***NordLaM Nordic Workshop* on**

"High resolution airborne and space-based remote sensing

for landscape level terrestrial monitoring "

Saturday to Monday, 3-5 November 2001 Turku, Finland.

Scale and scaling issues in Landscape Ecology and in Remote Sensing - and related problems with the use of spatial structure as an indicator of diversity

Niels Chr. Nielsen, M.Sc.

niels_c_nielsen@get2net.dk

JRC Project:

Development and evaluation of remote sensing based spatial indicators for the assessment of forest biodiversity and sustainability, using landscape metrics derived from high- to medium resolution sensors

Lancaster University thesis under way:

Development and test of spatial metrics derived from EO data for indicators of sustainable management of forest and woodlands at the landscape level

Structure of presentation:

- Scales and levels, in ”Nature” and of observation

- Remote Sensing and Landscape Ecology, from photographs to Fragstats

- Indicators of ”Sustainable Forest Management”

- Spatial metrics, definitions and uses

- Examples: structure (fragmentation) and diversity

- Moving or adaptive windows, a solution?

- Discussion of the use of thematic maps for monitoring of forest landscapes over space and time

Scale and level concepts

Scale (spatial, mathematical ratio) :

(..) one of the primary attributes in describing geographical data (Cao and Lam 1997)

- Cartographic scale or map scale is the proportion of a distance on a map to the corresponding distance on the ground (Cao and Lam 1997)

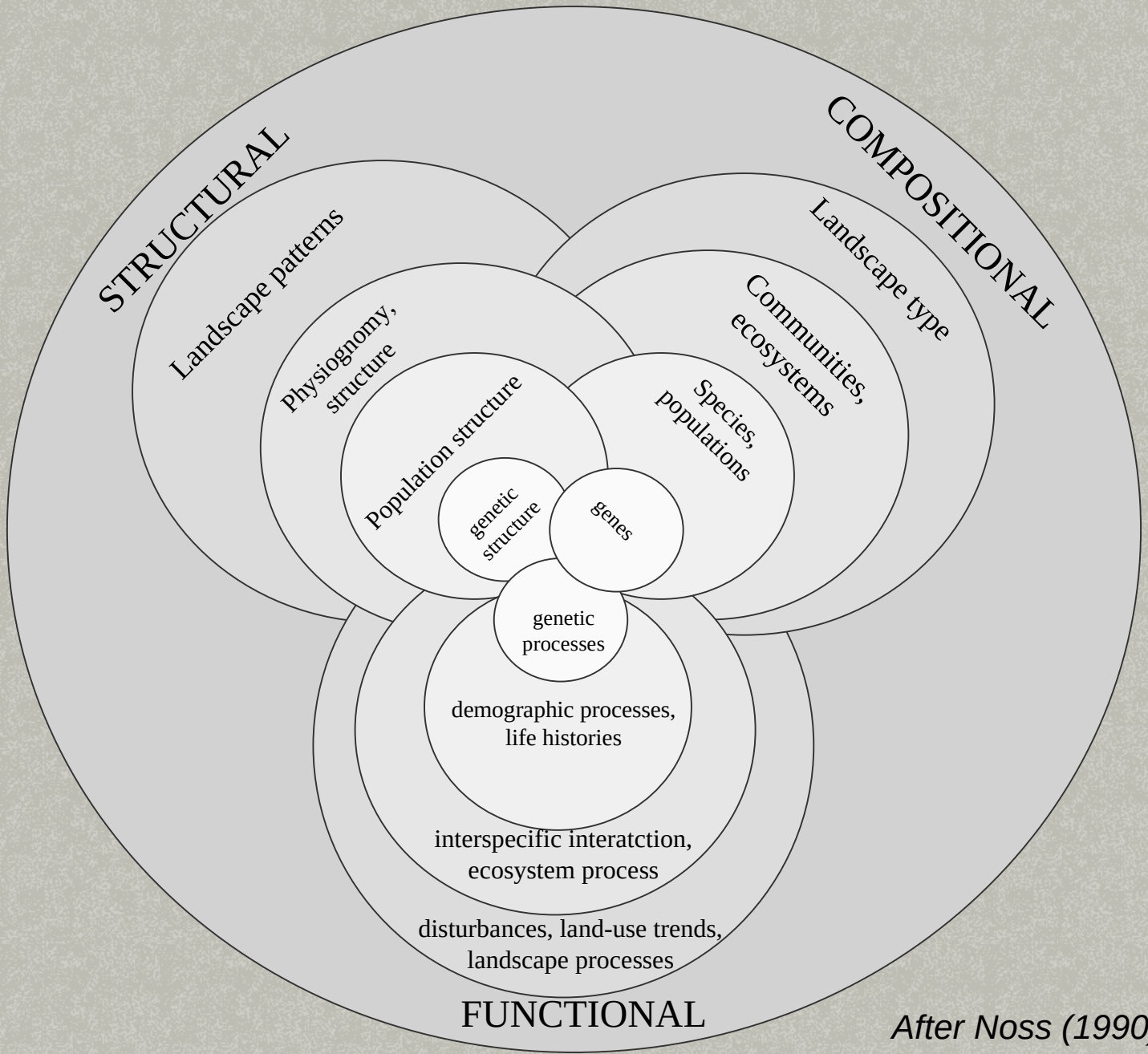
- The resolution at which patterns are measured, perceived or represented. (Morrison and Hall, 1999)

- Alternatively: A (imaginary) measuring instrument (as in fractal geometry)

Level (ecological, functional) :

- The level of organization revealed by observation at the scale under study (King 1990).

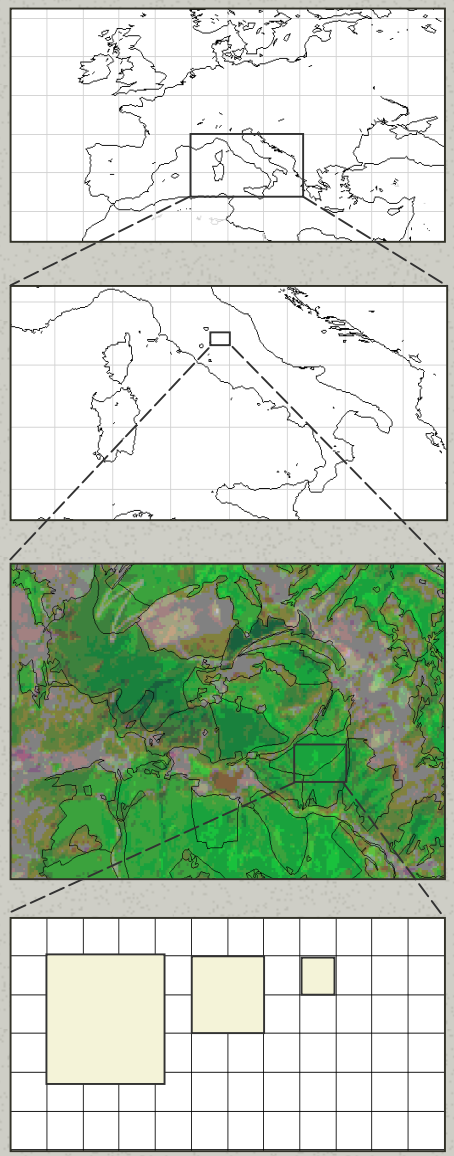
Spatial levels of biological diversity



After Noss (1990)

Levels of biological Diversity

Inventory diversities



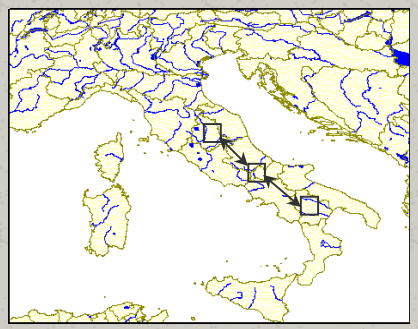
Epsilon / regional sampling unit: 1-100 mio. ha

Gamma / landscape sampling unit: 1000-1 mio. ha

Alpha / within community sampling units: 0.1 to 1000 ha

Point / microhabitat sampling units: 00.1 to 0.1 ha

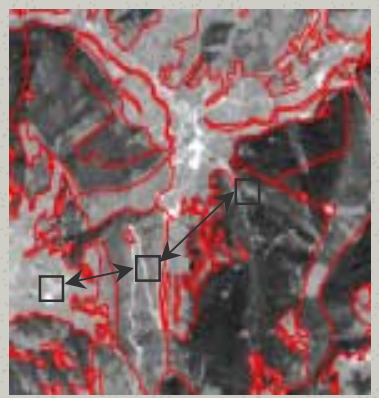
Differentiation diversities



Delta / geographic gradients; Sampling units: Alpha in same community type
Domain: landscape to region



Beta / environmental gradients; Sampling units: Alpha in different communities;
Domain: community to landscape



Pattern / micro gradients; Sampling units: Points in same community;
Domain: point to community

After: Stoms and Estes (1993)

Similarities RS - LE

Similarities RS – Landscape Ecology approaches:

** Different processes at different levels*

- *different scales of observation are relevant*

** Integrated (holistic) view*

** Pattern does matter(!) – studies of vegetation patterns*

** Dealing with spatial heterogeneity..*

** Search for Self-similarity, as reflected in fractal patterns*

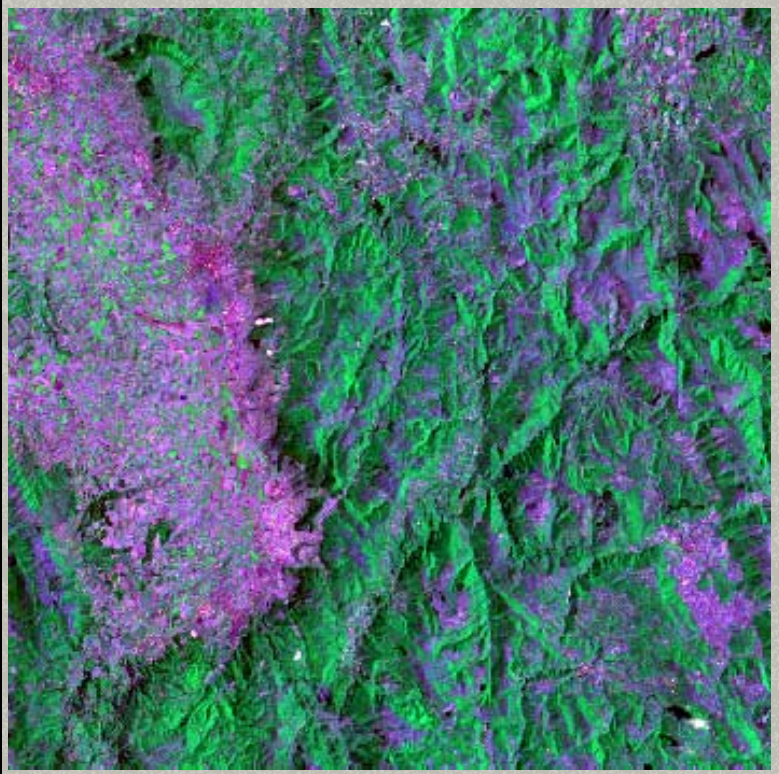
** Analysis of scaling effects*

** Minimum mapping unit: Grain = Pixel*

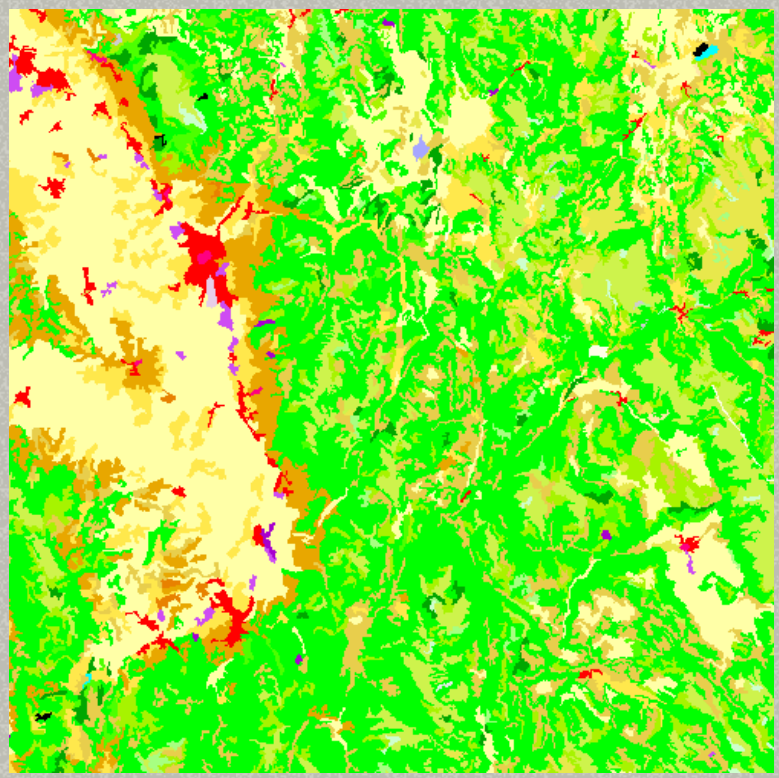
** Forest landscapes:*

- *mapping and monitoring the "shifting mosaic"*

Image data, medium resolution:

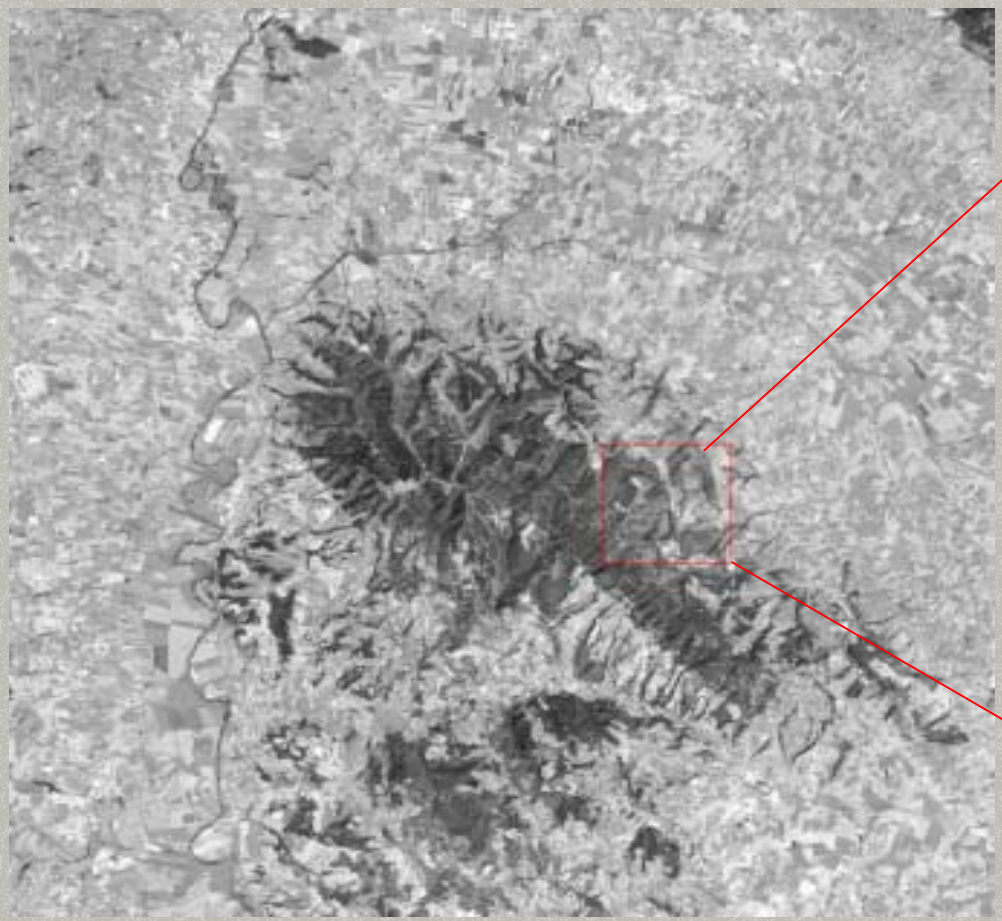


Landsat TM:
6bands (+1thermal)
resolution 30m

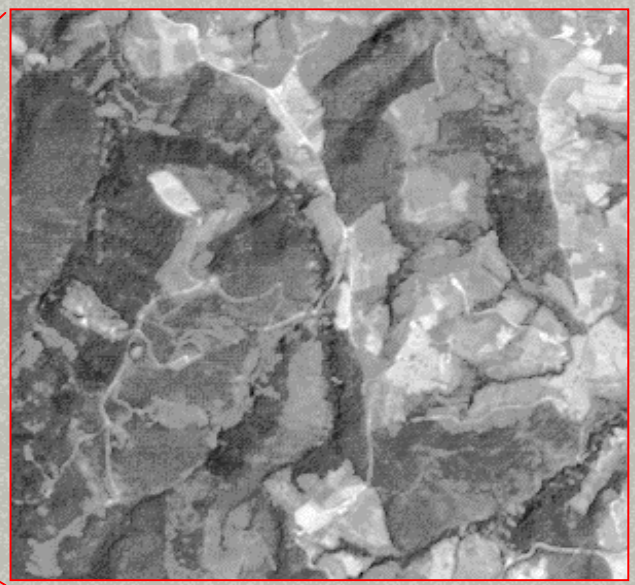


CORINE land cover database,
shown here as raster data
with 100m pixel size

Image data, high resolution :



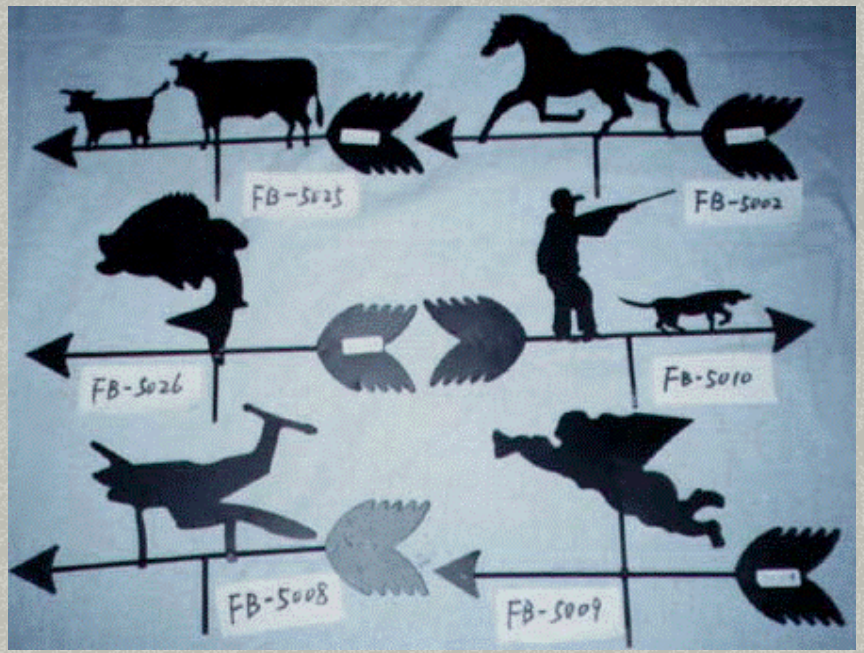
23 km



3 km

Example, SPOT-Panchromatic, 10m pixel size

What is an Indicator ?

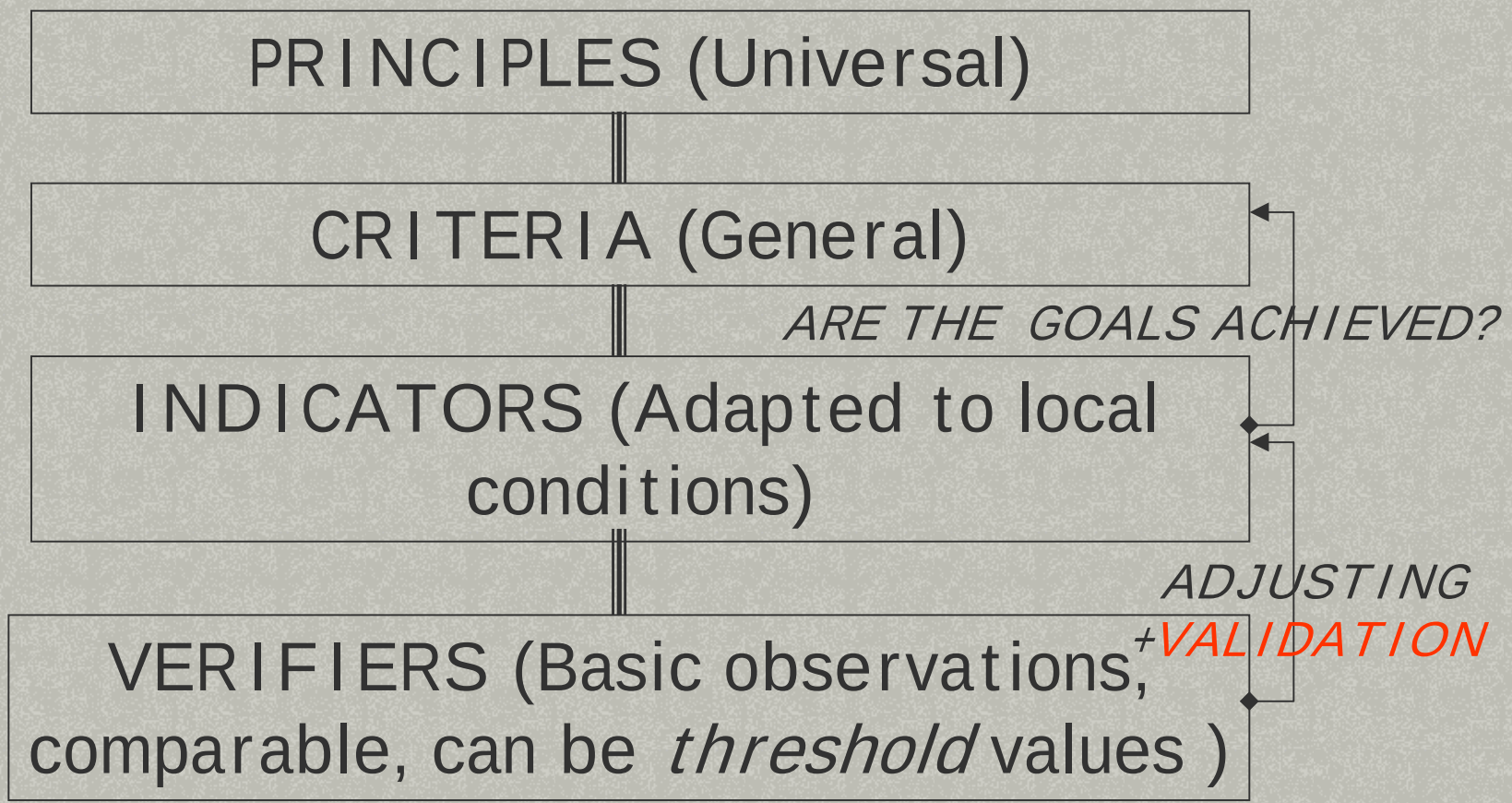




A measure (measurement) of an aspect of the criterion.

A quantitative or qualitative variable which can be measured or described and which, when observed periodically, demonstrates trends. (Montreal Process)

Sustainable Forest Management (SFM) hierarchy:



Why quantify landscape structure?

Purpose:

- Description of key features of images
- Characterisation of landscape structure
- Compression of complex information, making comparisons easier.

Assumptions:

- Relation to ecosystem functioning and to 'naturalness' of landscapes.
- When land cover data from different years are compared, trends can be revealed.

Types of spatial metrics

"Information Hierarchy" of Spatial Metrics

less

ADVANCED

more

Spatial information type	Describing..	Output units
Area	Land cover classes or patches	m^2 , ha, km^2, %
Count	Objects, patches (richness of)	Number
Shape	Structure: from patches to landscapes	Any (m^{-1}, FD normally unit-less)
Position, distance	Relative placement of patches	m, km
Topology	Context – connectivity, relative edge type proportions (weighted edge indices)	Unit-less number

Models in RS and ecology

Reality - Model - Quantified Model - Simplified Model

PROCESSES

STATES

LANDSCAPE

(FOREST)

ECOLOGY

GIS:

Metapopulation Ecology

Links with databases, models

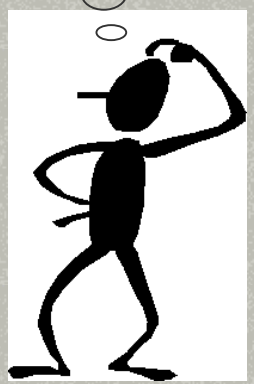
RS:

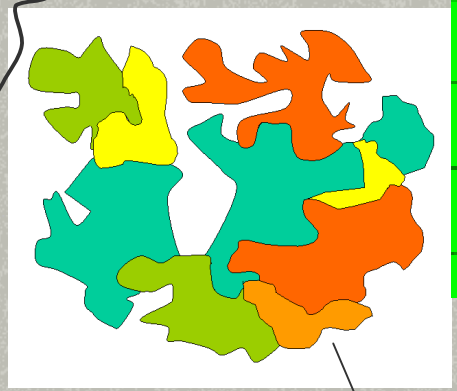
Grid, Grain

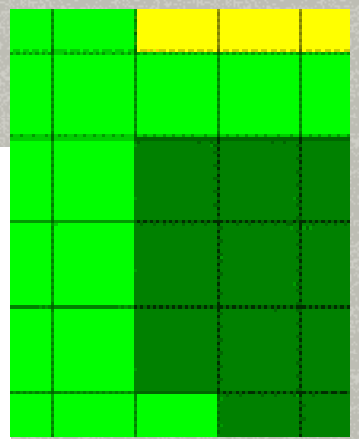
Ecotope!

Habitat!



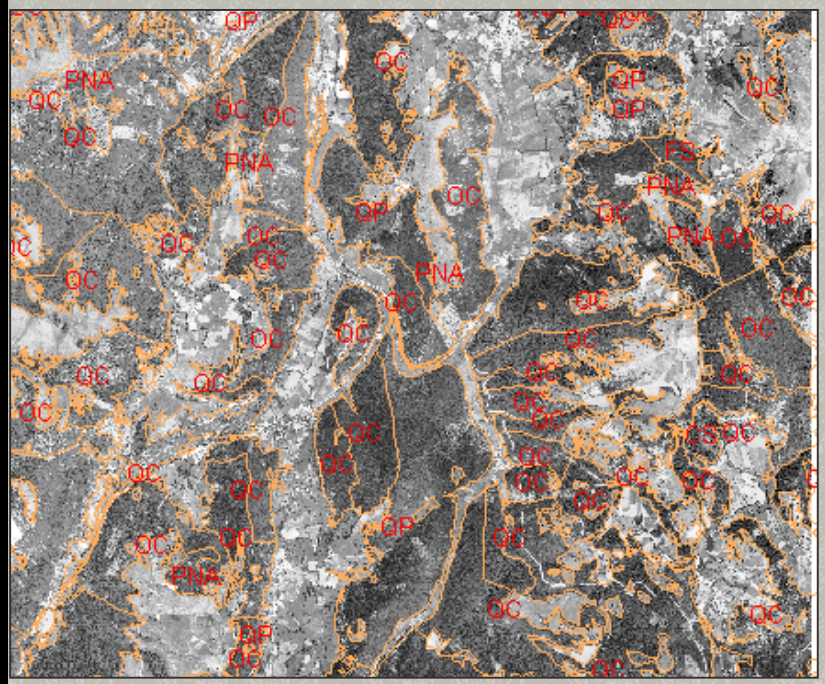




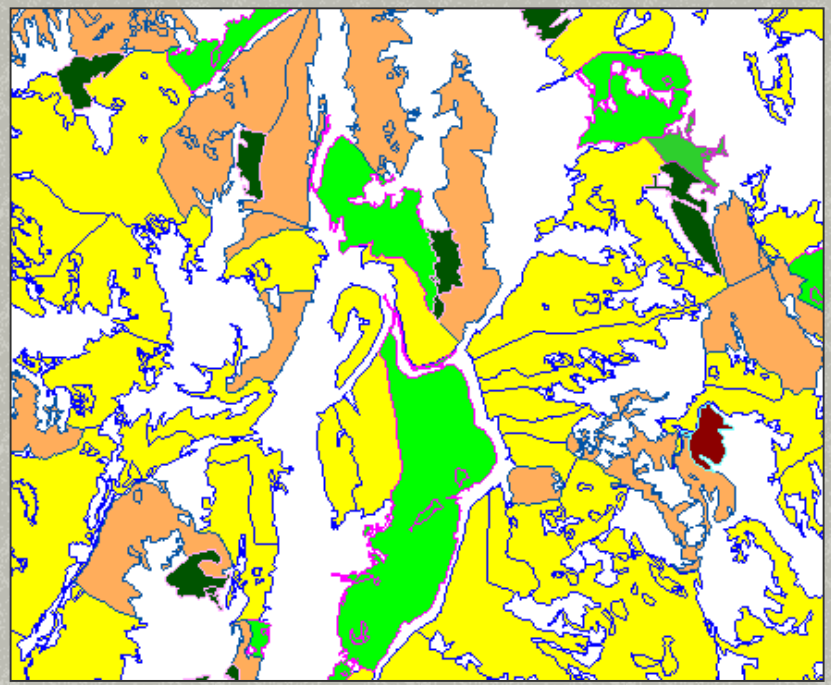


Metrics/ Indicators

High resolution data for detailed mapping



Aerial photo, resolution appr. 1m, with shape file outline (on screen digitisation, GIS)



Dominant vegetation type assigned to each polygon. Operational forest map, by Regione dell'Umbria

Selected spatial metrics, for quantification of 'forest fragmentation'

The test case:

One land cover type, the rest "background"
Fragmentation expressed through - edge, shape, patch number

Matheron index:

$$M = 10^* \frac{\text{number of runs between forest and other cover type pixels}}{\sqrt{(\text{number of forest pixels})} * \sqrt{(\text{total number of pixels})}} \quad [1]$$

Number of Patches Per Unit area (ha) :

$$\text{PPU} = \frac{m}{(n * \lambda)} \quad [2]$$

Squareness (regularity) of Patches :

$$\text{SqP} = 1 - \frac{4*\sqrt{A}}{P} \quad [3]$$

Location of study area

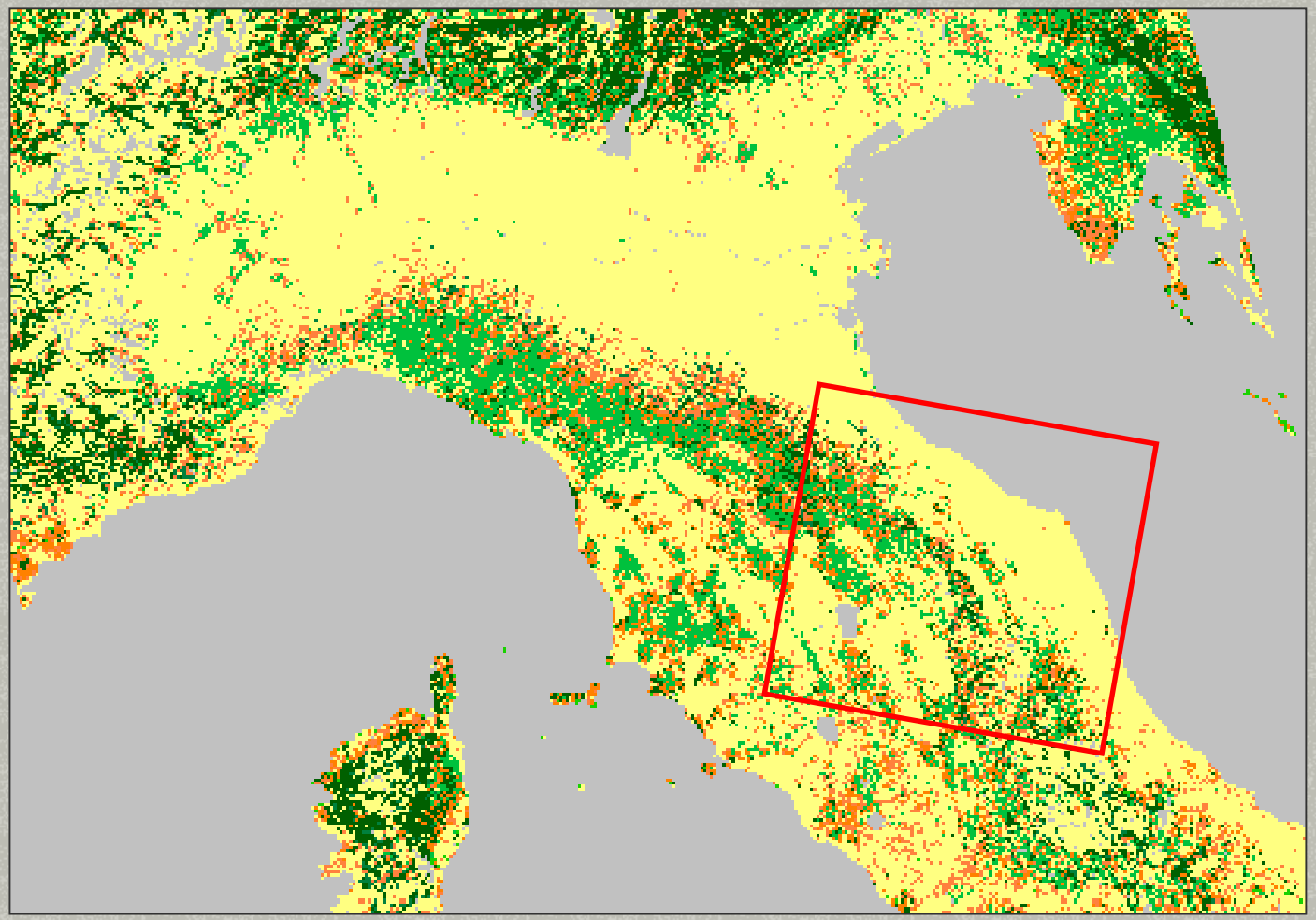


Image Data

Landsat TM, scene 191-030 acquired 12 July 1996

Pixel size 28.5 m, resampled to 25m

IRS-C, WiFS, image acquired 2 Sept. 1997

Pixel size 188 m, resampled to 200m

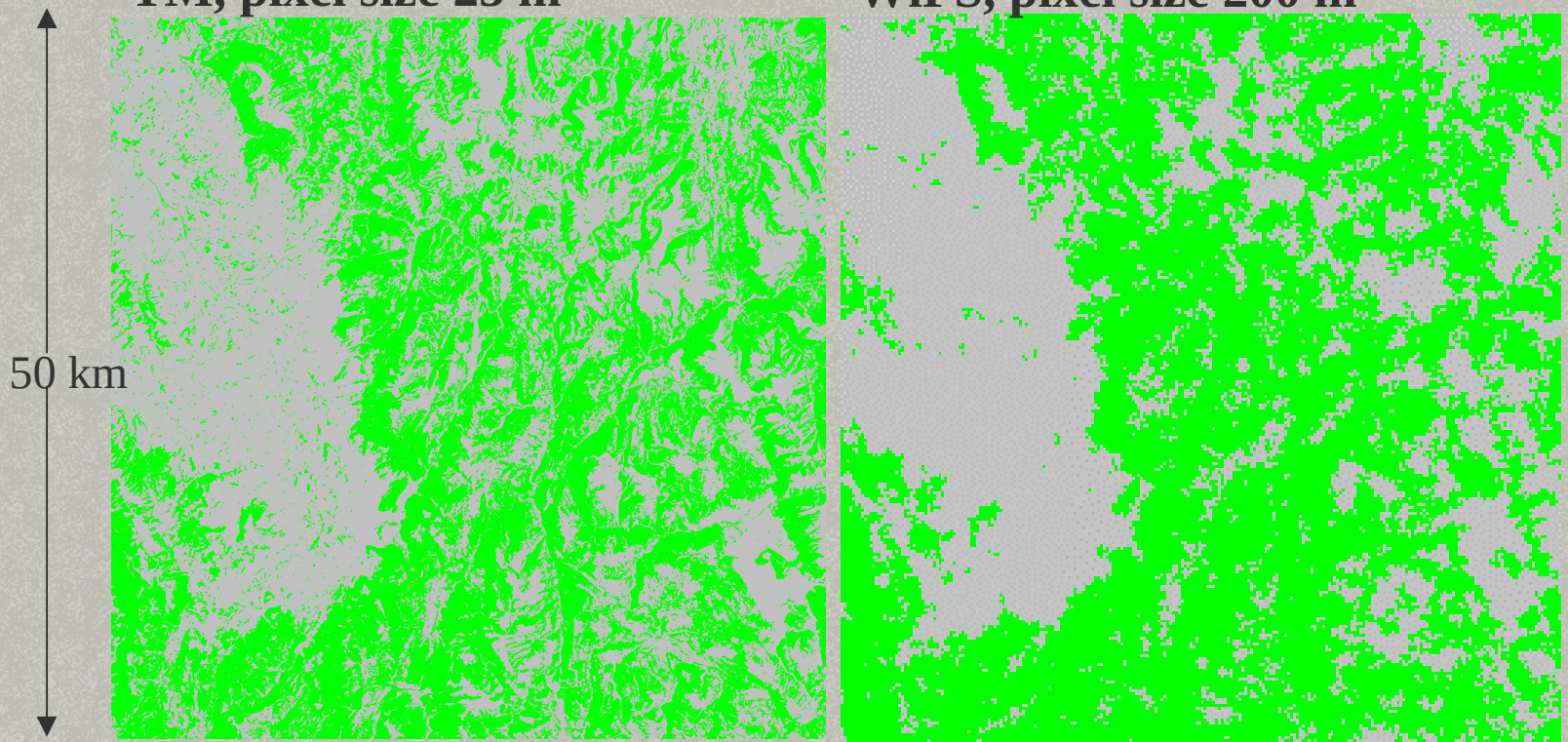
	Landsat TM		IRS WiFS	
	band nr.	wavelgt. µm	band nr.	wavelgt. µm
red	3	0.63-0.69	1	0.62-0.68
NIR	4	0.76-0.90	2	0.77-0.86
MIR	5	1.55-1.75		

GIS coverage digitized from 1:10.000 forest maps (based on aerial photography appr. 1m resolution)

Classified (unsupervised) images

TM, pixel size 25 m

WiFS, pixel size 200 m

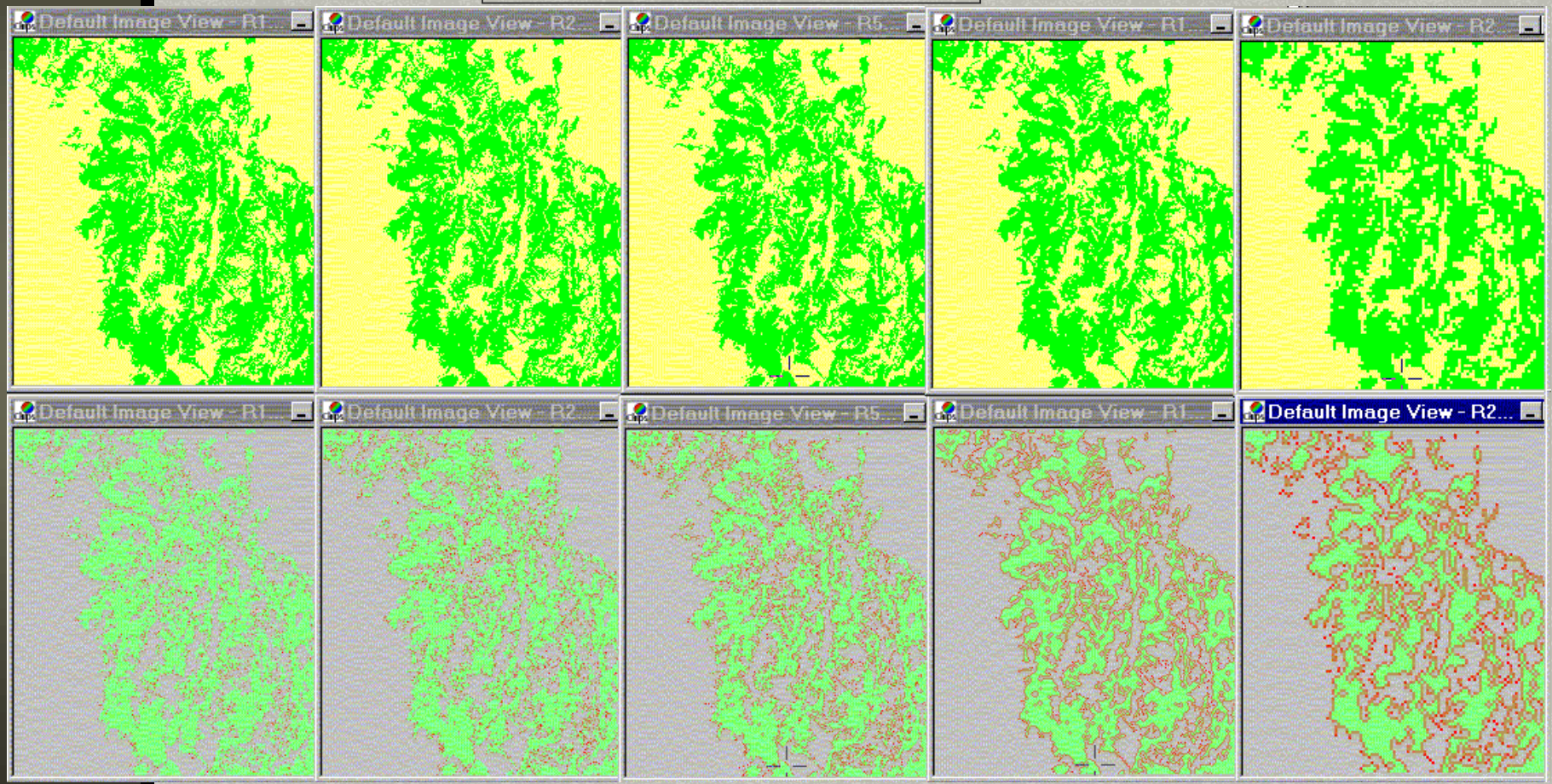


Detected forest cover 44.9%

Detected forest cover 54.9%

Synthetic images, degradation:

Apply majority filter to start (12.5m) image

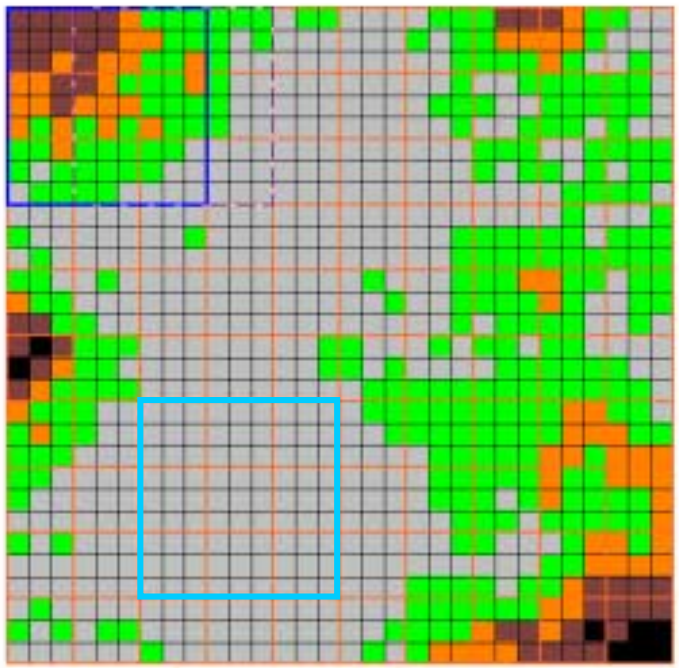


”Moving Windows” Approach

- ***As implemented with calculation of Fragstats-derived and other spatial metrics for “sub-landscapes”***

INPUT: “cover type” map(1)

OUTPUT: metrics/index value map(2)



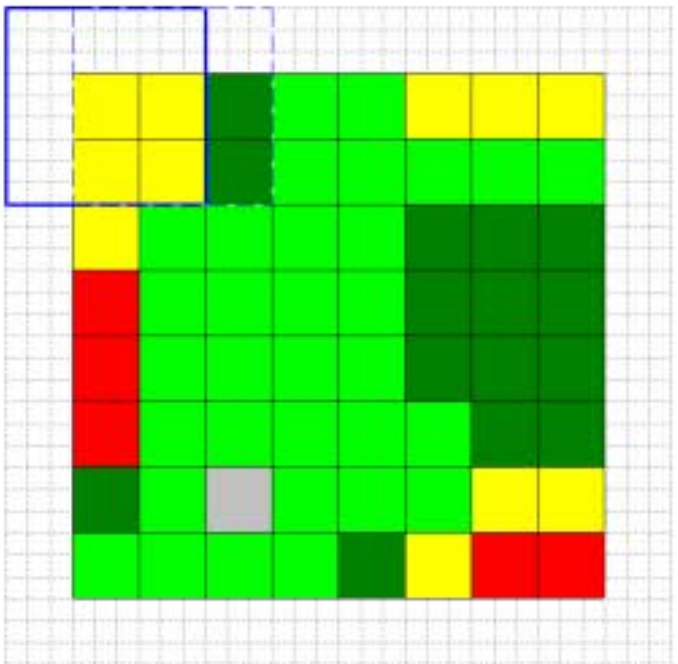
Calculate

(e.g.)

Patch type

Richness

1 2 3 4 5



Map 1: ◄---------- *Applied to* ----------

Window (user choice): ----------*Determines*----------►

Map 2:

Grain = pixel size = 30m

Extent = 30*30 pix = 900*900 m

Size (extent) = 9 pixels = 270 m

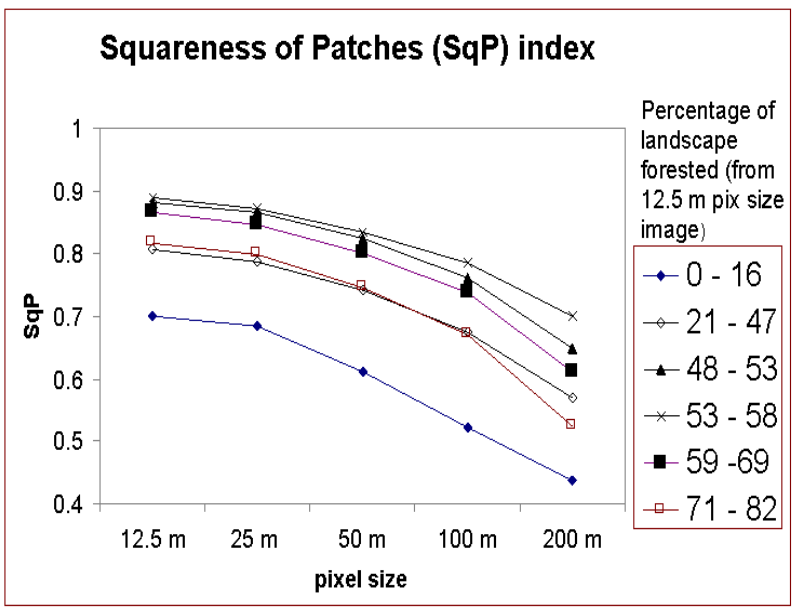
Step = 3 pixels = 90 m

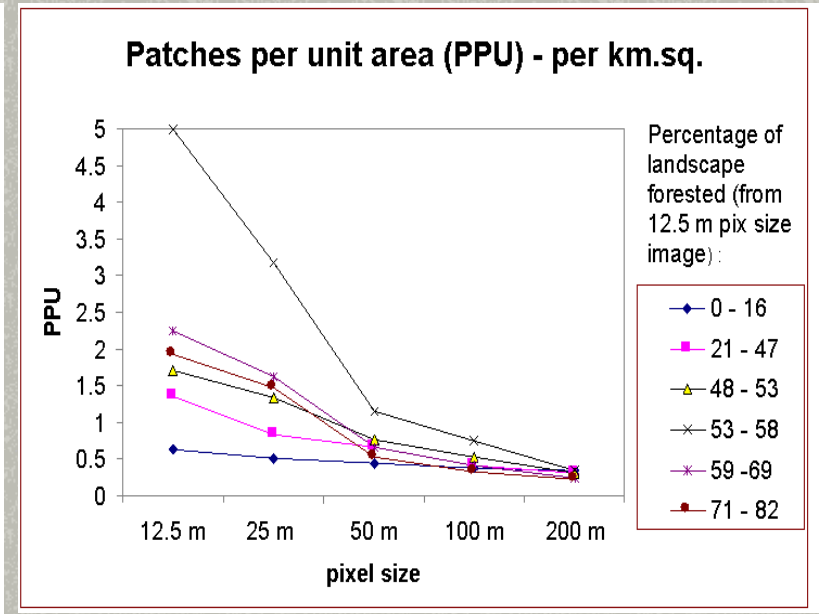
equals

Grain = pixel size = 90 m

Extent = 8*8 pixels = 720*720 m

Scaling behaviour of metrics





SqP	*Area12.5*	*12.5*	*25*	*50*	*100*
Area12.5	1				
12.5	0.533924	1			
25	0.526287	0.997263	1		
50	0.50381	0.990373	0.991971	1	
100	0.472774	0.970723	0.974048	0.987853	1
200	0.343242	0.918761	**0.928397**	0.936453	0.96009

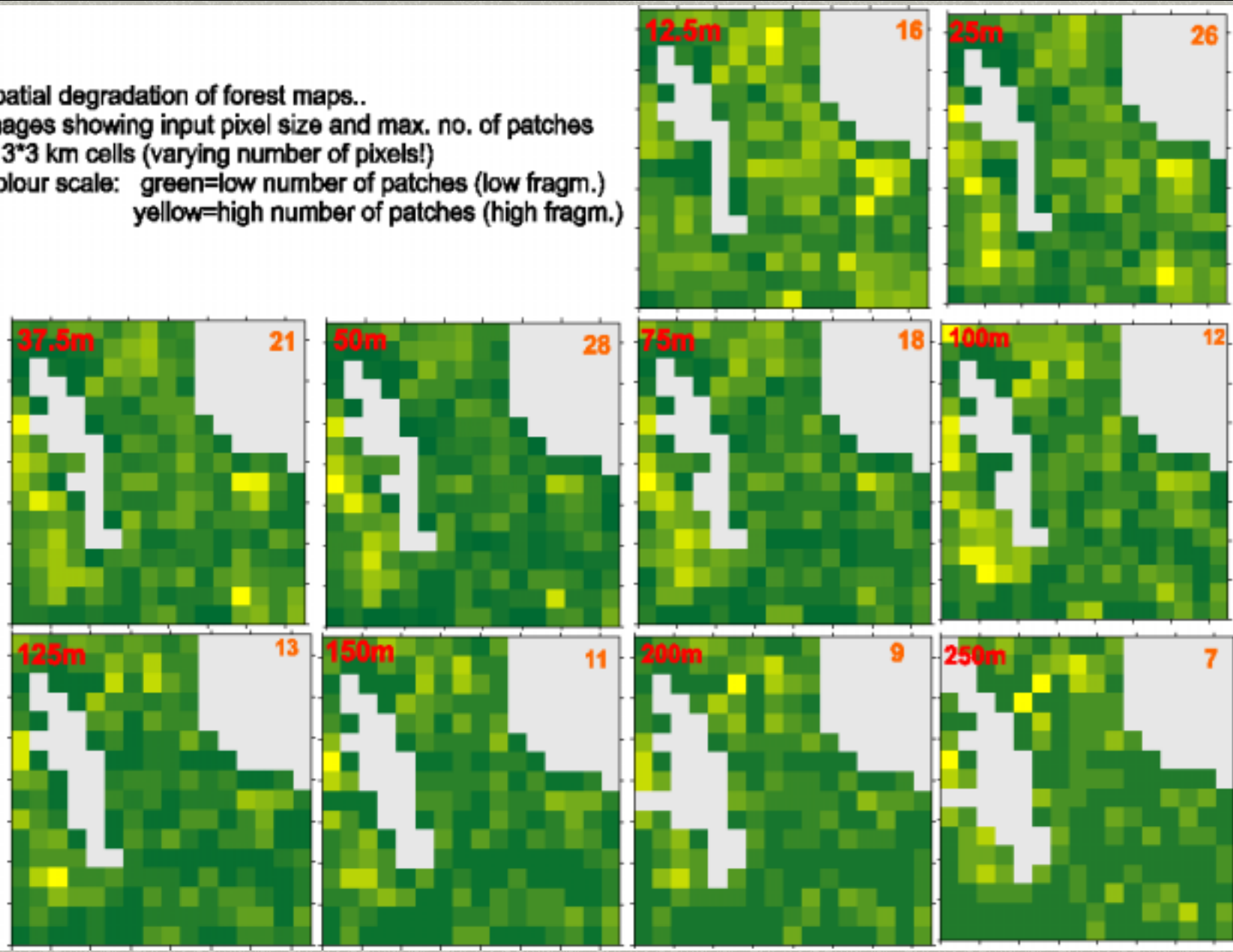
Correlation of the SqP metric derived from different pixel sizes. n=53

PPU	*Area12.5*	*12.5*	*25*	*50*	*100*
Area12.5	1				
12.5	0.480305	1			
25	0.498294	0.912379	1		
50	0.460977	0.726954	0.805893	1	
100	0.42592	0.589735	0.690656	0.877039	1
200	0.350249	0.372709	**0.358311**	0.668289	0.764104

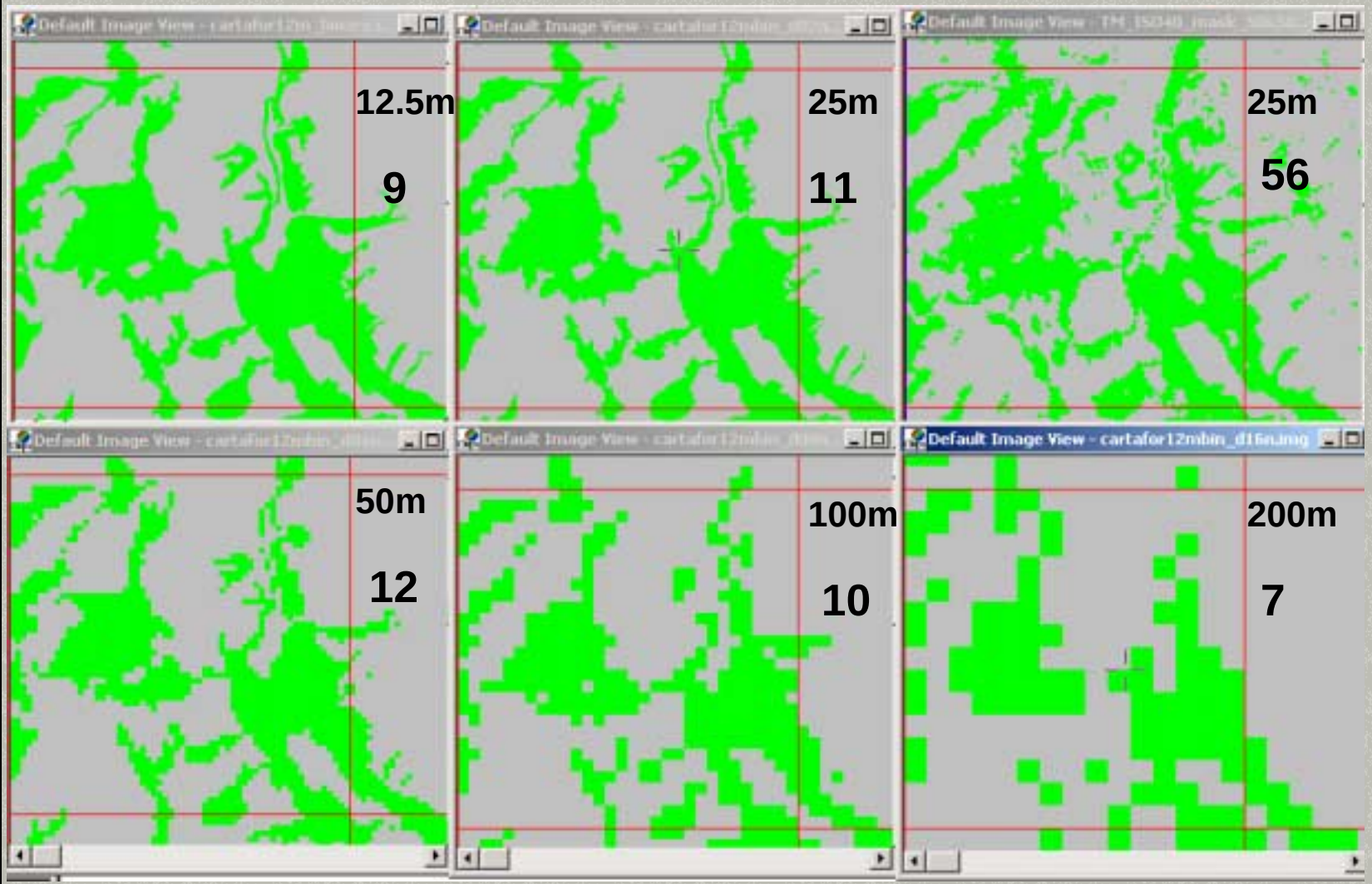
Correlation of the PPU metric derived from different pixel sizes. n=64

Example: Patches per unit area

Spatial degradation of forest maps..
images showing input pixel size and max. no. of patches
in 3*3 km cells (varying number of pixels!)
Colour scale: green=low number of patches (low fragm.)
yellow=high number of patches (high fragm.)

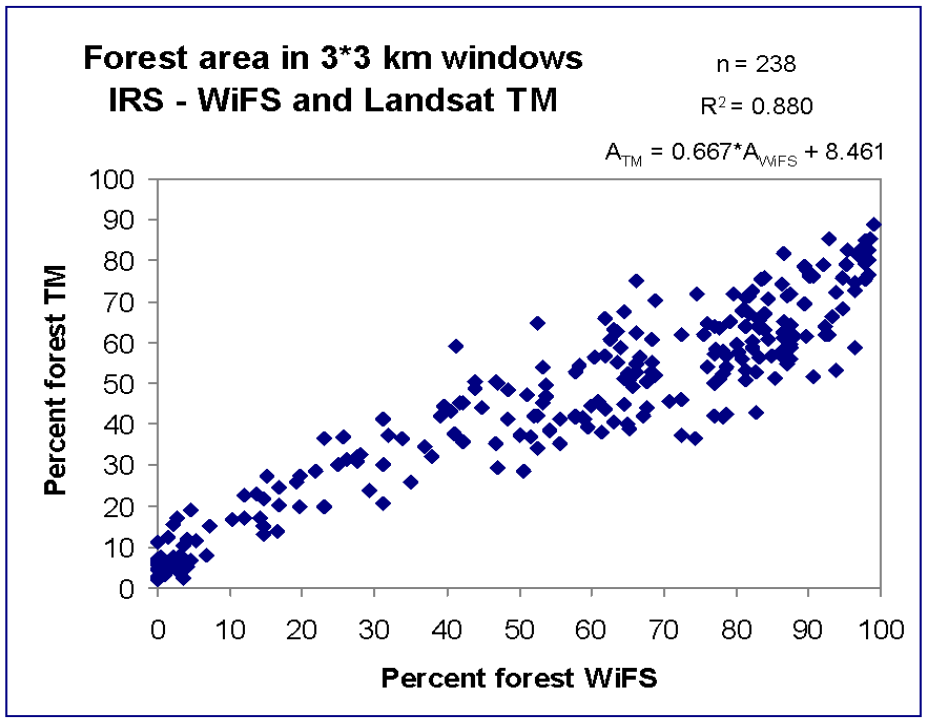


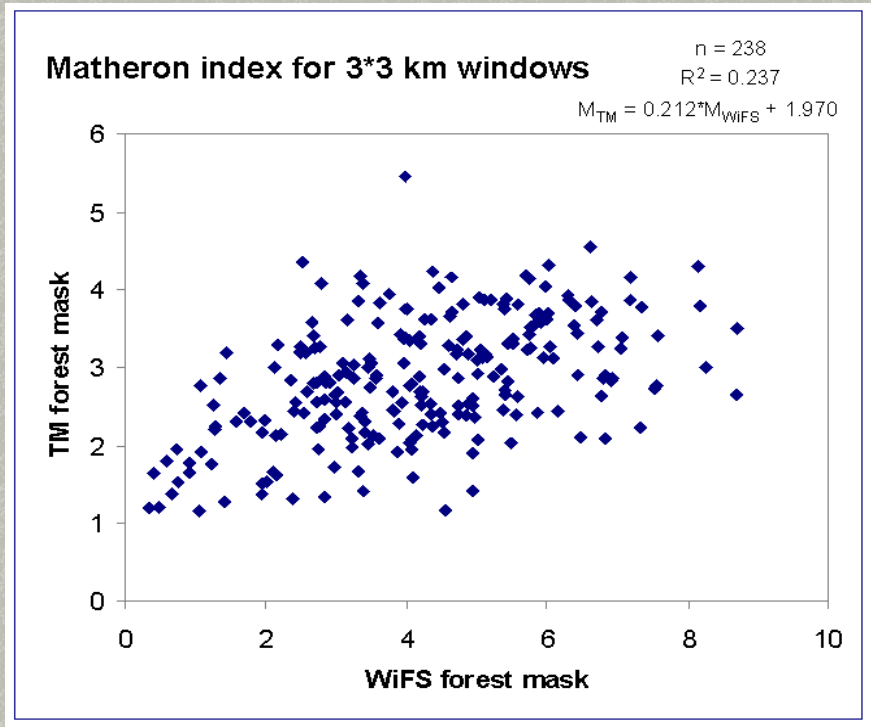
Number of patches varying with resolution



Agreeement btw. Satellites: areas and metrics

Satellite images, agreement and Matheron index values





Scale effects on diversity metrics:

Small classes disappear with increasing pixel size (although depending on their spatial distribution, clumped or scattered)..

-> Apparantly diminishing diversity.

- Must use hierarchical classification to go along with change of scale

Using land cover maps for landscape monitoring..

- Should we try to establish 'baseline' or 'threshold' values of spatial properties (with related metrics) for different landscapes?

- How to 'unmix' sensor and methodological biases on the map products?

- Is it clear what properties of and processes in the landscape that we want to follow/monitor? And are Land Cover maps useful to those ends??

- What is a patch – similar to forest stand (=smallest management unit)?

- Flexible, hierarchical nomenclature available?