Remote sensing in invasive ecology? Detection, monitoring and control of alien plant species

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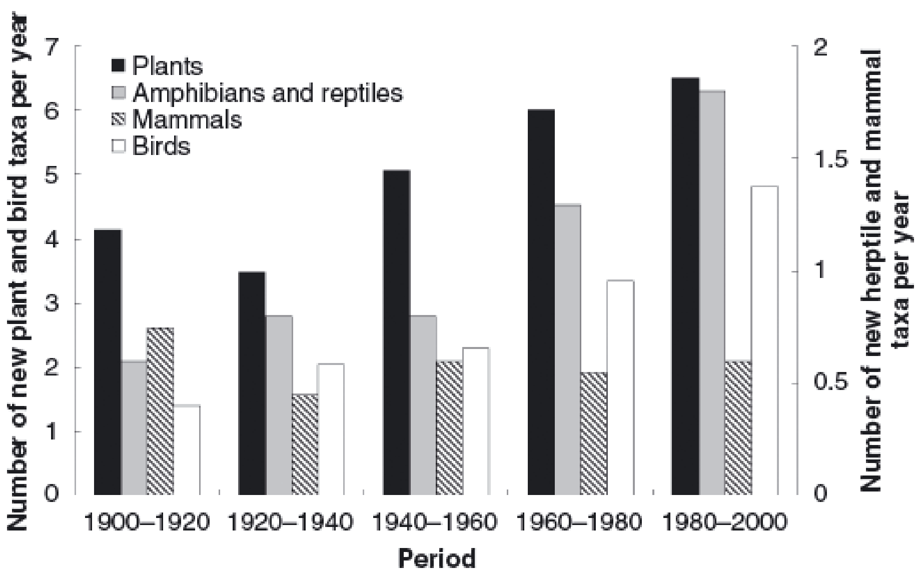
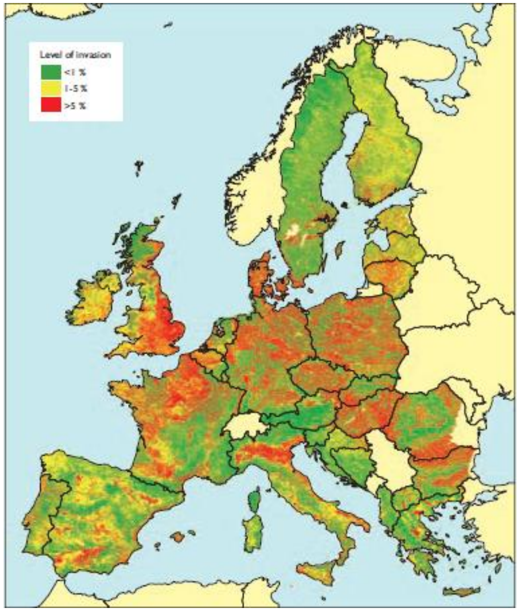
Why plant invasions?

- threat to biodiversity, ecosystem functioning, and character of traditional landscapes
- impact grows despite the worldwide efforts to control and eradicate
- new techniques for monitoring and providing information on spatial structure of invasions are needed
- once fully established invaders grow rapidly, outcompete native flora and are hard to permanently eliminate → fast and precise monitoring is crucial for rapid actions



Pyšek P. et Hulme P.E (2011) in Richardson (ed.) Fifty Years of Invasion Ecology. Blackwell Publ.

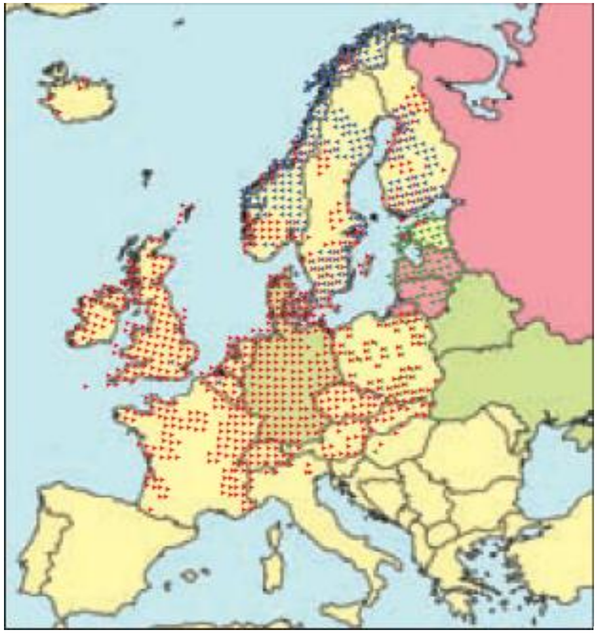


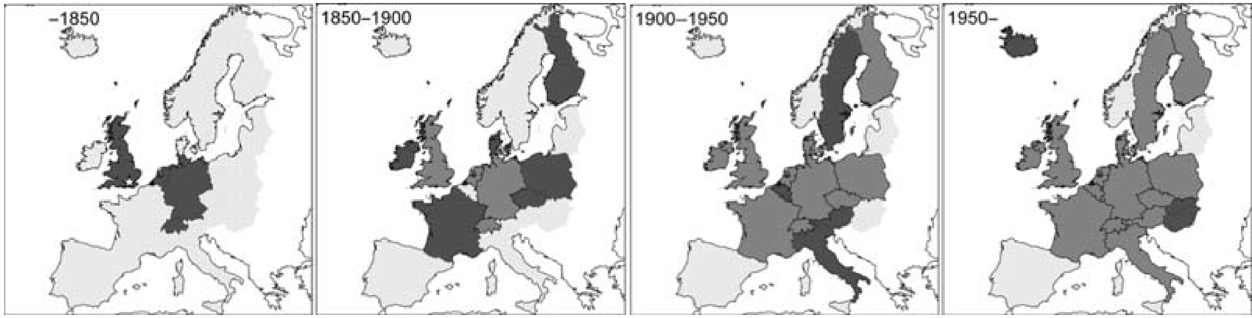
Pyšek et al. (2010): ALARM Biodiversity Atlas, Pensoft.

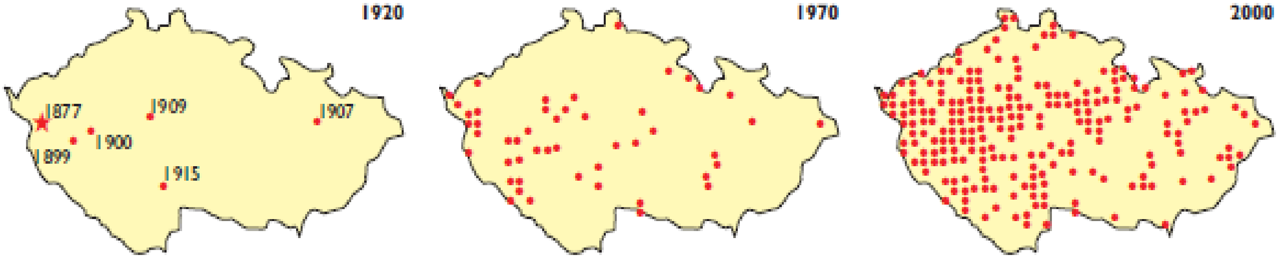
GIANT HOGWEED
(Heracleum mantegazzianum)

- herbaceous perennial up to 4–5 m tall with white round flower heads up to 2 m in diameter - easy to recognize from VHR imagery
- native to the Western Greater Caucasus, introduced to Europe as garden ornamental in the 19th century

GIANT HOGWEED
(Heracleum mantegazzianum)



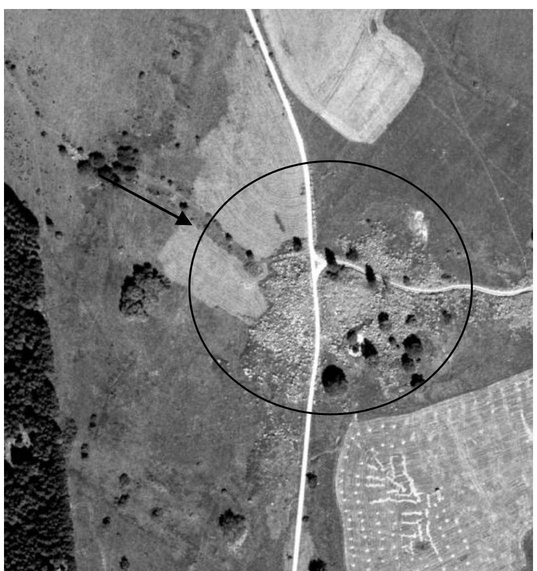


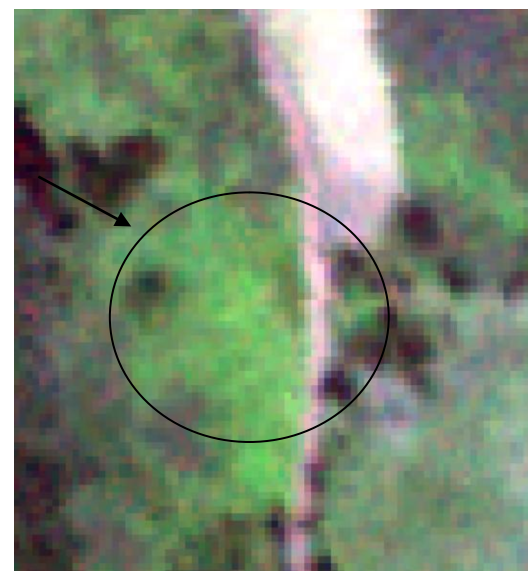


Pyšek et al (2010): Hogweed story. ALARM Biodiversity Atlas, Pensoft.

Giant hogweed

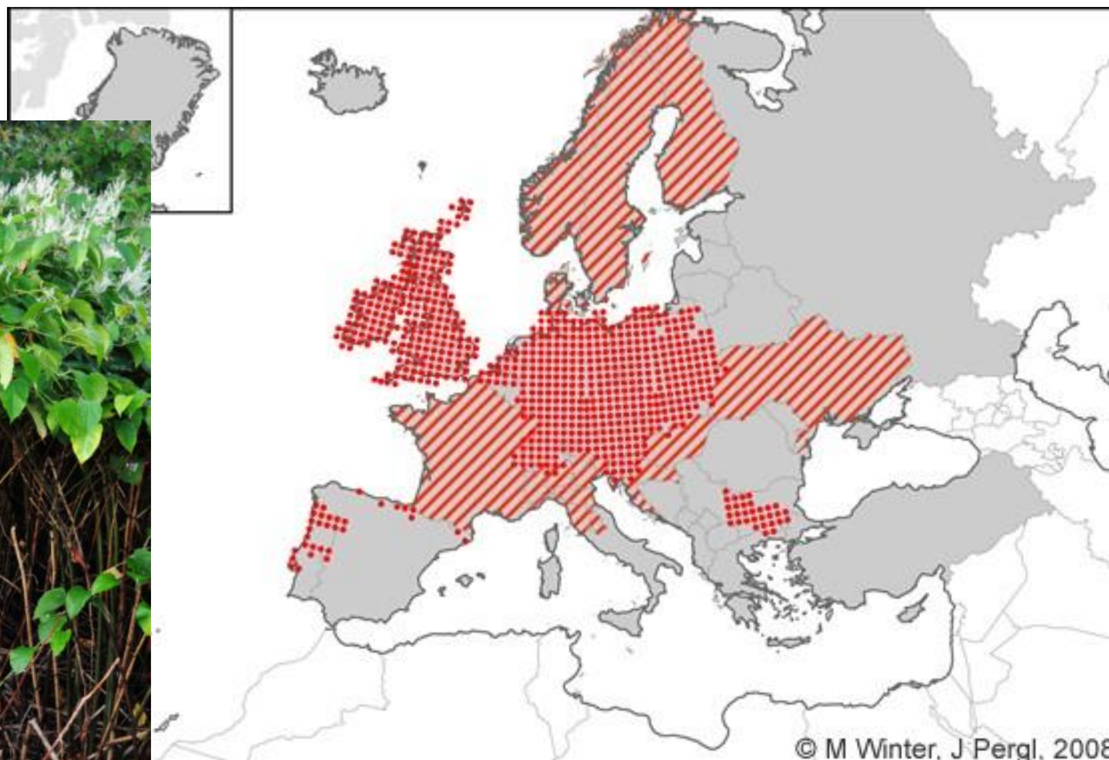




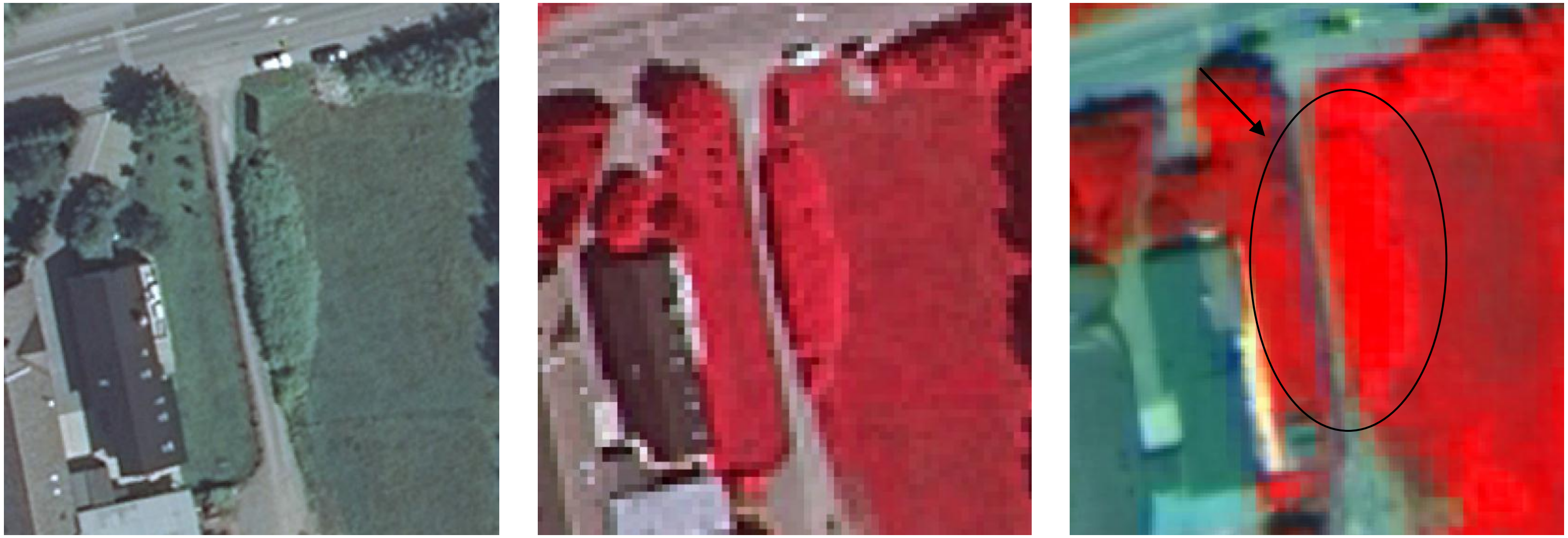


JAPANESE KNOTWEED
(*Fallopia japonica*)

- herbaceous perennials up to 4 m tall
- native to East Asia, introduced to Europe as garden ornamental in the 19th century



Japanese knotweed



Typical representation of J. knotweed – RGB (2006), IR, and WV-2(2010).

AIMS

- to test and evaluate the potential of spectrally (panchromatic, multispectral and color) and spatially (aerial and satellite) different RS data for automatic detection of invasive species
- to establish relatively fast, repeatable and efficient computer-assisted methods that could be used to monitor invasions at larger spatial scales

Species	Year	Date	Resolution [m]	Source	Spectral resolution
g. hogweed	1962	25.7	0.5	aerial	panchromatic
	1973	11-16..8	0.5	aerial	panchromatic
	1987	21-23.8	0.5	aerial	multispectral (4 CH)
	1991	23.7	0.5	aerial	panchromatic
	2006	18.7	0.5	aerial	color orthophotos (RGB)
	2010	8.7	5	satellite (RapidEye)	multispectral (5 CH)
J. knotweed	2006	11.6, 27.6	0.5 (RGB) 1(NIR)	aerial	color orthophotos + NIR band (CIR)
	2010	10.8	0.5 (pansharp.) 1.8 (MSS)	satellite (WorldView-2)	multispectral (8 CH + panchrom. band)
	2011*	20.4	0.5 m	aerial	color orthophotos (RGB)

*not classified, served only for visual interpretation – training and accuracy assessment

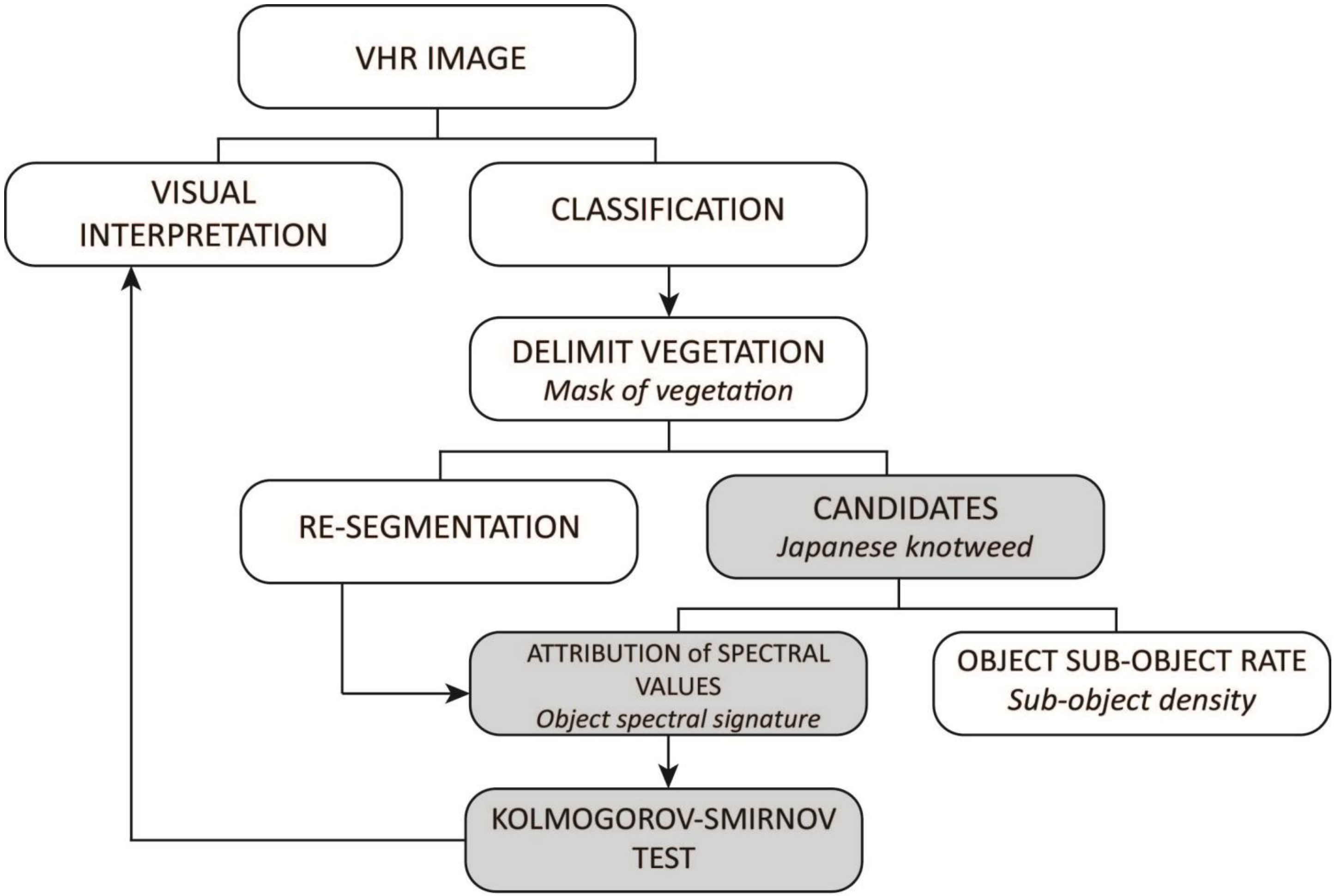
PROBLEMS

- *different spectral* (panchromatic, multispectral and color) and *spatial* (aerial < 0.5 m; satellite - 5 m) *resolution* of data ►different processing methods
- *low recognizability* of J. knotweed (heterogeneous canopy structure)
- *low spectral resolution* of historical aerial photographs (panchromatic), low quality of some data
- *varying time of the data acquisition* ►different phenological stage: early flowering to ripe fruiting
- *large amount of data* and a need of fine segmentation ► time consuming segmentation process ► need for automatization

J. KNOTWEED

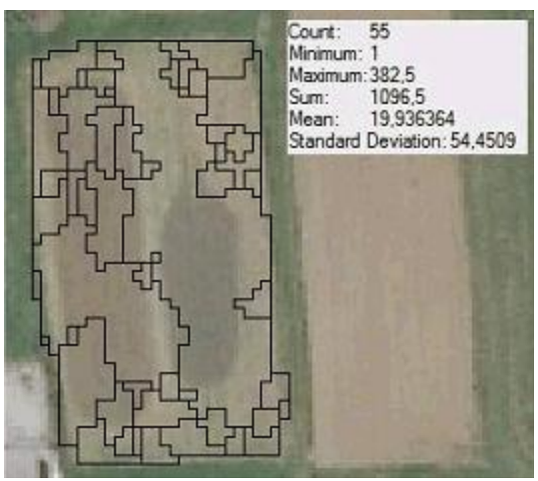
- urban fringe of Ljubljana city, Slovenia
- classification difficult since it is not so distinct from surrounding vegetation → hybrid approach combining pixel and OBIA classification
- ENVI object-based feature extraction module supplemented by the sub-object pixel-based approach (developed in Matlab)
- initial image segmentation of VHR CIR aerial data followed by sub-object spectral and structural analysis (mainly measure of object fragmentation, i. e. heterogeneity of canopy architecture)




VHR IMAGE
VISUAL INTERPRETATION
CLASSIFICATION
DELIMIT VEGETATION
Mask of vegetation
RE-SEGMENTATION
CANDIDATES
Japanese knotweed
ATTRIBUTION of SPECTRAL VALUES
Object spectral signature
OBJECT SUB-OBJECT RATE
Sub-object density
KOLMOGOROV-SMIRNOV TEST

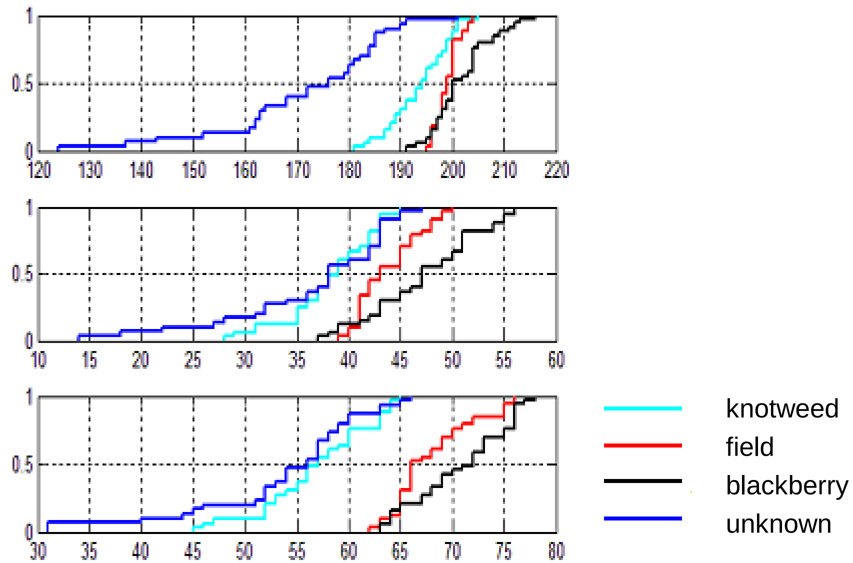
Sub-object structural domain

- ratio between the total area of the object (outer boundaries) and the number of segments (sub-objects) in the object at a given observation scale
- a measure of the object fragmentation (texture) characteristic
- fragmentation of J. knotweed is significantly higher compared to farmlands



Sub-object spectral domain

- associated with the **object** spectral signature.
- spectral object signature can be represented as a distribution function similar to the histogram distribution or as a **cumulative frequency distribution function** (CDF)
- two sample **Kolmogorov-Smirnov test** (K-S, nonparametric statistical test estimating similarity of the two samples through the comparison of their empirical distribution functions)



Empirical distribution functions for the IR 2006

RESULTS

Classification results for knotweed detection verified in the field

Green polygons - identified J. knotweed candidates

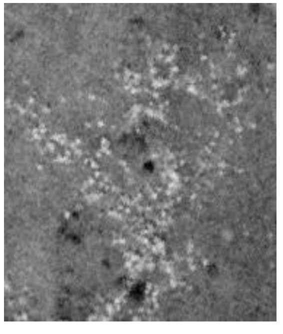
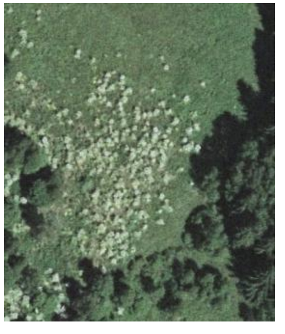
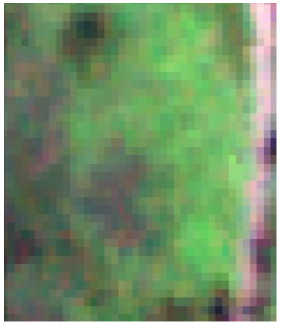
Red dots - actual knotweed occurrences (field survey)

RESULTS

- not possible to recognize individual plants, stands recognized thanks to the branch architecture
- K-S based classifier improved greatly the classification accuracy compared to conventional OBIA
- from the 32 sites of knotweed mistreated by OBIA on 2006 CIR ortophoto imagery, 17 additional sites were recognized using the K-S tests, i.e. 53% of the otherwise neglected areas
- coincidence of the reference data and the detected polygons is relatively large
- some false-negative sites – mainly stream embankments (hidden by tree crowns)
- approach enabled detection of different stages of knotweed growth and differentiation from similar blackberry and other species, considerably improving the accuracy

G. HOGWEED

- Slavkovský les Protected Landscape Area, Czech Republic
- species well recognized on VHR imagery (even panchromatic → historical analysis)
- testing various data and approaches
- data (panchromatic/MSS, aerial/satellite, high/medium spatial resolution)
- pixel-based approach (supervised, unsupervised)
- object-based approach – uses both spectral and spatial information (texture, spatial characteristics, context and topology)
- classification rules related to: spectrum, shape, texture, context

Classification
(hierarchical, iterative, semi-automated)

course segmentation in Definiens

course classification of „Hogweed region“ class characterized by spectral values and high heterogeneity

fine segmentation within the „Hogweed region“ class

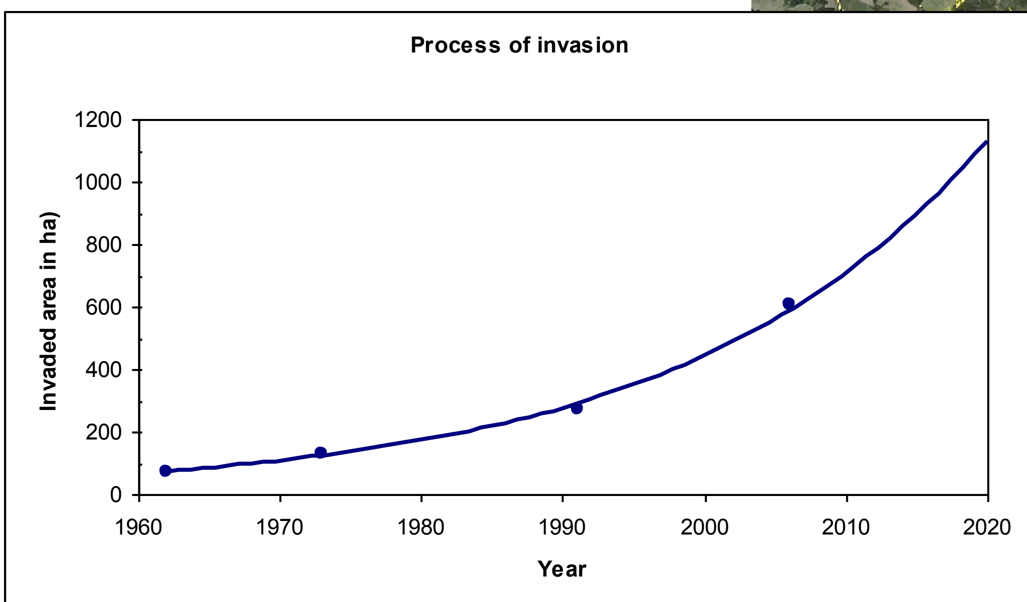
detailed mapping of individual hogweed plants

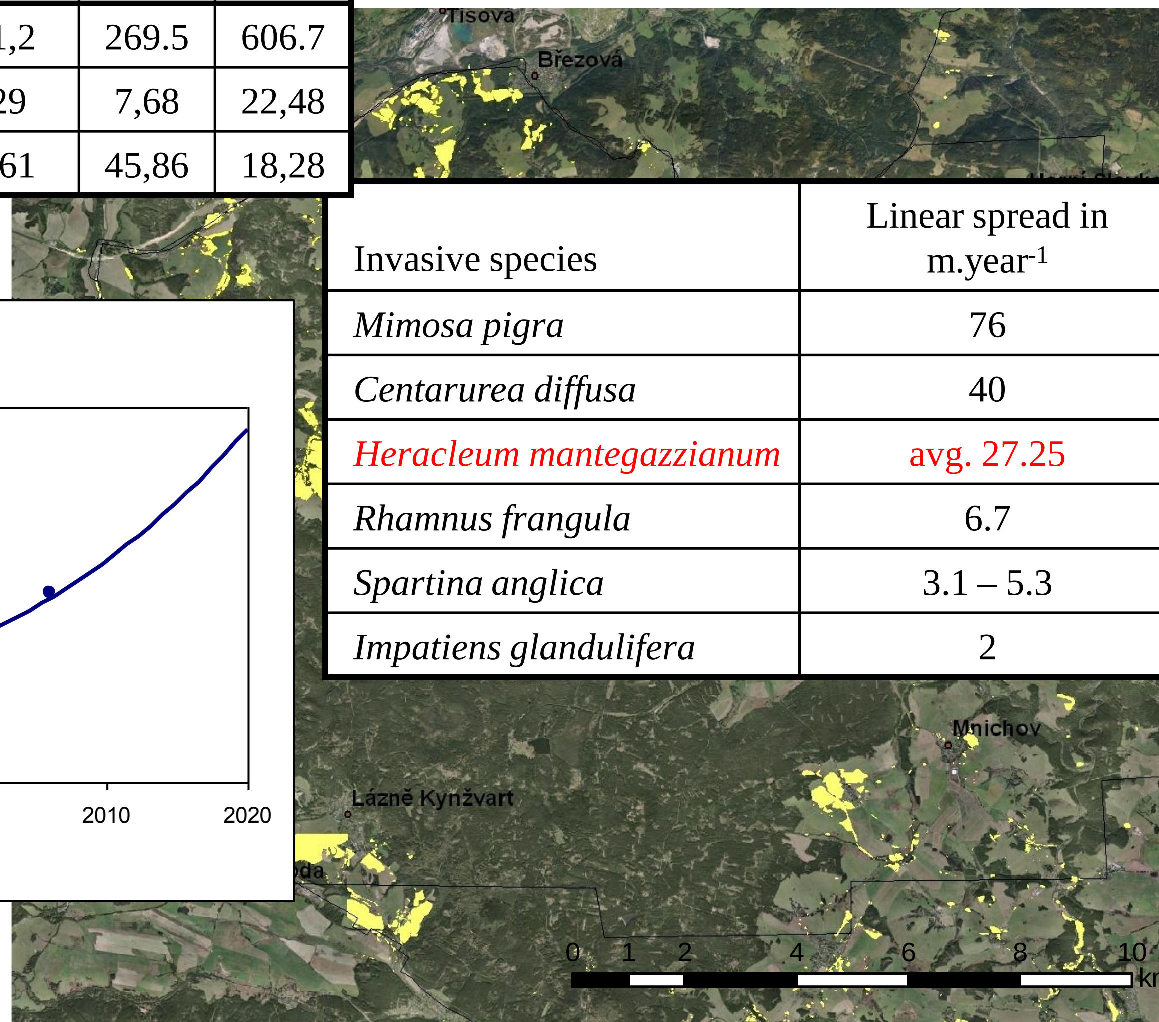
RESULTS

- **historical panchromatic VHR** imagery – recognition of individual plants, **OBIA** more successful (accuracy over 80%, **good to excellent Kappa** except for the imagery from the late season)
- **satellite data** of lower spatial resolution - recognition of larger homogeneous patches, **pixel-based** better accuracy (Maximum Likelihood – acc. 65%, **moderate** Kappa)
- classification success influenced by the **phenological stage** of hogweed - best results for the mid-flowering phase (July, avg. UA and PA for VHR imagery above 84%), at later stages (end of flowering/fruiting) hogweed stands not so distinct → detection problematic
- automated vs manual - **manual less complex** (especially at the later stages of invasion with larger area invaded

Invasion at the landscape level

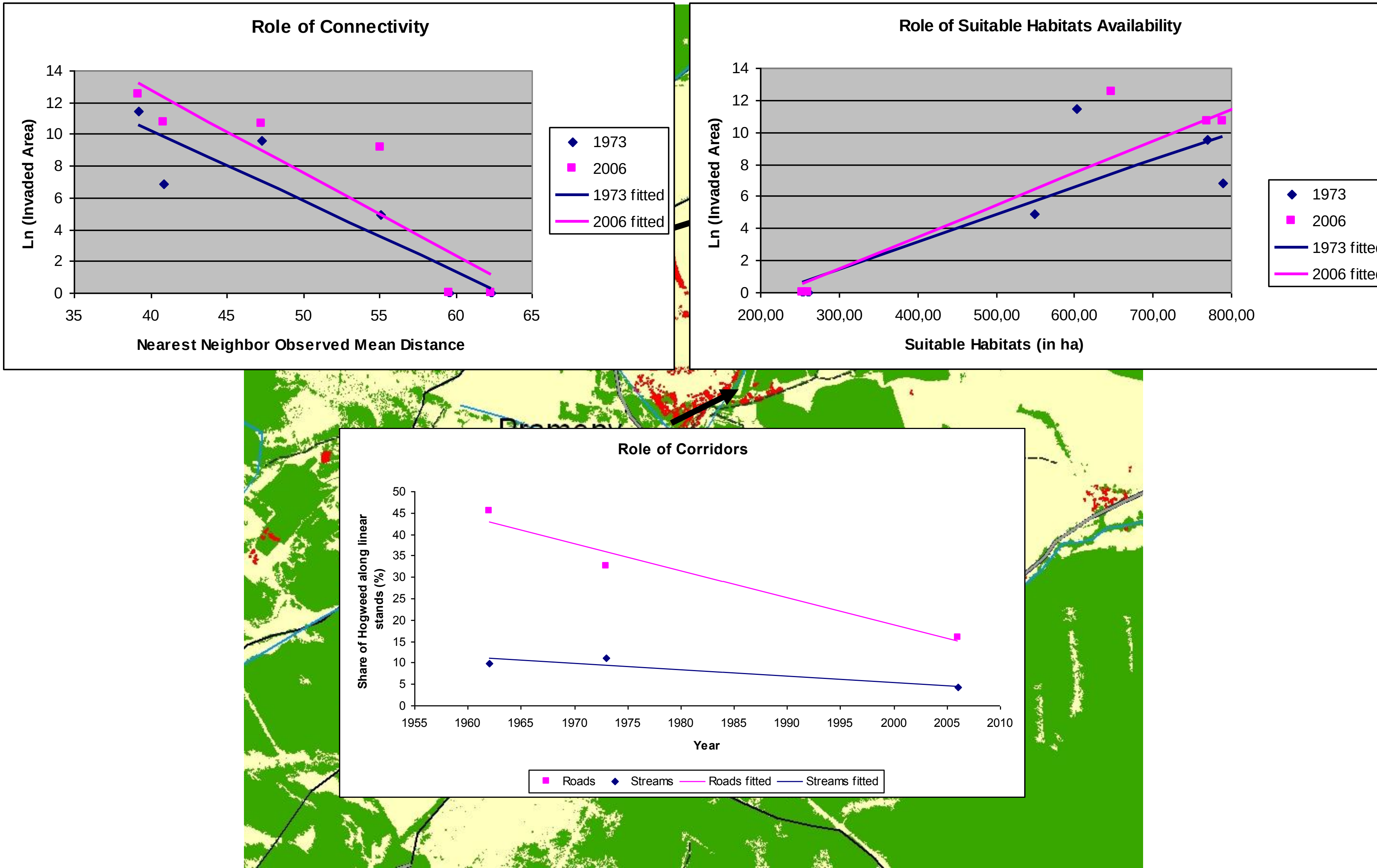
	1962	1973	1991	2006
Invaded area (ha)	73	131,2	269.5	606.7
Rate of areal spread (ha.year^{-1})	-	5,29	7,68	22,48
Rate of linear spread (m.year^{-1})	-	17,61	45,86	18,28

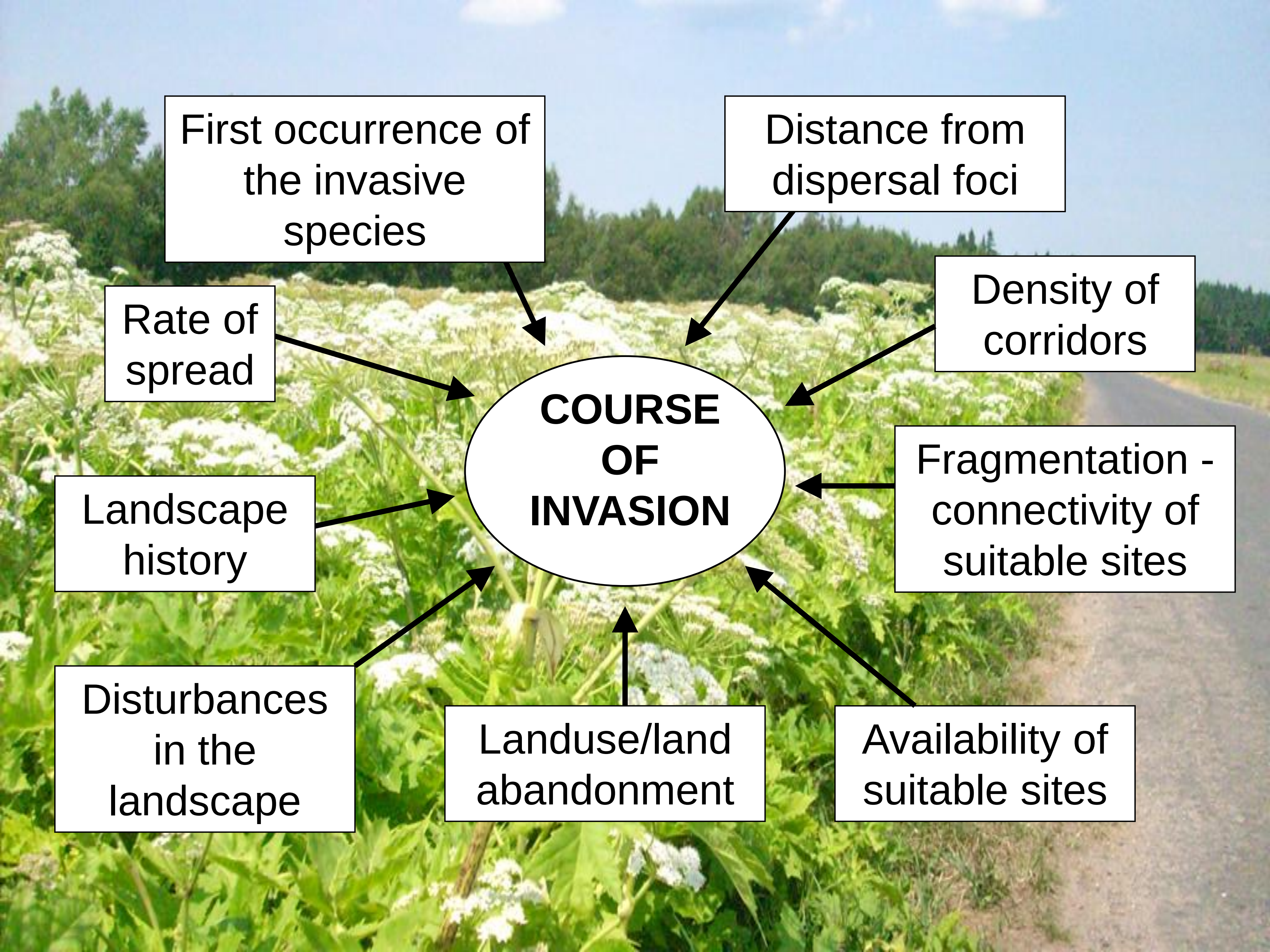




Invasive species	Linear spread in m.year^{-1}
Mimosa pigra	76
Centarurea diffusa	40
Heracleum mantegazzianum	avg. 27.25
Rhamnus frangula	6.7
Spartina anglica	3.1 – 5.3
Impatiens glandulifera	2

Landscape Patterns




First occurrence of the invasive species
Distance from dispersal foci
Density of corridors
Rate of spread
COURSE OF INVASION
Landscape history
Fragmentation - connectivity of suitable sites
Disturbances in the landscape
Landuse/land abandonment
Availability of suitable sites

Implications for mapping strategy

1. RS helps to **identify areas at highest invasion risk** and choose the **appropriate management** (focus on linear features – corridors, and newly colonized - dispersal foci)
2. **VHR imagery** - high detail, but for larger areas difficult to handle → satellite data of medium resolution
3. the best mapping strategy must reflect **morphological and structural features** of the plant
4. it is crucial to use **suitable data** - for species detected in flowering, the data collected at its peak, for less distinct species, the high spectral resolution data necessary
5. methods incorporating **both textural and spectral information** are valuable for the species detection

Thanks for your attention!

- Müllerová et al. (2013): Remote sensing as a tool for monitoring plant invasions. ***Int. J. Appl. Earth Observ.Geoinformation*** 25: 55–65.
- Đurić (2011): Object Oriented Classification for the Identification of Tree Species and the Detection of Japanese Knotweed. *BSc. thesis. Ljubljana*
- Müllerová et al. (2005): Aerial photographs as a tool for assessing the regional dynamics of the invasive plant species H.mantegazzianum. ***Journal of Applied Ecology*** 42(6): 1-12.