GuidosToolbox 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

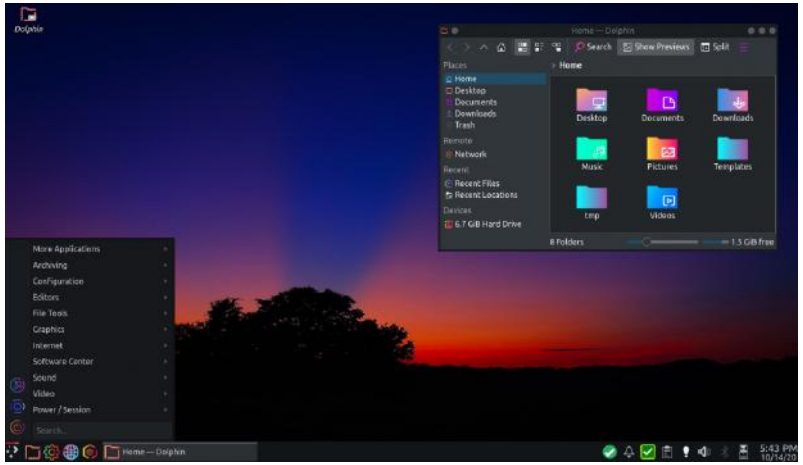
Who is this guy anyway?

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)

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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

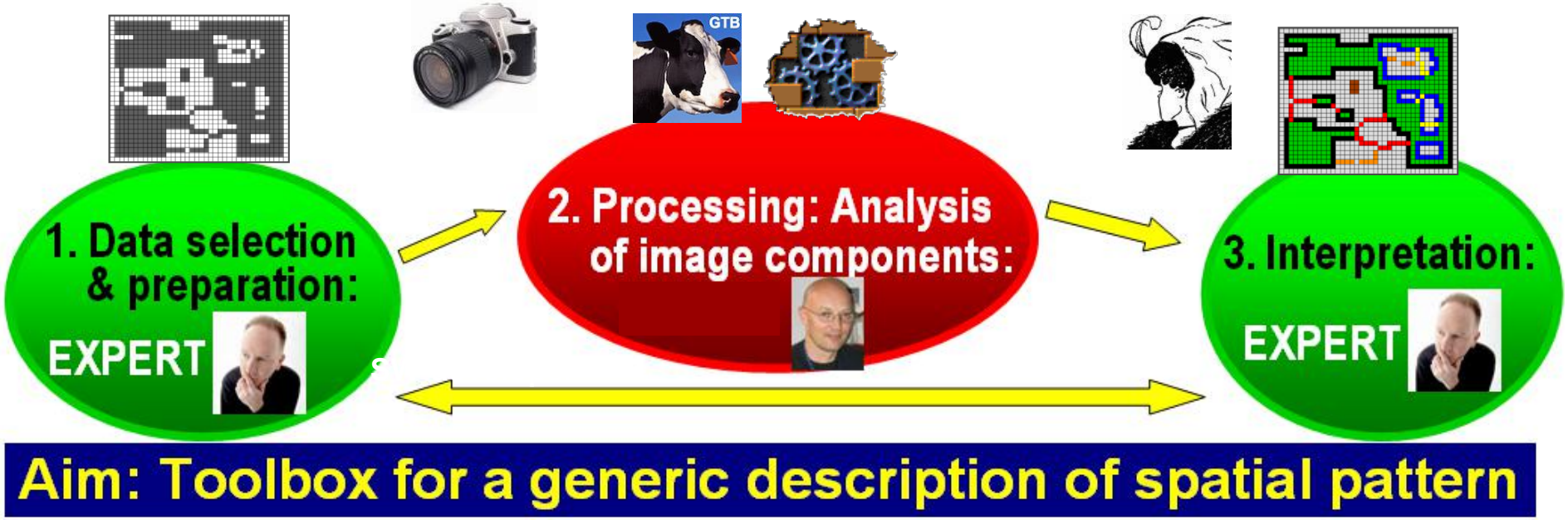
GWS 4: Hands-on examples using training data:

a) Data preparation, MSPA, Google Earth overlays, batch process

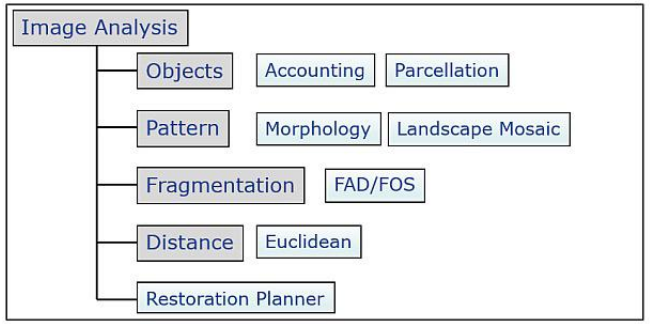
b) Distance, fragmentation, network, restoration, change, …

GuidosToolbox: Generic Geometric Image Object Analysis

Graphical **U**ser **I**nterface for the **D**escription of image **O**bjects and their **S**hapes



- GuidosToolbox (GTB)[1]: interactive desktop application (macOS, Linux, MS-Windows)
- GuidosToolbox Workbench (GWB)[2]: command-line Linux server application
- Documentation[1]: 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/

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Generic Geometric Image Object Analysis

1. Input - Critical

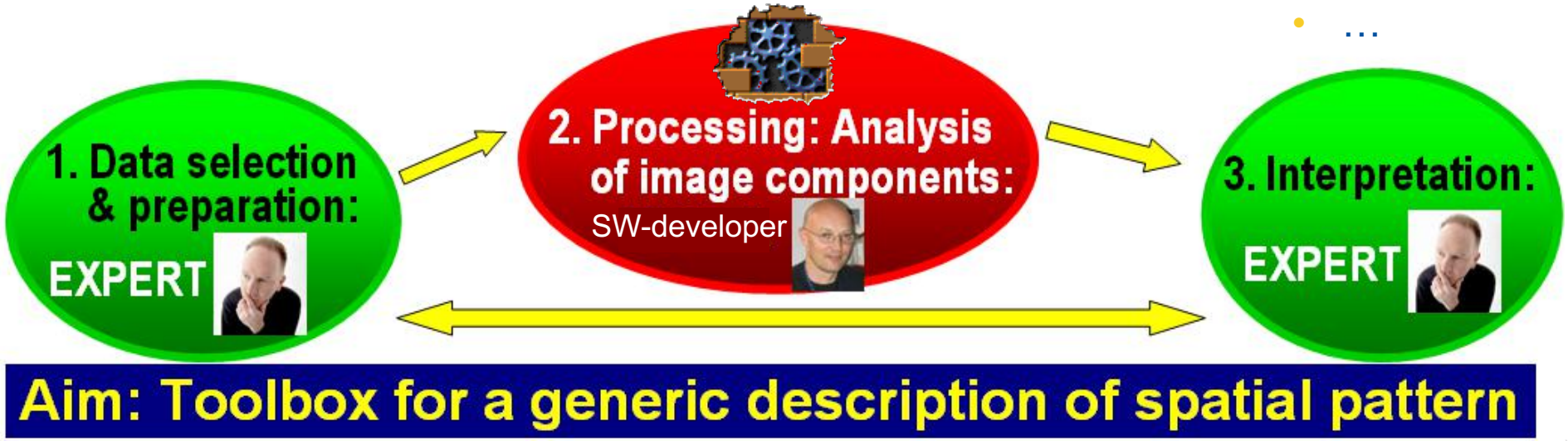
- What exactly is the scope?
- What does the customer expect?
- Which feature do I need?
- Are customer and I on the same track?
- Which dataset is appropriate?
- Availability, cost, quality, scale?
- Legal: Public or proprietary data?
- Ready to use or pre-processing needed?
- …

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?
- …



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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.

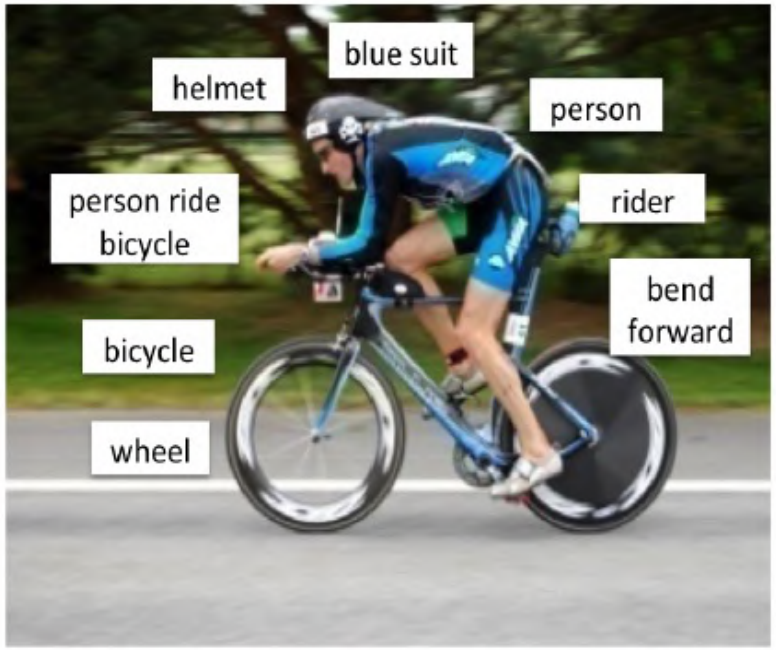
A temporal overview …

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?



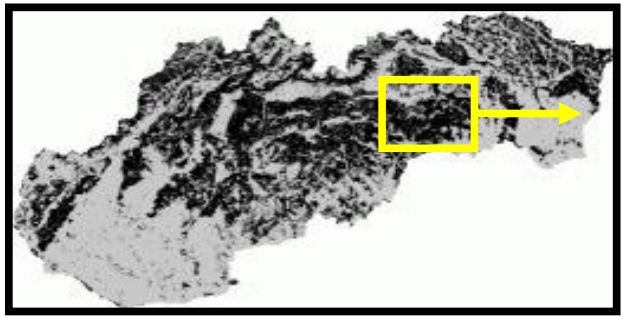
Show 5 people the same image and ask them what they see.
You will get 5 different answers, all different to what you expected.
So, who is right? - Everybody, if you adopt their mindset…
Interpretation is, by definition, **subjective** because it is driven by individual interest, priorities, requirements, or personal preference…

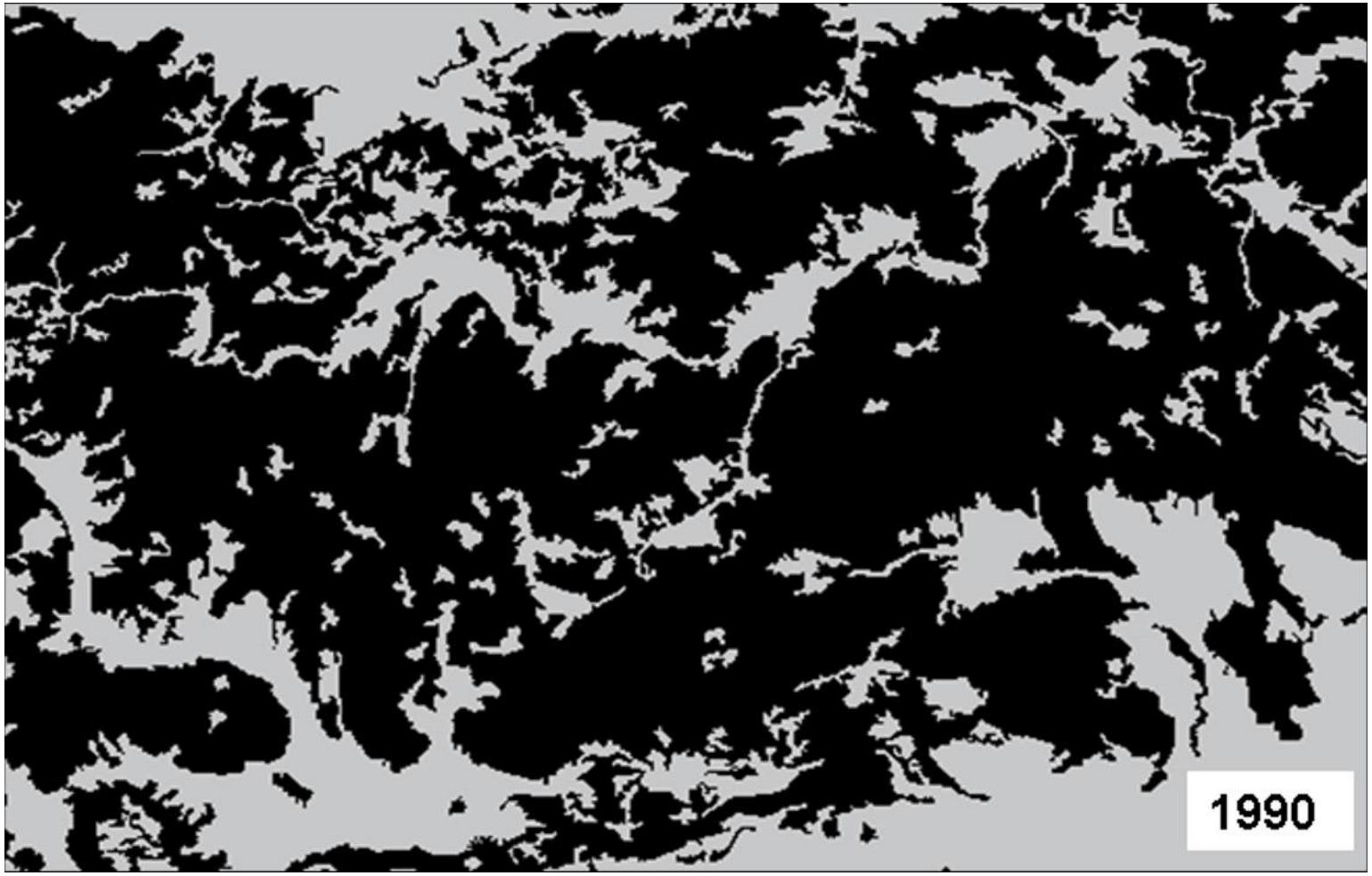
A philosophical question: *truth* ↔ *subjectivity* (Søren Kierkegaard)

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

Background: Landscape Metrics

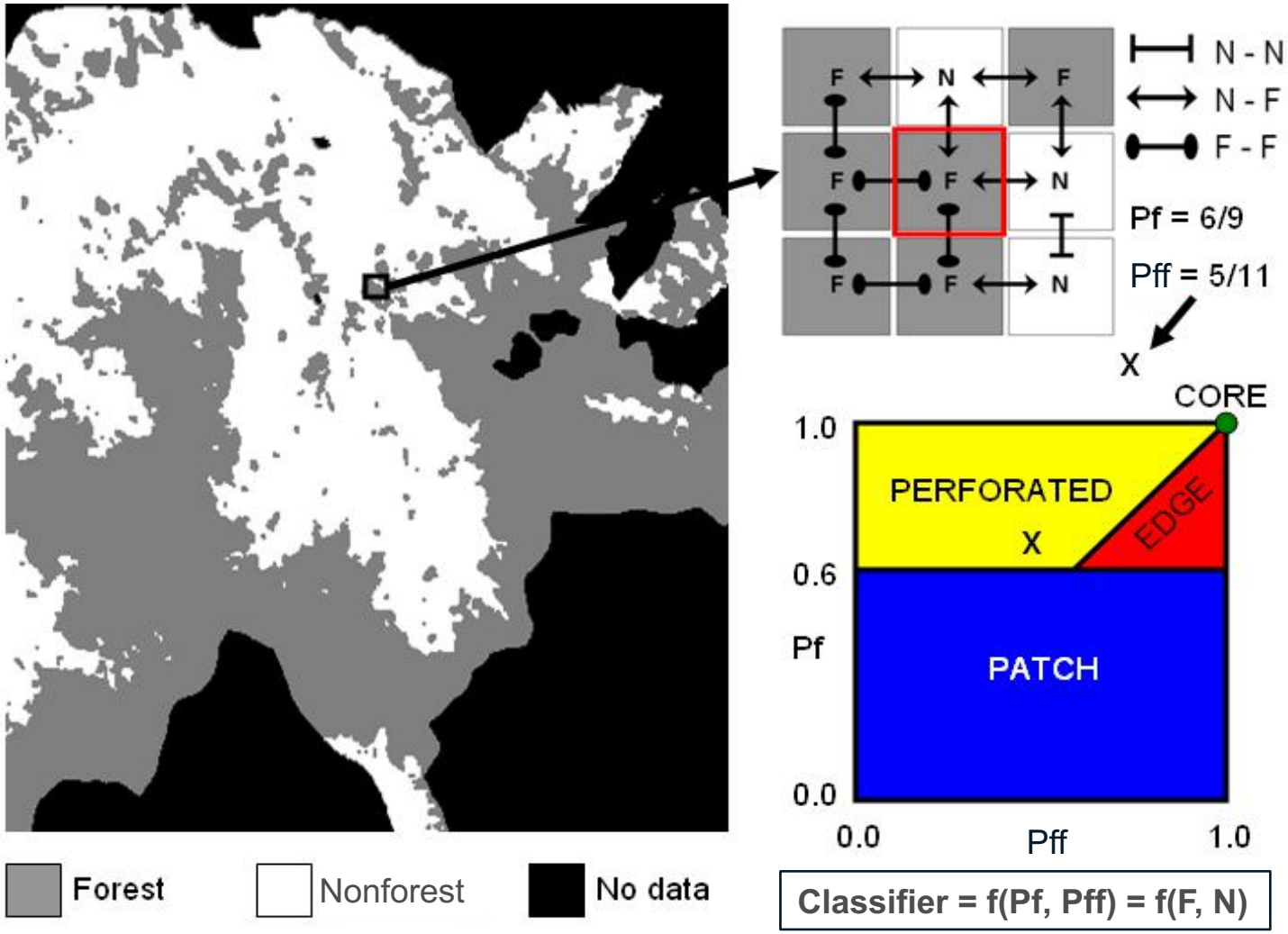
Riitters et al. 2000:
2. FSP = f(Pf, Pff)

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



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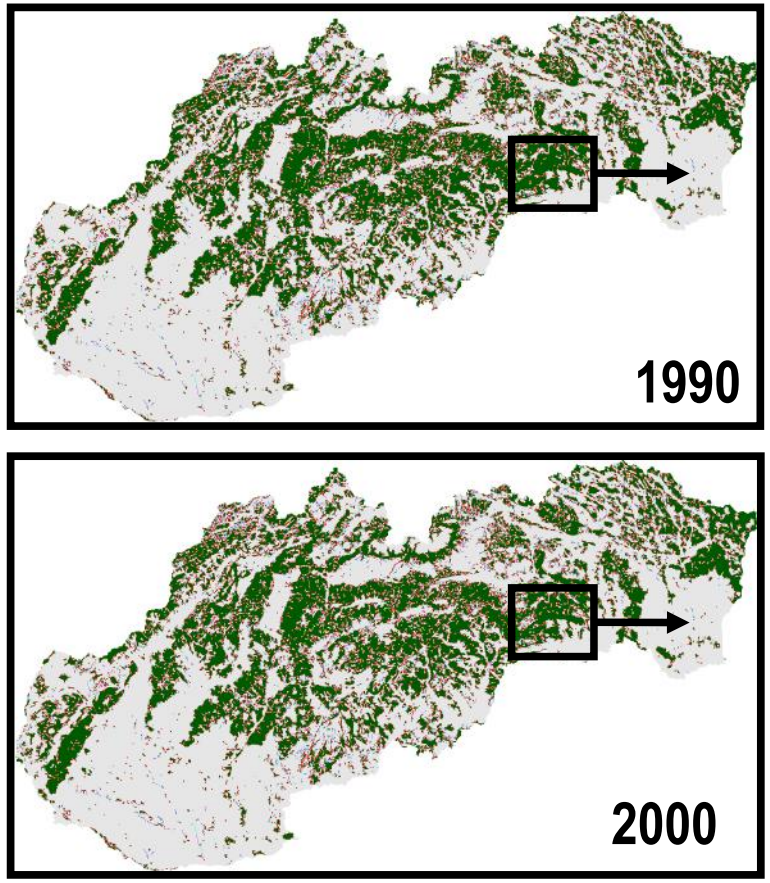
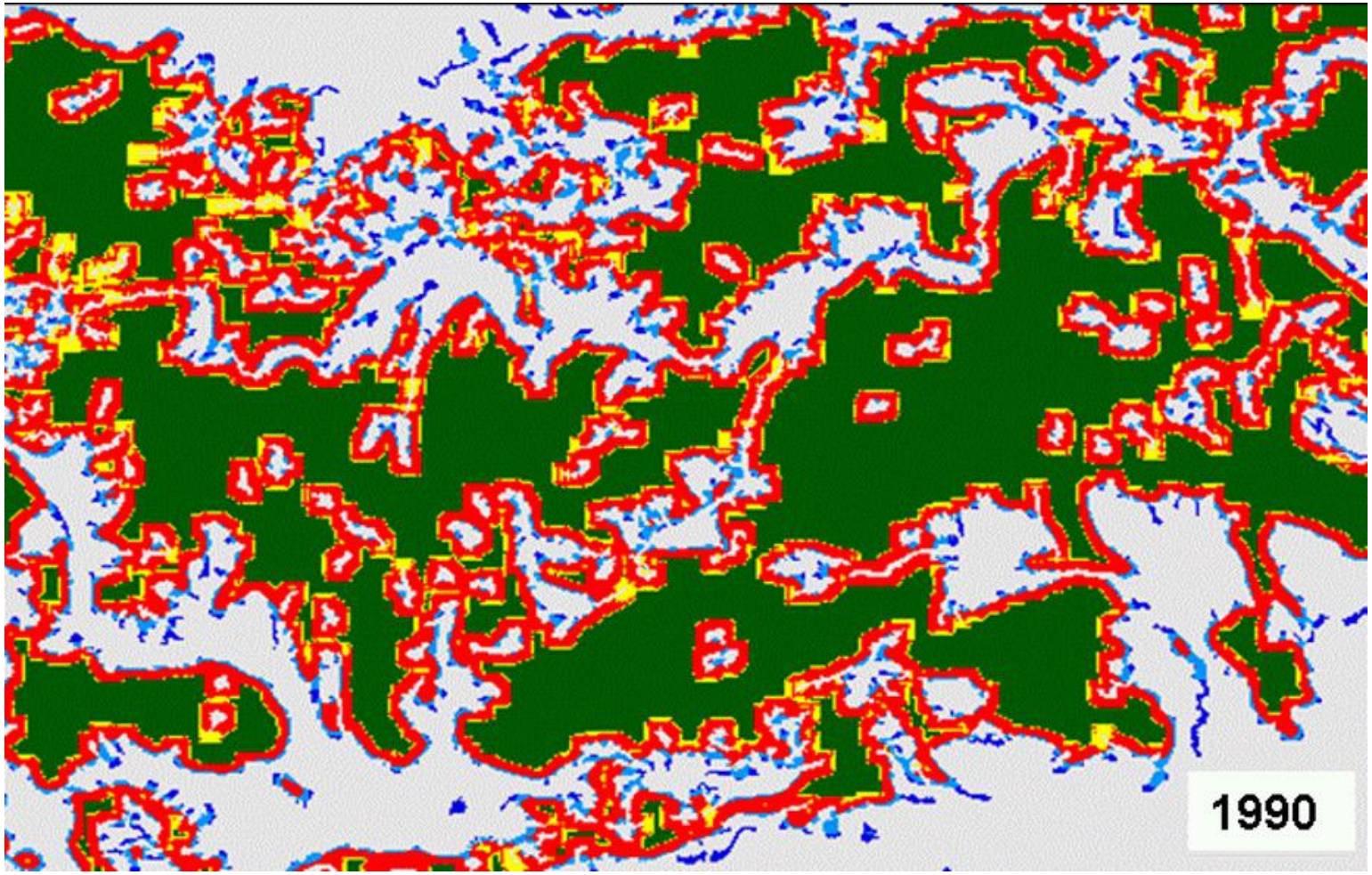
Background: Landscape Metrics

Slovakia: change!



Spatial information but confusion at pixel level…

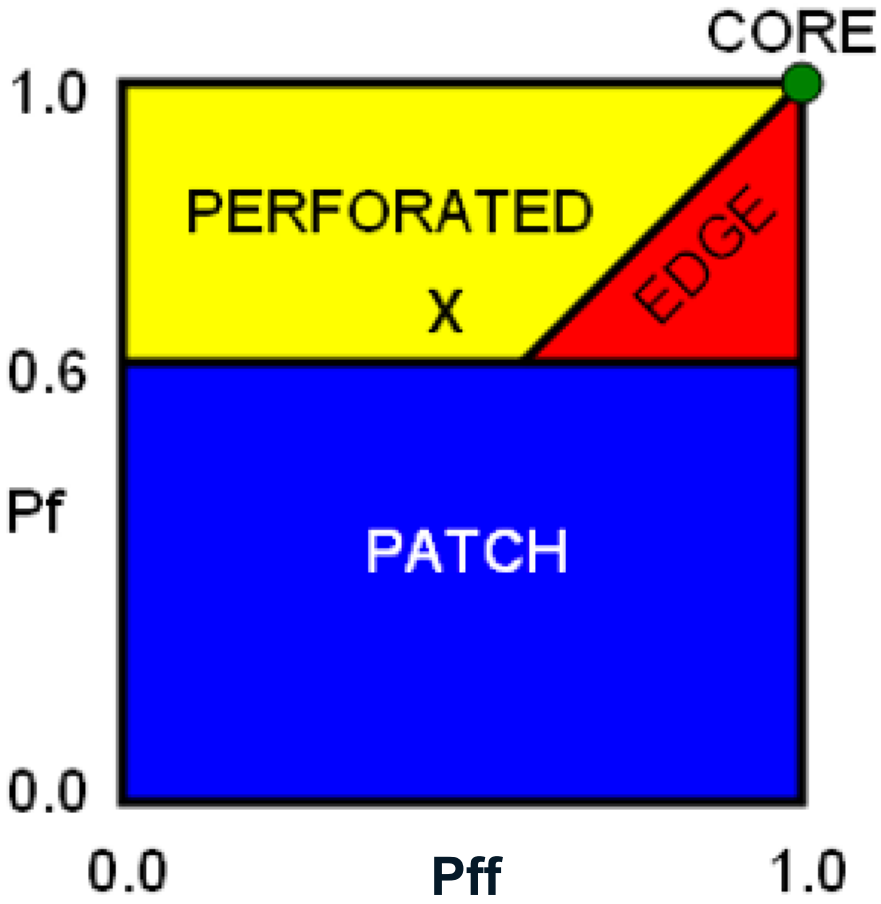


Background: MSPA (version 1)

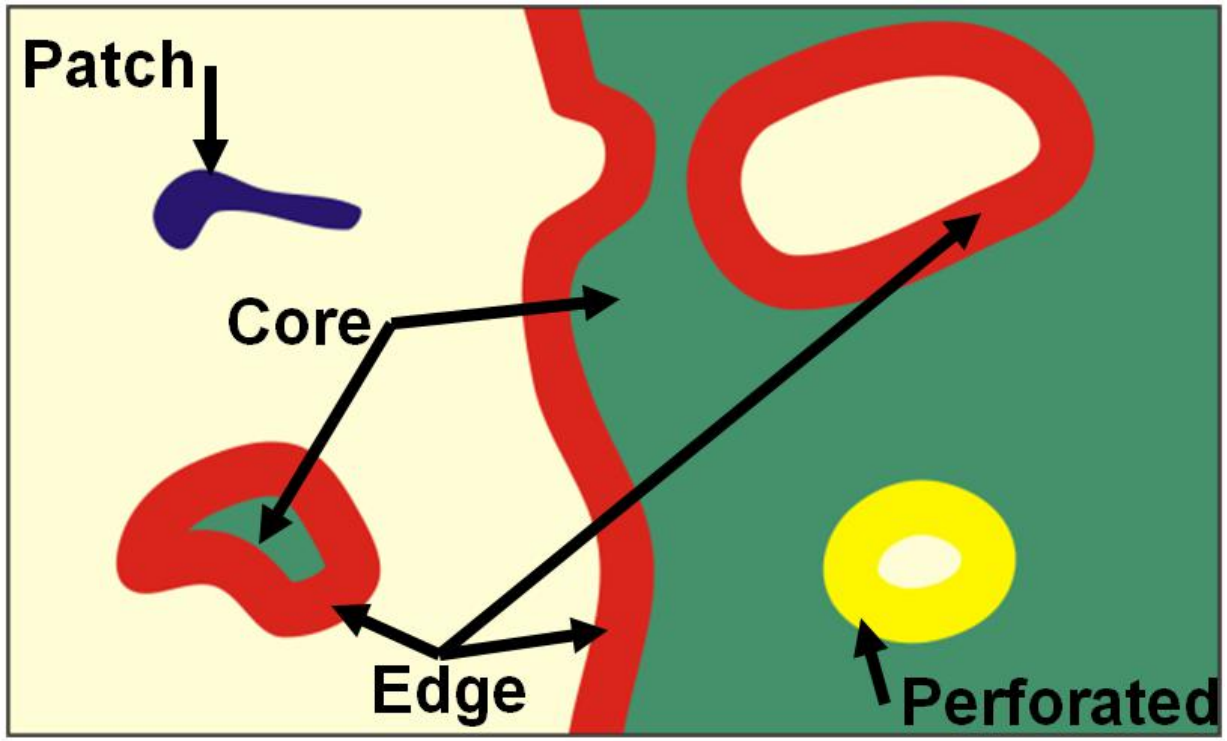
Pf/Pff: 4 thematic classes →

Morphological implementation

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



CORE PATCH EDGE PERFORATED



Background: MSPA (version 1)

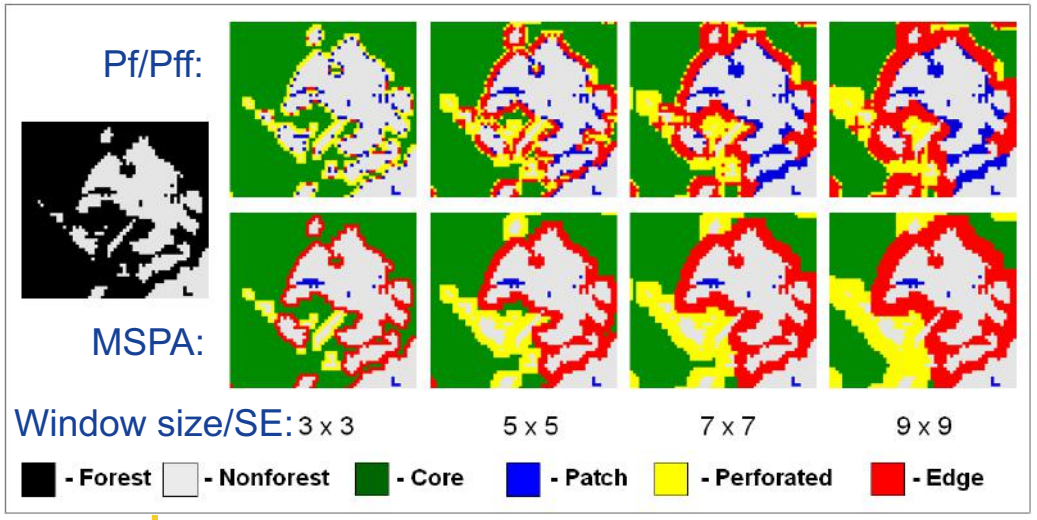
Vogt et al. 2007a: *replace* moving window with math. morphology

3. FSP = f(morphology)

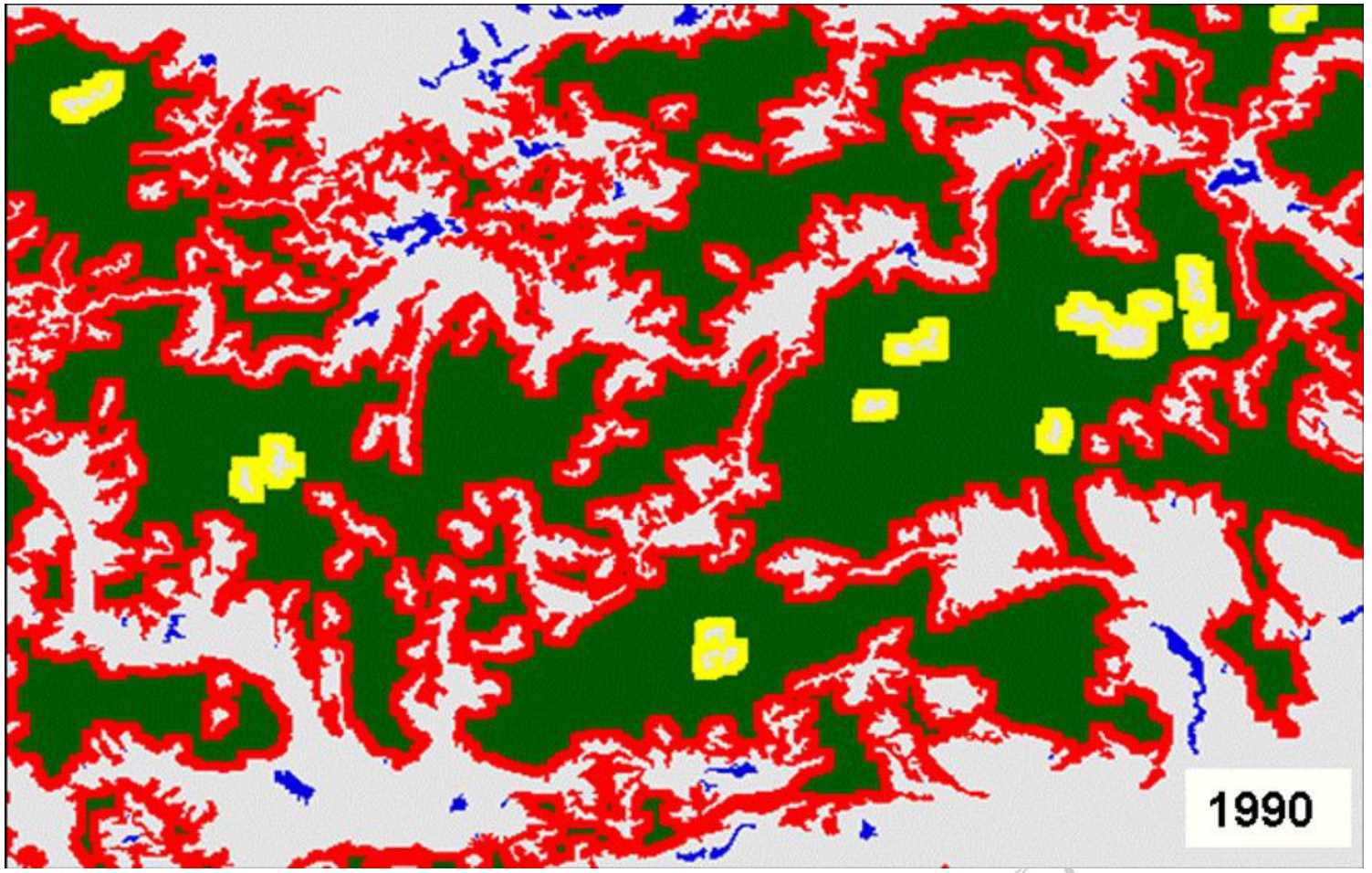
4 classes: *Core*, *Patch*, *Perforated*, *Edge*.

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

Con: nothing



Morphology: no confusion at pixel level.



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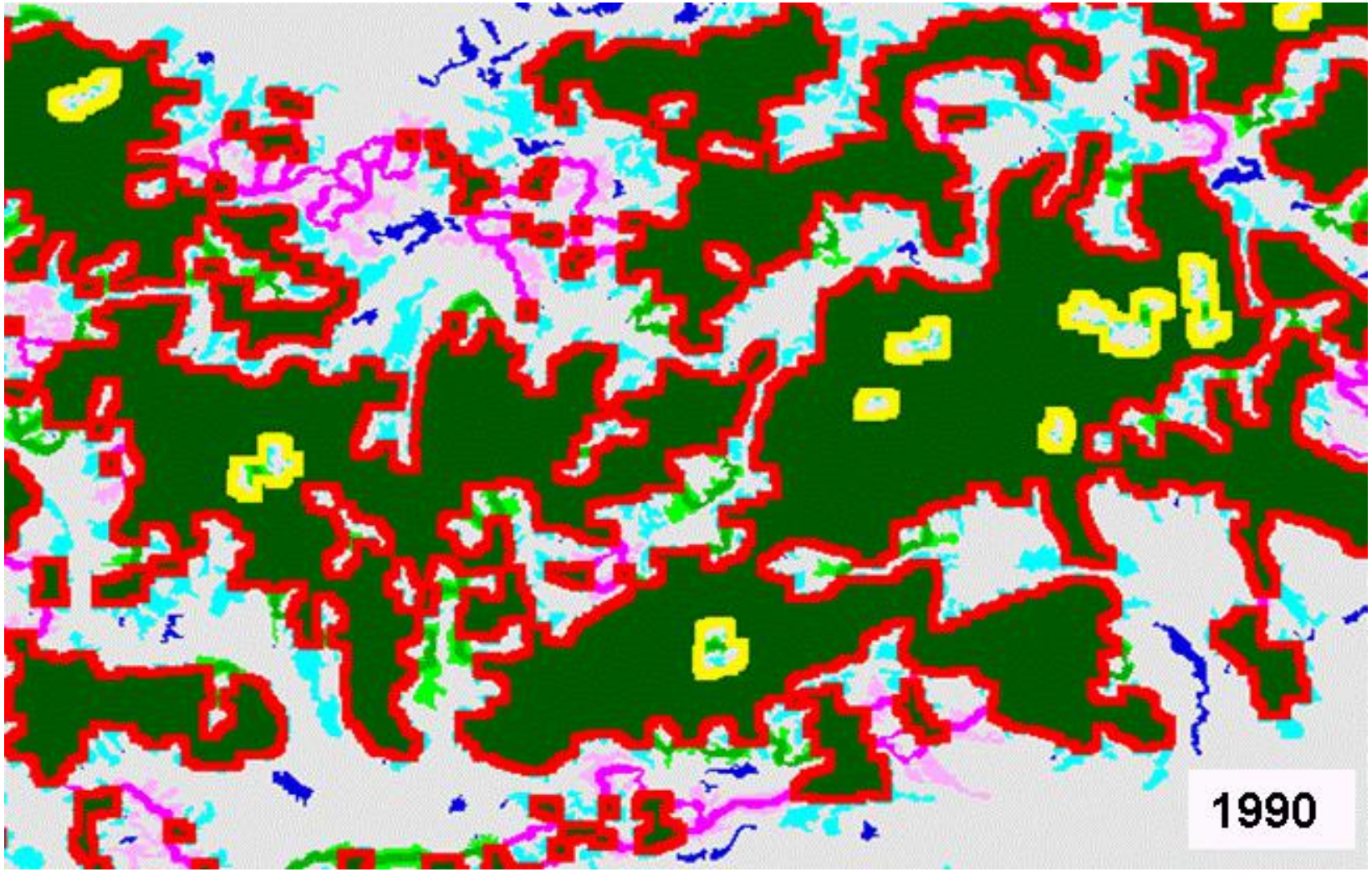
Background: MSPA (version 2)

Vogt et al. 2007b: morphology including structural connectivity

FSP = f(morphology)

Pro:
structural connectors!

Con: ?



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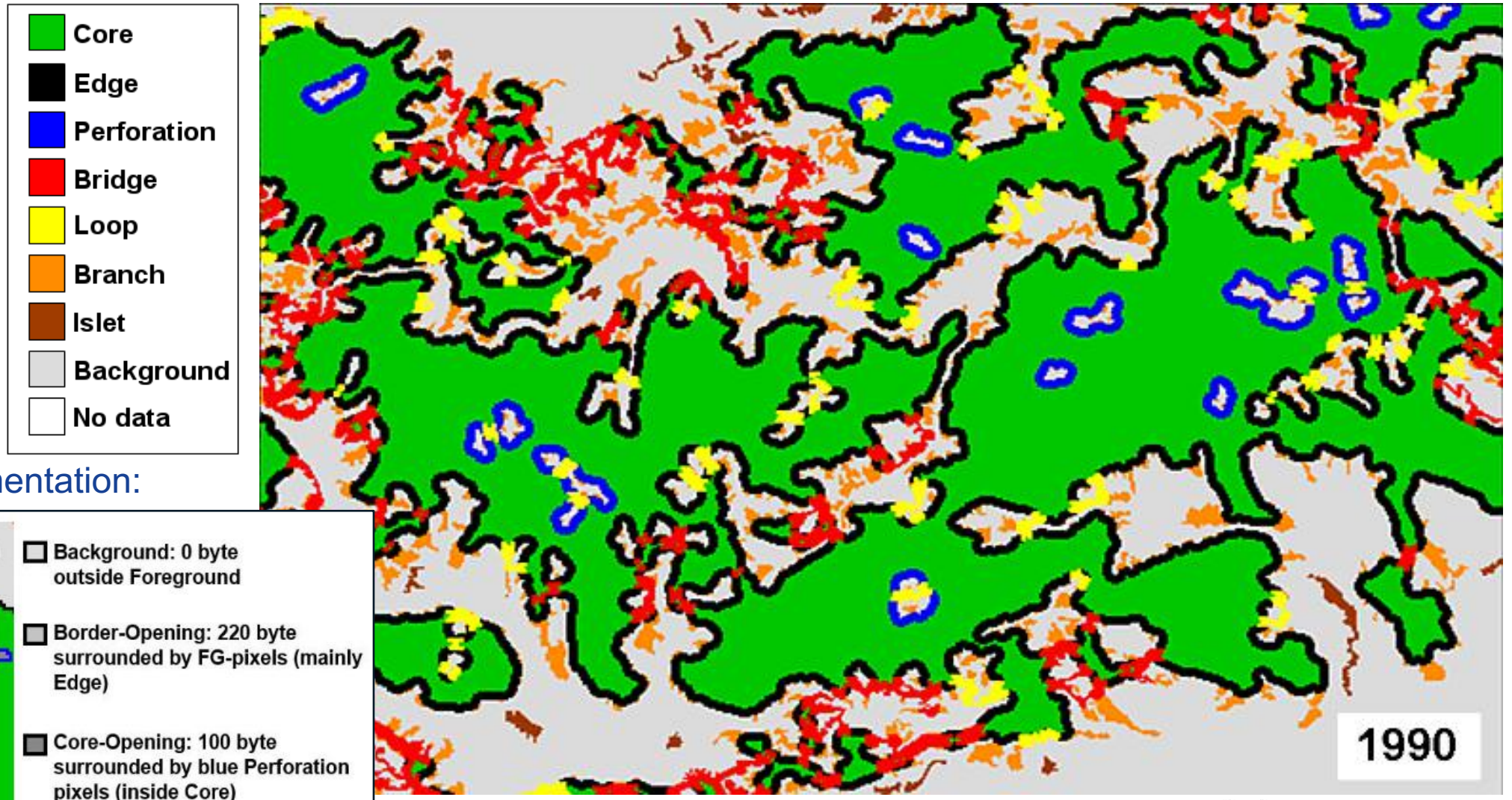
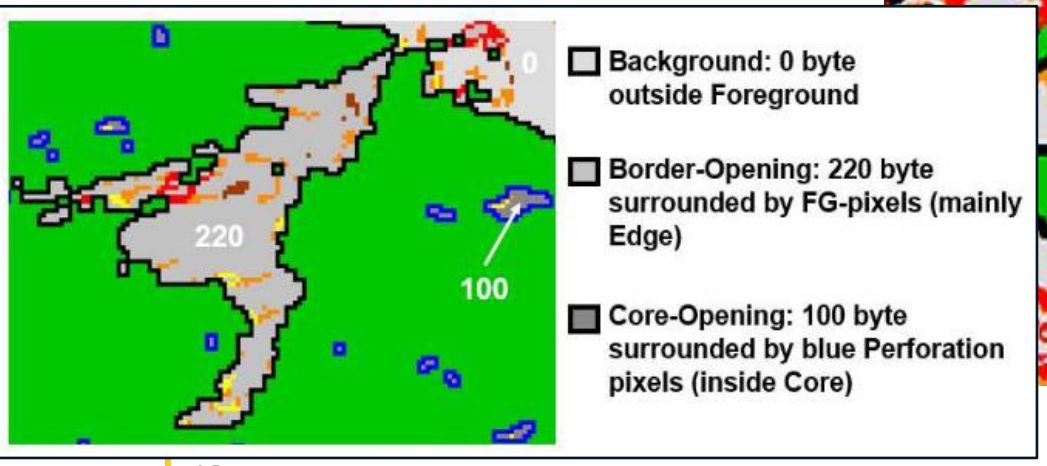
Background: MSPA (final)

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



2018 Background segmentation:



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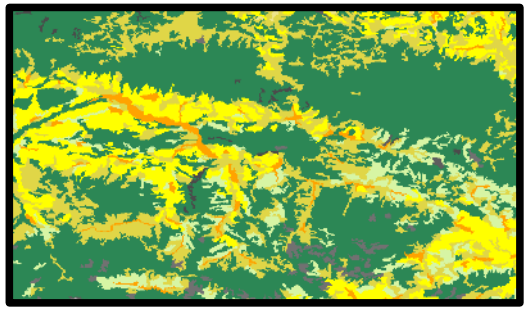
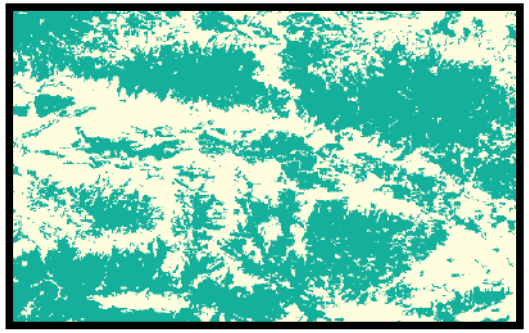
MSPA processing principle: 3 steps

1. input



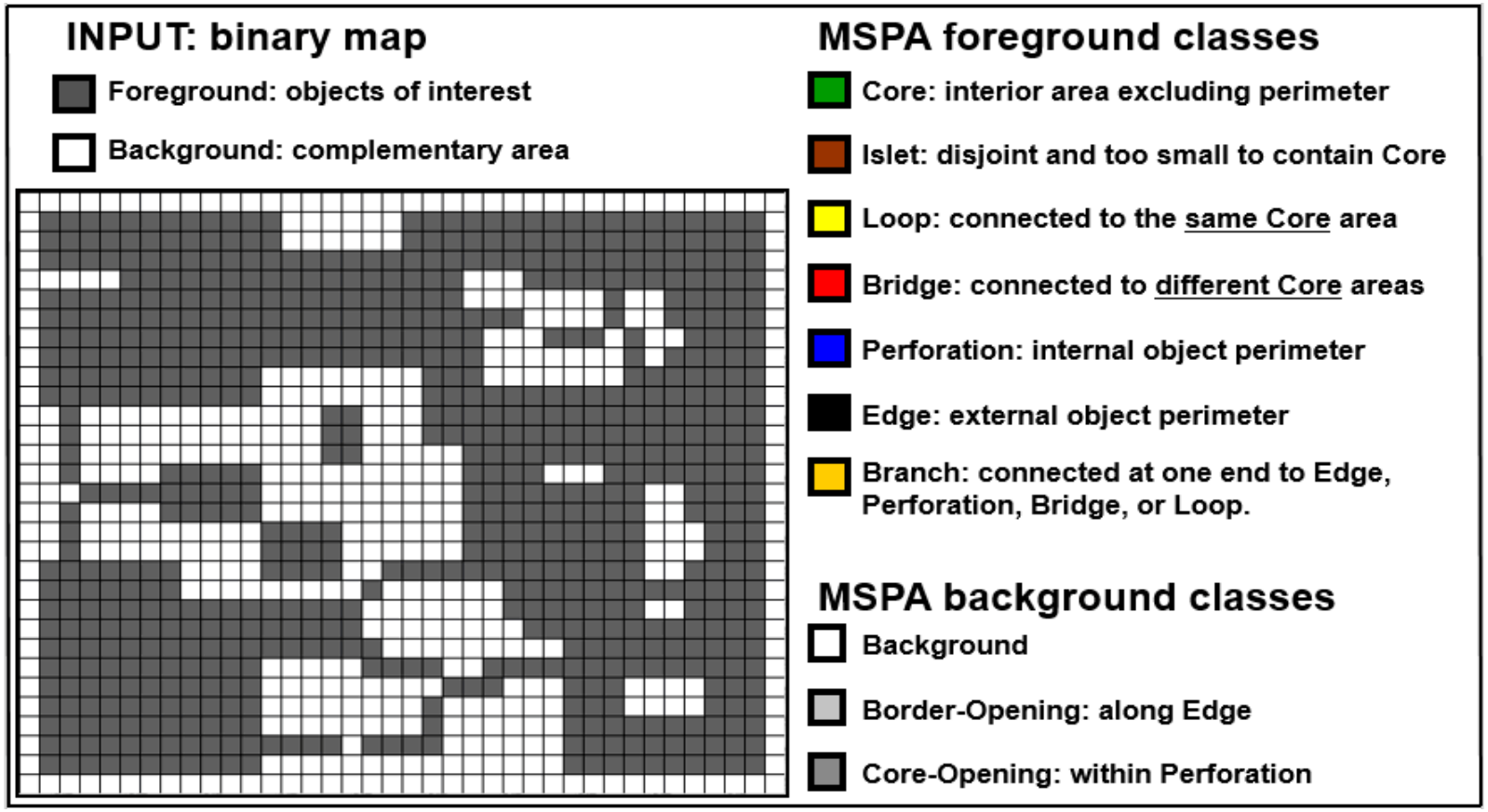
Raster map: land cover, species distribution, dispersal, …

2. foreground/background



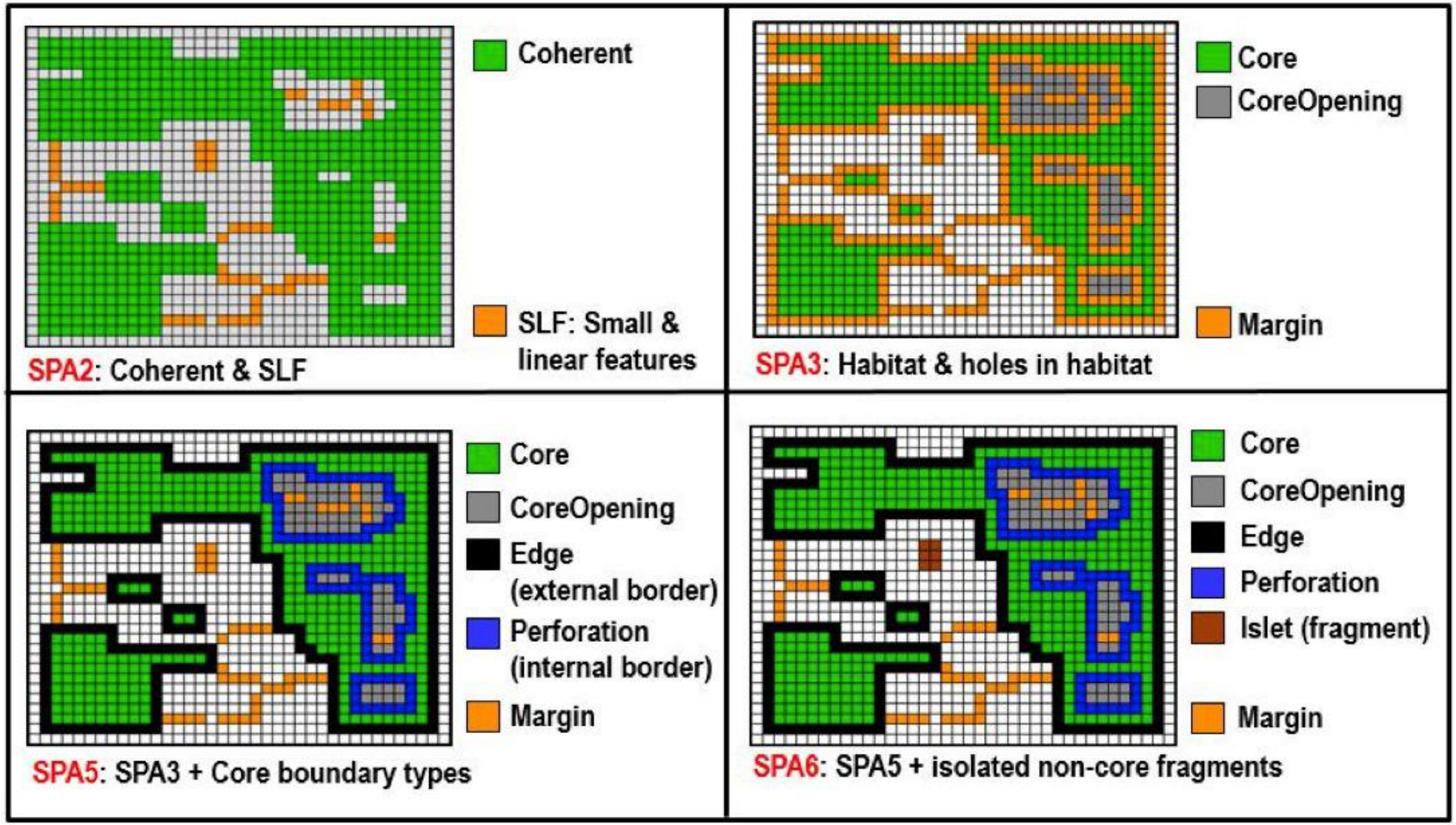
Binary mask: forest, habitat, grassland, movement, …

3. MSPA segmentation



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)

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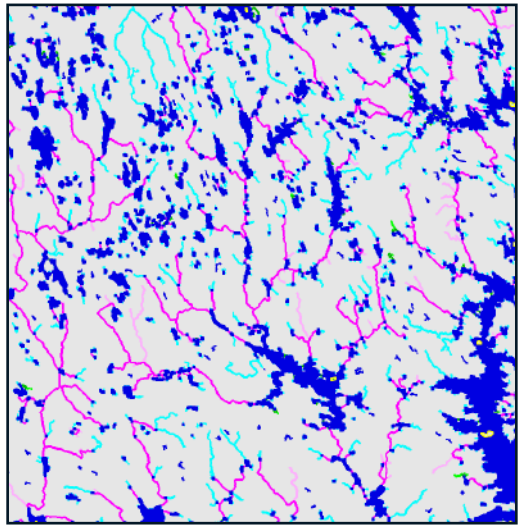
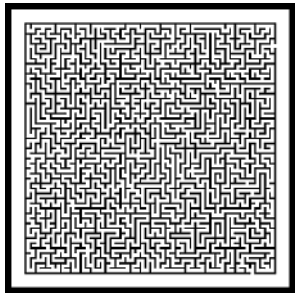
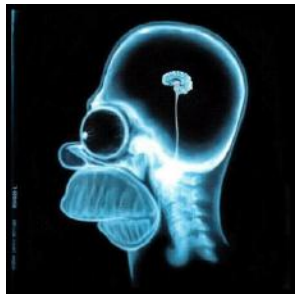
1) *Structural* pattern analysis…

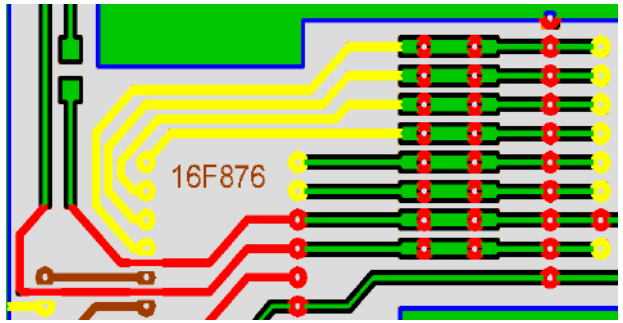
Rivers & wetlands, Finland



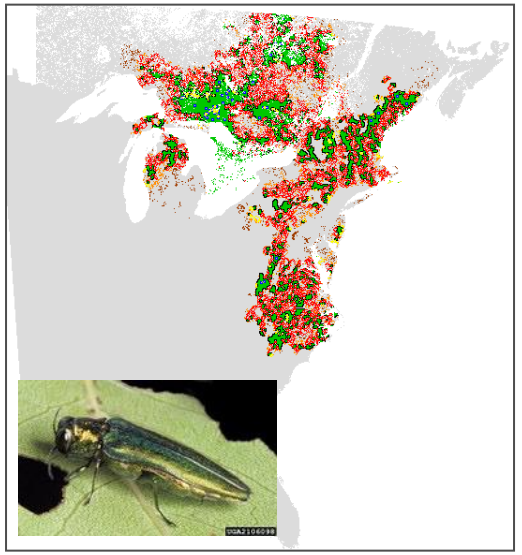
Maze, medical, manufacturing…



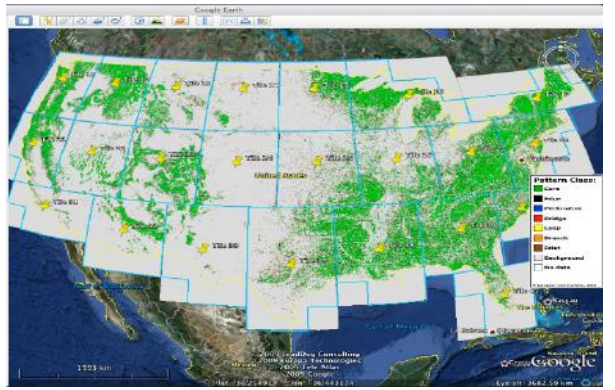


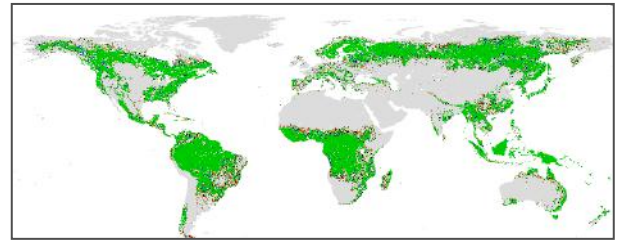


Disease spread pattern



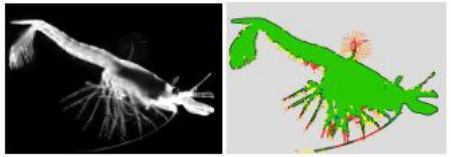
National/global forest pattern



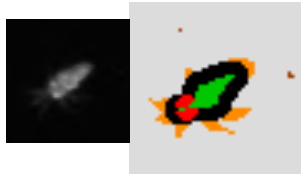


Automatic zooplankton recognition, (Schmid et al. 2016)

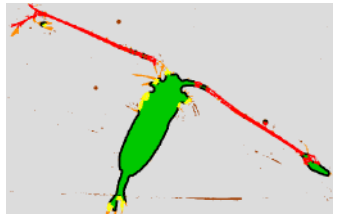
Deploying LOKI



Mysid (opossum) shrimp

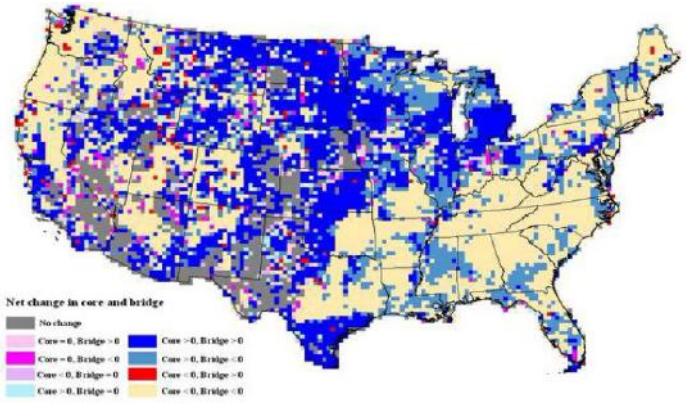


Nauplius larvae stage of copepod (~0.2mm)

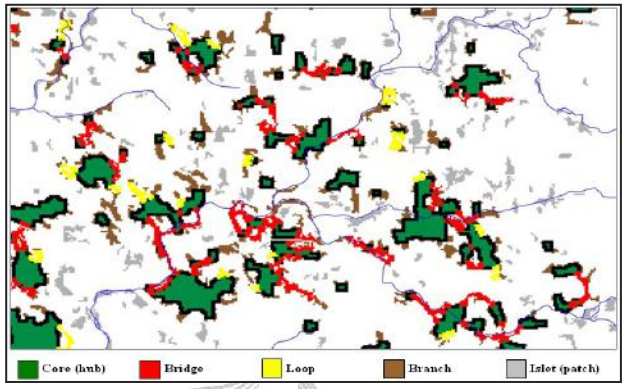


Adult copepod, extremely important in the food chain since it has vast lipid reserves

US GI Assessment, (Wickham et al. 2010)



Habitat conservation….

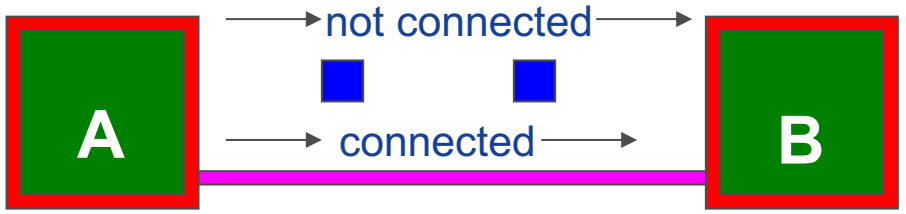


US-EPA: Enviroatlas (Landscape Pattern)

2) *Functional* pattern analysis…

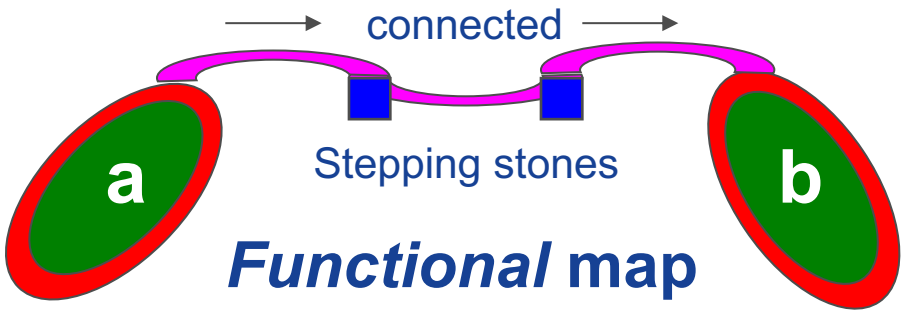
MSPA: maps morphological features/connectivity on *any kind* of digital data map

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

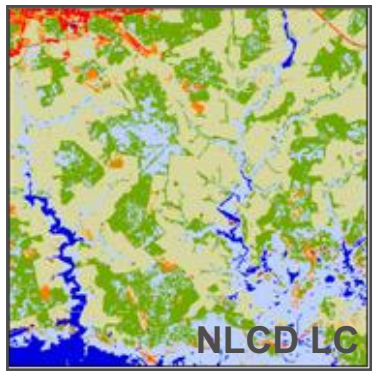


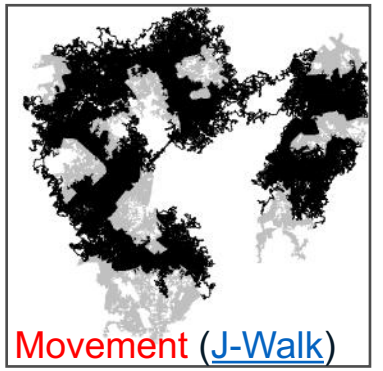
***Structural* map**

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

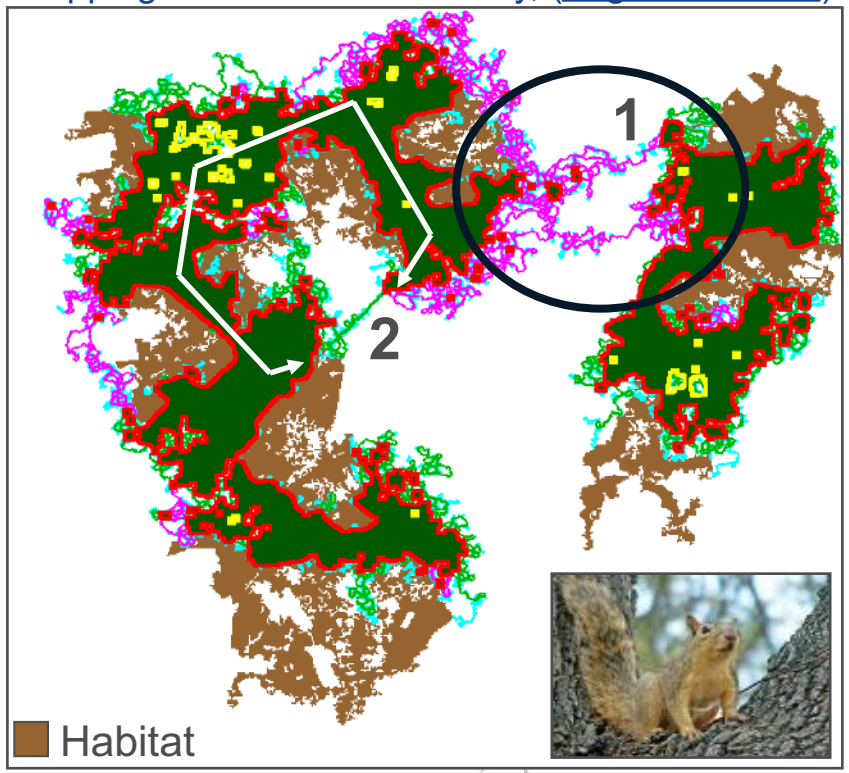


***Functional* map**





Mapping functional connectivity, (Vogt et al. 2009)



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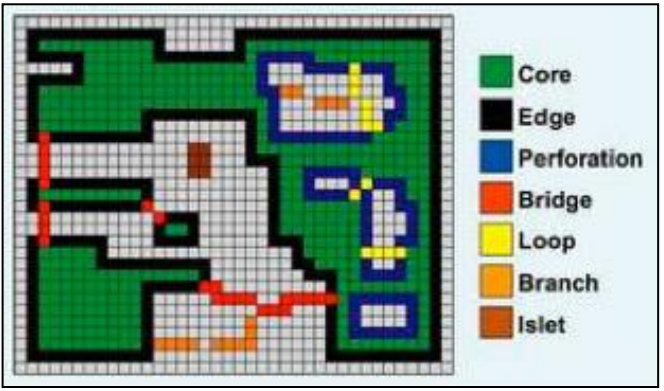
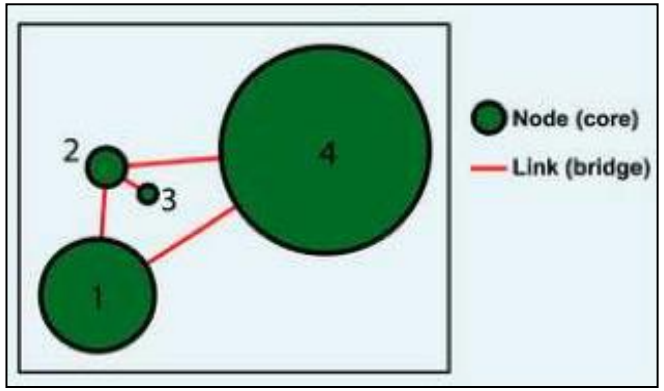
3) Combining Pattern and Connectivity…

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

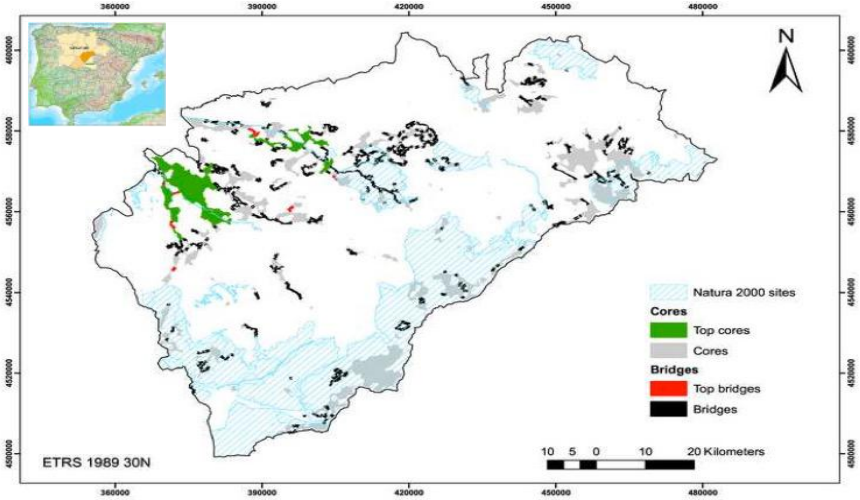
MSPA



Graph theory (Conefor)



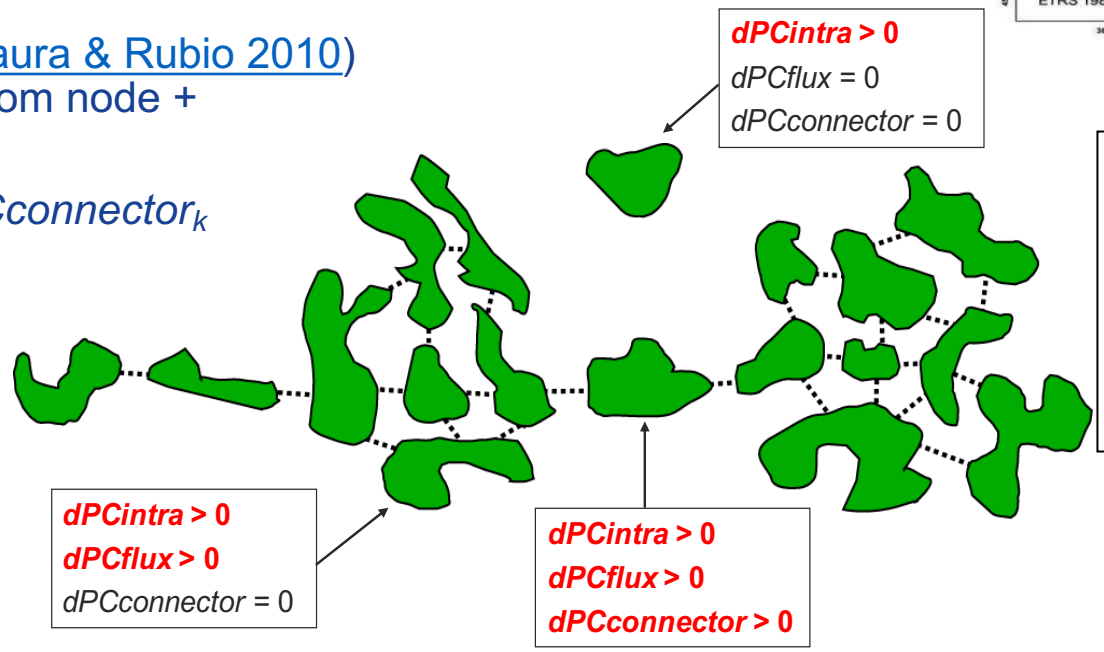
Key connectors & habitats (Saura et al. 2011)



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

$dPC_k = dPCintra_k + dPCflux_k + dPCconnector_k$

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



Intra: Habitat resource within a patch

Flux: How well connected is the patch

Connector: Patch importance for the others to remain connected

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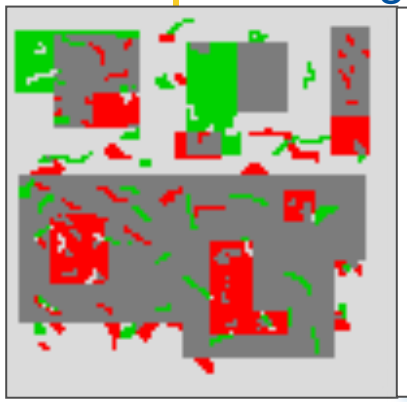
GuidosToolbox Workshop

4) Change analysis…

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

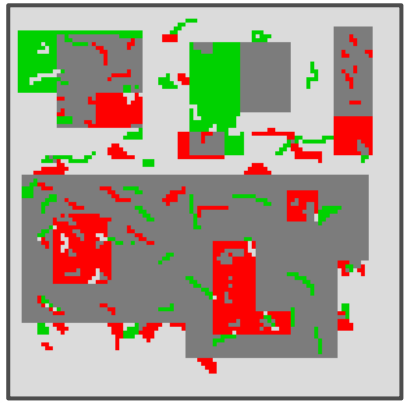
Change map



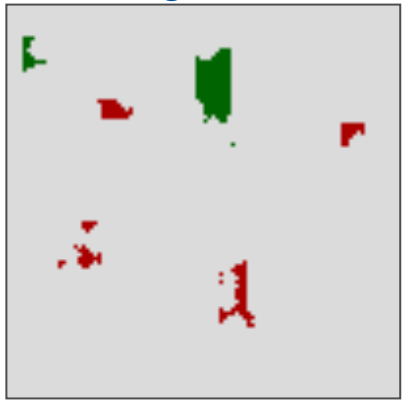
Changed:
Gain
Loss

Unchanged:
Forest
Non-forest

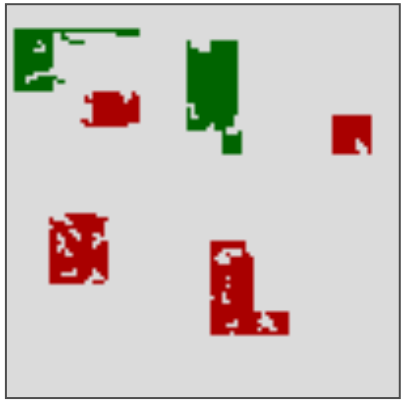
Morph. erosion



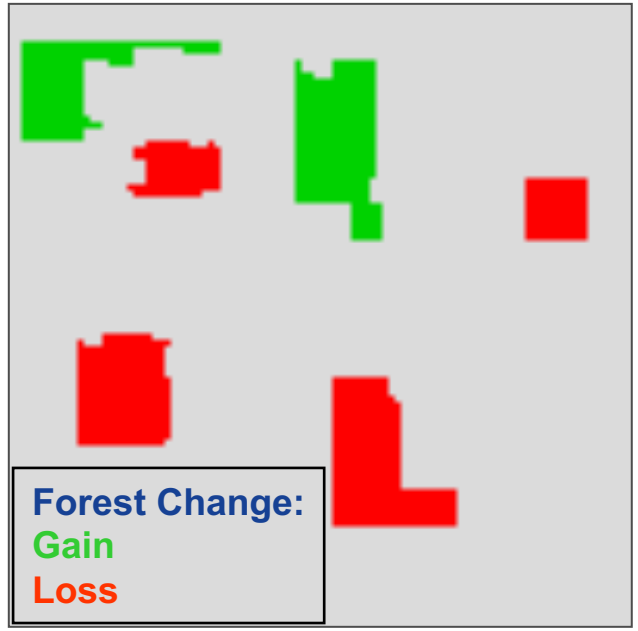
Change seeds



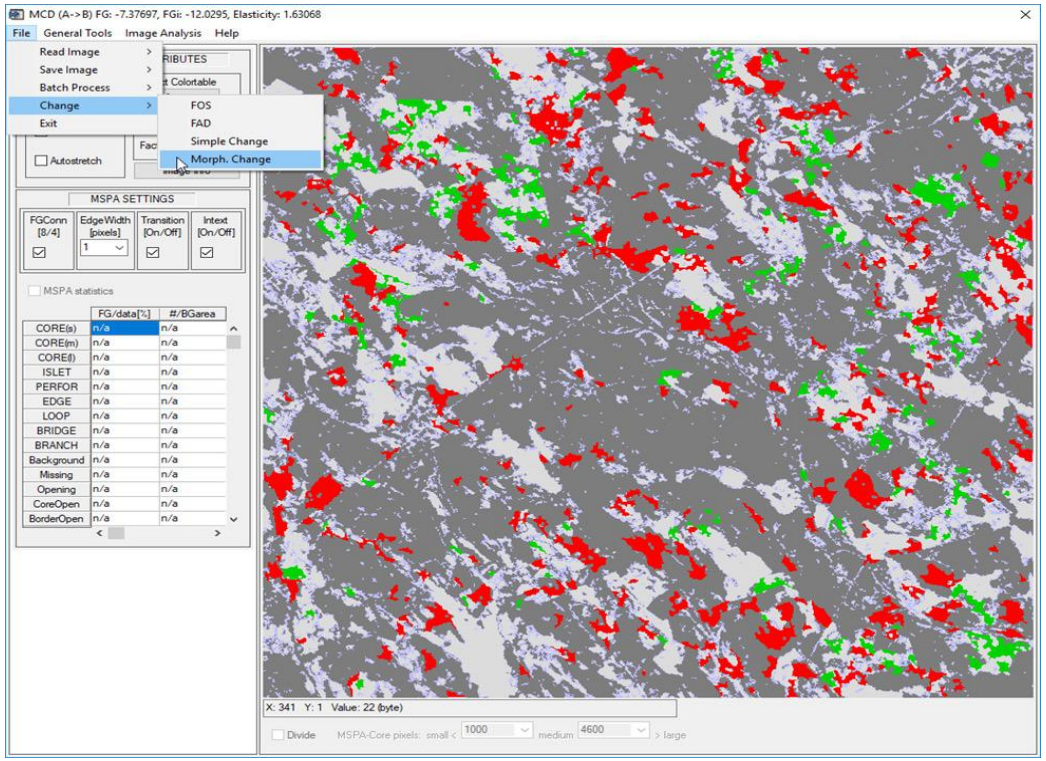
Reconstruction



Filling & final change product

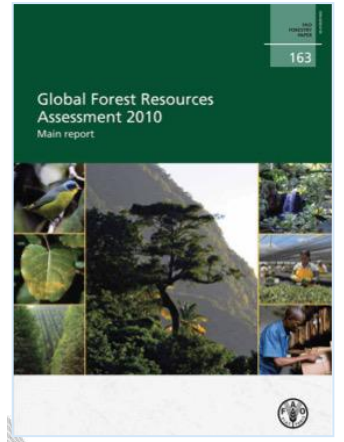


Forest Change:
Gain
Loss



MCD (Seebach et al. 2013)

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



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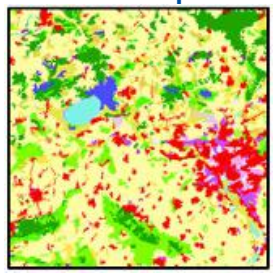
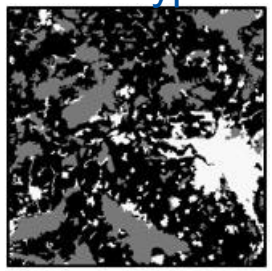
5) Landscape Mosaic…

How big is the impact of dominant land cover types: Agriculture/Natural/Developed?

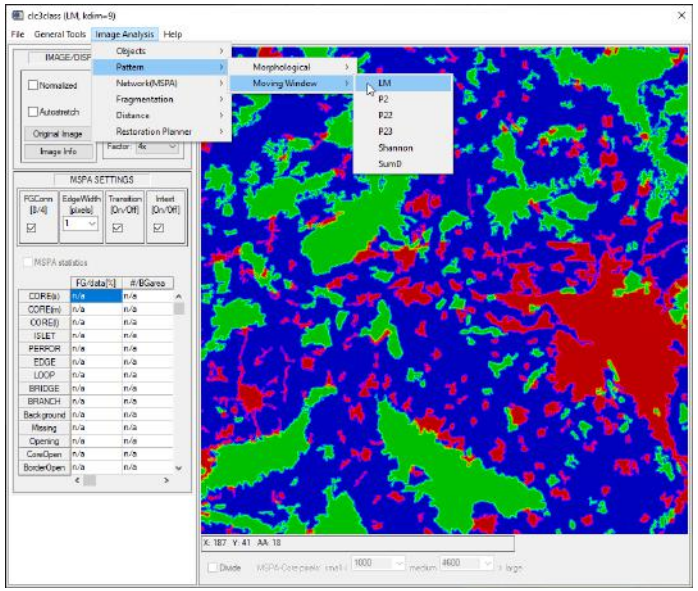
LC map



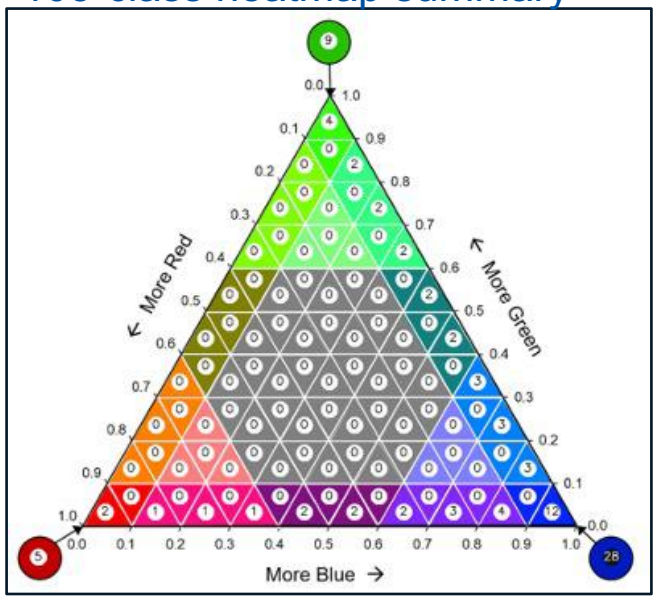
3 LC types



LM: moving window analysis

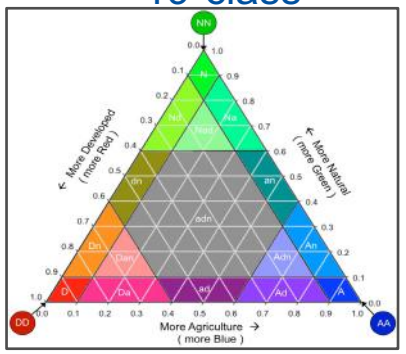


103-class heatmap summary

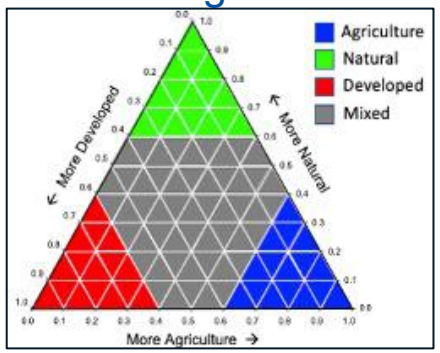


Define an adequate reporting scheme:

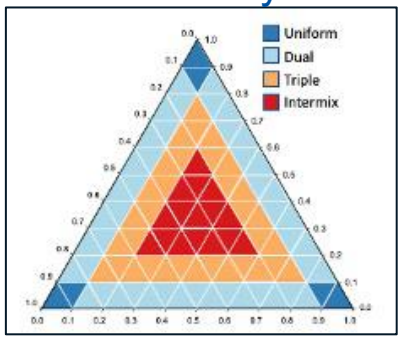
19-class



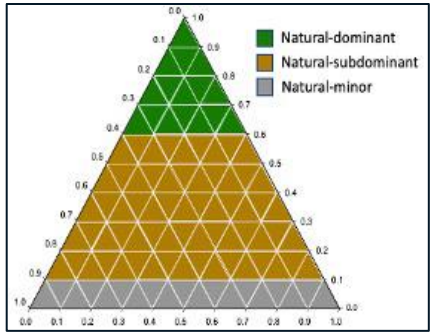
Background



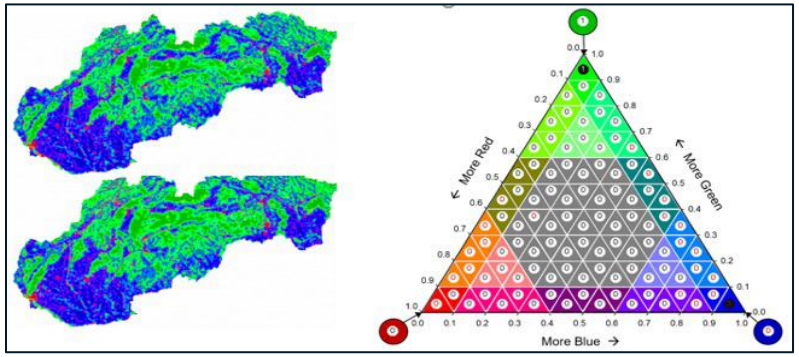
Diversity



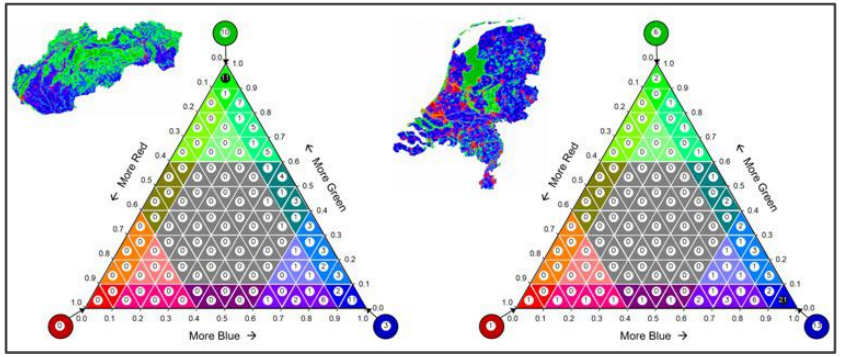
Naturalness



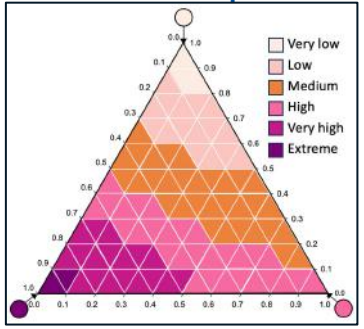
Change over scale or over time



Compare different countries



Anthropic



RESEARCH ARTICLE PLOS ONE

Revisiting the Landscape Mosaic model

Peter Vogt[1]*, James Wickham[2], José Ignacio Barredo[3], Kurt Riitters[3]

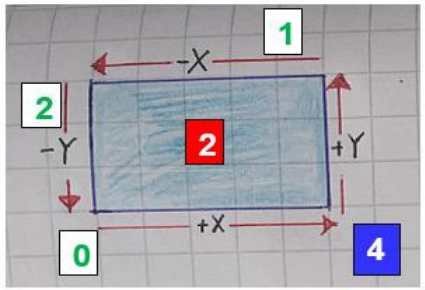
MAES

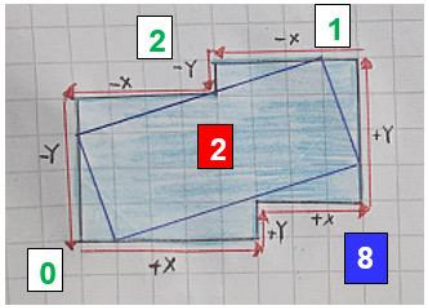
6) Contortion analysis…

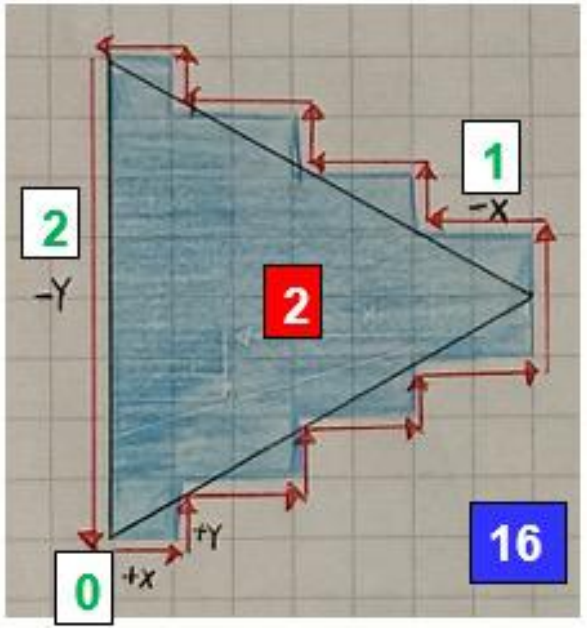
From a spatial perspective: evidence of anthropogenic activities…

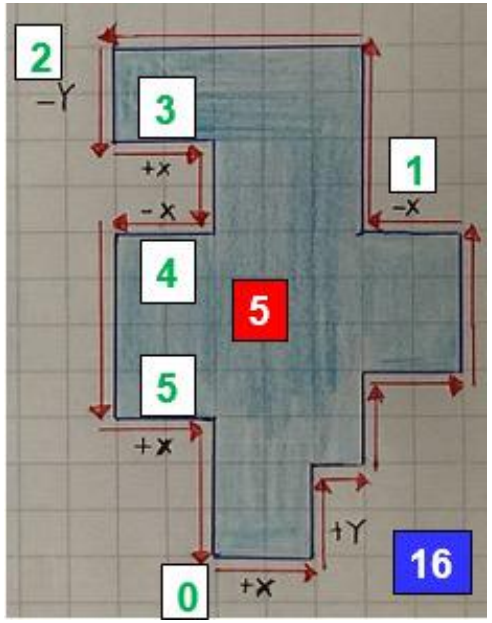
Humans create regular-shaped objects (buildings, agricultural fields, …)

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









Contortion features:

- **Rotation invariant**
- **Low count:**

  Anthropogenic objects
- **High count:**

  Natural objects

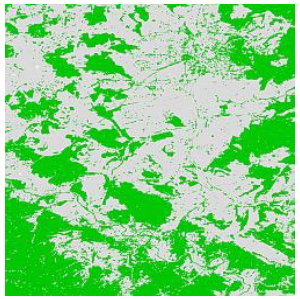
– Object perimeter X Contortion X Corner count

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

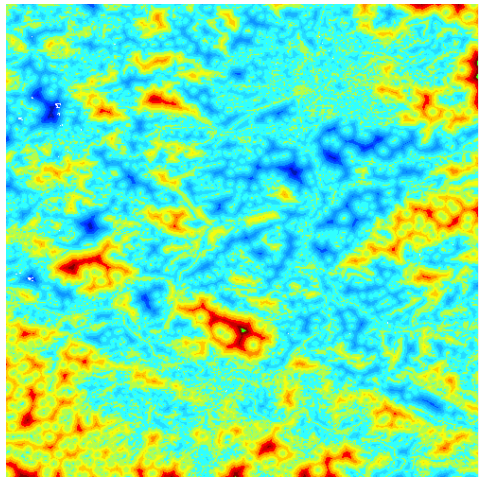
7) Distance analysis…

Euclidean distance, influence zones, buffer zones, proximity…

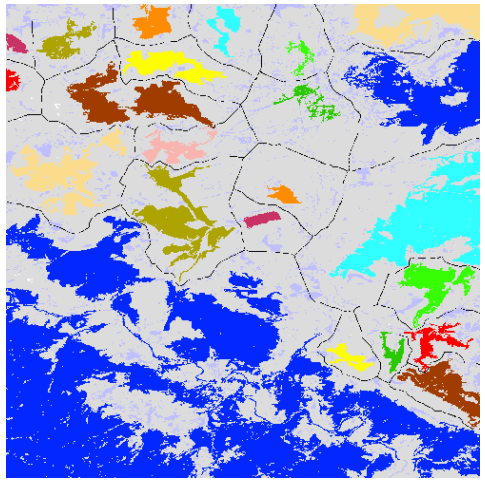
Mask



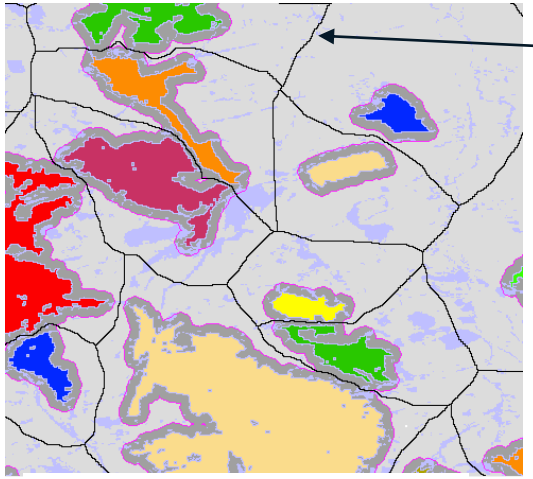
Euclidean distance



Influence zones

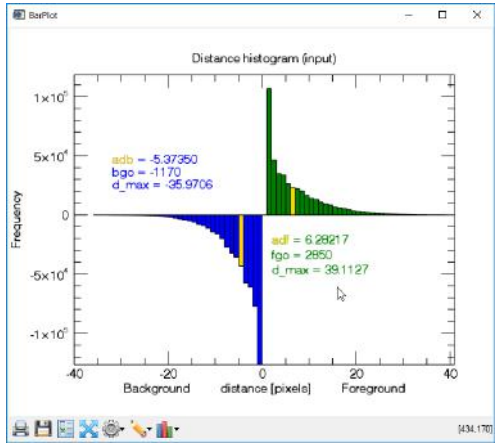


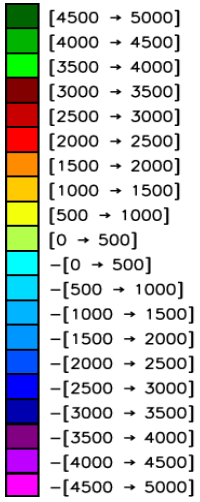
Buffer zones



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

Distance [m]



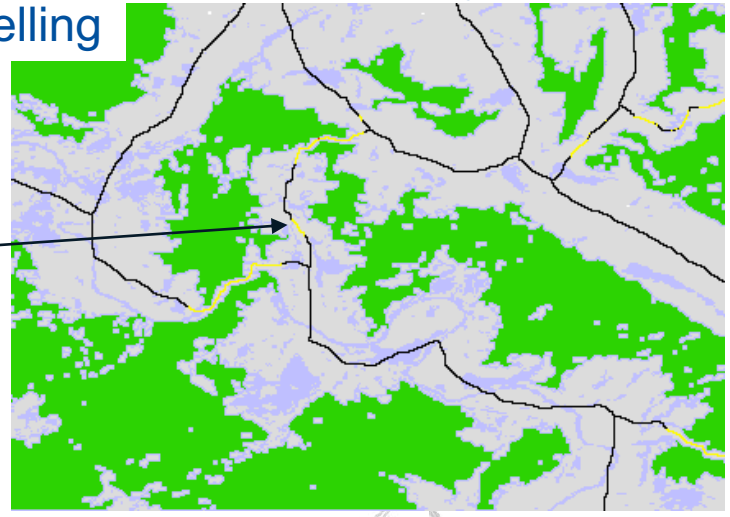


Distance between objects > X hectare

Pest risk modelling

Locations where pairwise distance < X (restoration planning)

Proximity



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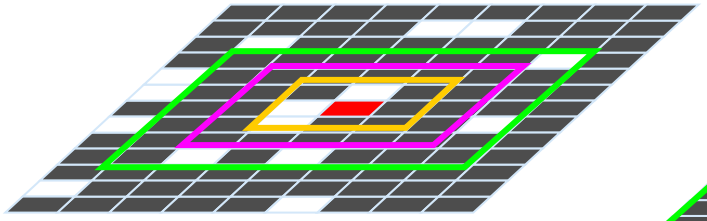
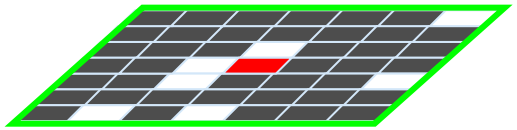
Aim: generic geometric approach: normalized [0,100]% spatial index

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

Select a focal pixel as the center of a neighborhood

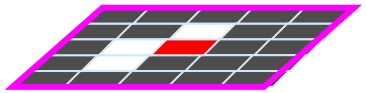




And so on... using 5 neighborhood sizes

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%

5 maps – one for each neighborhood size

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

(Courtesy of K. Riitters, US-FS)

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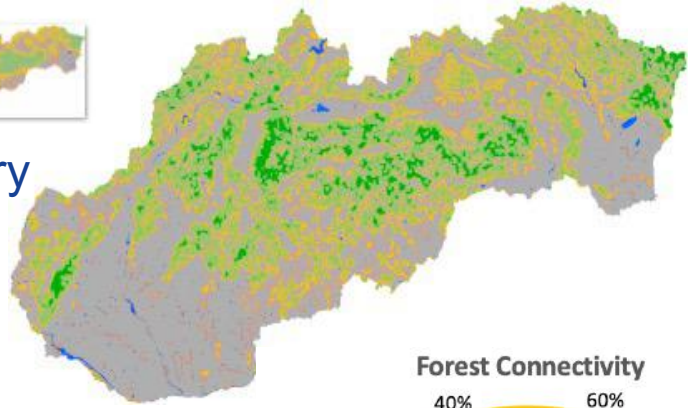
8) Fragmentation analysis…

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

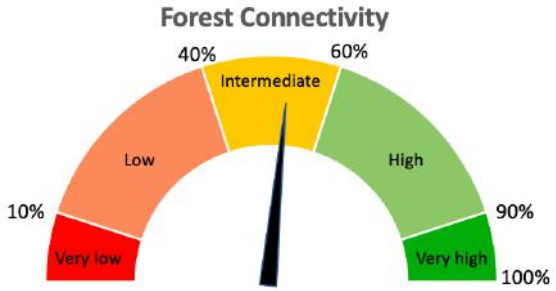
and add across-scale fragmentation summary

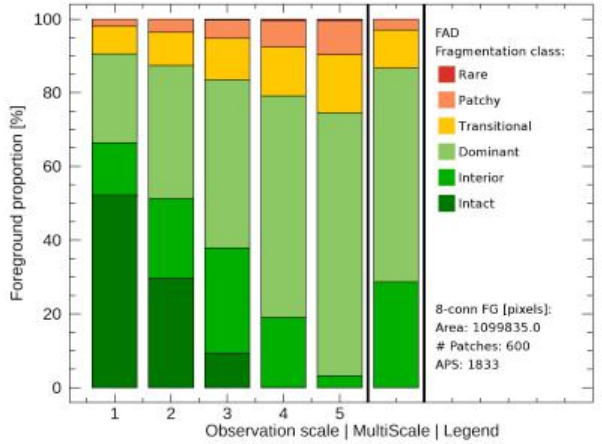


Fragmentation class	Color	FAD range
1 - Rare		FAD < 10%
2 - Patchy		10% ≤ FAD < 40%
3 - Transitional		40% ≤ FAD < 60%
4 - Dominant		60% ≤ FAD < 90%
5 - Interior		90% ≤ FAD < 100%
6 - Intact		FAD = 100%

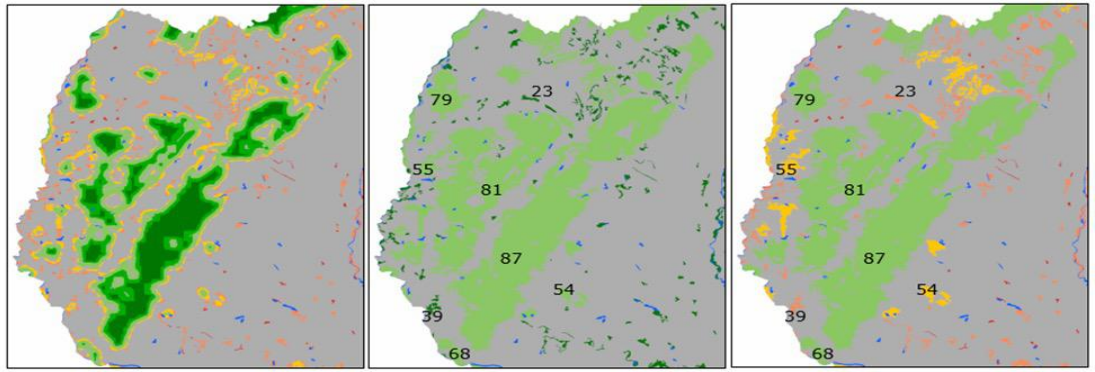
2) Statistics for area and fragmentation classes

```
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
================================================================================
```

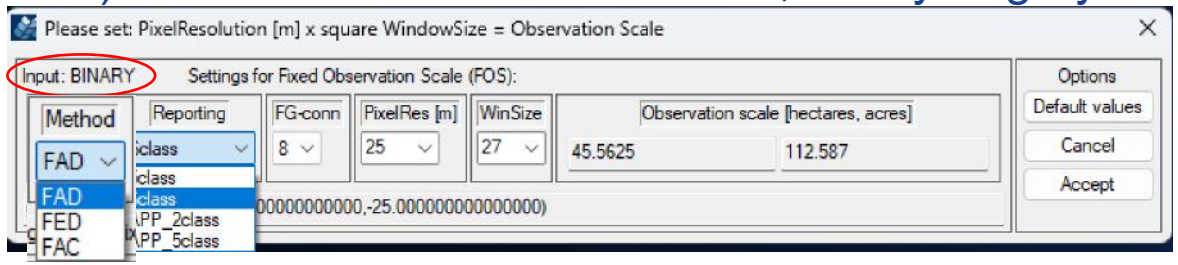


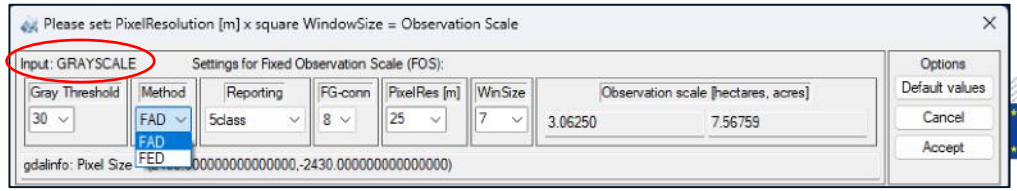


3) Per-pixel or Average Per-Patch fragmentation classes



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





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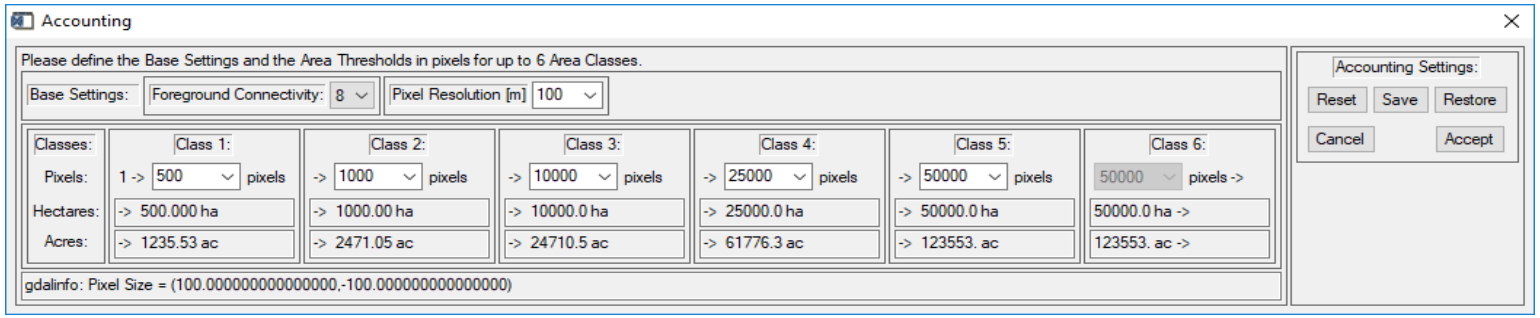
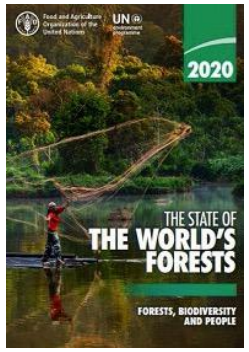
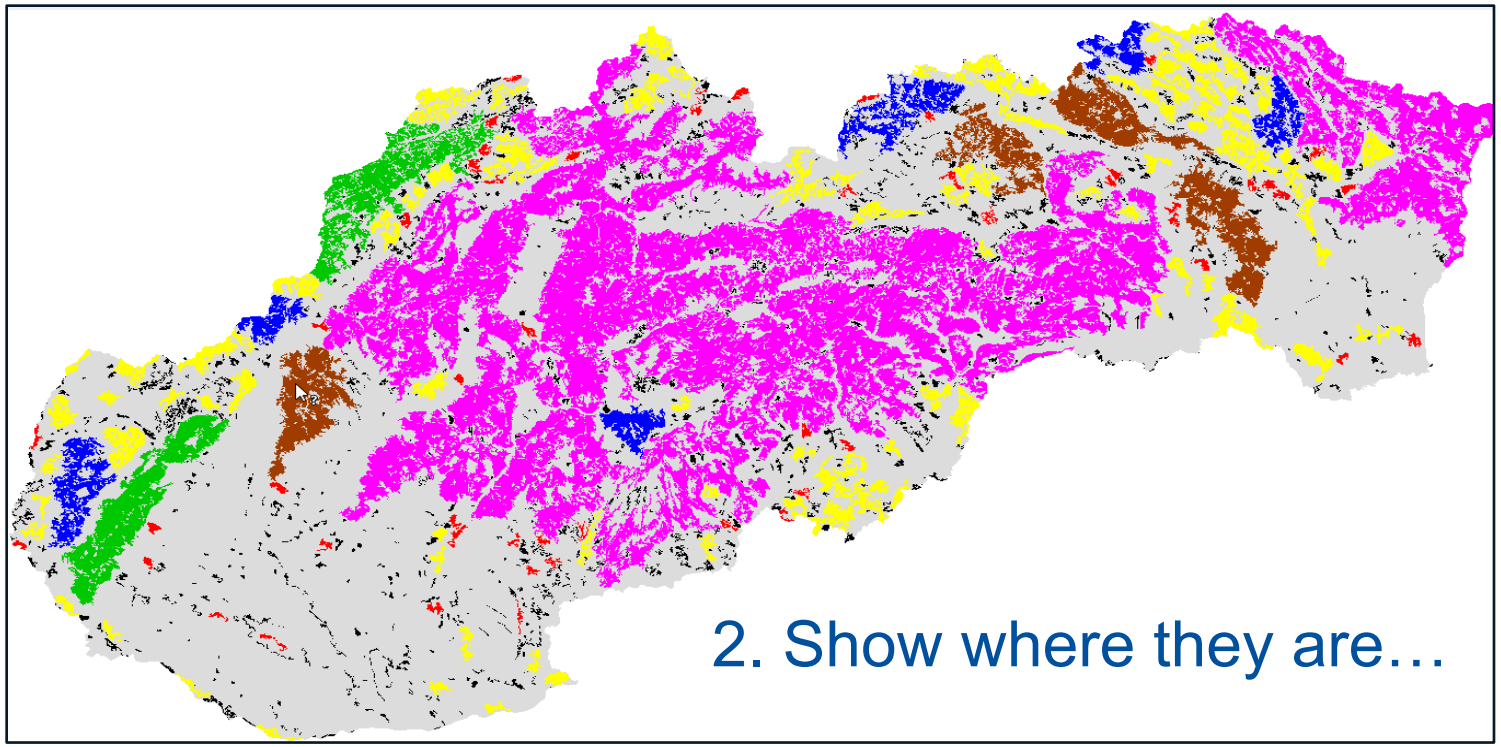
9) Accounting…

Where is the forest and what is the patch size class distribution?

1. Define up to 6 patch size classes:

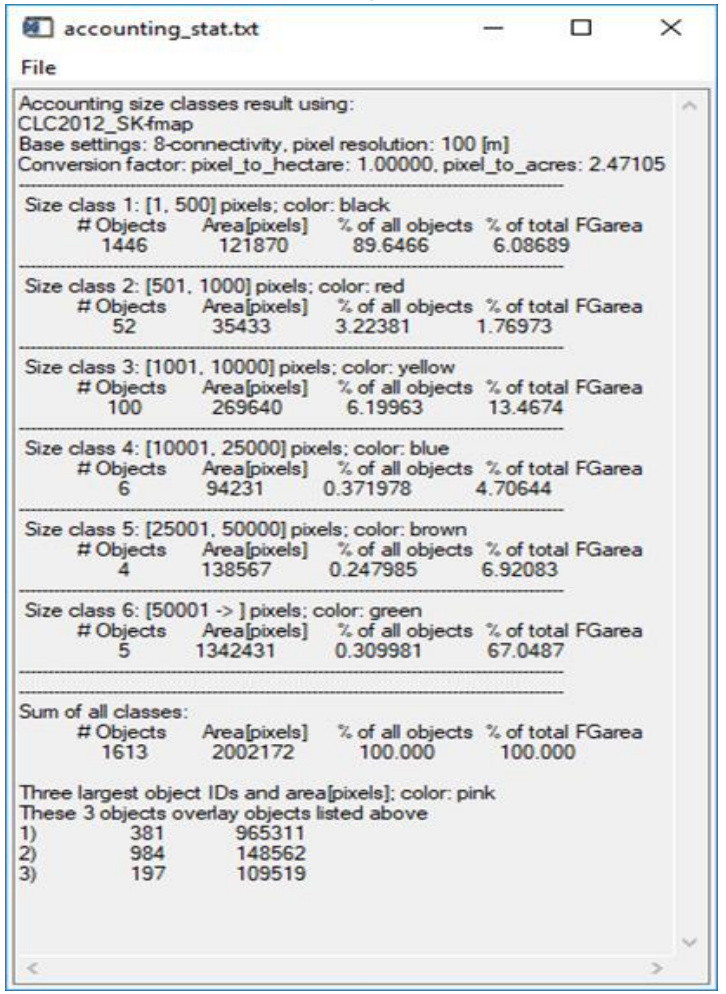






2. Show where they are…

3. Summary statistics:



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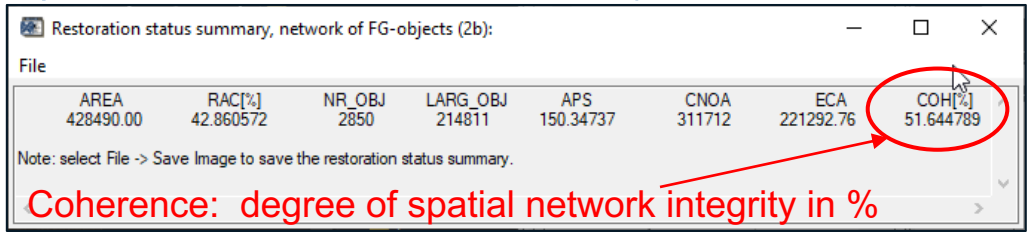
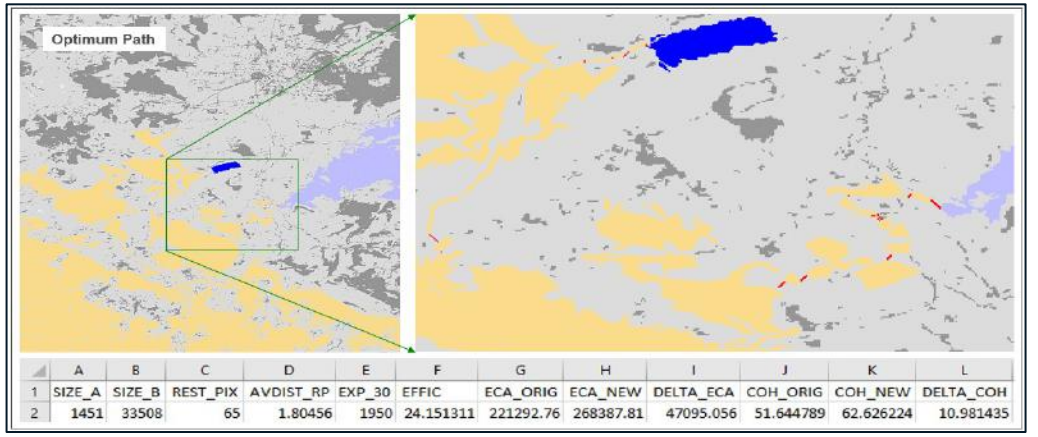
Spatial integrity of a network (Coherence). Evaluation of restoration scenarios.

1) Network status summary.

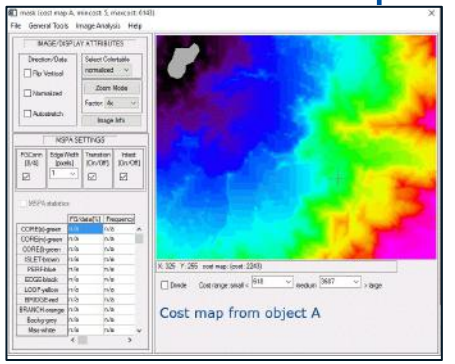


Locate optimum path between start and target habitat

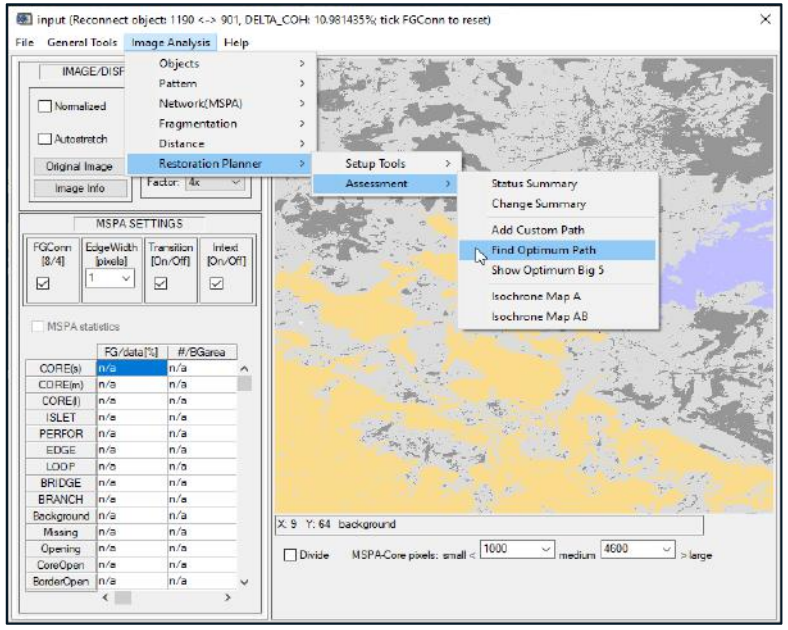


	A	B	C	D	E	F	G	H	I	J	K	L
1	SIZE_A	SIZE_B	REST_PIX	AVDIST_RP	EXP_30	EFFIC	ECA_ORIG	ECA_NEW	DELTA_ECA	COH_ORIG	COH_NEW	DELTA_COH
2	1451	33508	65	1.80456	1950	24.151311	221292.76	268387.81	47095.056	51.644789	62.626224	10.981435

Isochrone map



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

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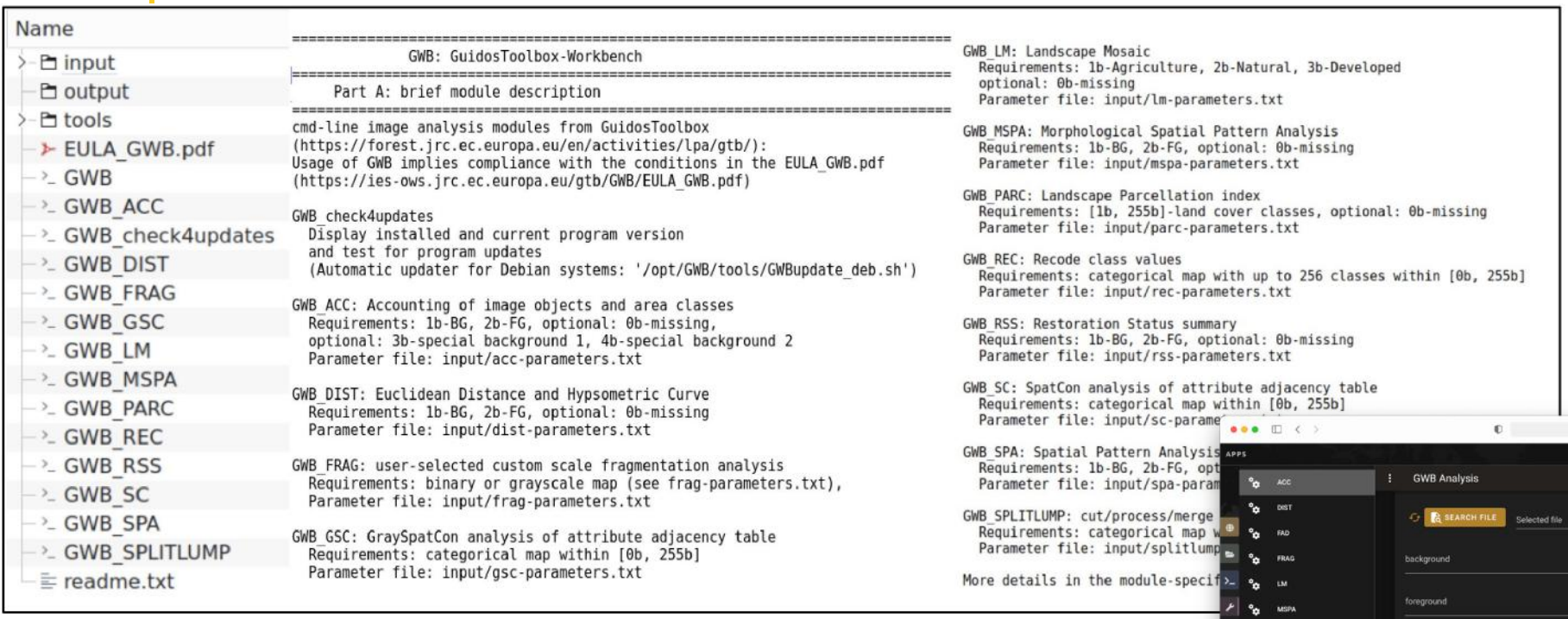
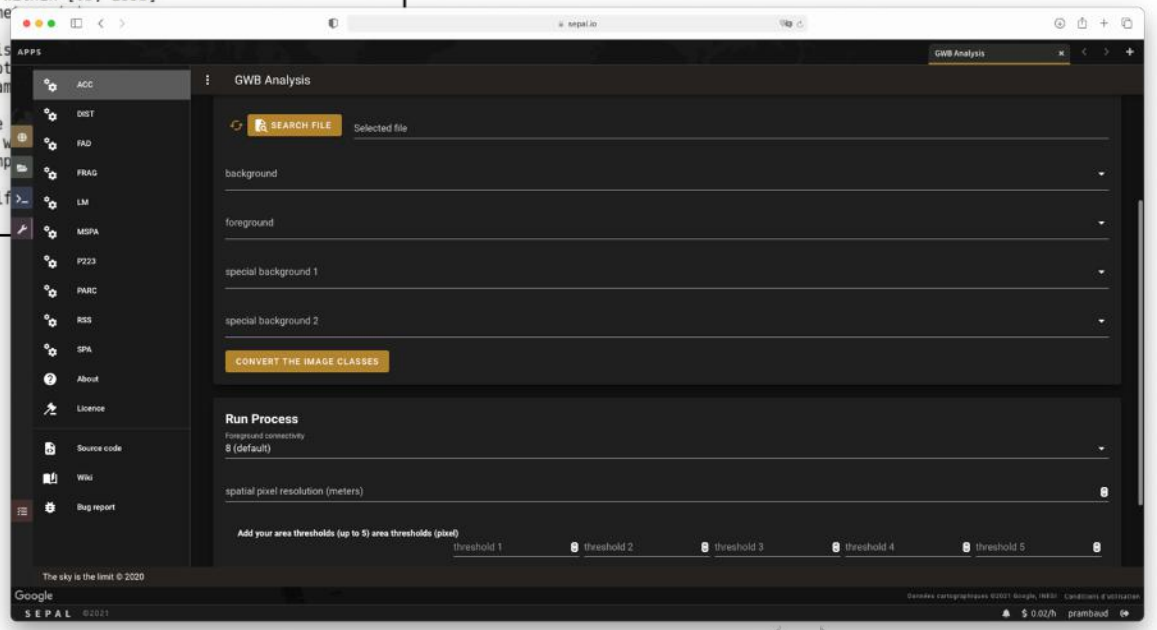
GWB: The most popular GTB tools as command-line modules for Linux servers.



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

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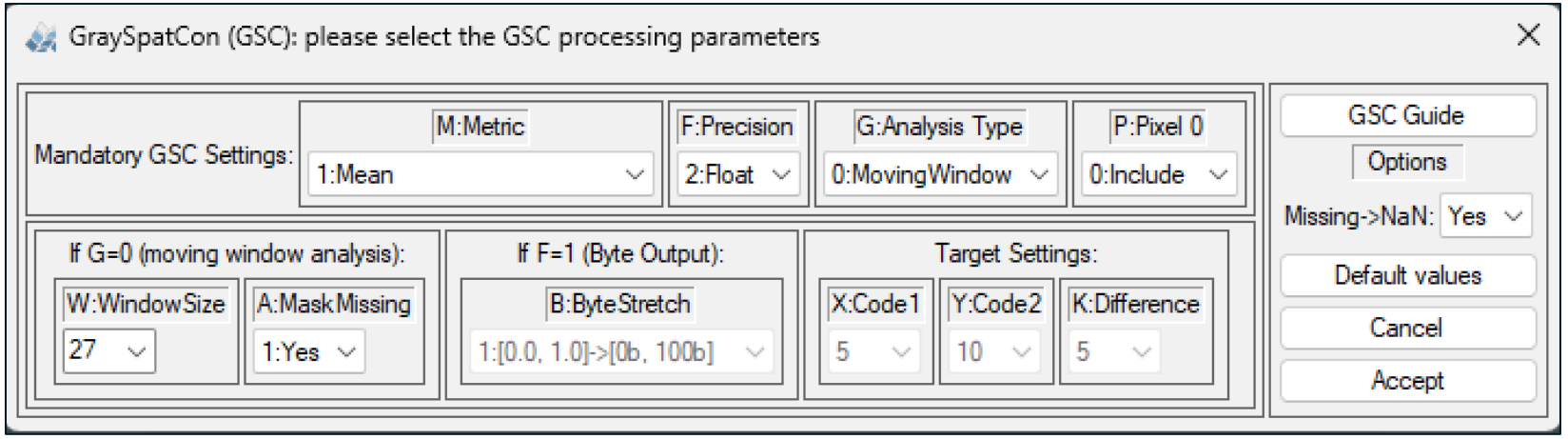
Transition from analyzing binary input maps with *SpatCon* to analyzing grayscale input maps in [0, 100]%, i.e., tree cover density, resistance, probability, etc.

GraySpatcon (GSC): choice of 52 moving window metrics



- 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

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Thank you

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