



Guidos Toolbox Workshop

Part 1: Introduction & Motivation

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Time schedule for a 1-day workshop:

- 09:00 – 12:30: Introduction, motivation, and examples for new ways of image object analysis.

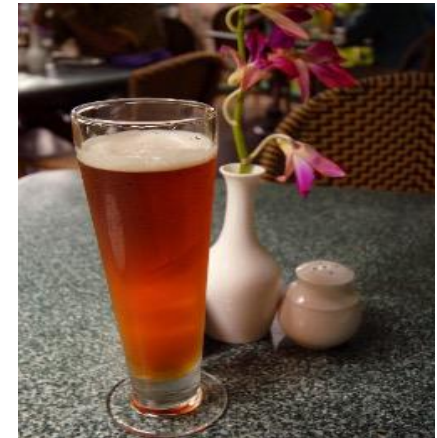


GuidosToolbox: Features, processing options; GWS 1-3.pptx

- 12:30 – 13:30: Lunch break



- 13:30 – 17:00: Hands-on training, discussion, suggestions, ... GWS 4.pptx



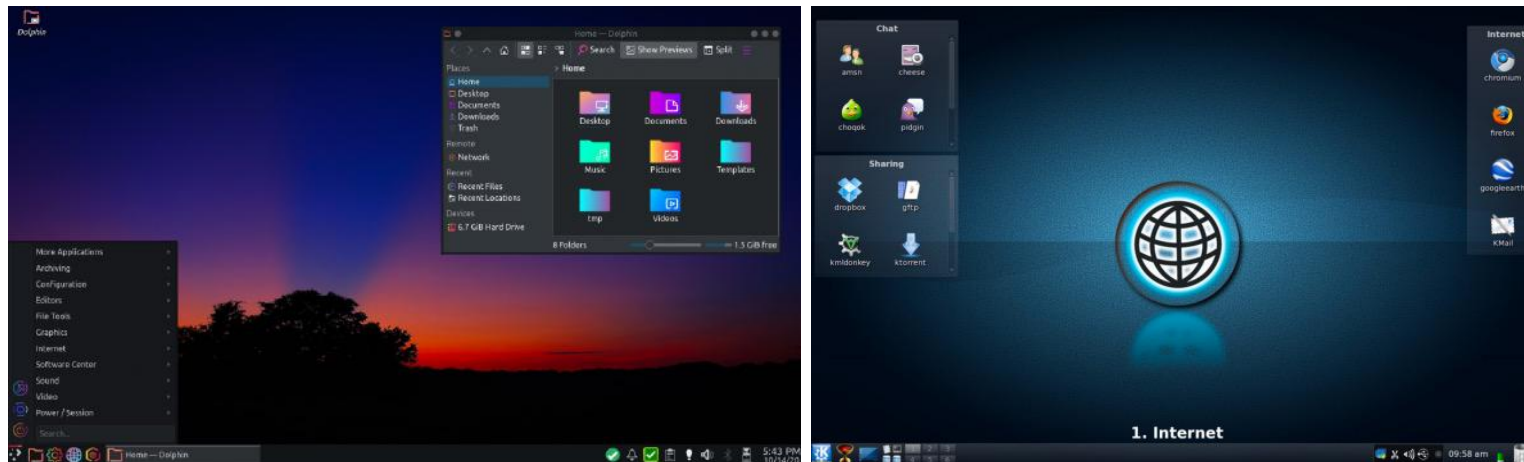
Who is this guy anyway?

Personal: German

Education: Free University Berlin, Germany

- 1992: MSc Meteorology: atmospheric Rad. Transfer
- 1997: PhD GeoSciences: RT-vegetation, BRDF, LAI, f_{APAR}

Developer and team member of PCLinuxOS





Professional background:

- 1992-93: Inst. Space Sciences Berlin: Radiative Transfer in Ocean & Atmosphere
- 1993-97: Inst. Planetary Research, DLR: RT in Vegetation, BIRD, BRDF, LAI, f_{APAR}
- 1998: Raytheon ITSS, USA: VIIRS/NPOESS: albedo algorithm development
- 1999-present: Joint Research Centre, European Commission, Italy:
 - * BRDF: biophysical parameters [[AnisView](#)], atmospheric correction
 - * Atmosphere: vertically resolved actinic flux, surface UV-radiation, skin cancer
 - * Water: eutrophication risk in coastal waters, detection & monitoring of illicit oil spill discharges [[Oil_GUI](#), [Oil_dbase](#)],
 - * Land: satellite image processing: small water bodies, desert locust, cloud masking, change detection, image overlays; forest: fires, spatial pattern, connectivity, fragmentation, restoration,... [GuidosToolbox ([GTB](#), [GWB](#))]



JRC sites

Headquarters in **Brussels**
and research facilities located
in **5 Member States**:

- Belgium (Geel)
- Germany (Karlsruhe)
- Italy (Ispra)
- The Netherlands (Petten)
- Spain (Seville)





The workshop will address the following topics:

GWS 1: Introduction/motivation for new ways of image analysis

GWS 2: Pattern Analysis (M)SPA

GWS 3: GuidosToolbox: program features and processing options

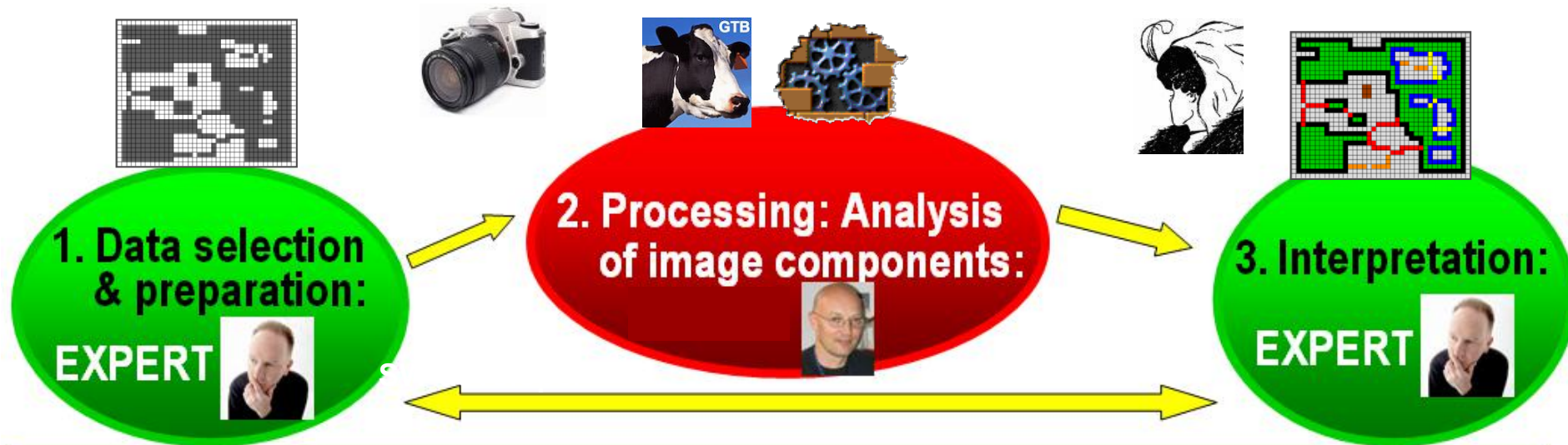
GWS 4: Hands-on examples using training data:

- a) Data preparation, MSPA, Google Earth overlays, batch process
- b) Distance, fragmentation, network, restoration, change, ...



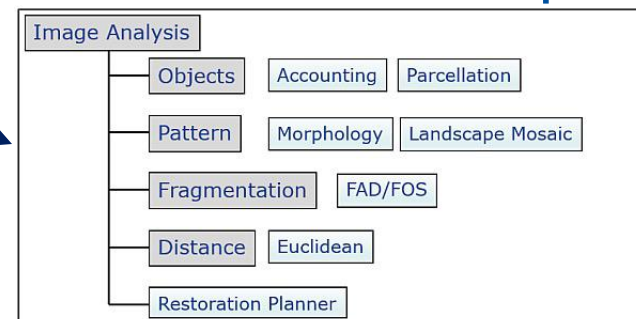
GuidosToolbox: Generic Geometric Image Object Analysis

Graphical User Interface for the Description of image Objects and their Shapes



Aim: Toolbox for a generic description of spatial pattern

- GuidosToolbox (GTB)¹: interactive desktop application (macOS, Linux, MS-Windows)
- GuidosToolbox Workbench (GWB)²: command-line Linux server application
- Documentation¹: detailed product sheets and extensive workshop material...



(1): <https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/>

(2): <https://forest.jrc.ec.europa.eu/en/activities/lpa/gwb/>



Generic Geometric Image Object Analysis



1. Input - Critical

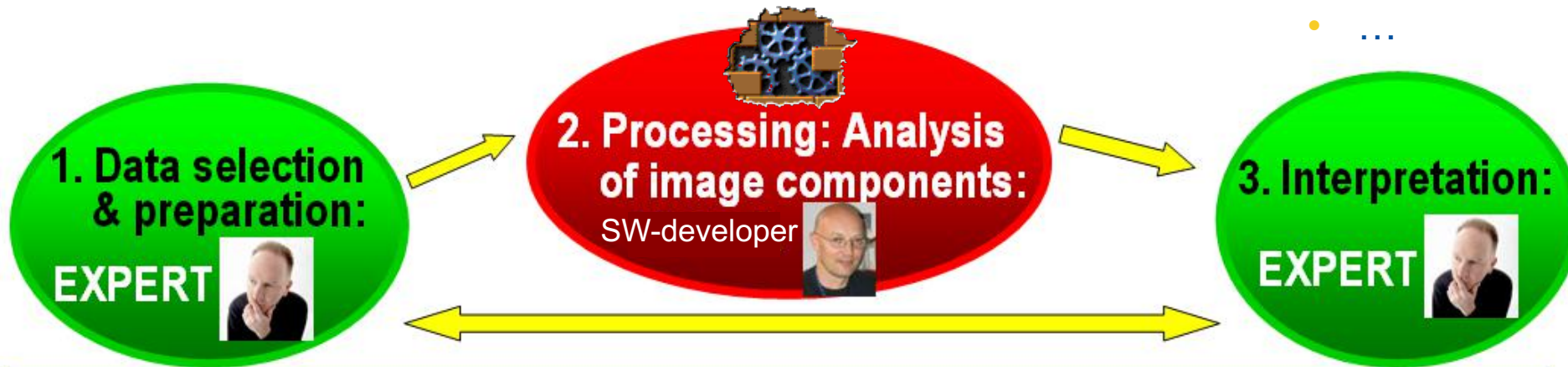
- What exactly is the scope?
- What does the customer expect?
- Which feature do I need?
- Are customer and I on the same track?
- Which dataset is appropriate?
- Availability, cost, quality, scale?
- Legal: Public or proprietary data?
- Ready to use or pre-processing needed?
- ...

2. Software

- Which SW is most appropriate?
- Do I have access to it?
- Which analysis tool is needed?
- Applicability and limitations?
- Can I do this myself?
- Do I need additional SW or help?
- Will the customer understand it?
- ...

3. Output

- Interpretation is subjective
- Post-processing needed?
- What is the key message?
- Best reporting style?
- Are the expectations met?
- Analysis tool adequate?
- Analysis settings adequate?
- Adequate for customer?
- Input data appropriate?
- ...



Aim: Toolbox for a generic description of spatial pattern



And why Generic Geometric Image Object Analysis?

A blank image has no information. **Image objects form pattern!**

Note: *We constantly* do pattern analysis (while watching, reading, driving, ...)



3 principles of GTB analysis

1. Spatial information:

Only maps show spatial variability, permit to locate hotspots and temporal changes. Maps are mandatory for spatial planning, ...

2. Quantitative measures:

Clear and intuitive indicators – ideally in %, imperative for efficient communication.

3. Generic, flexible analysis:

Applicable to any thematic layer & any scale, can be fine-tuned to meet custom reporting styles. ***Pattern as a reference product*** serves as a base for a variety of end-users.



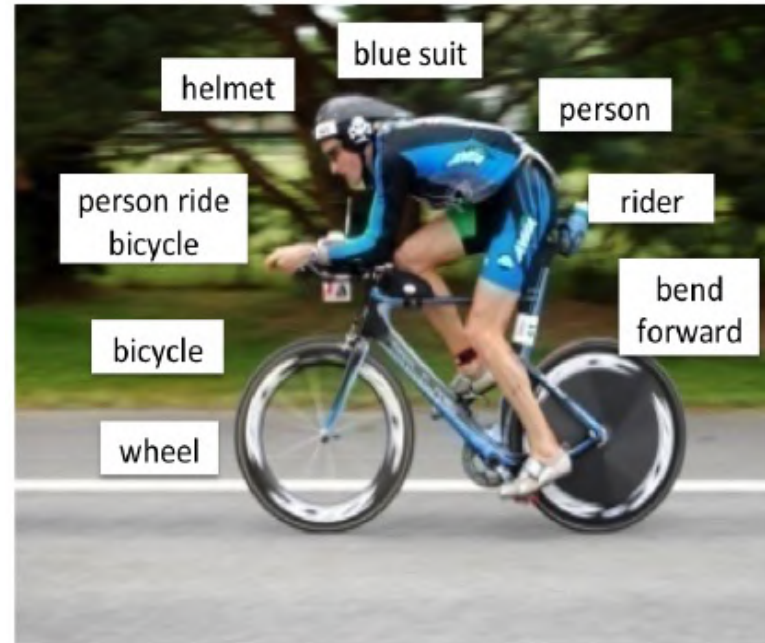
2003 – present

- 1) Structural Pattern Analysis ...
- 2) From Structural to Functional Pattern ...
- 3) Combining Pattern With Connectivity ...
- 4) Change Analysis ...
- 5) Landscape Mosaic ...
- 6) Contortion Analysis ...
- 7) Distance Analysis ...
- 8) Fragmentation Analysis ...
- 9) Accounting ...
- 10) Restoration Analysis ...
- 11) GWB



1) Structural Pattern Analysis: what are we actually talking about?

How can we describe digital image features in an objective way?



Show 5 people the same image and ask them what they see.

You will get 5 different answers, all different to what you expected. So, who is right? - Everybody, if you adopt their mindset...

Interpretation is, by definition, **subjective** because it is driven by individual interest, priorities, requirements, or personal preference...

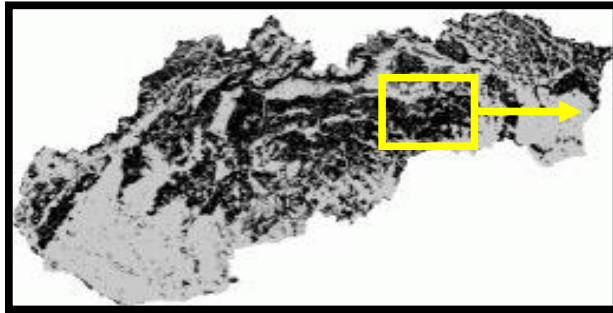
A philosophical question: *truth* ↔ *subjectivity* (Søren Kierkegaard)



Task: Report on Forest Spatial Pattern in EU member states.

1. FSP = f(average patch size, total forest area)

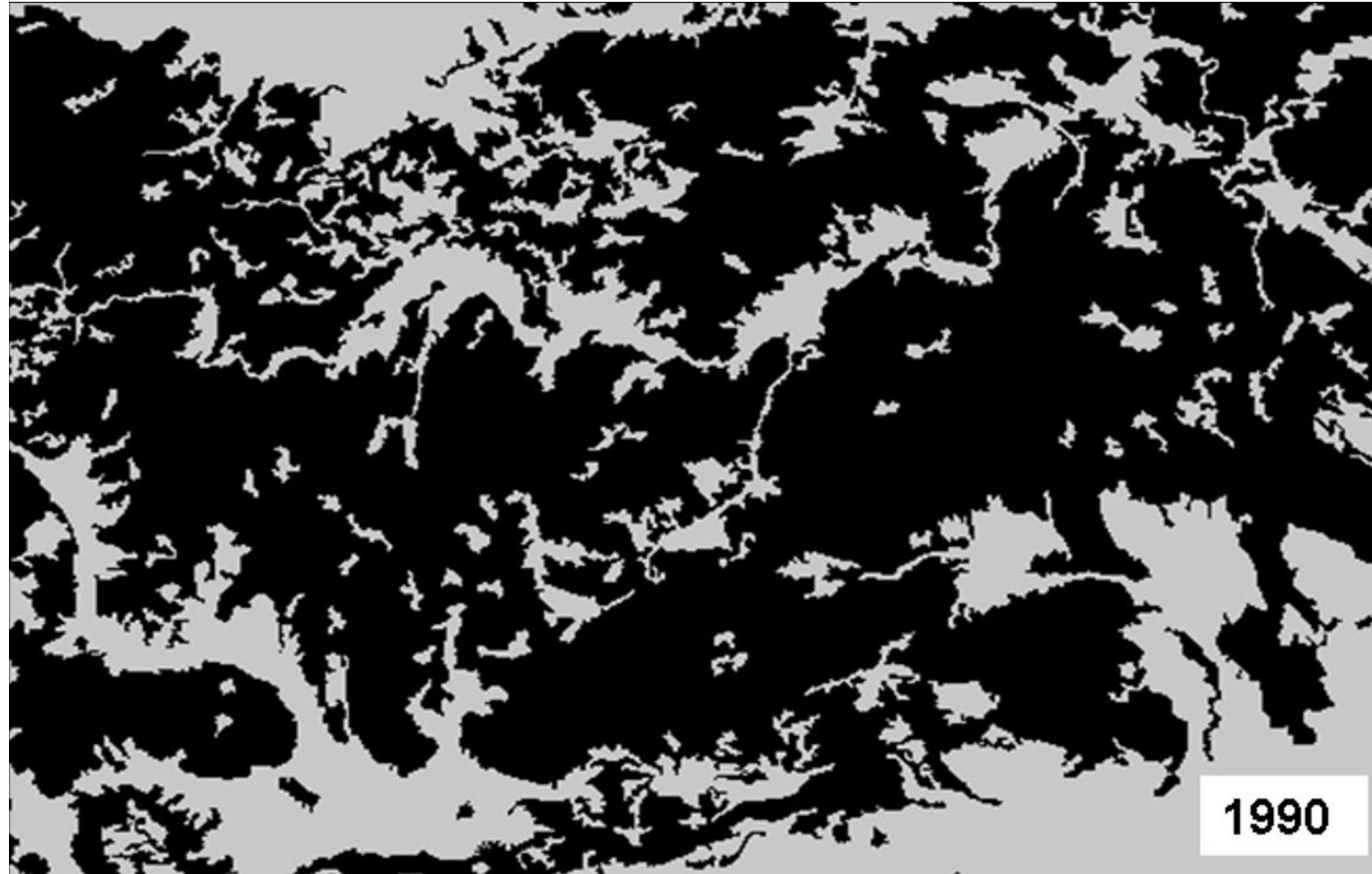
Slovakia: constant, no change?



2 parameters: APS, Area.

Pro: intuitive

Con: inconclusive & no map
→ no reliable statistics





Riitters et al. 2000:

2. $FSP = f(P_f, P_{ff})$

4 classes:

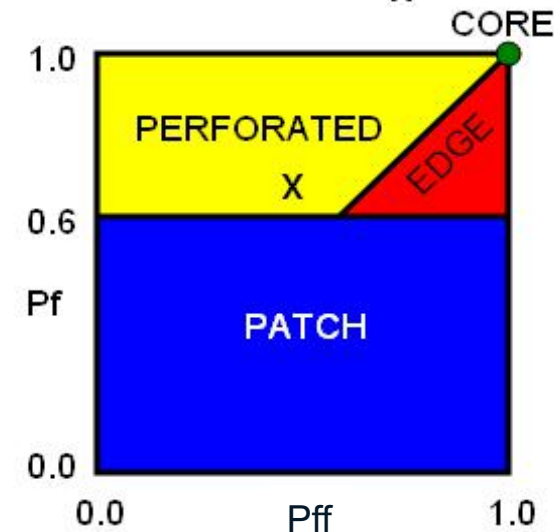
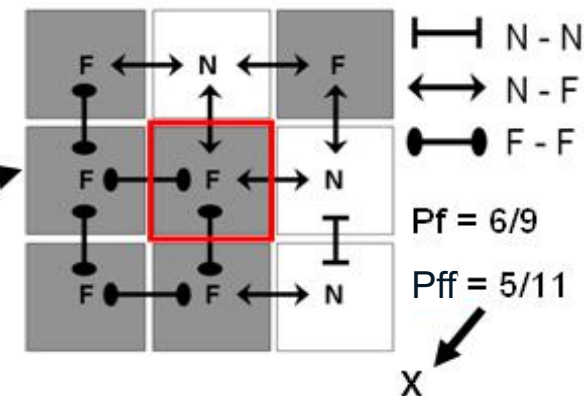
Core, Patch, Perforated, Edge.

Pro:

intuitive, independent, *flexible*,
spatial information, *perforated*

Con: confusion at pixel level
→ no reliable statistics

Moving window over each forested pixel

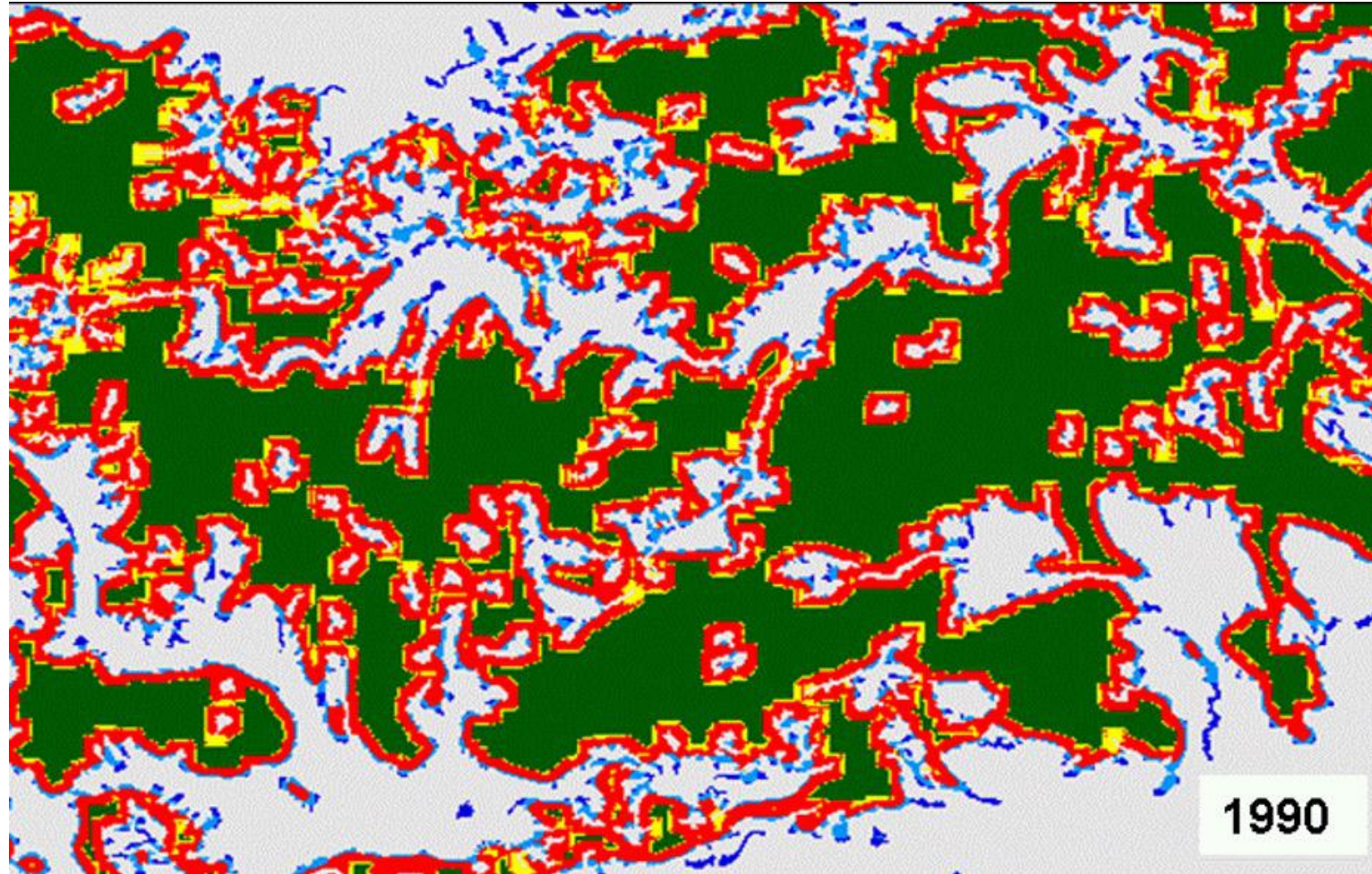
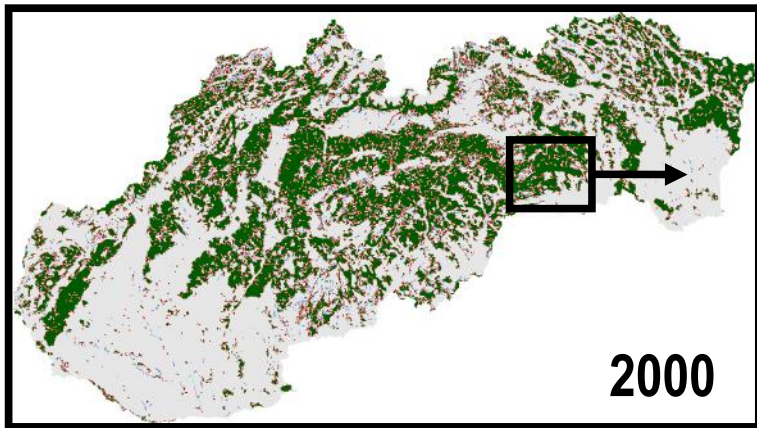


Classifier = $f(P_f, P_{ff}) = f(F, N)$



Spatial information but confusion at pixel level...

Slovakia: change!



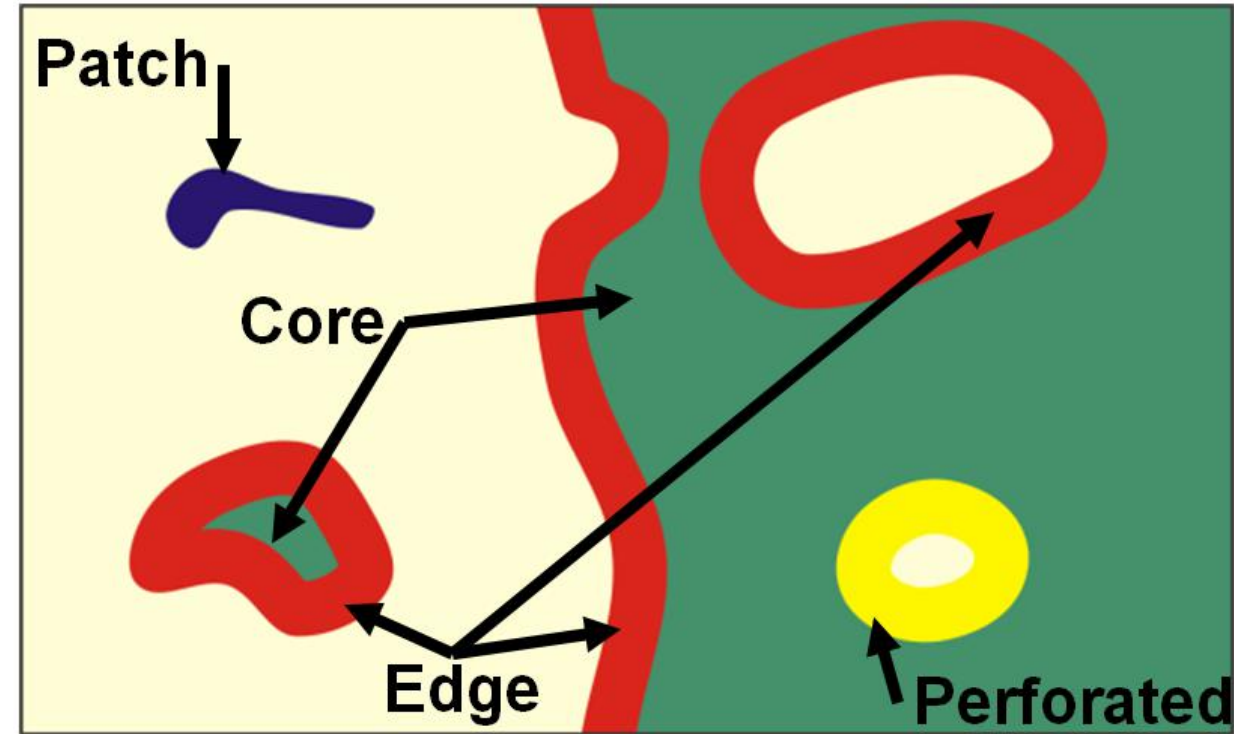
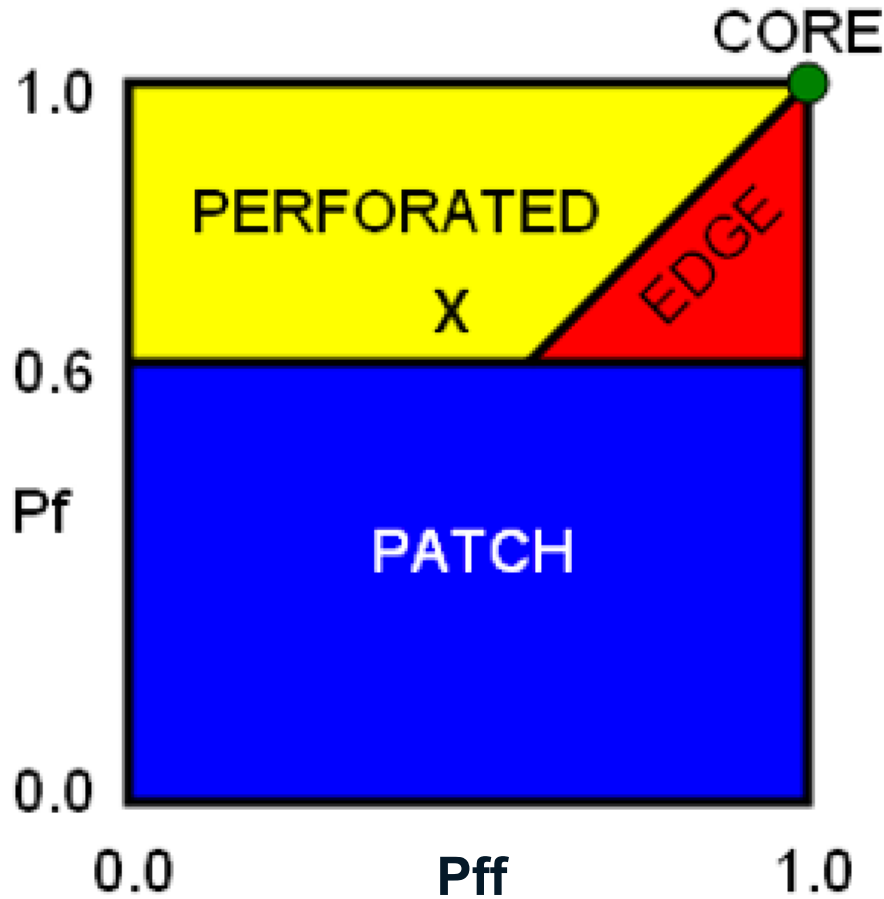


Pf/Pff: 4 thematic classes →

Morphological implementation

Analyzing a binary mask with morphological filters to derive the spatial pattern classes:

CORE **PATCH** **EDGE** **PERFORATED**





Vogt et al. 2007a: *replace* moving window with math. morphology

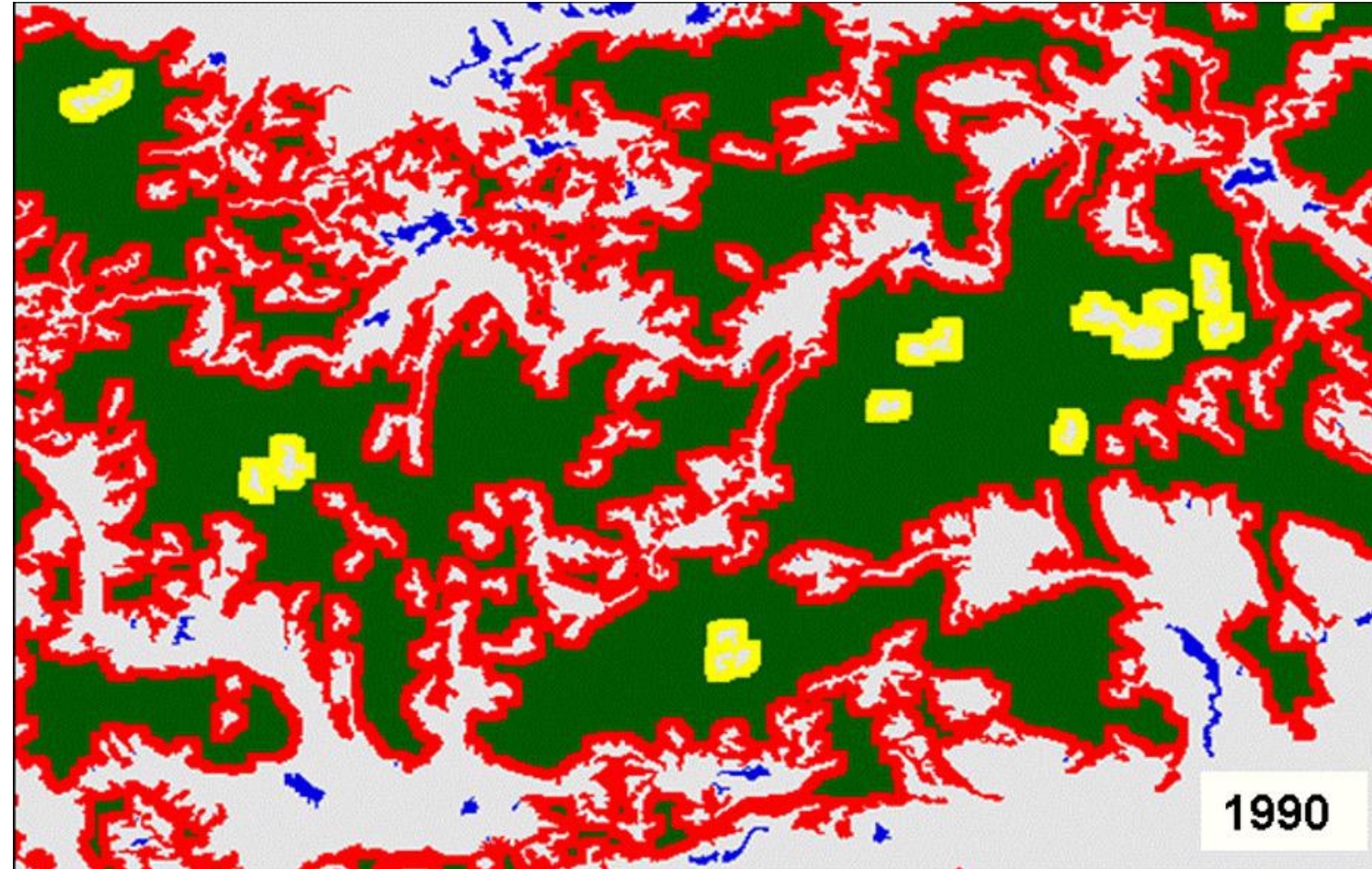
3. FSP = f(morphology)

4 classes: *Core*, *Patch*, *Perforated*, *Edge*.

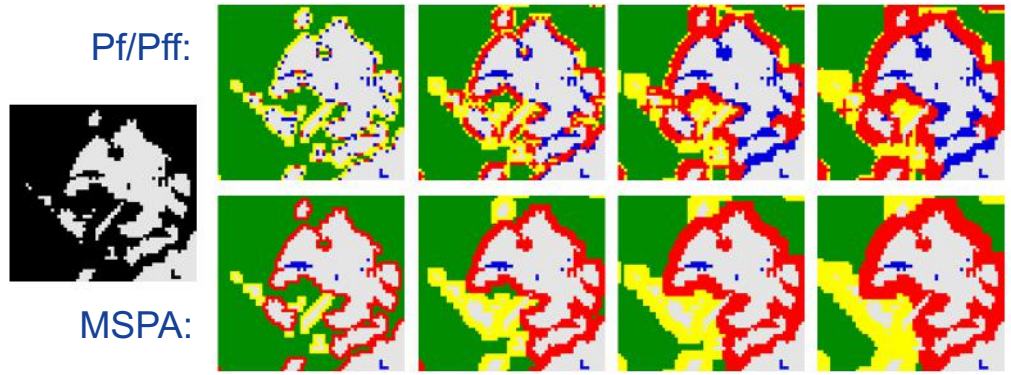
Pro: intuitive, independent, *flexible*, *spatial information*, *perforated*, → reliable statistics

Con: nothing

Morphology: no confusion at pixel level.



1990



Window size/SE: 3 x 3 5 x 5 7 x 7 9 x 9

- Forest
 - Nonforest
 - Core
 - Patch
 - Perforated
 - Edge












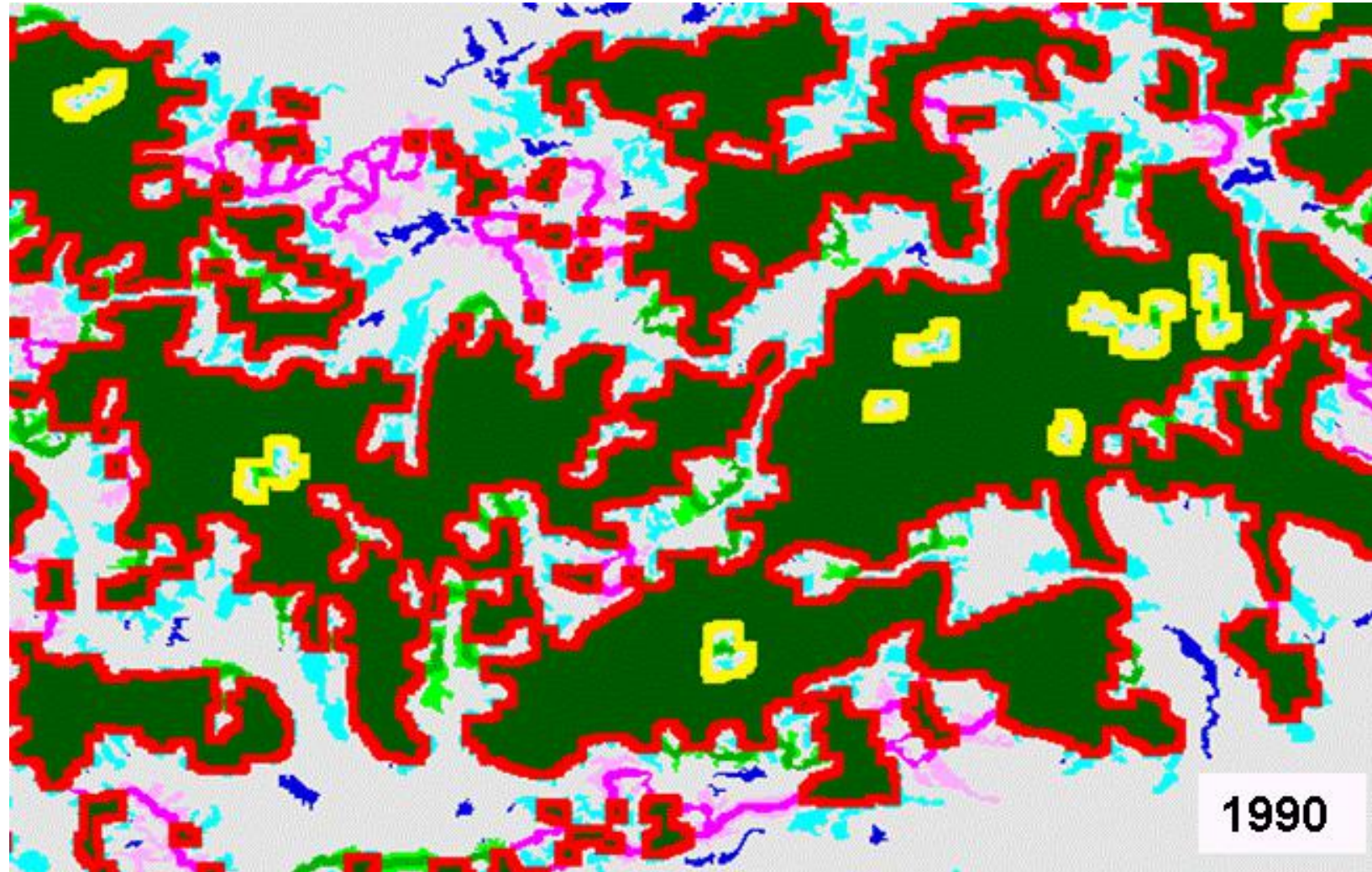
Vogt et al. 2007b: morphology including structural connectivity

FSP = f(morphology)

Pro:
structural connectors!

Con: ?

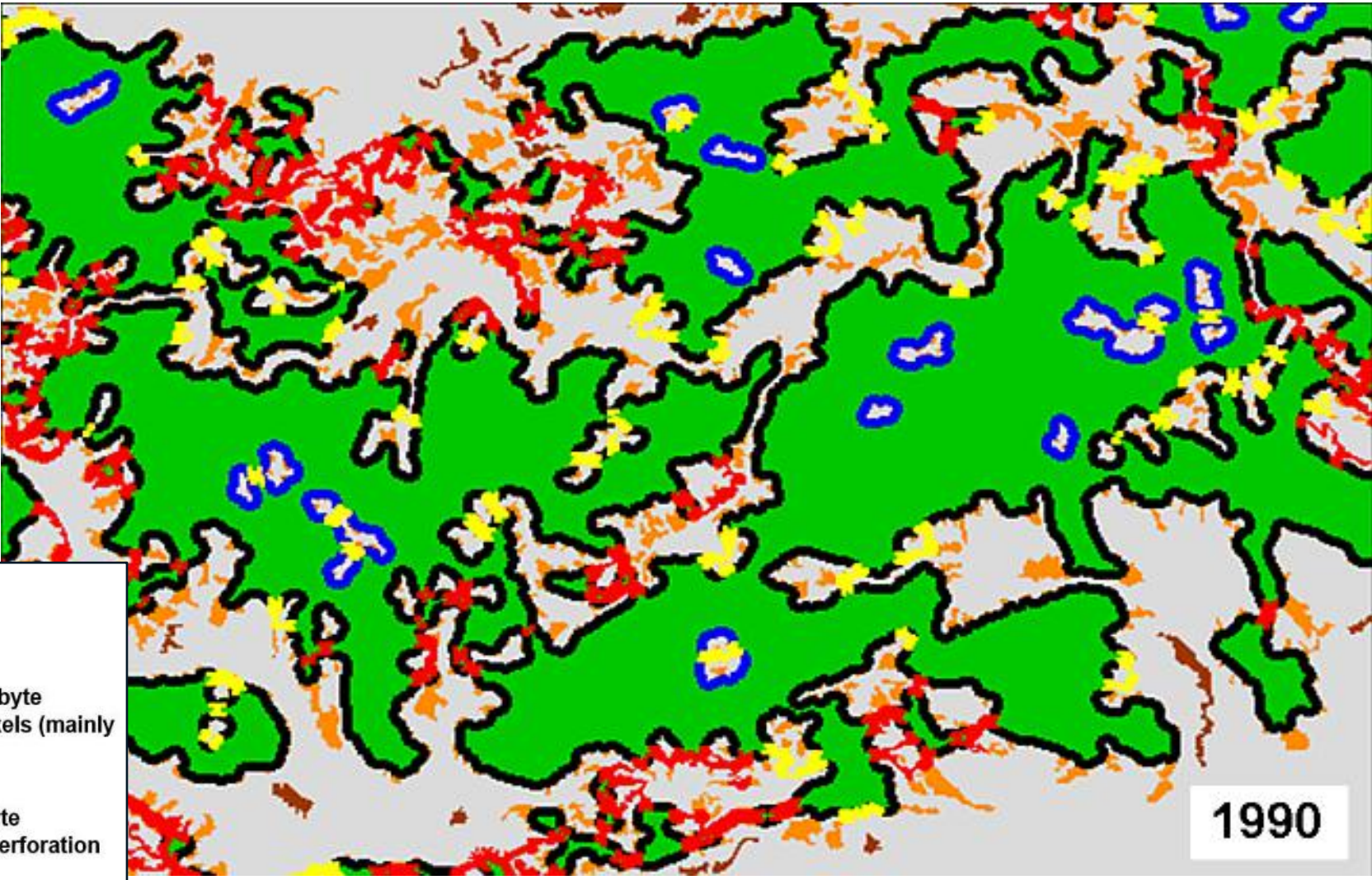
	Core
	Patch
	Perforated
	Edge
	Branch of Edge
	Shortcut
	Branch of Shortcut
	Corridor
	Branch of Corridor



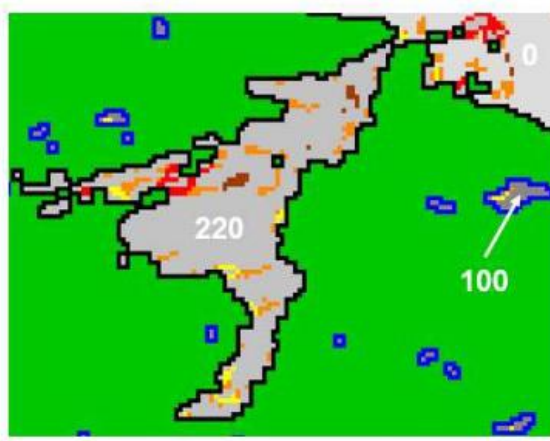


Soille&Vogt 2009: MSPA (with up to 25 classes...), $FSP = f(MSPA)$

- Core
- Edge
- Perforation
- Bridge
- Loop
- Branch
- Islet
- Background
- No data



2018 Background segmentation:

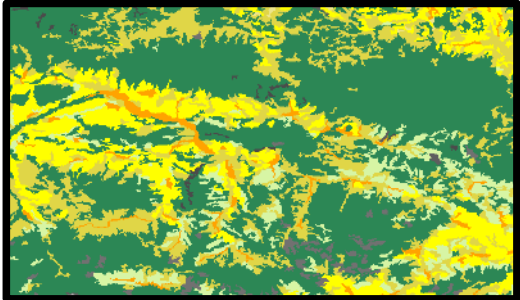


- Background: 0 byte outside Foreground
- Border-Opening: 220 byte surrounded by FG-pixels (mainly Edge)
- Core-Opening: 100 byte surrounded by blue Perforation pixels (inside Core)

1990

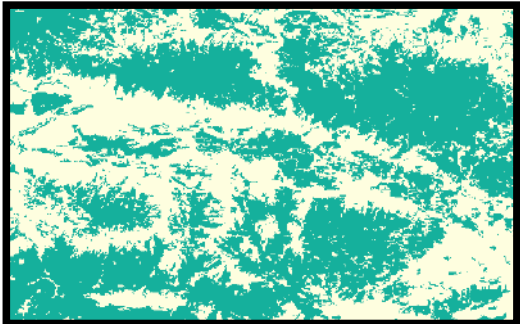


1. input



Raster map: land cover, species distribution, dispersal, ...

2. foreground/background

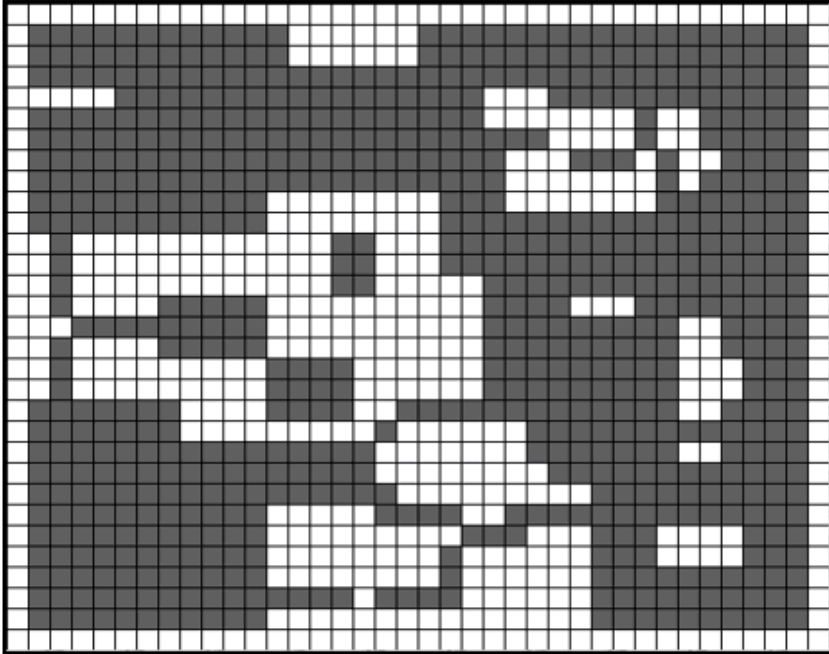


Binary mask: forest, habitat, grassland, movement, ...

3. MSPA segmentation

INPUT: binary map

- Foreground: objects of interest
- Background: complementary area



MSPA foreground classes

- Core: interior area excluding perimeter
- Islet: disjoint and too small to contain Core
- Loop: connected to the same Core area
- Bridge: connected to different Core areas
- Perforation: internal object perimeter
- Edge: external object perimeter
- Branch: connected at one end to Edge, Perforation, Bridge, or Loop.

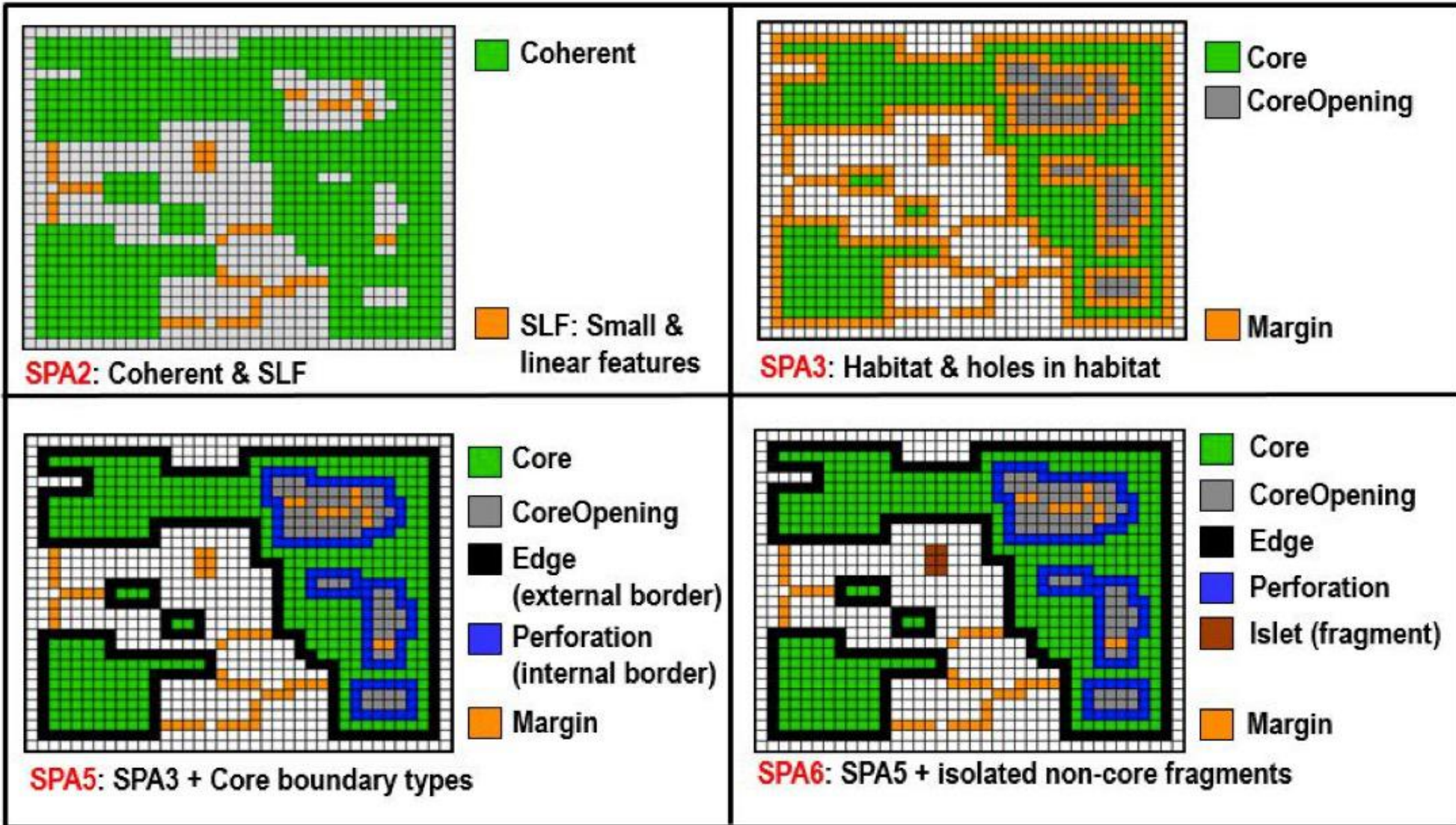
MSPA background classes

- Background
- Border-Opening: along Edge
- Core-Opening: within Perforation

Morphological feature classes
(more details in part 2 of this workshop)



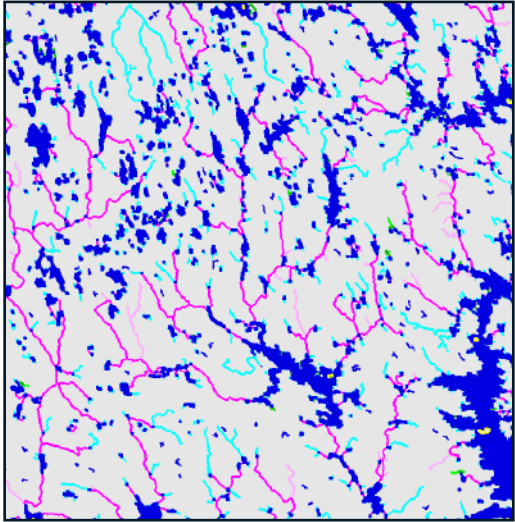
MSPA subset: flexible but fewer classes → clearer message



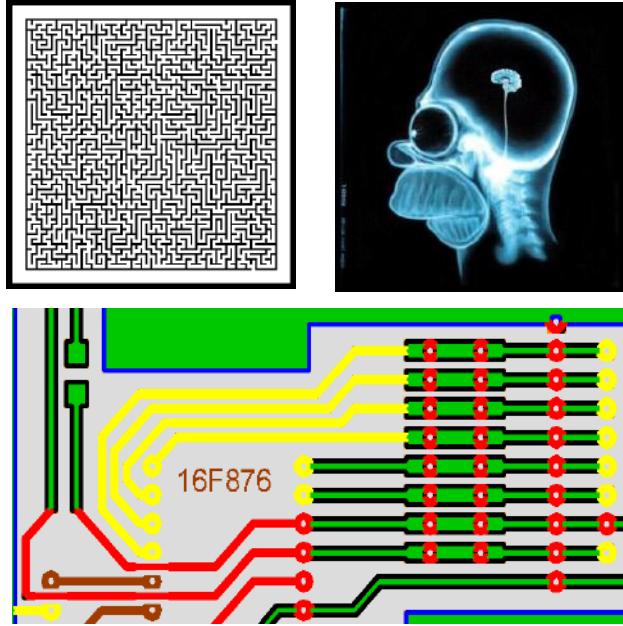
(more details in part 2 of this workshop)



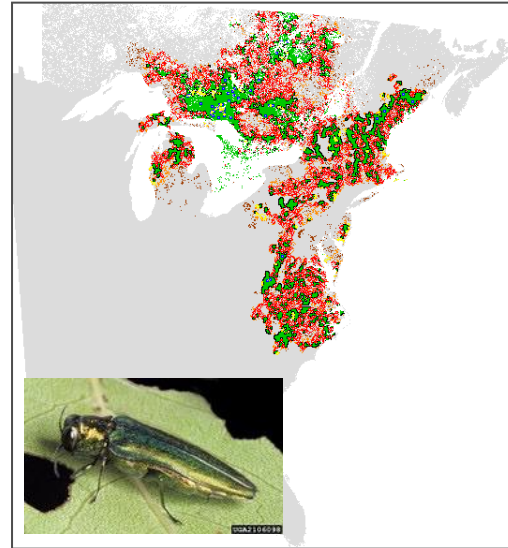
Rivers & wetlands, Finland



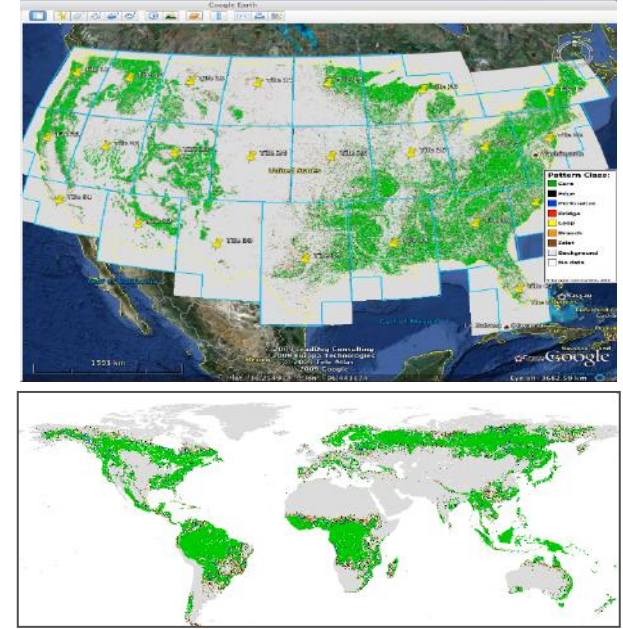
Maze, medical, manufacturing...



Disease spread pattern



National/global forest pattern



Automatic zooplankton recognition, (Schmid et al. 2016)

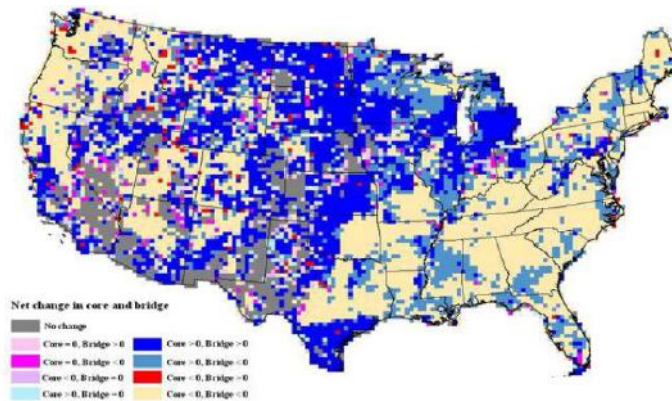
Deploying LOKI

Mysid (opossum) shrimp

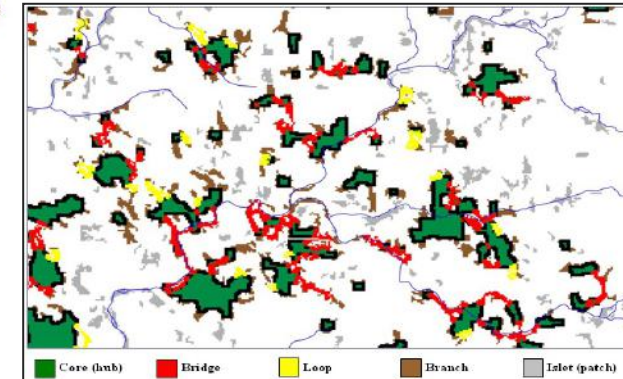
Nauplius larvae stage of copepod (~0.2mm)

Adult copepod, extremely important in the food chain since it has vast lipid reserves

US GI Assessment, (Wickham et al. 2010)



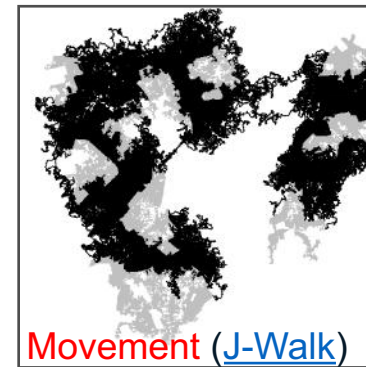
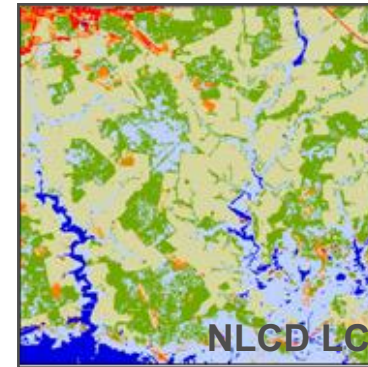
Habitat conservation....



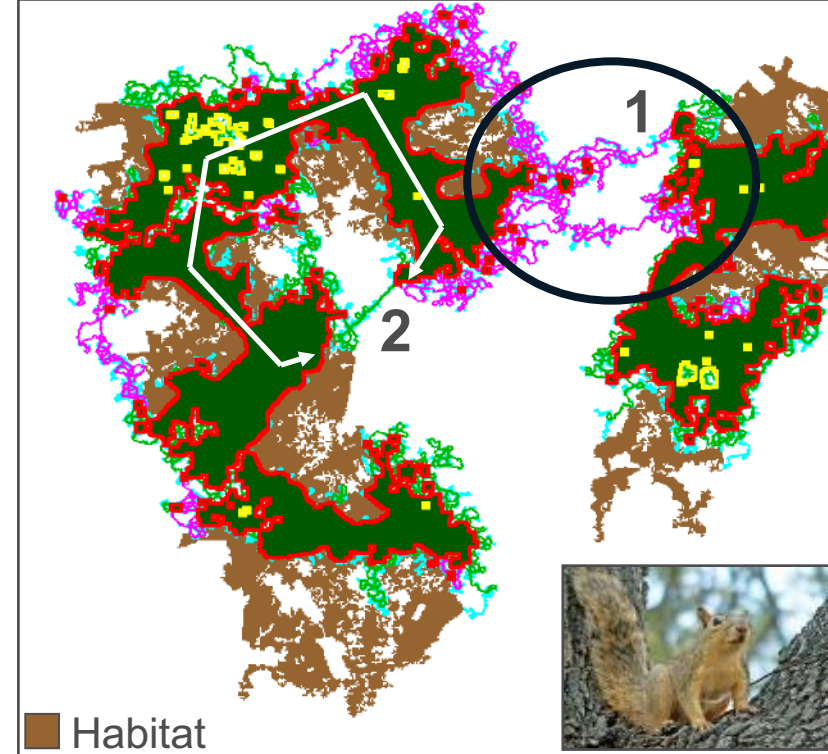
US-EPA: [Enviroatlas](#) (Landscape Pattern)



MSPA: maps morphological features/connectivity on *any kind* of digital data map

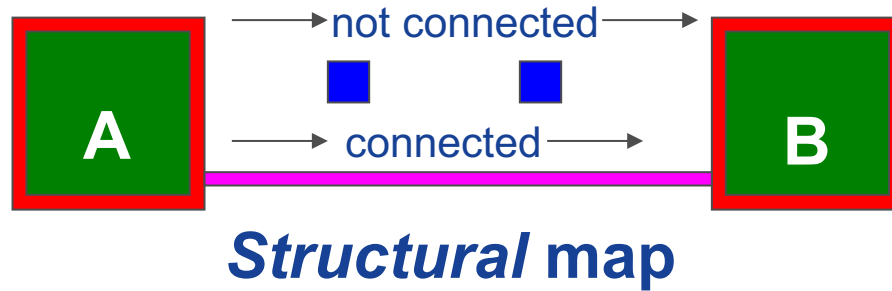


Mapping functional connectivity, (Vogt et al. 2009)

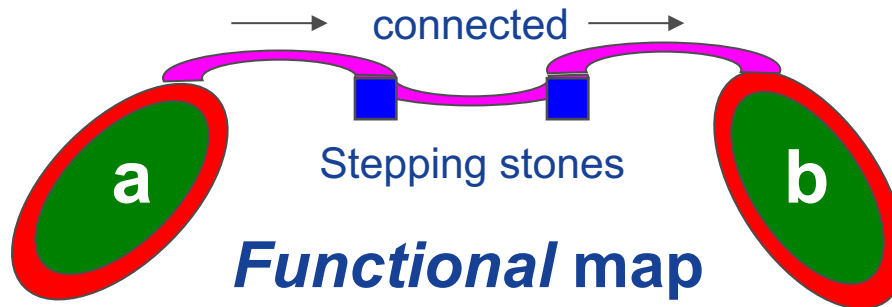


Habitat

1) *Structural* pattern: map of forest, grass-, wetland, habitat, ...



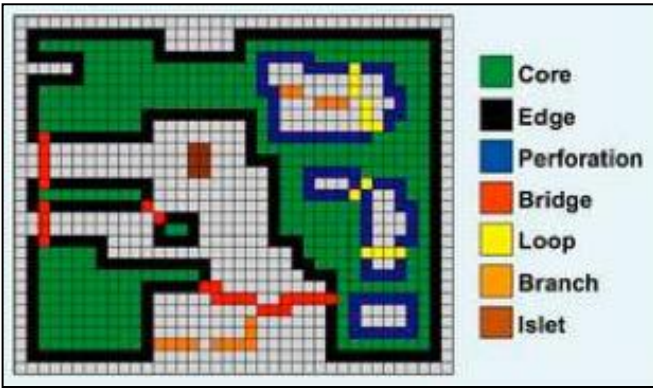
2) *Functional* pattern: map of movement, dispersal, telemetry, ...



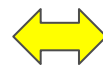
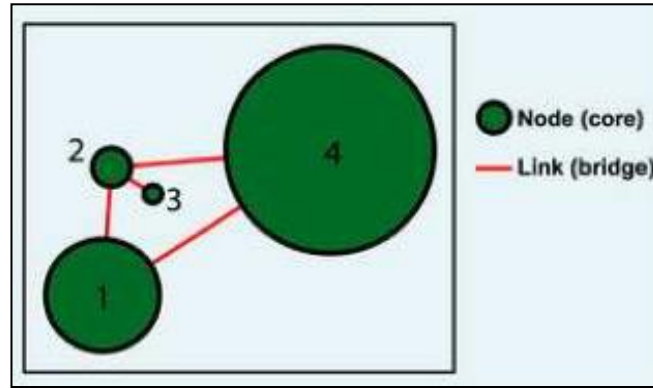


MSPA reliably finds connectors but how *important* is each connector?

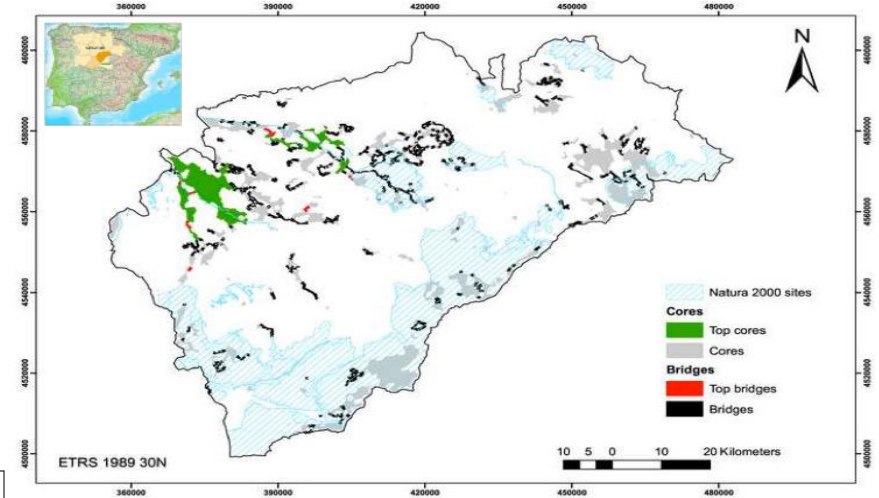
MSPA



Graph theory (Conefor)



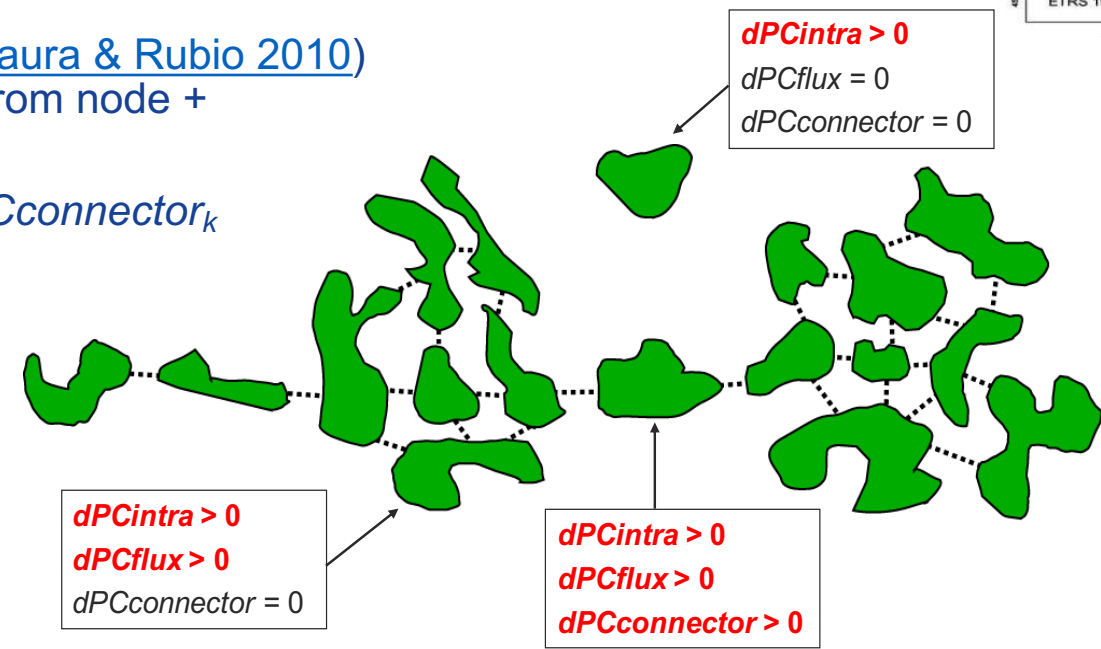
Key connectors & habitats (Saura et al. 2011)



Probability of Connectivity (PC), (Saura & Rubio 2010)
 = Intranode connectivity + flux to/from node + connectivity for other nodes:

$$dPC_k = dPC_{intra_k} + dPC_{flux_k} + dPC_{connector_k}$$

$$dPC_k = 100 \cdot \frac{PC - PC_{remove,k}}{PC}$$



$dPC_{intra} > 0$
 $dPC_{flux} = 0$
 $dPC_{connector} = 0$

$dPC_{intra} > 0$
 $dPC_{flux} > 0$
 $dPC_{connector} = 0$

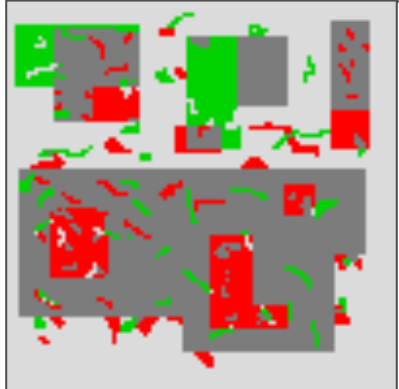
$dPC_{intra} > 0$
 $dPC_{flux} > 0$
 $dPC_{connector} > 0$

Intra: Habitat resource within a patch
Flux: How well connected is the patch
Connector: Patch importance for the others to remain connected



How can we detect and measure *essential* changes in an objective way?

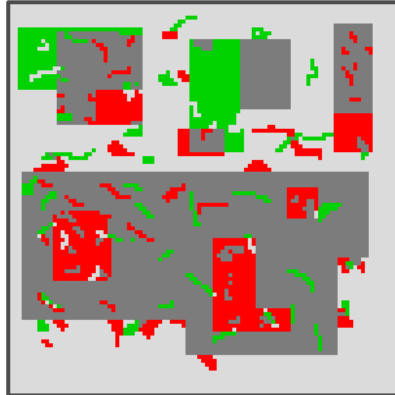
Change map



Changed:
Gain
Loss

Unchanged:
Forest
Non-forest

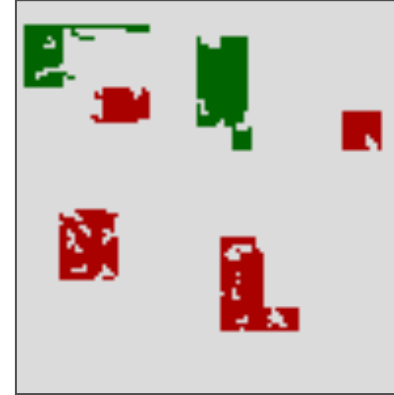
Morph. erosion



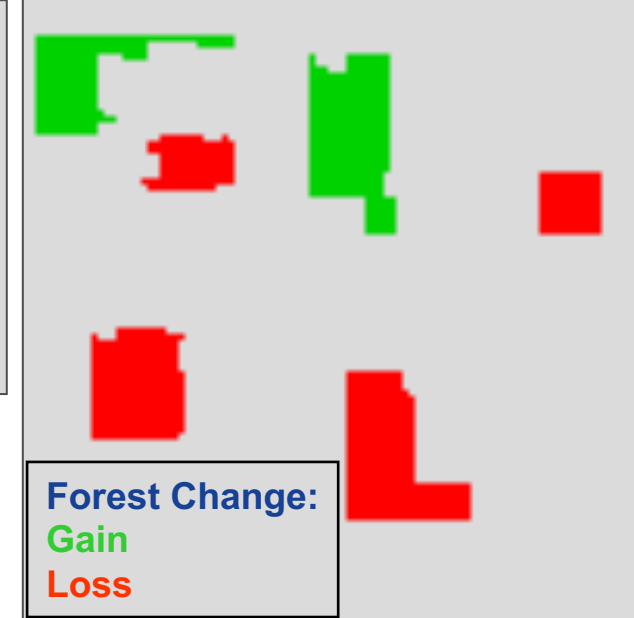
Change seeds



Reconstruction



Filling & final change product



Forest Change:
Gain
Loss

MCD (A->B) FG: -7.37697, FGI: -12.0295, Elasticity: 1.63068

File General Tools Image Analysis Help

Read Image > RIBUTES
Save Image > Colortable
Batch Process > Colortable

Change > FOS
Exit > FAD
Simple Change
Morph. Change

Autostretch

MSPA SETTINGS

FGConn [0/4]	EdgeWidth [pixels]	Transition [On/Off]	Intext [On/Off]
<input checked="" type="checkbox"/>	1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

MSPA statistics

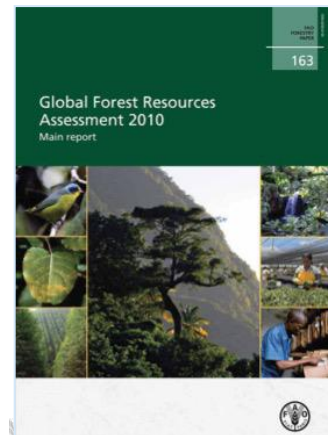
	FG/data[%]	#/BGarea
CORE(a)	n/a	n/a
CORE(m)	n/a	n/a
CORE(f)	n/a	n/a
ISLET	n/a	n/a
PERFOR	n/a	n/a
EDGE	n/a	n/a
LOOP	n/a	n/a
BRIDGE	n/a	n/a
BRANCH	n/a	n/a
Background	n/a	n/a
Missing	n/a	n/a
Opening	n/a	n/a
Core-Open	n/a	n/a
Border-Open	n/a	n/a

X: 341 Y: 1 Value: 22 (byte)

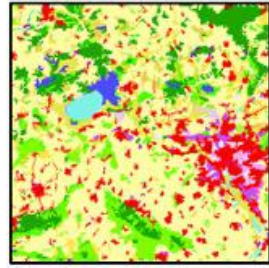
Divide MSPA-Core pixels: small < 1000 medium 4600 > large

MCD ([Seebach et al. 2013](#))

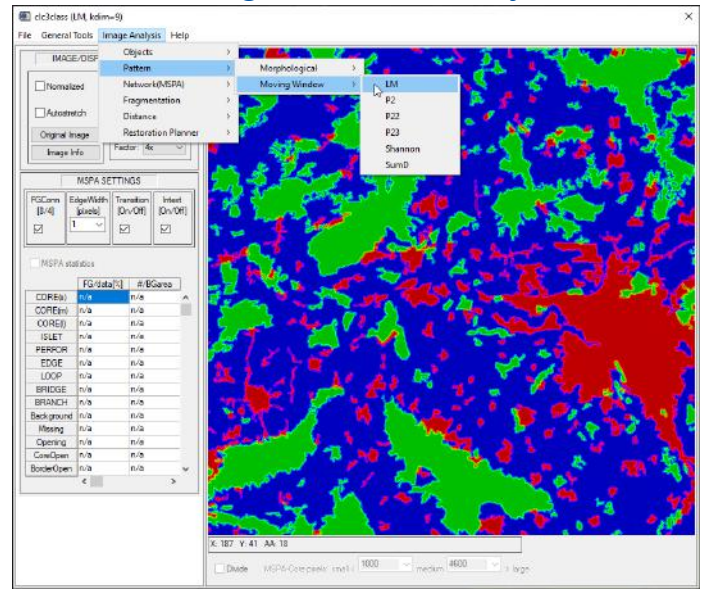
- Essential loss areas
- Essential gain areas
- Remove unwanted spurious changes



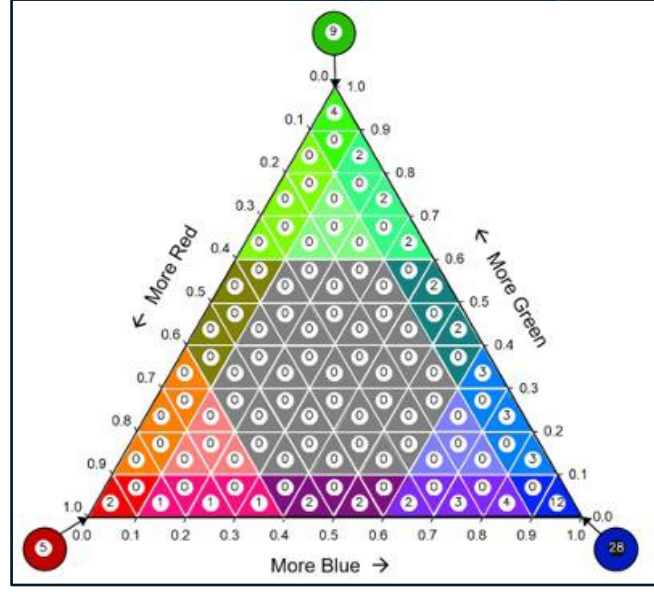
LC map



LM: moving window analysis

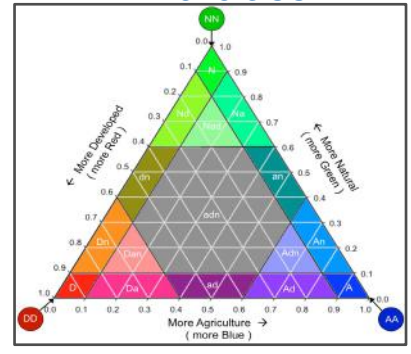


103-class heatmap summary

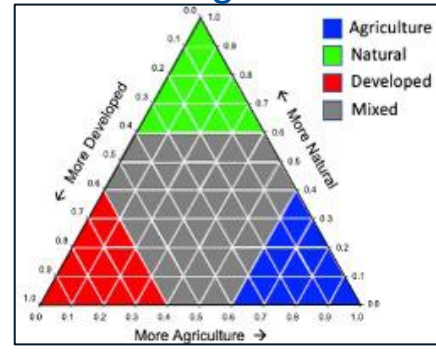


Define an adequate reporting scheme:

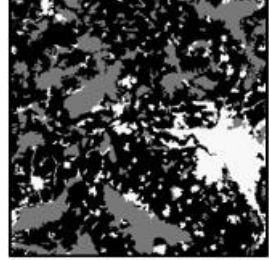
19-class



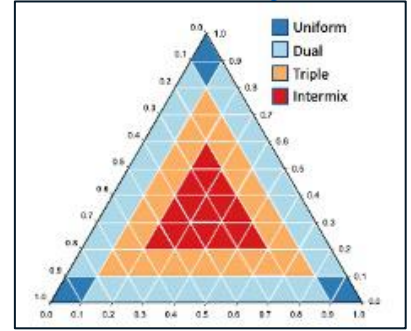
Background



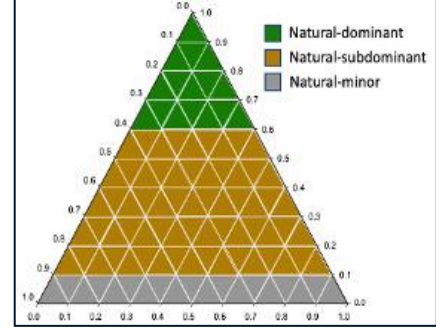
3 LC types



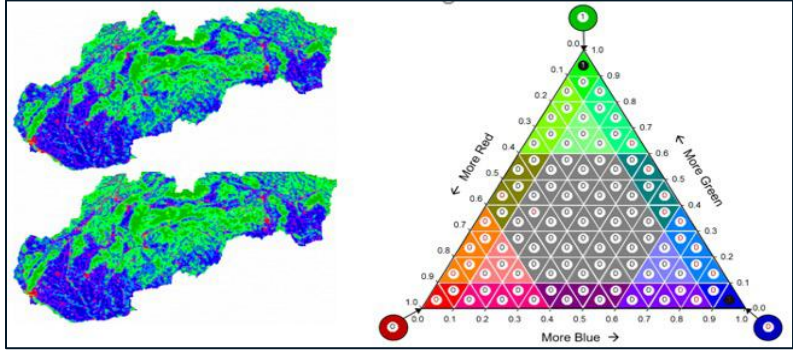
Diversity



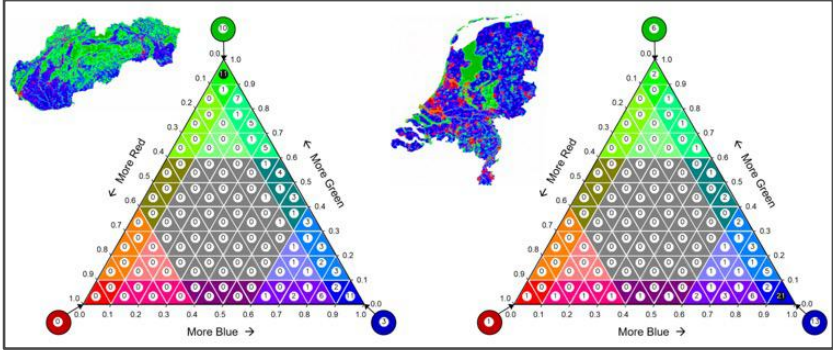
Naturalness



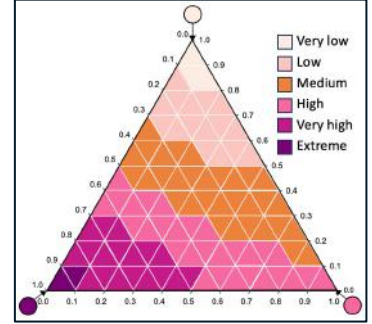
Change over scale or over time



Compare different countries



Anthropic



RESEARCH ARTICLE [PLOS ONE](https://doi.org/10.1371/journal.pone.0171111)
 Revisiting the Landscape Mosaic model
 Peter Vogt^{1*}, James Wickham², José Ignacio Barredo³, Kurt Ritters^{4,5}



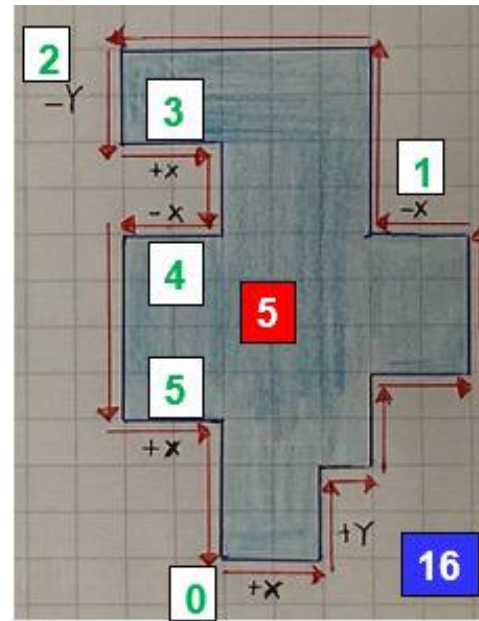
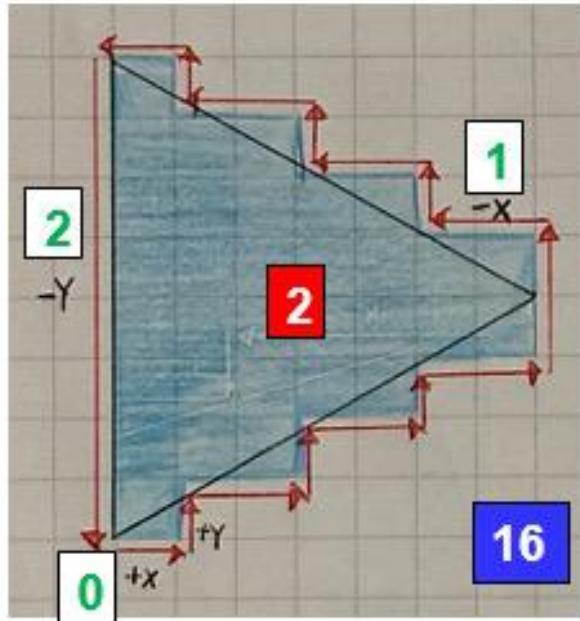
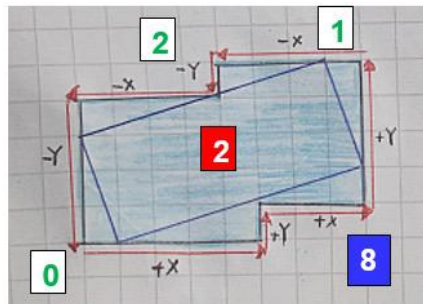
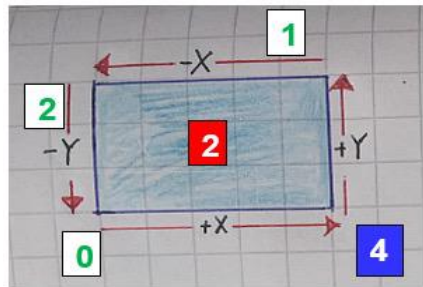


From a spatial perspective: evidence of anthropogenic activities...



Humans create regular-shaped objects (buildings, agricultural fields, ...)

Contortion: count directional changes in x/y along raster representation of object perimeter: *Object complexity* (\neq Corner count!)



Contortion features:

- **Rotation invariant**
- **Low count:**
Anthropogenic objects
- **High count:**
Natural objects

– Object perimeter

x Contortion

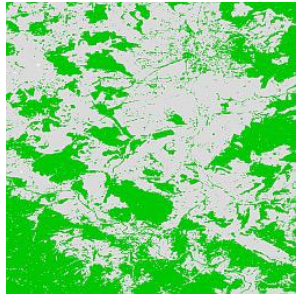
x Corner count

■ Pixel representation of image of object and its perimeter in a raster grid

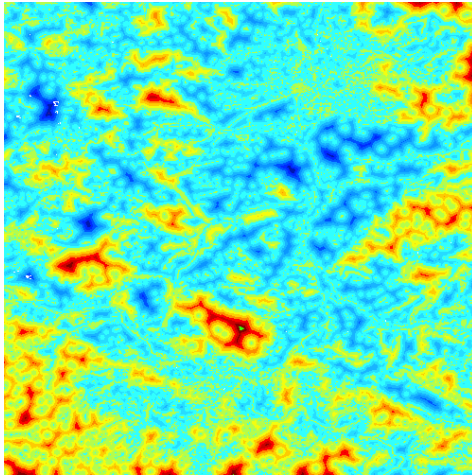


Euclidean distance, influence zones, buffer zones, proximity...

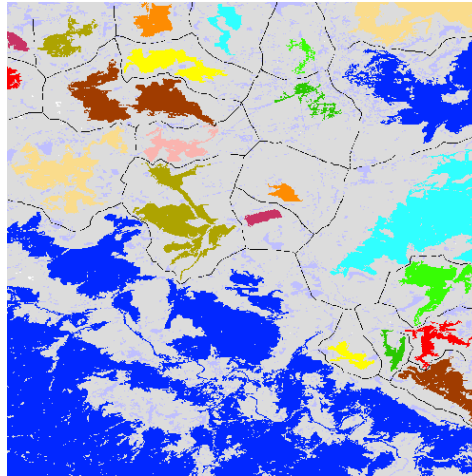
Mask



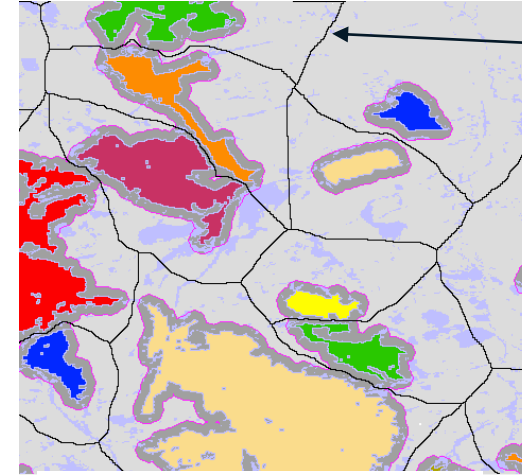
Euclidean distance



Influence zones



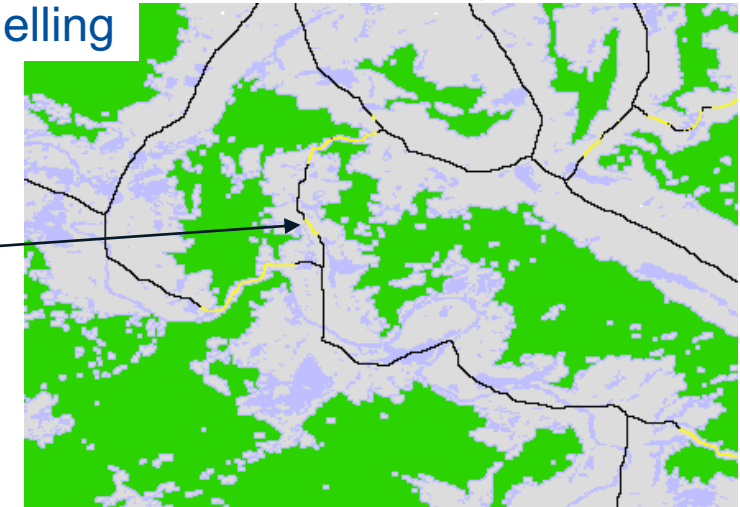
Buffer zones



Watershed line: delineating equal distance to direct neighbors (influence zone)

Proximity

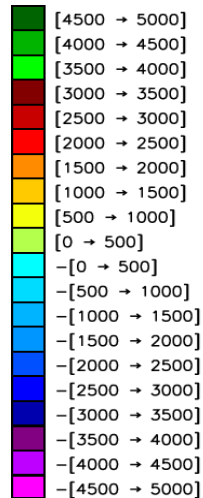
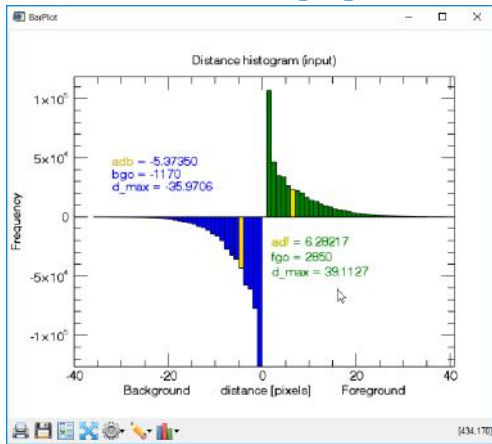
Pest risk modelling



Distance between objects > X hectare

Locations where pairwise distance < X (restoration planning)

Distance [m]

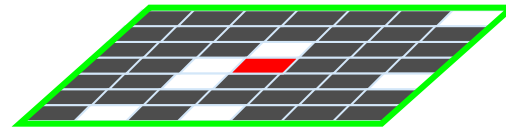
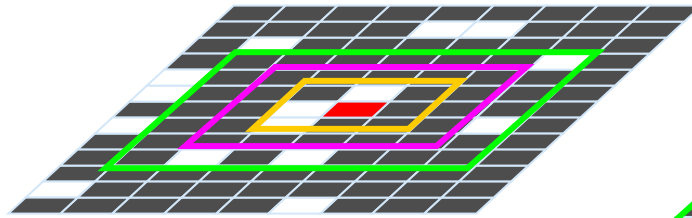




Aim: generic geometric approach: normalized [0,100]% spatial index

For each forest pixel: Get **Forest Area Density (FAD)** at 5 neighborhood scales

Select a focal pixel as the center of a neighborhood

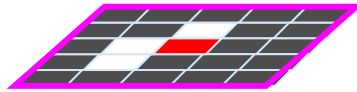


- Fragmentation (FAD):**
- Spatial feature
 - Scale-dependent
 - Maps FG and BG
 - Structural measure

Measure the proportion of forest in the neighborhood:
 $P = 6/9 = 67\%$

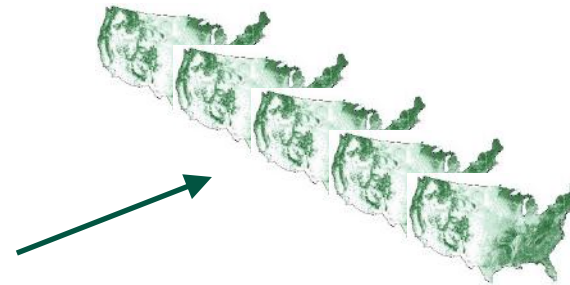


Repeat for a larger neighborhood:
 $P = 22/25 = 88\%$

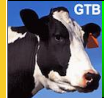


And so on... using 5 neighborhood sizes

Store the results at the location of the focal pixel and repeat for all pixels.



5 maps – one for each neighborhood size

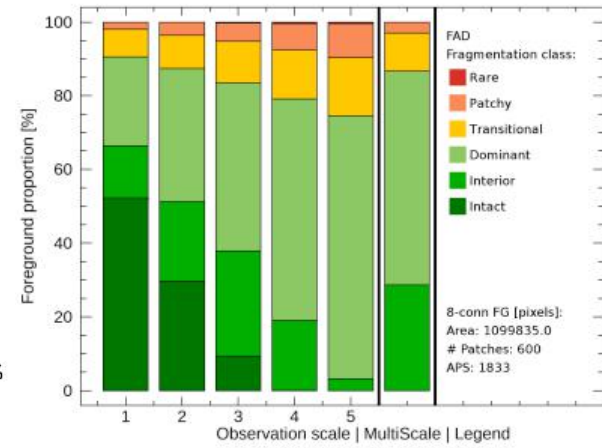
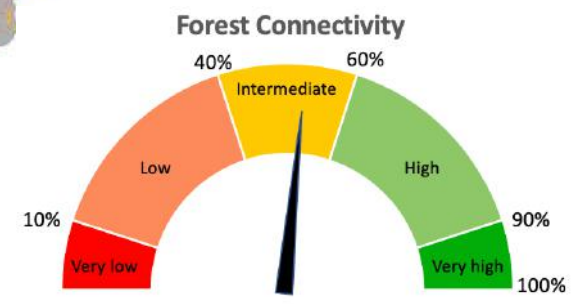
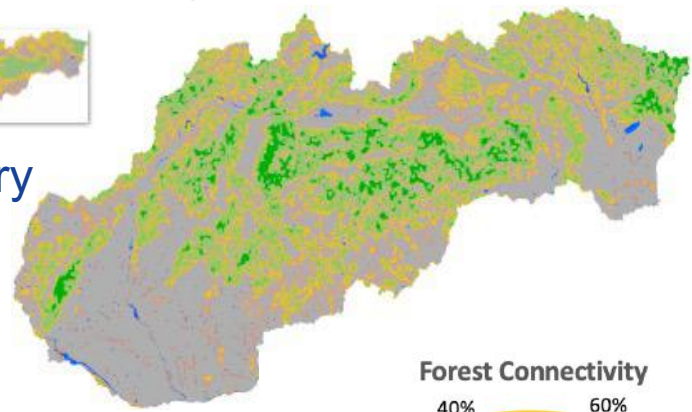


1) Measure FAD at 5 different scales, show in six fragmentation classes



and add cross-scale fragmentation summary

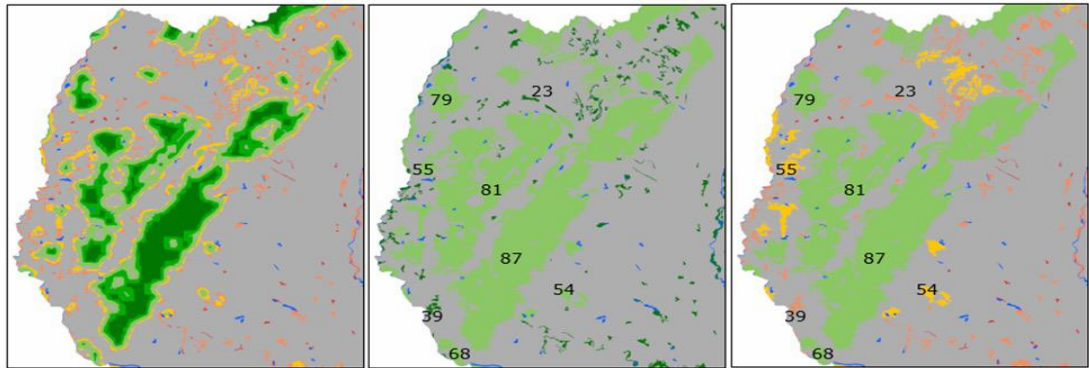
Fragmentation class	Color	FAD range
1 - Rare	Red	FAD < 10%
2 - Patchy	Orange	10% ≤ FAD < 40%
3 - Transitional	Yellow	40% ≤ FAD < 60%
4 - Dominant	Light Green	60% ≤ FAD < 90%
5 - Interior	Green	90% ≤ FAD < 100%
6 - Intact	Dark Green	FAD = 100%



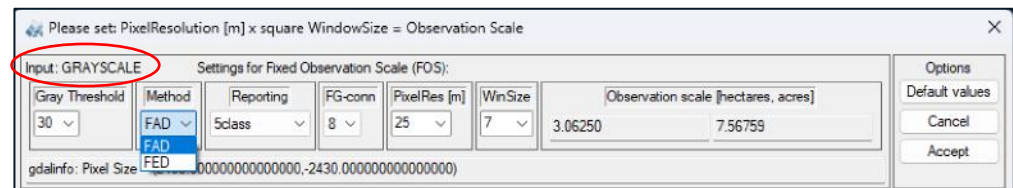
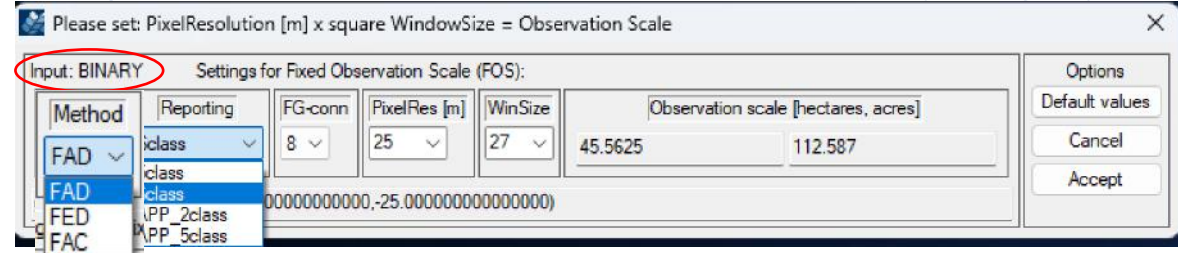
2) Statistics for area and fragmentation classes

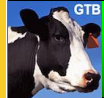
```
FAD: Foreground Area Density summary analysis for image:
C:\GuidosToolbox\data\NFinland_A.tif
-----
8-conn FG: area, # patches, aps [pixels]: 1099835.0, 600, 1833
Fragmentation class: foreground proportion at observation scale/area:
Observation scale: 1 2 3 4 5 mscale
Neighborhood area: 7x7 13x13 27x27 81x81 243x243
-----
Rare: 0.0033 0.0242 0.2450 0.3786 0.3976 0.0186
Patchy: 1.9327 3.5649 4.9045 7.1666 9.1789 2.8774
Transitional: 7.5076 8.9589 11.3673 13.3002 15.8747 10.3957
Dominant: 24.1627 36.2559 45.5856 60.1687 71.3635 58.0553
Interior: 14.1438 21.5234 28.4999 18.8959 3.1853 28.6529
Intact: 52.2498 29.6727 9.3977 0.0900 0.0000 0.0000
-----
```

3) Per-pixel or Average Per-Patch fragmentation classes



4) User-defined scale: 3 methods, binary or grayscale input





Spatial integrity of a network (Coherence). Evaluation of restoration scenarios.

1) Network status summary.

Restoration status summary, network of FG-objects (2b):

AREA	RAC[%]	NR_OBJ	LARG_OBJ	APS	CNOA	ECA	COH[%]
428490.00	42.860572	2850	214811	150.34737	311712	221292.76	51.644789

Note: select File -> Save Image to save the restoration status summary.

Coherence: degree of spatial network integrity in %

Locate optimum path between start and target habitat

	A	B	C	D	E	F	G	H	I	J	K	L
1	SIZE_A	SIZE_B	REST_PIX	AVDIST_RP	EXP_30	EFFIC	ECA_ORIG	ECA_NEW	DELTA_ECA	COH_ORIG	COH_NEW	DELTA_COH
2	1451	33508	65	1.80456	1950	24.151311	221292.76	268387.81	47095.056	51.644789	62.626224	10.981435

Isochrone map

Cost map from object A

2) Setup & evaluate restoration scenarios.

	A	B	C	D	E	F	G	H	I	J
1	REST_PIX	AVDIST_RP	EXP_30	EFFIC	ECA_ORIG	ECA_NEW	DELTA_ECA	COH_ORIG	COH_NEW	DELTA_COH
2	200	5.46738	6000	0.069359776	221292.76	221708.92	416.15865	51.644789	51.717772	0.072982592

Interactively draw and evaluate the efficiency of any custom restoration scenario



GWB: The most popular GTB tools as command-line modules for Linux servers.

Name	Content
> input	=====
> output	Part A: brief module description
> tools	cmd-line image analysis modules from GuidosToolbox (https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/): Usage of GWB implies compliance with the conditions in the EULA_GWB.pdf (https://ies-ows.jrc.ec.europa.eu/gtb/GWB/EULA_GWB.pdf)
> EULA_GWB.pdf	
> GWB	
> GWB_ACC	GWB_check4updates
> GWB_check4updates	Display installed and current program version and test for program updates (Automatic updater for Debian systems: '/opt/GWB/tools/GWBupdate_deb.sh')
> GWB_DIST	
> GWB_FRAG	
> GWB_GSC	GWB_ACC: Accounting of image objects and area classes Requirements: 1b-BG, 2b-FG, optional: 0b-missing, optional: 3b-special background 1, 4b-special background 2 Parameter file: input/acc-parameters.txt
> GWB_LM	
> GWB_MSPA	
> GWB_PARC	GWB_DIST: Euclidean Distance and Hypsometric Curve Requirements: 1b-BG, 2b-FG, optional: 0b-missing Parameter file: input/dist-parameters.txt
> GWB_REC	
> GWB_RSS	GWB_FRAG: user-selected custom scale fragmentation analysis Requirements: binary or grayscale map (see frag-parameters.txt), Parameter file: input/frag-parameters.txt
> GWB_SC	
> GWB_SPA	
> GWB_SPLITLUMP	GWB_GSC: GraySpatCon analysis of attribute adjacency table Requirements: categorical map within [0b, 255b] Parameter file: input/gsc-parameters.txt
> readme.txt	

GWB LM: Landscape Mosaic
Requirements: 1b-Agriculture, 2b-Natural, 3b-Developed
optional: 0b-missing
Parameter file: input/lm-parameters.txt

GWB MSPA: Morphological Spatial Pattern Analysis
Requirements: 1b-BG, 2b-FG, optional: 0b-missing
Parameter file: input/mspa-parameters.txt

GWB PARC: Landscape Parcellation index
Requirements: [1b, 255b]-land cover classes, optional: 0b-missing
Parameter file: input/parc-parameters.txt

GWB REC: Recode class values
Requirements: categorical map with up to 256 classes within [0b, 255b]
Parameter file: input/rec-parameters.txt

GWB RSS: Restoration Status summary
Requirements: 1b-BG, 2b-FG, optional: 0b-missing
Parameter file: input/rss-parameters.txt

GWB SC: SpatCon analysis of attribute adjacency table
Requirements: categorical map within [0b, 255b]
Parameter file: input/sc-parameters.txt

GWB SPA: Spatial Pattern Analysis
Requirements: 1b-BG, 2b-FG, optional: 0b-missing
Parameter file: input/spa-parameters.txt

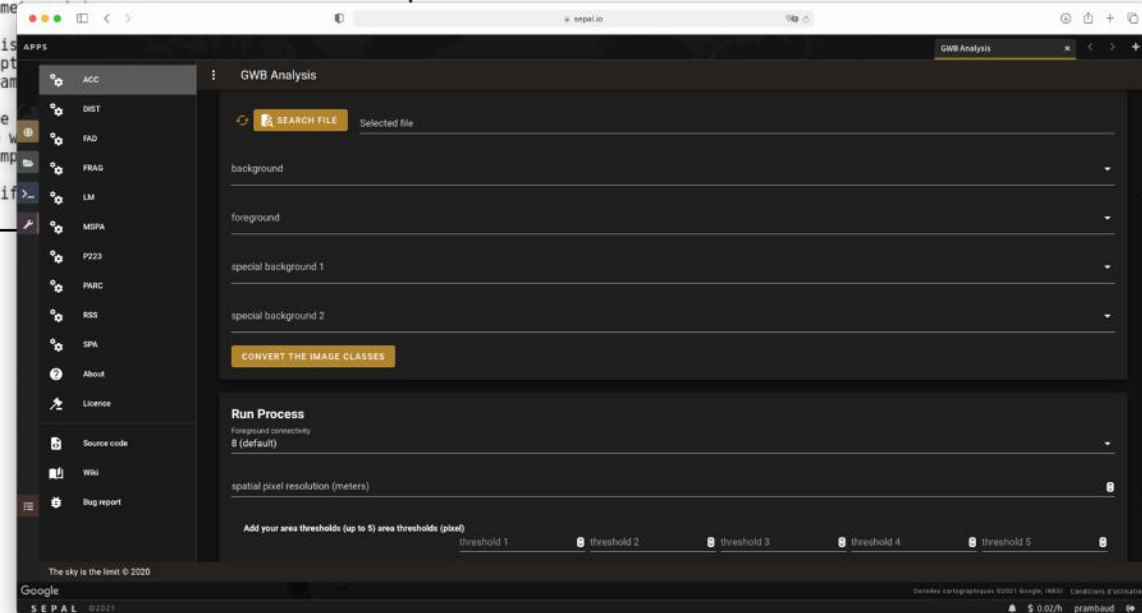
GWB SPLITLUMP: cut/process/merge
Requirements: categorical map within [0b, 255b]
Parameter file: input/splitlump-parameters.txt

More details in the module-specific documentation.

[GWB online manual](#)

Cmd-line or browser-based application on FAO [SEPAL](#) cloud computing platform.

- Automated mass-processing
- Standalone, single directory setup
- System-wide installation or user account only
- Fully compatible with GTB





Transition from analyzing binary input maps with SpatCon to analyzing grayscale input maps in $[0, 100]\%$, i.e., tree cover density, resistance, probability, etc.

GraySpatcon (GSC): choice of 52 moving window metrics

GraySpatCon (GSC): please select the GSC processing parameters

Mandatory GSC Settings:

- M:Metric: 1:Mean
- F:Precision: 2:Float
- G:Analysis Type: 0:MovingWindow
- P:Pixel 0: 0:Include

If G=0 (moving window analysis):

- W:WindowSize: 27
- A:Mask Missing: 1:Yes

If F=1 (Byte Output):

- B:ByteStretch: 1:[0.0, 1.0]->[0b, 100b]

Target Settings:

- X:Code1: 5
- Y:Code2: 10
- K:Difference: 5

Buttons: GSC Guide, Options, Missing->NaN: Yes, Default values, Cancel, Accept

- Exploit additional information of gradient versus binary data
- Available in GTB, GWB, or as a standalone cmd-line application
- Open-source code on GitHub

Papers:

[Interpreting texture metrics](#)

[Patterns on numerical & categorical maps](#)

[Binary vs grayscale paper](#)

Thank you



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