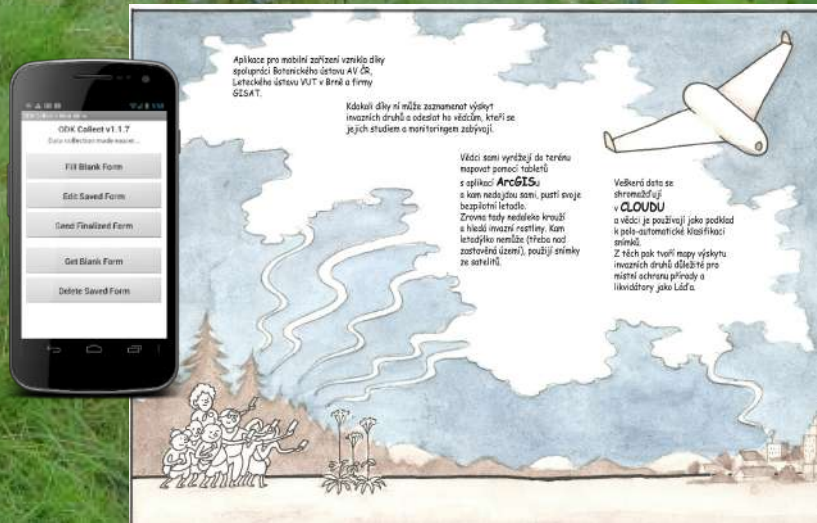


Lessons learned, practical implications

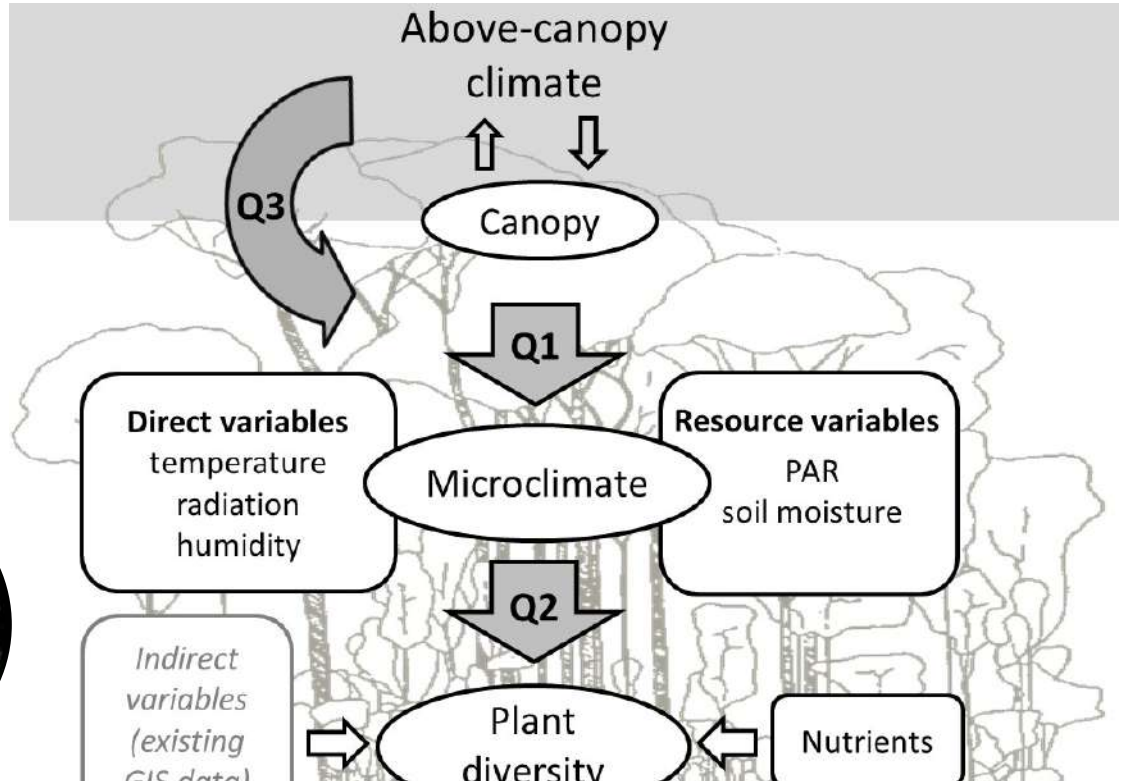
1. RS advantages x limits
2. Methodology must reflect phenology, morphology and structure of the target plant
3. Data choice - crucial, depends on the purpose
4. Acceptable accuracy differs, depends on the purpose
5. Trade-off between species and data

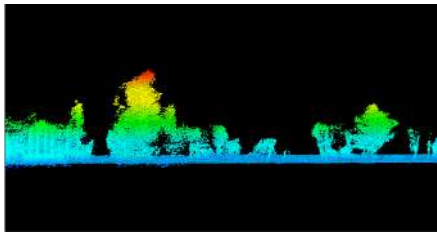
Current research

1. Assessing efficiency of eradication campaigns
2. Operational use of remote sensing in nature conservation
3. Role of the landscape history in shaping the invasion
4. Socio-economic impact of invasions
5. Engaging the public (citizen science, raising awareness)



Forest microclimate - neglected link between plant diversity and climate change





1) What is the range of microclimate variability at different spatial and temporal scales and how is it related to forest canopy cover?
2) How is plant diversity related to microclimate and canopy cover?
3) Is there a direct link between above and below-canopy climate?

Special Session
“RS of Vegetation for Biodiversity Research”

Bremen IAVS 2019


Thank you for your attention!
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