Visualising Types of Uncertainty in Spatial Information

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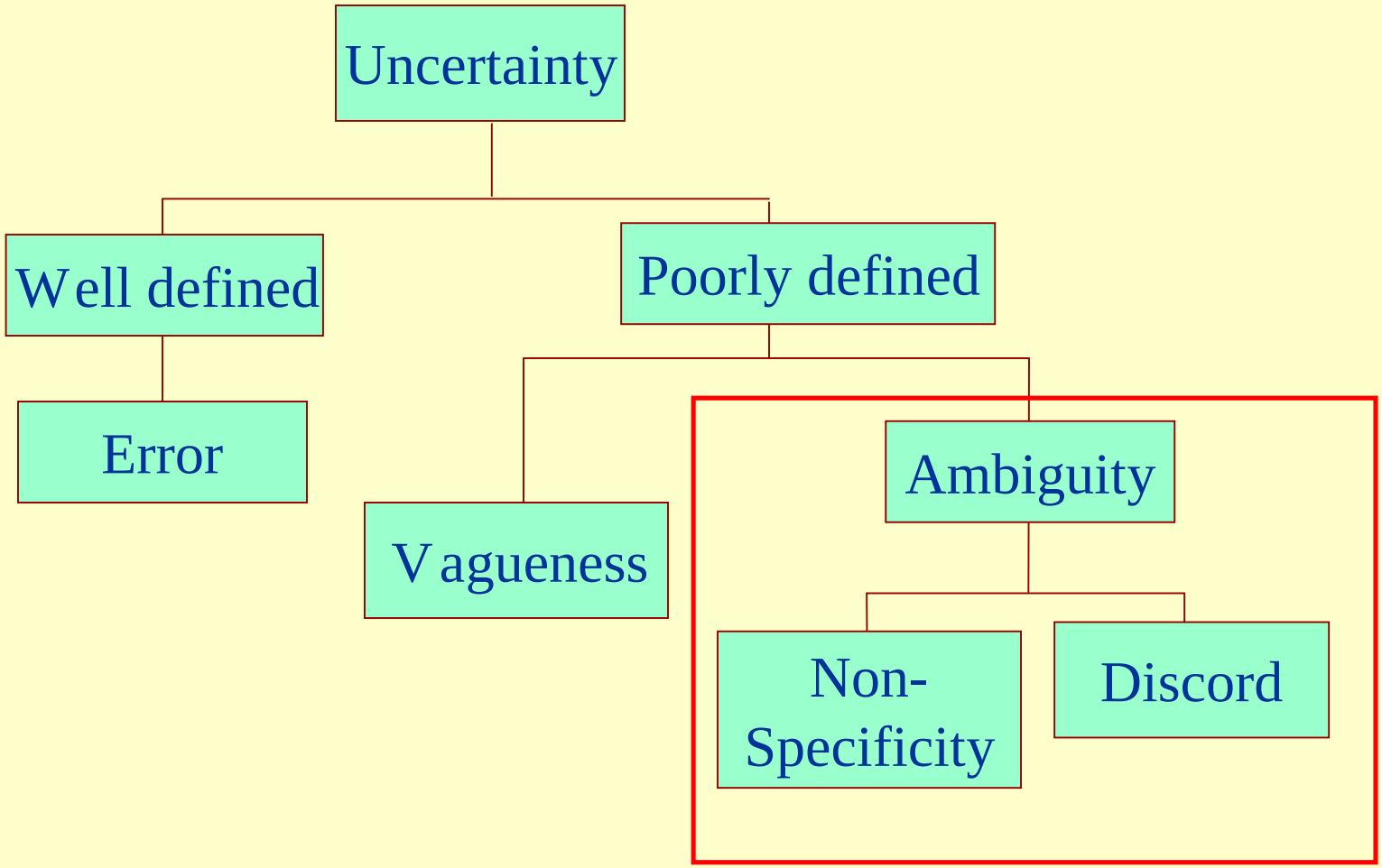
Outline

- Issues
  - The Problem
  - The variety and levels of uncertainty
- Some solutions?
  - Monochrome or multihue maps
  - Static (error) animation
  - Sound
  - Linked windows
- But there are other dimensions to uncertainty
  - Here we will explore these other dimensions

The Problem

- Uncertainty about mapped information
- The map fills the available display space
- BUT
- We know that the map is in error,
- or is uncertain, to some degree
- How can we display this *extra* information?

A Taxonomy of Uncertainty

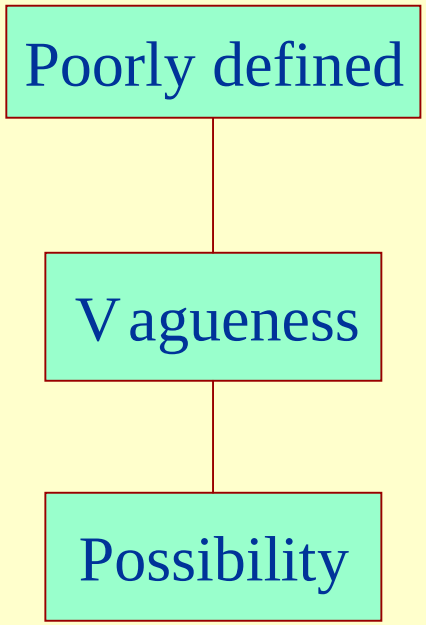


Object level uncertainty

- Uncertainty can be at any level
  - The object mapped
  - The legend category within the theme
  - The theme
  - The map across themes
- We may need different methods for the different levels

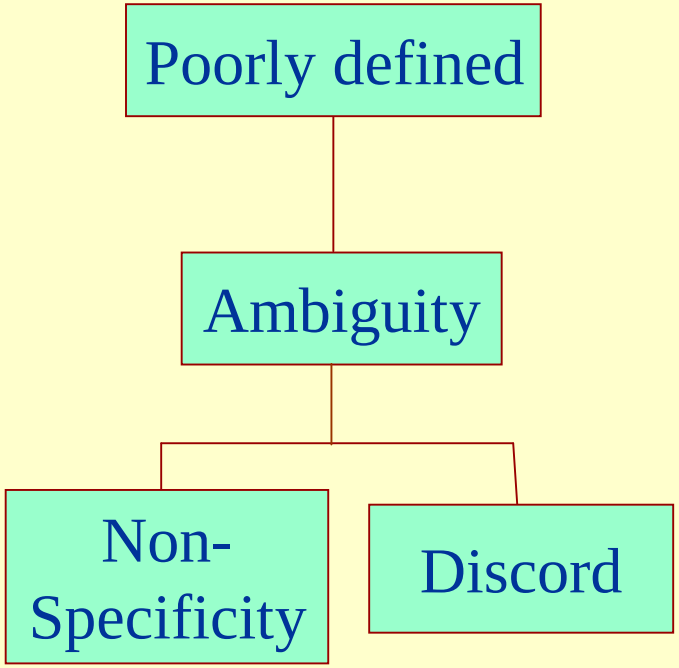
Vagueness - Possibility

- Grounded in Philosophical Vagueness
- Sorites Paradox
- Semantic and epistemic vagueness *may* be addressed by Fuzzy Set theory
- Uses the same visualisation methods?
- Is this a good idea?



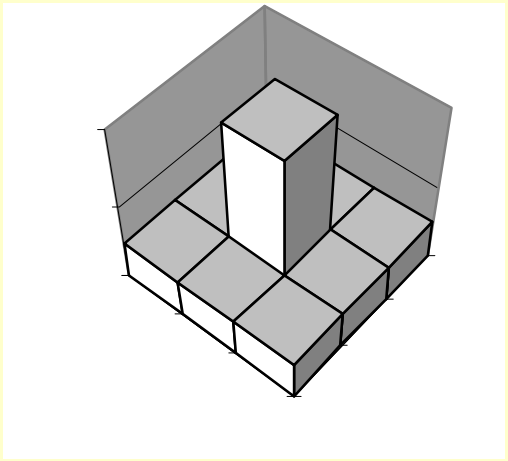
Ambiguity

- Two, or more, different views of the same thing due to:
  - Non-Specificity
  - Discord

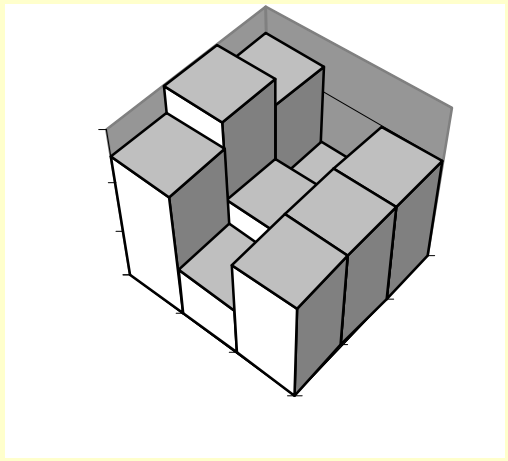


Non-Specificity

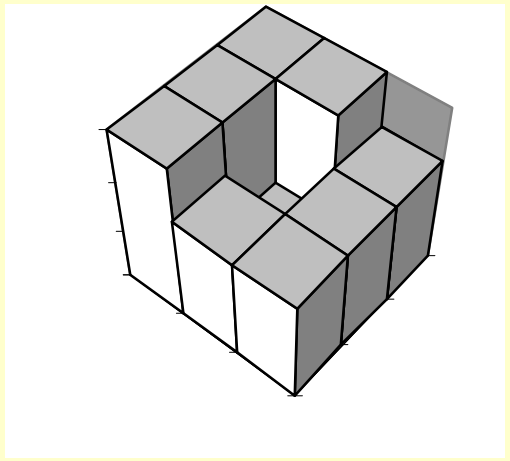
- The parameterisation is poorly specified
- An example
  - Landscape classification by morphometry
  - Morphometry
    - A specific algorithm
    - But how should be it measured?



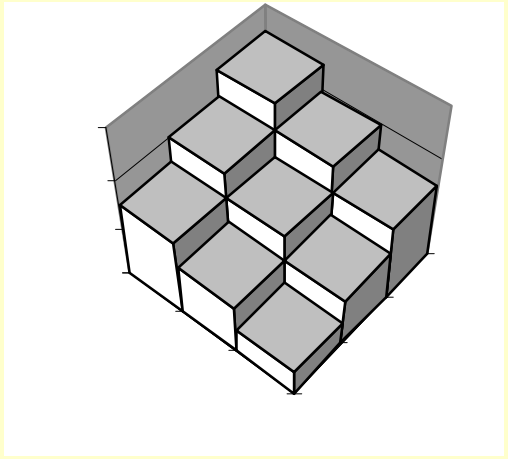
Peak



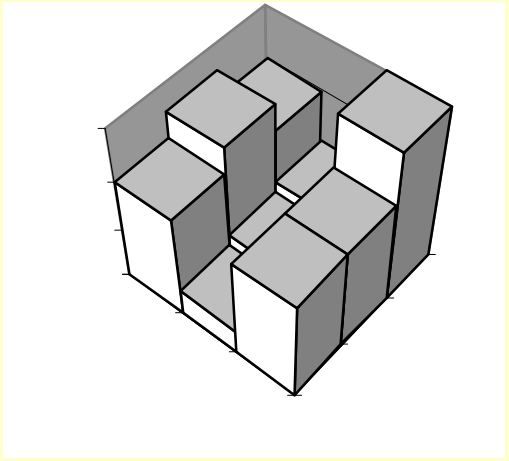
Pass



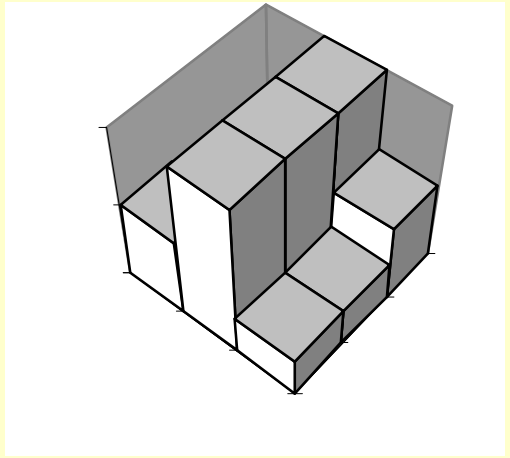
Pit



Planar



Channel



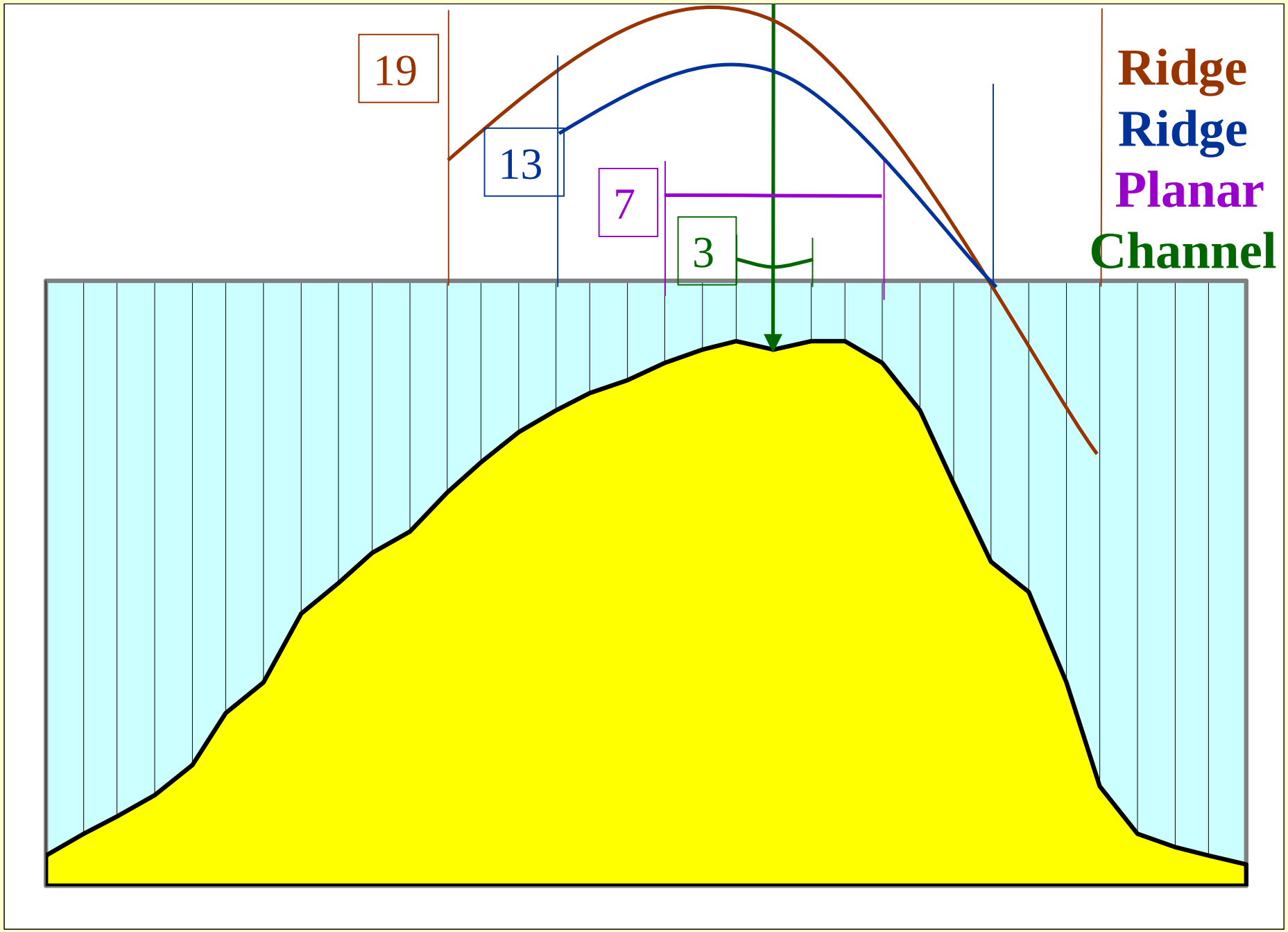
Ridge

More formally

- The Landform, *L*, at any location, *x*

$$L_x = [A]$$

- where [A] is a set of Boolean morphometric classes
  - [ridge, peak, pass, channel, pit, planar]
- And so for five A $m_{Ax} = [0]$
- And for only one A $m_{Ax} = [1]$

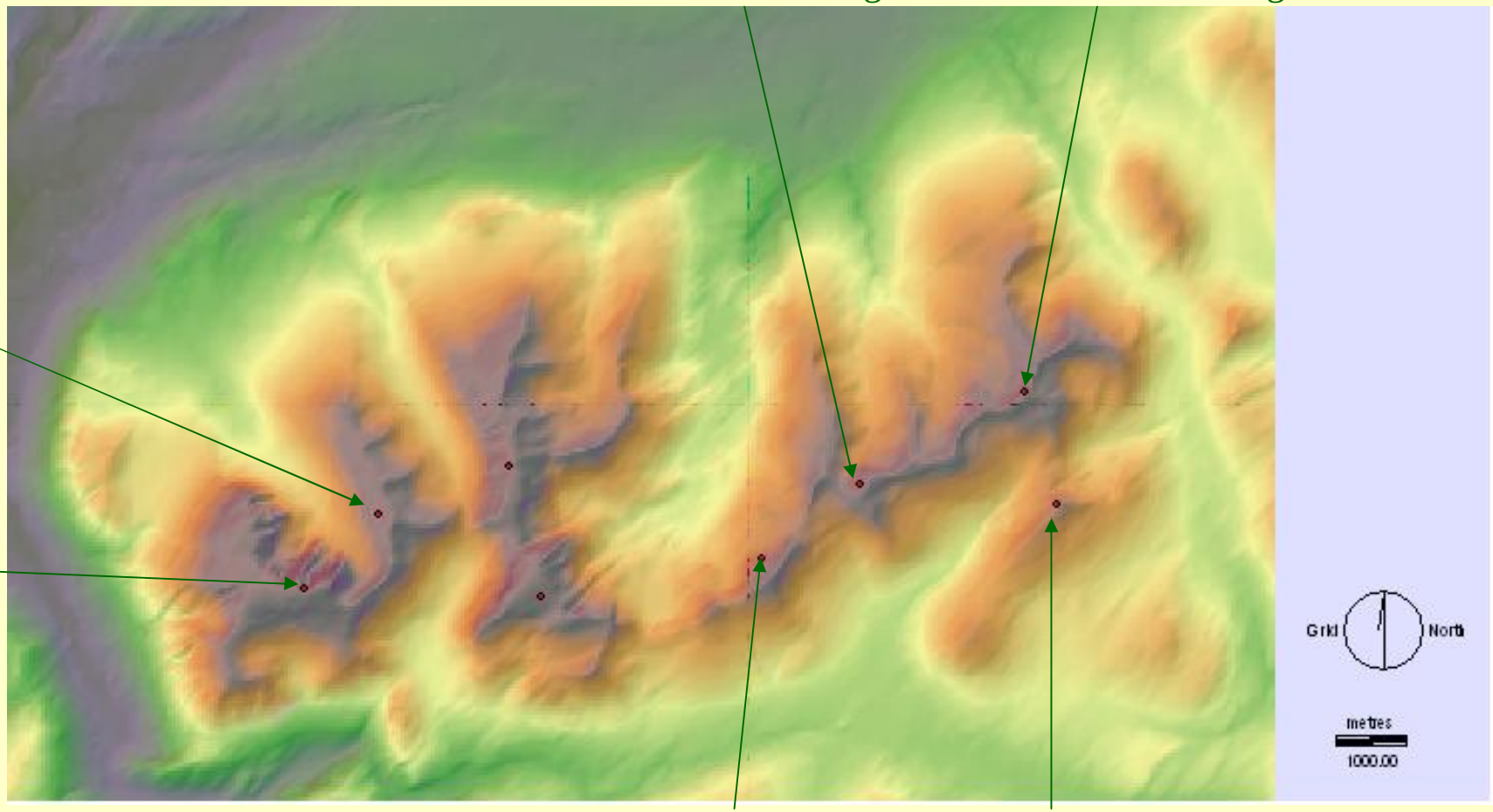

19
13
7
3
Ridge
Ridge
Planar
Channel

So resolution (scale) is important

- Many people have recognised the inconsistency of classification as ERROR
- BUT $L_{xs_1} = L_{xs_2} \neq L_{xs_3} \ldots.$
- where s1, s2, etc indicate different scales of measurement
- Therefore for each A, the fuzzy membership of that morphometric class is

$$m_{Ax} = \frac{\sum_{i=1}^{n} m_{Axs_i}}{n}$$

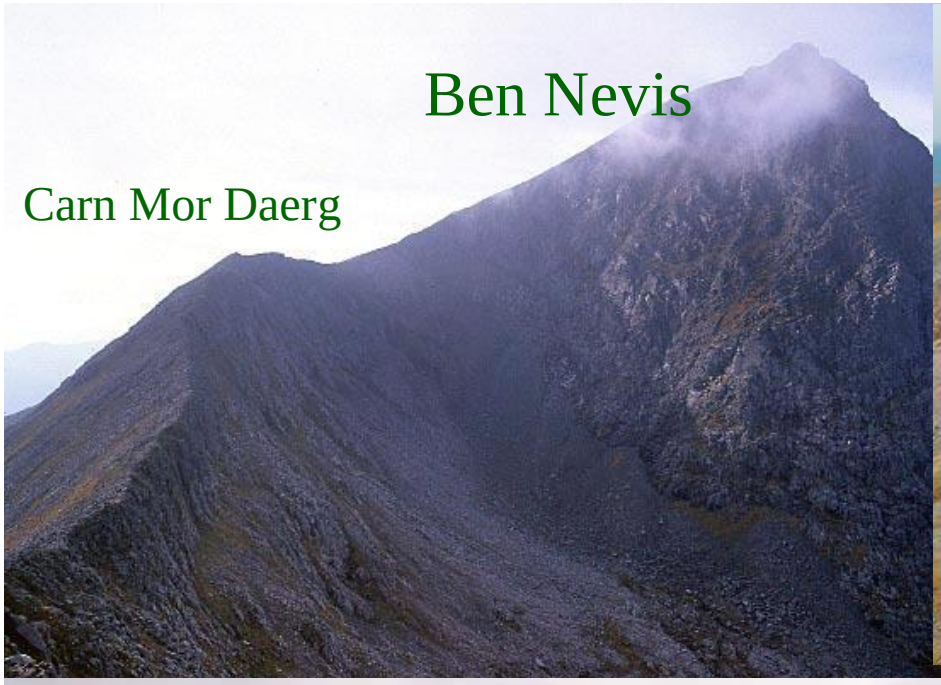
The Grey Corries



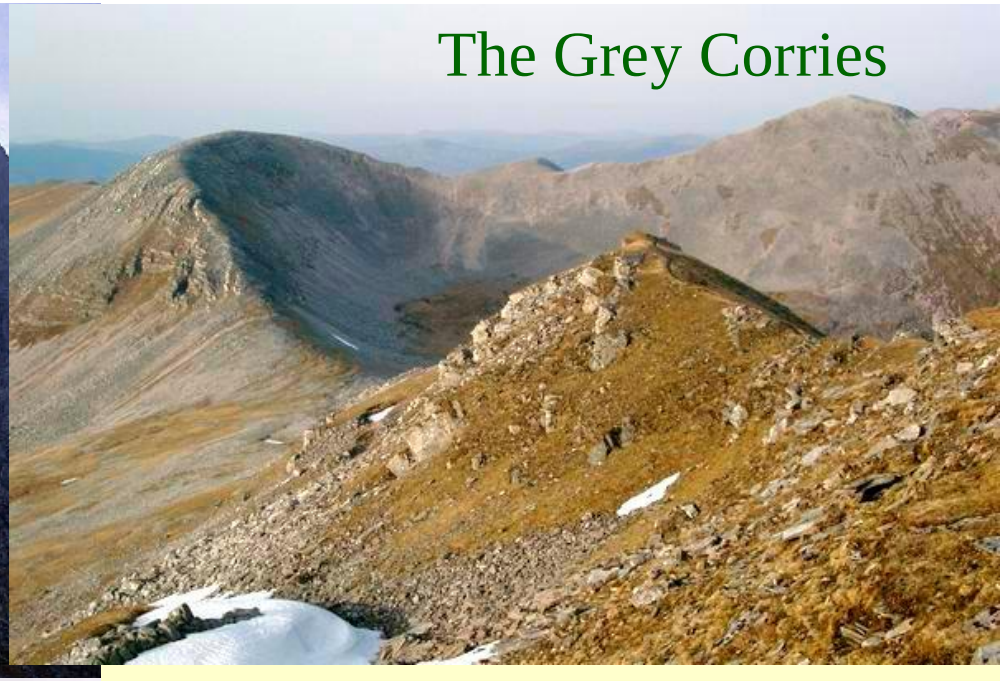
8 of the Scottish Munros (Peaks over 3000 ft)

Ben Nevis

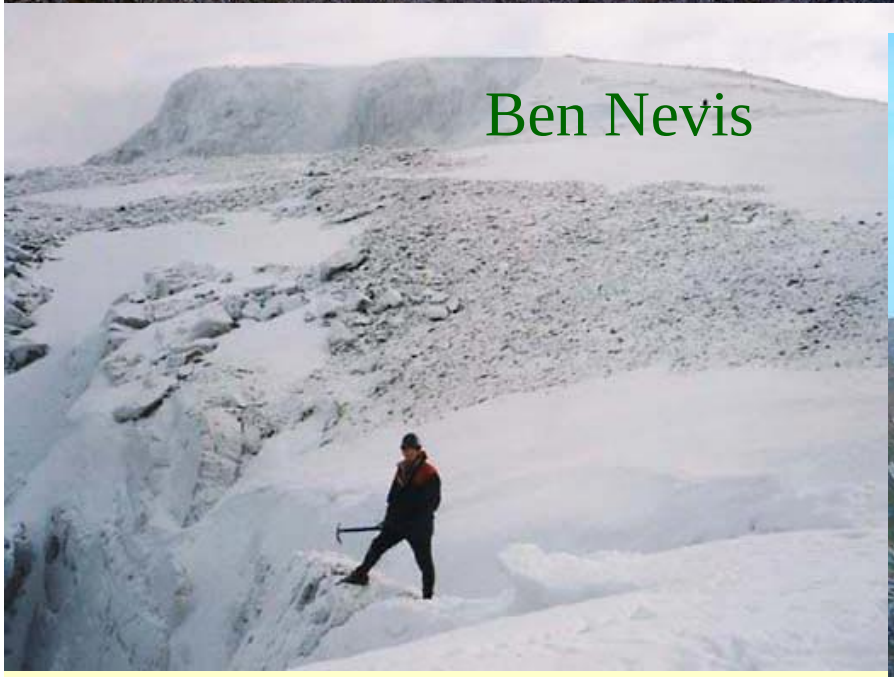
Carn Mor Daerg



The Grey Corries



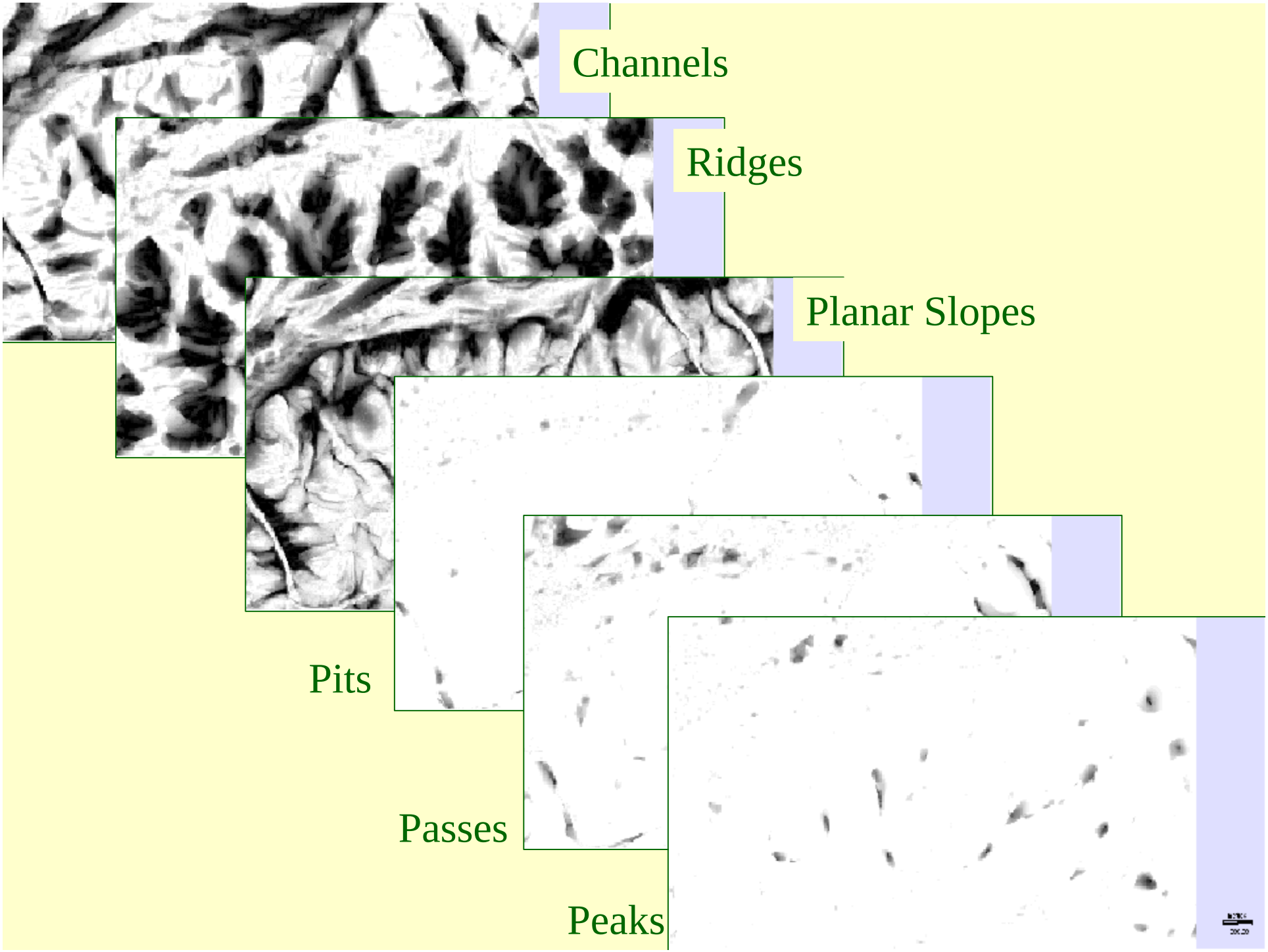
Ben Nevis



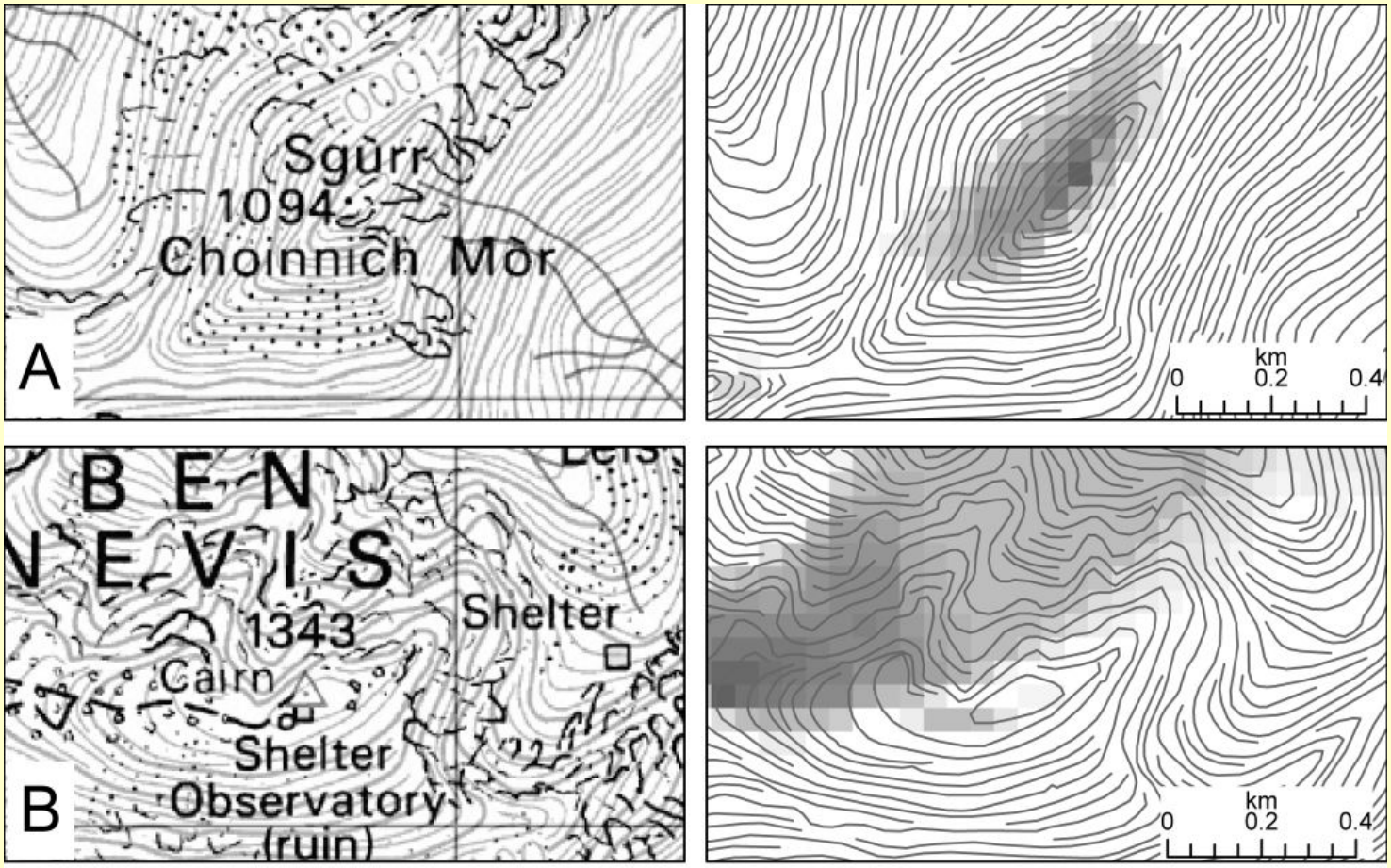
Sgurr Choinnich Mor

Stob Coire Claurigh

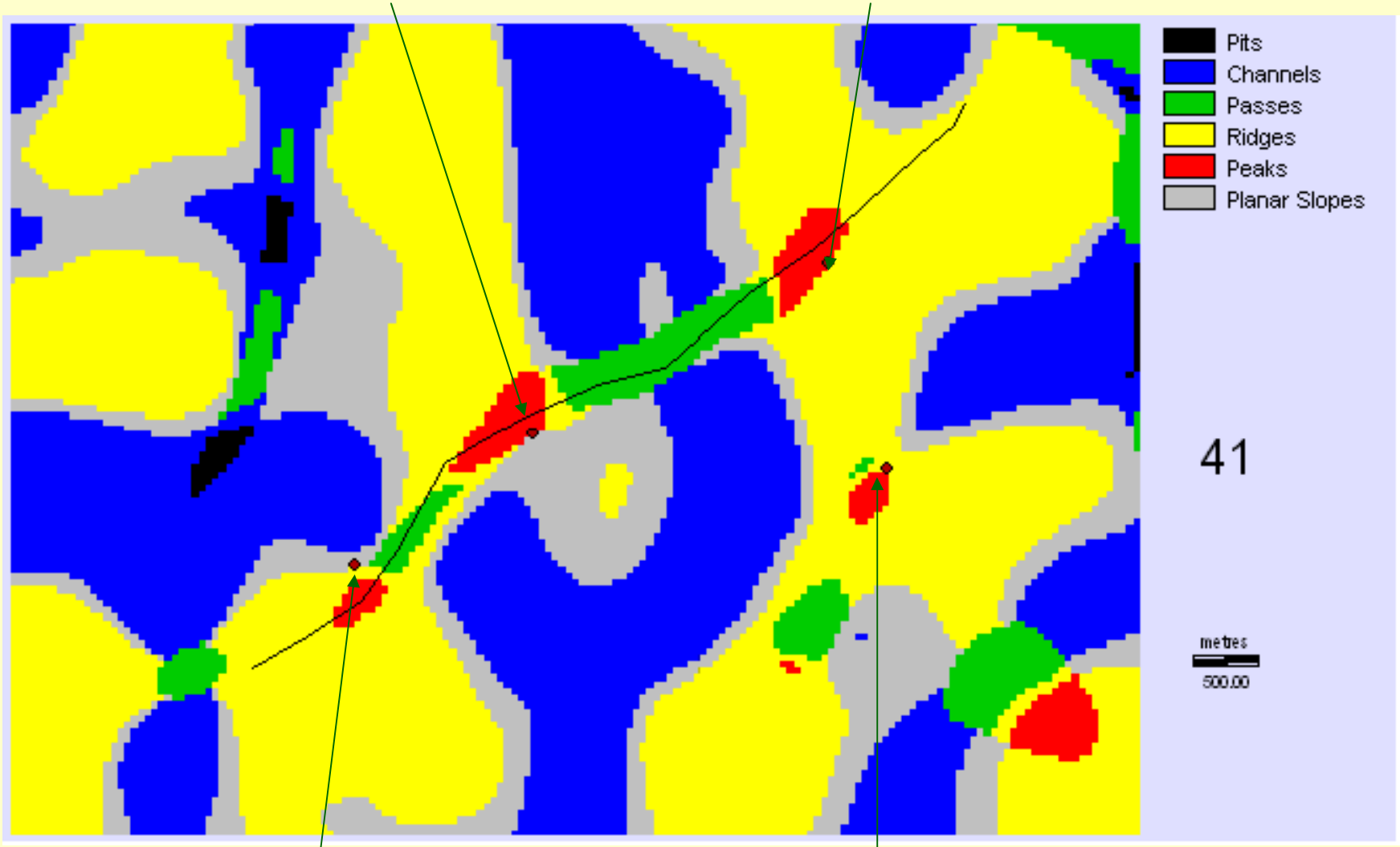
From www.munromagic.com


Channels
Ridges
Planar Slopes
Pits
Passes
Peaks

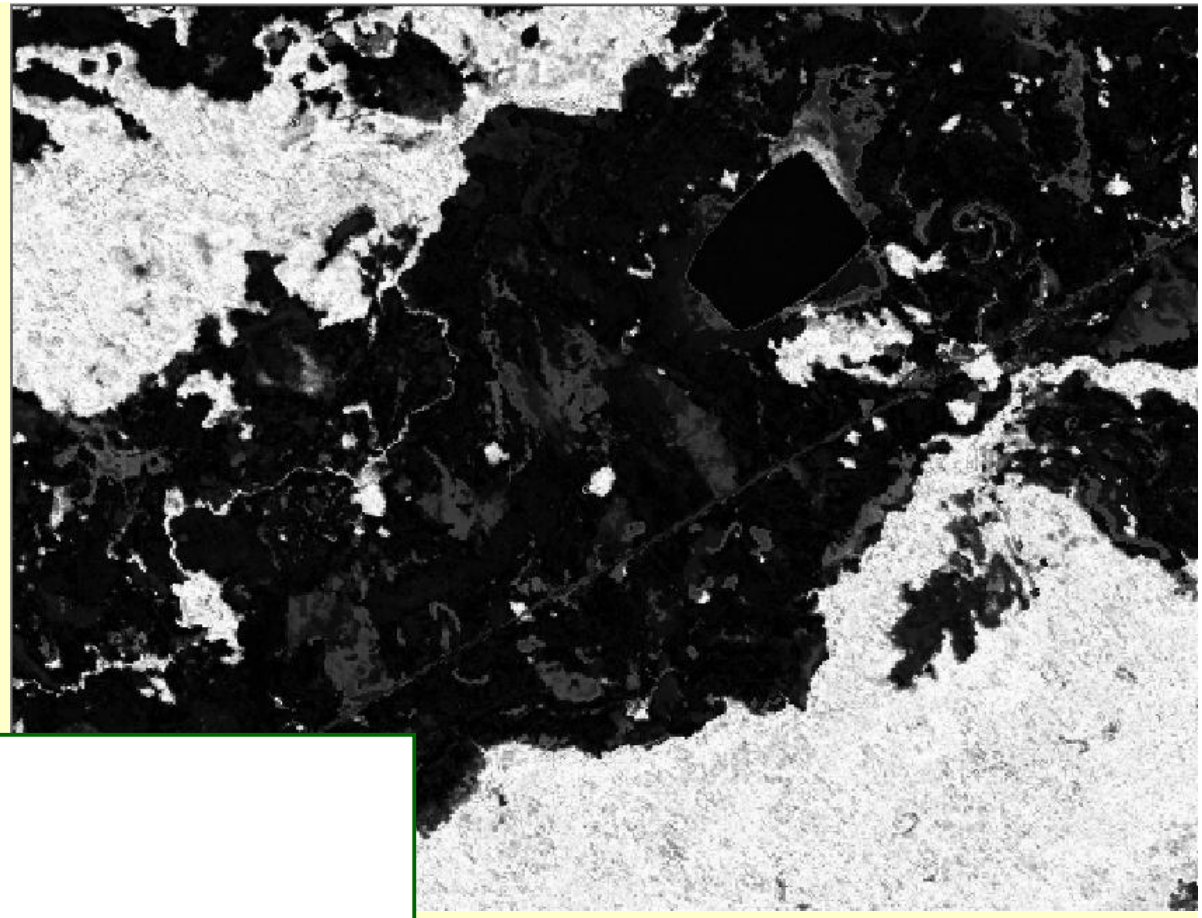
Mountain Locations

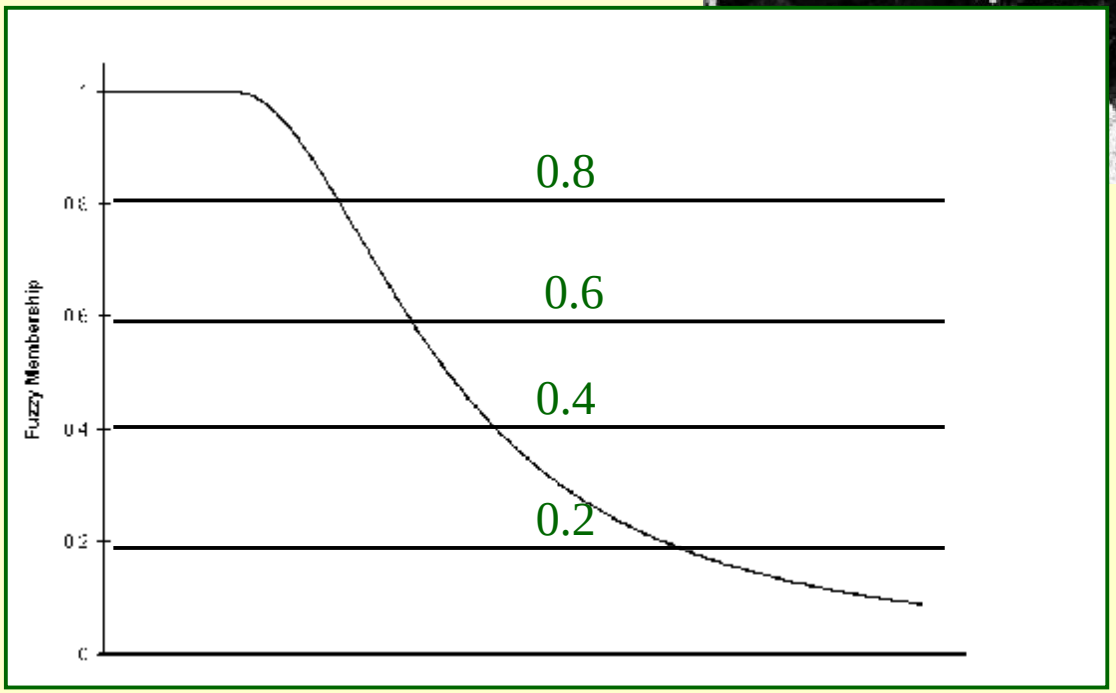


Alternate Resolution Realisations of the Grey Corries



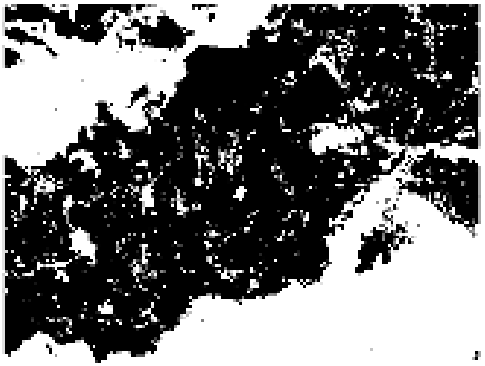
Fuzzy Memberships as α cuts

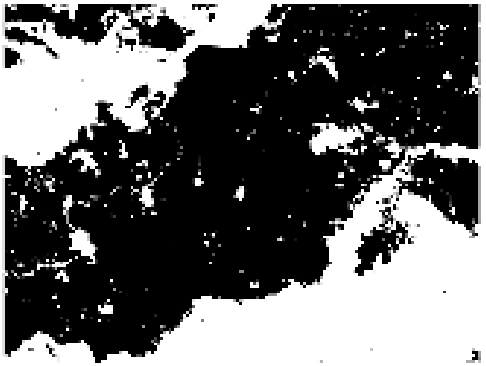




α cuts are only boolean representations!

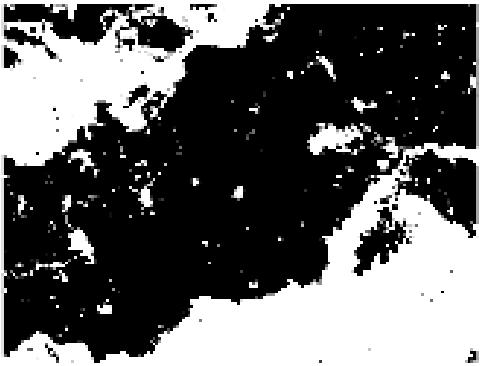
0.1

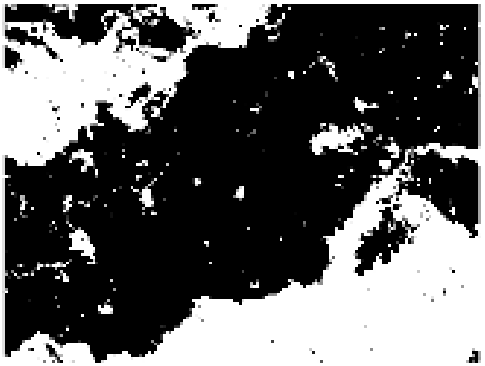


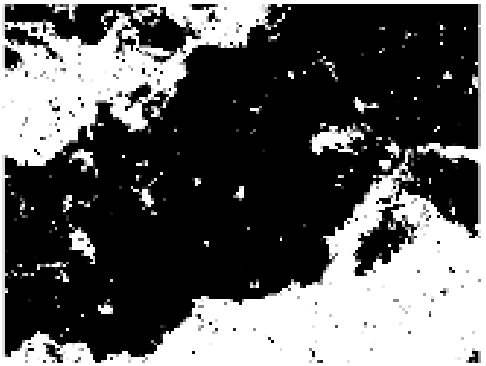


0.3

0.4

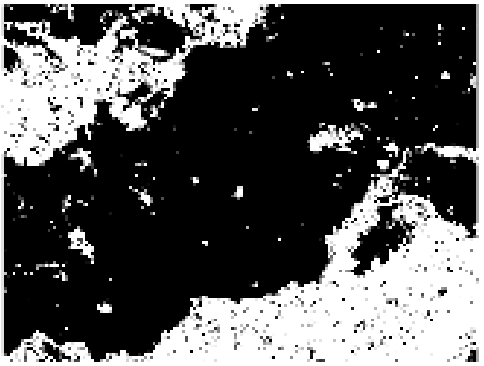


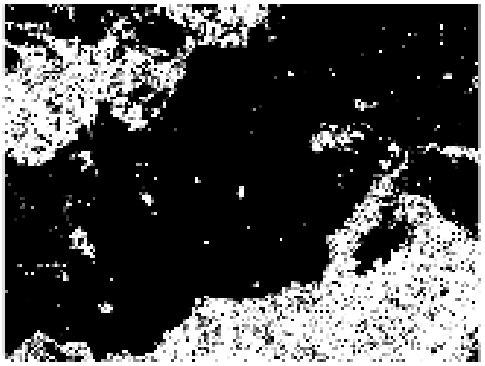


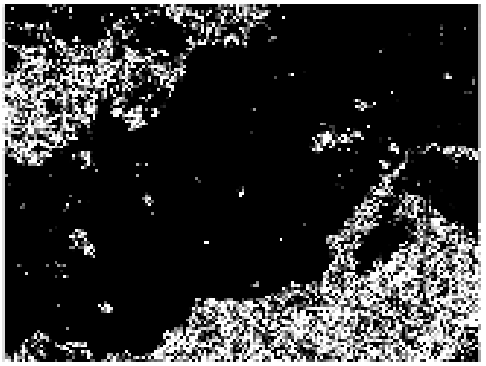


0.6

0.7

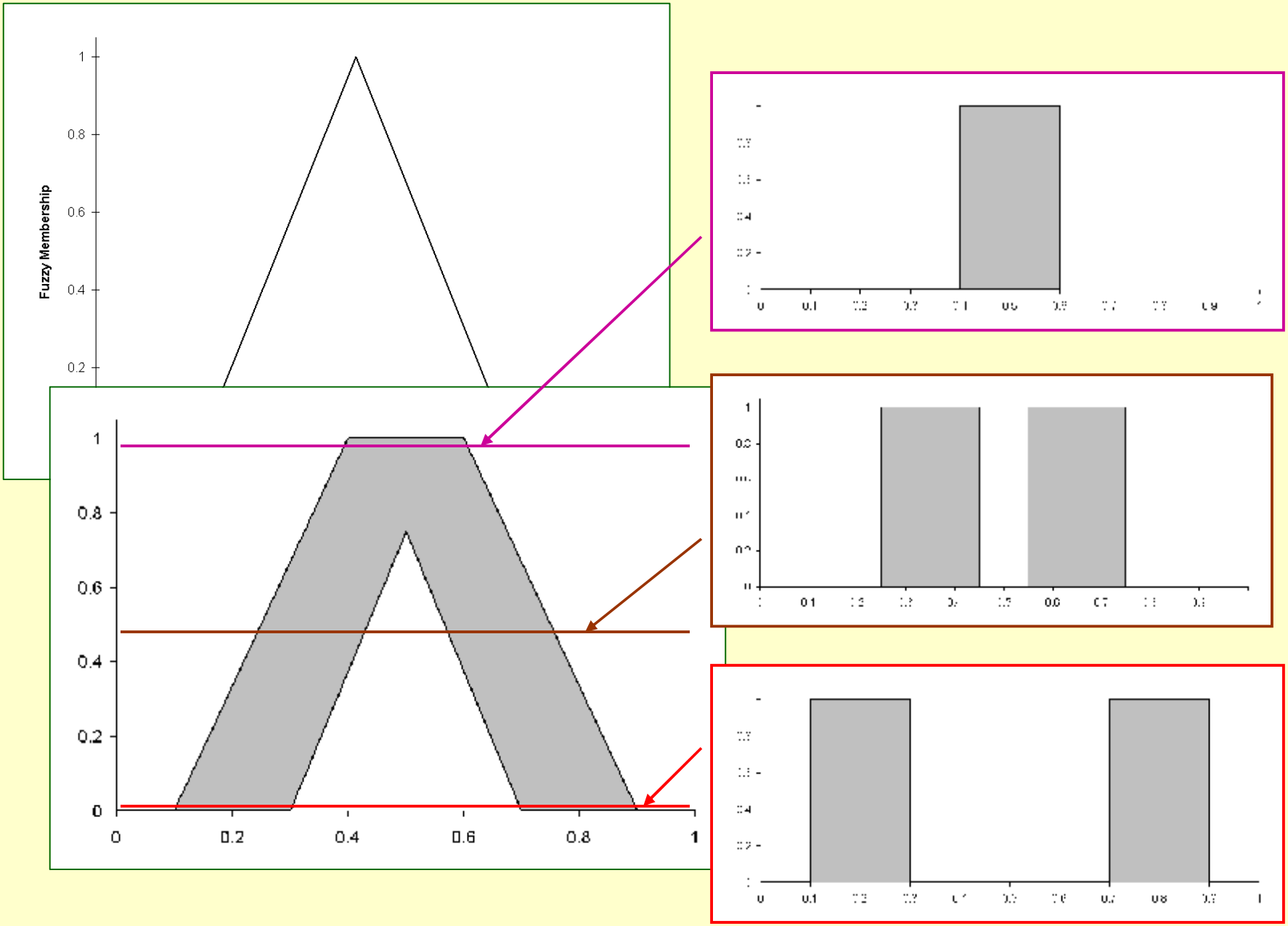






0.9

An interval type-2 fuzzy set

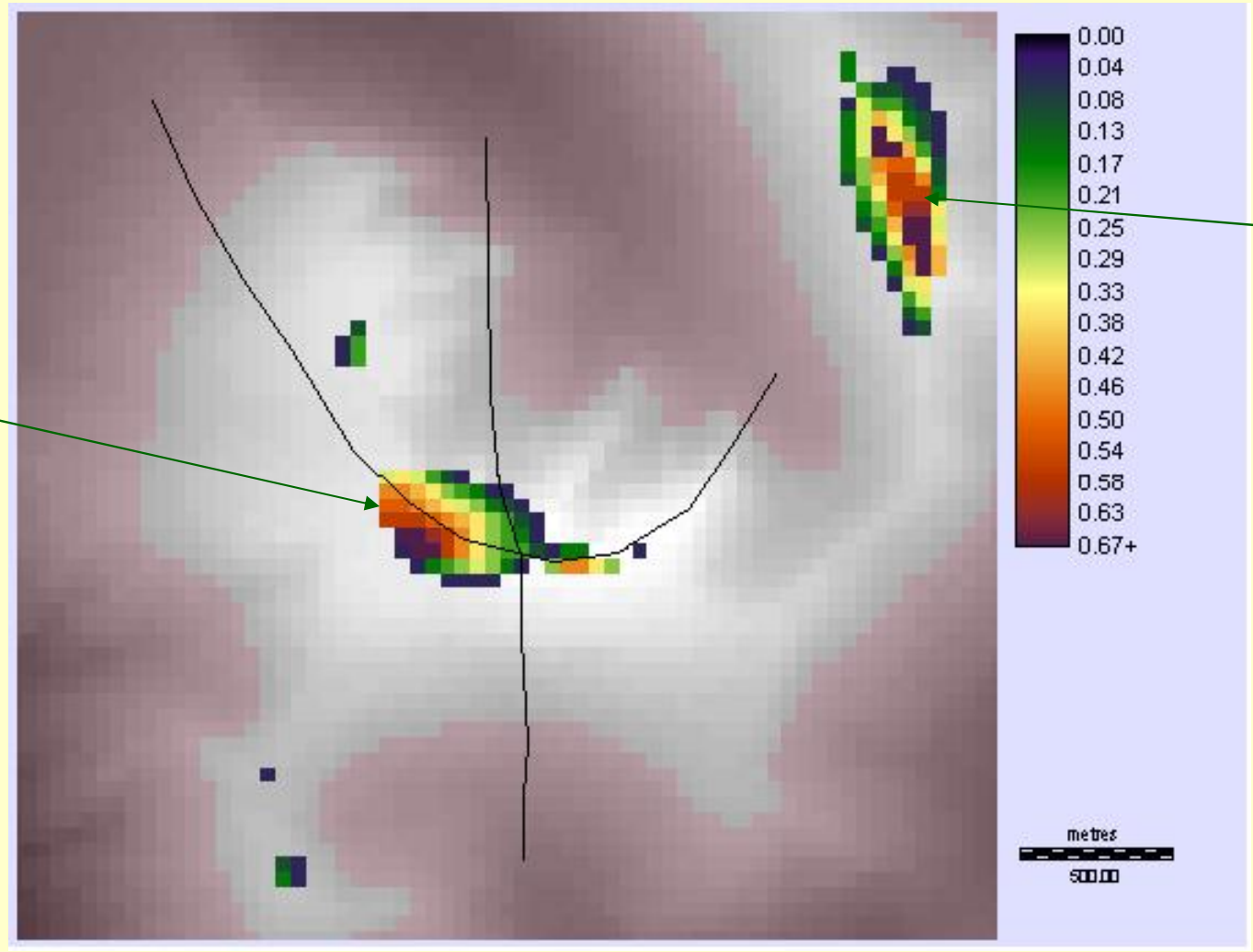


Type 2 Fuzzy sets correspond to higher order vagueness

So is there a higher order vagueness to a peak?

- Alternative smoothing methods
- Alternative parameterisation of the “peak”
  - Slope threshold

Alternate Resolution Realisations of the Ben Nevis

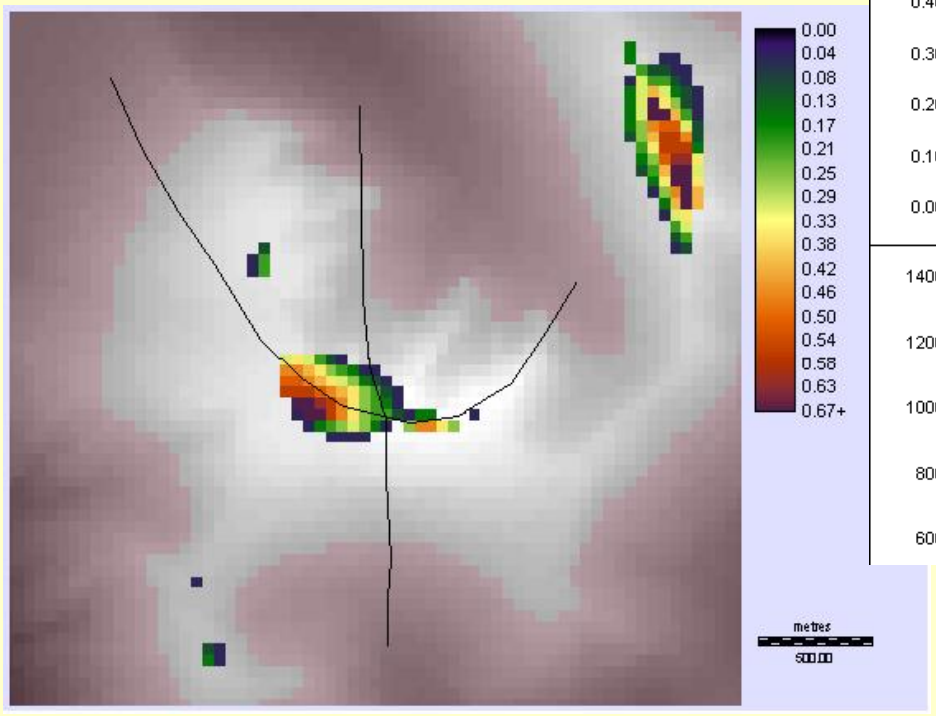


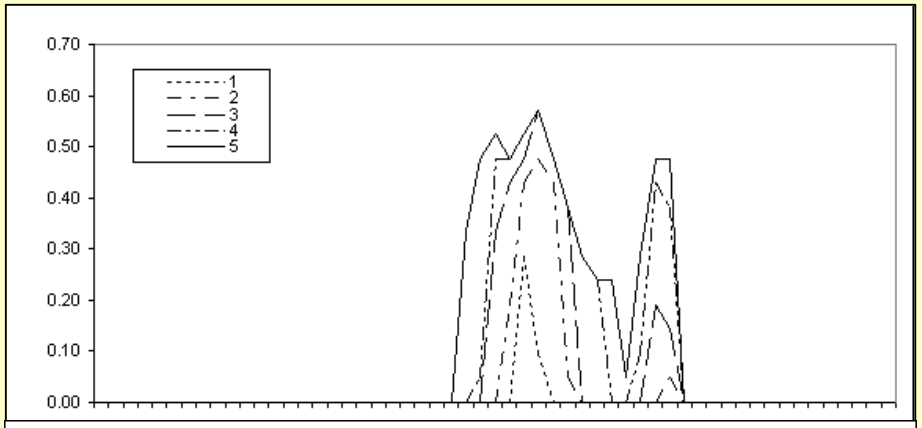
Ben Nevis

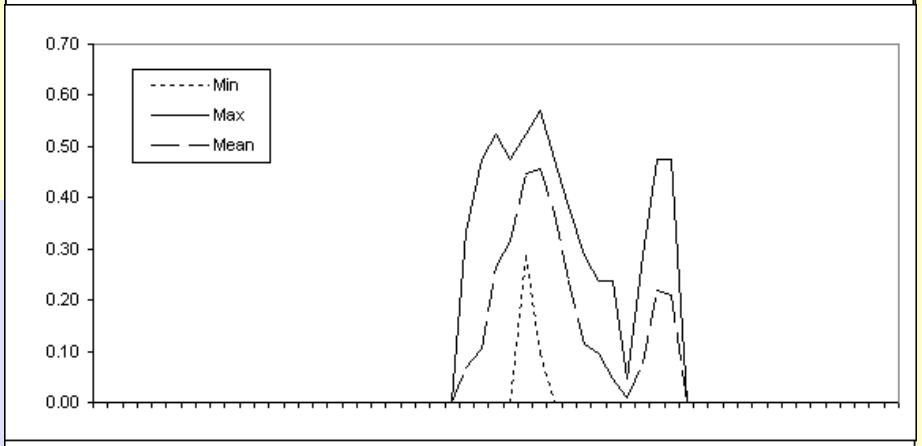
Carn Mor Dearg

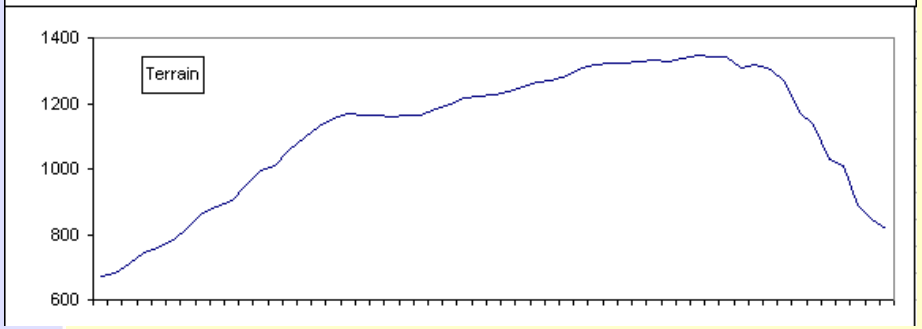
Type 2 Fuzzy sets of Ben Nevis

Distribution and Bounds





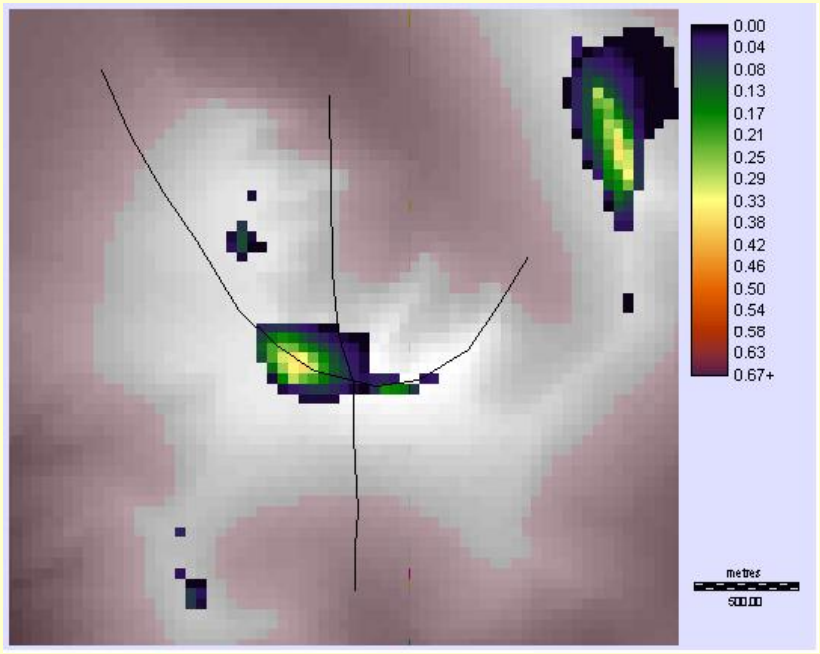


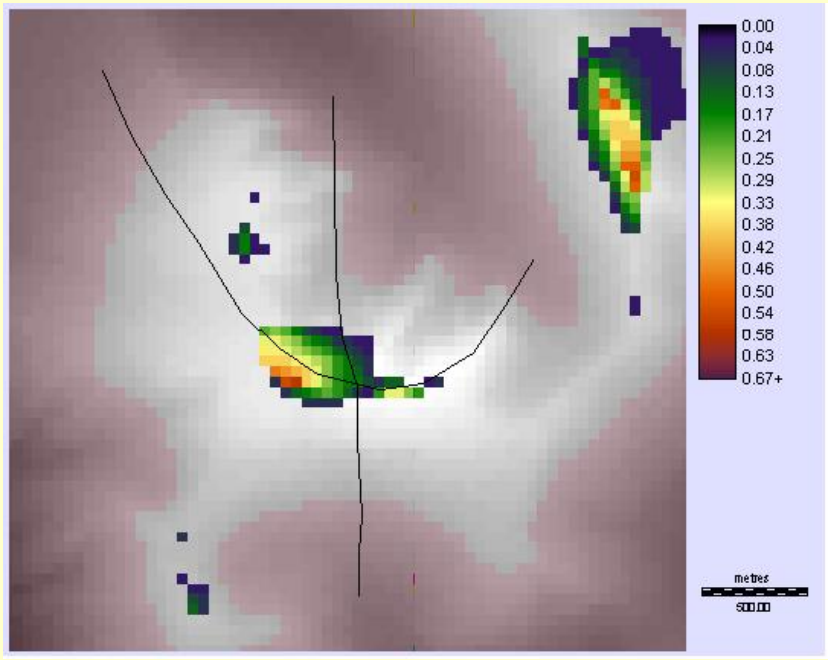


Maximum Membership

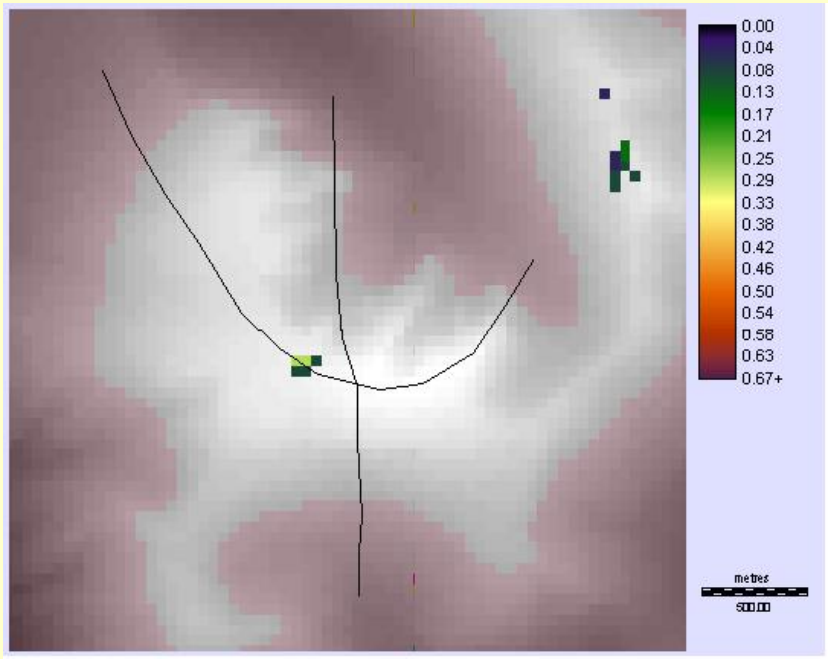
Bounds

Mean Membership



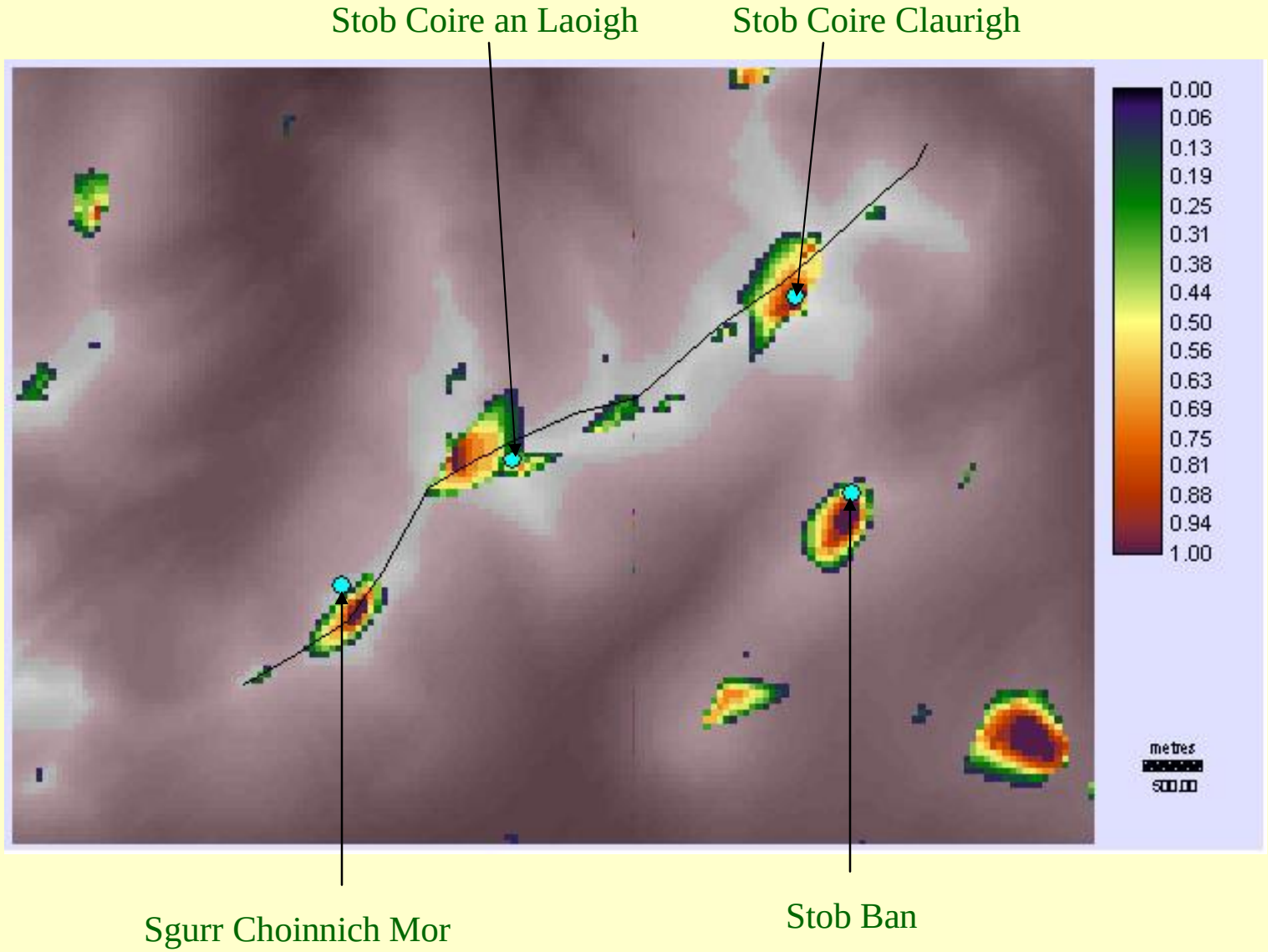


Type 2 Fuzzy Set of Ben Nevis



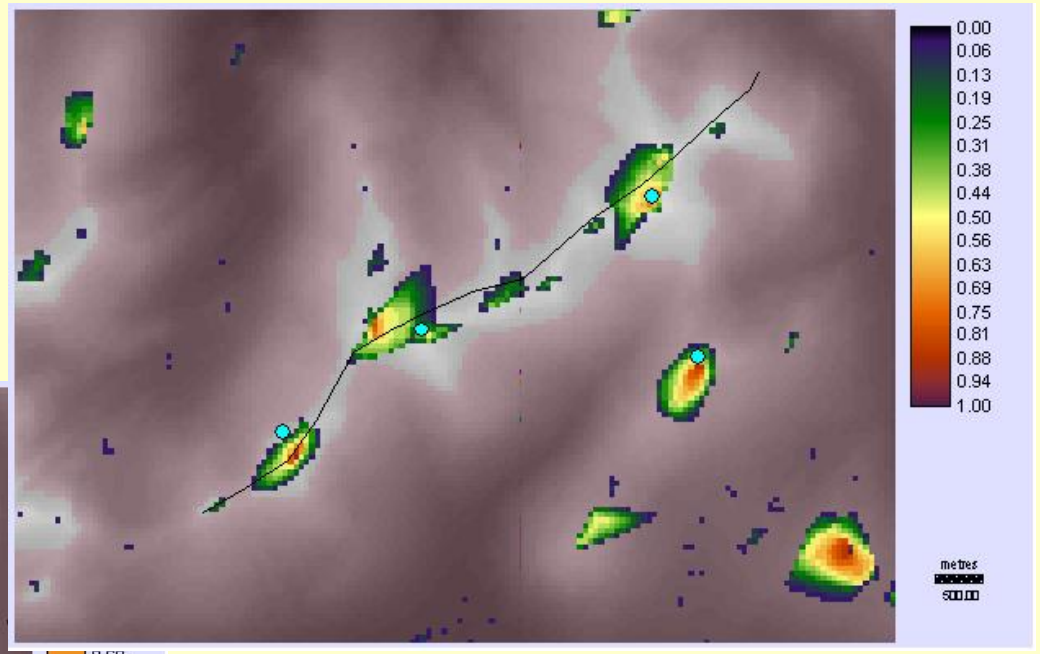
Minimum Membership

Alternate Resolution Realisations of the Grey Corries

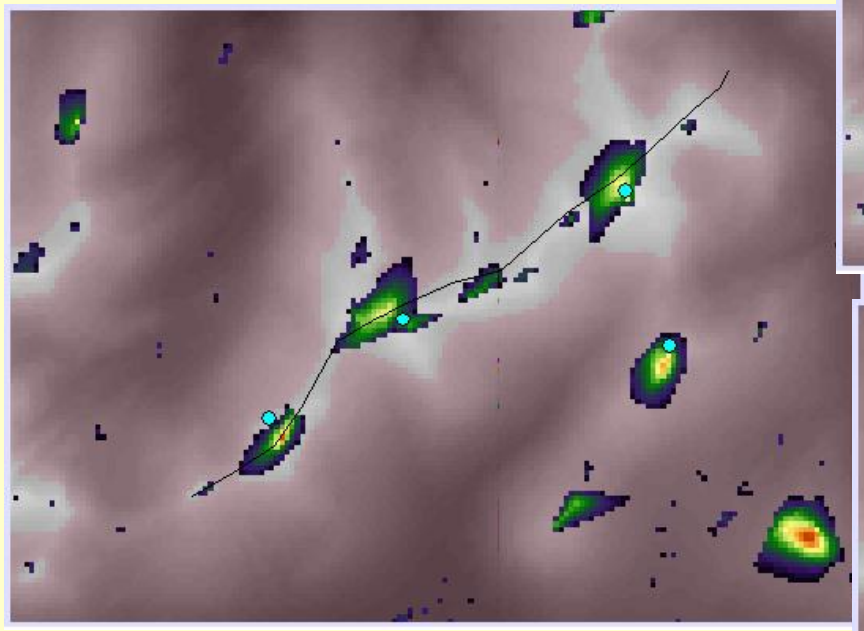


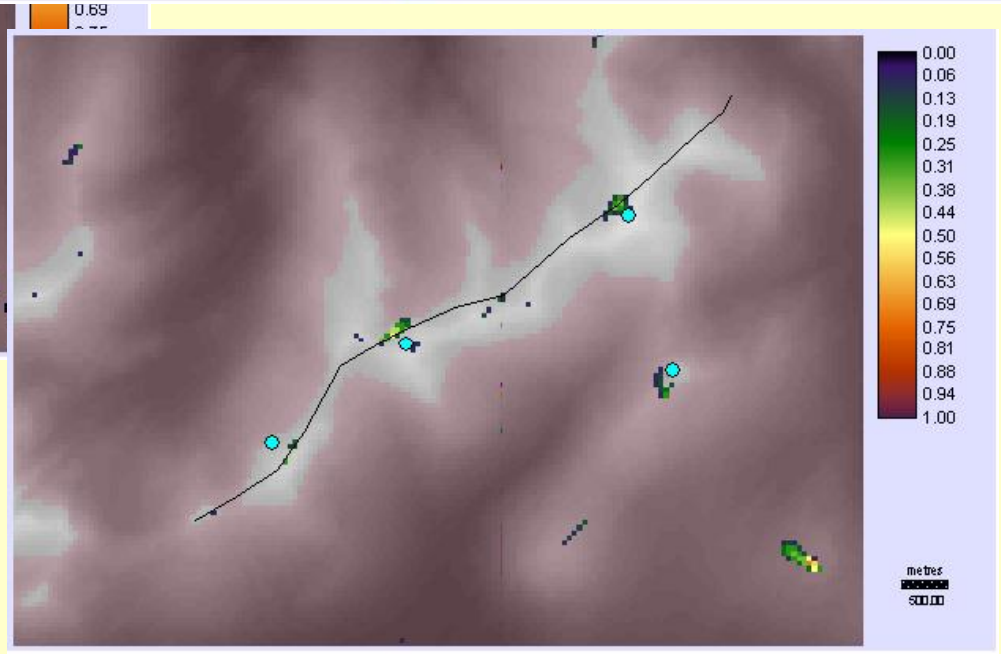
Maximum Membership

Bounds



Mean Membership

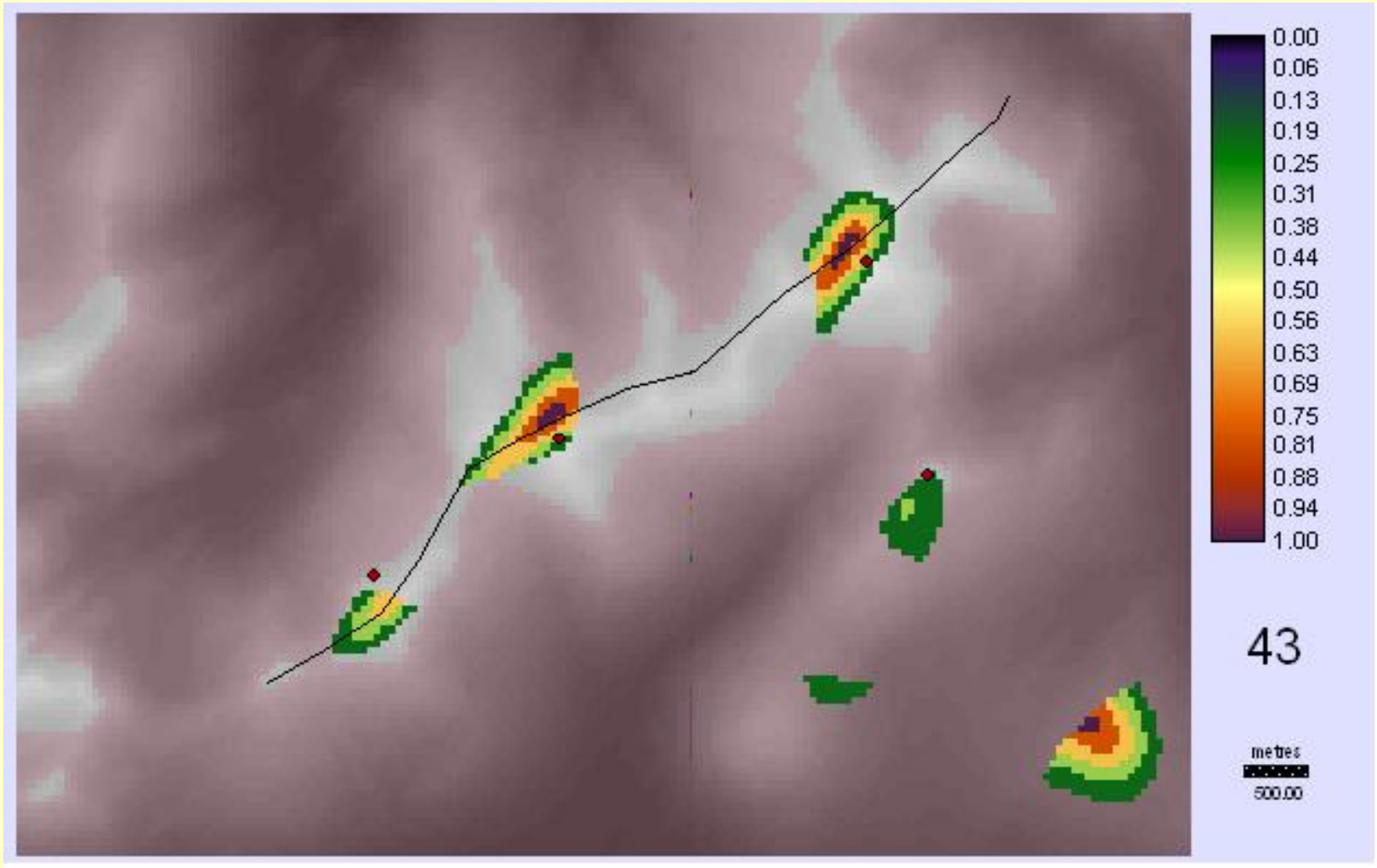




Type 2 Fuzzy Set of Grey Corries

Minimum Membership

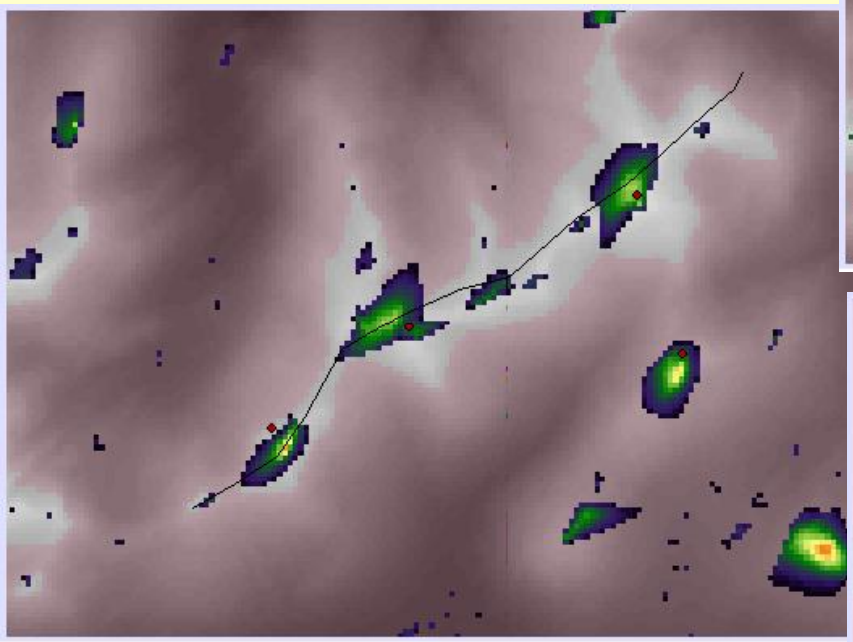
Alternate Slope Threshold Realisations of the Grey Corries

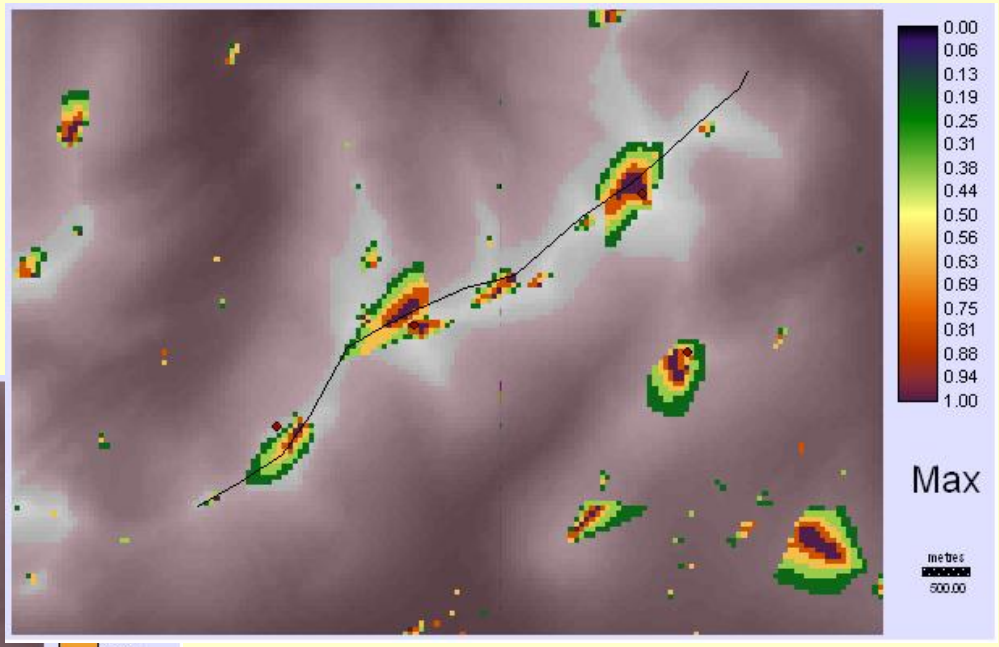


Maximum Membership

Bounds

Mean Membership





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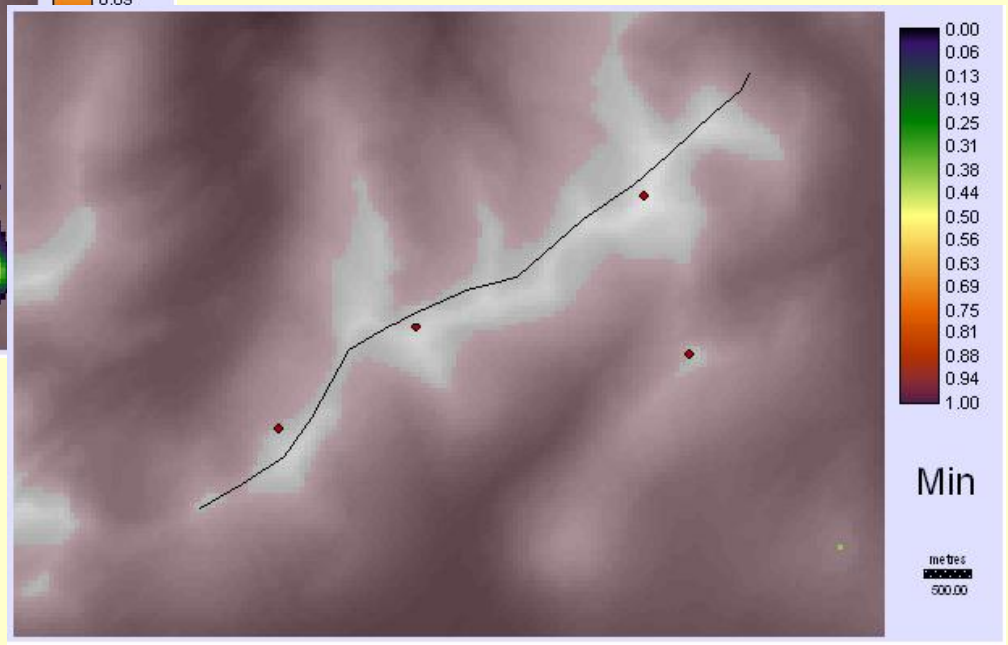
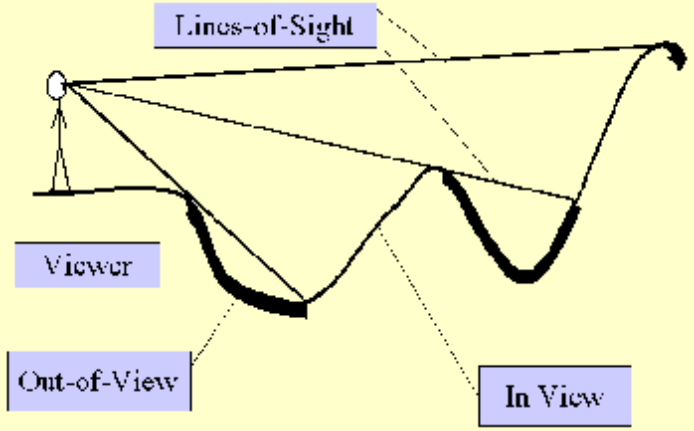


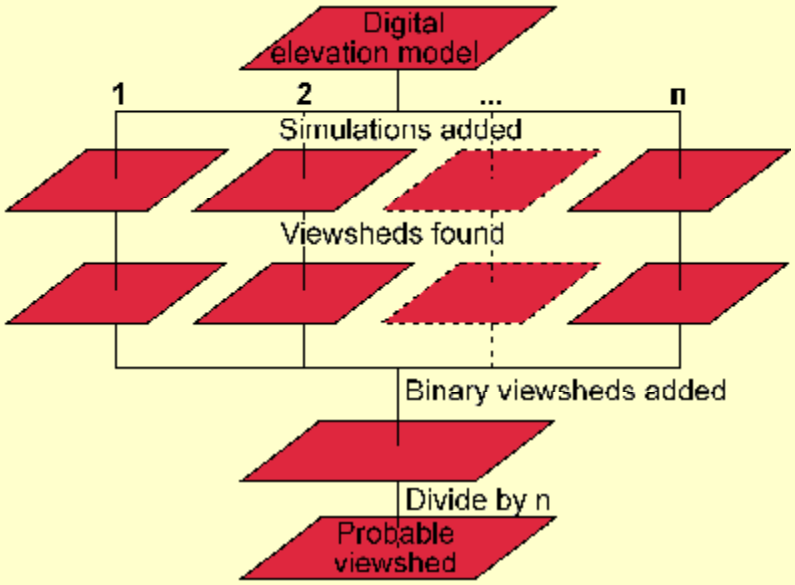
Alternate Type 2 Fuzzy Set of Grey Corries

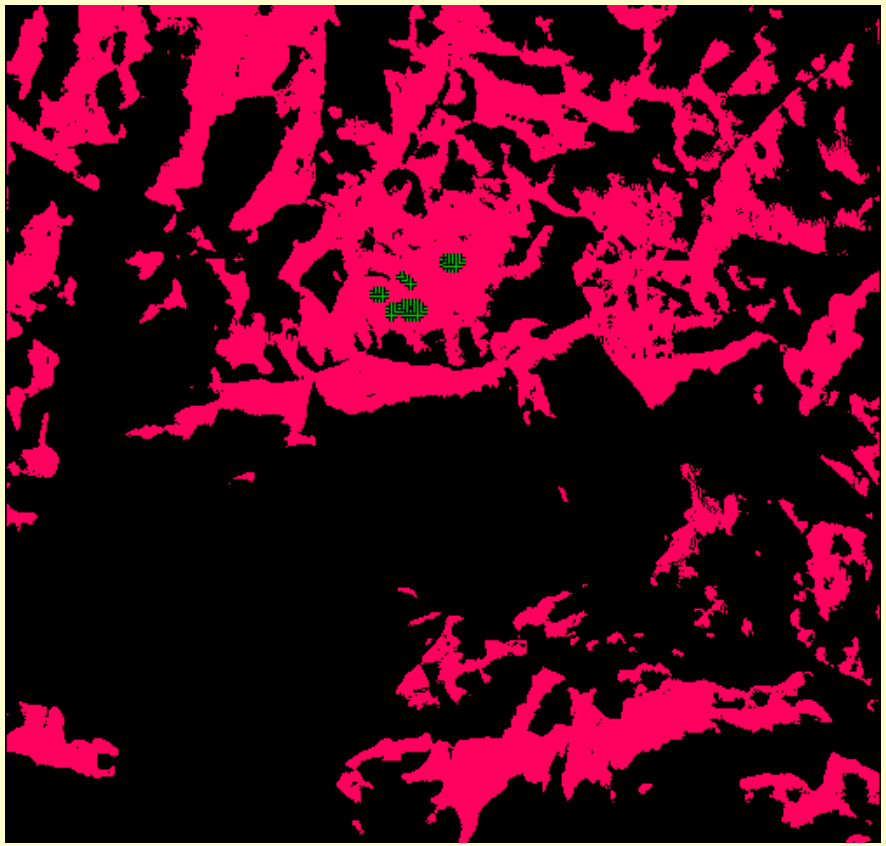
Minimum Membership

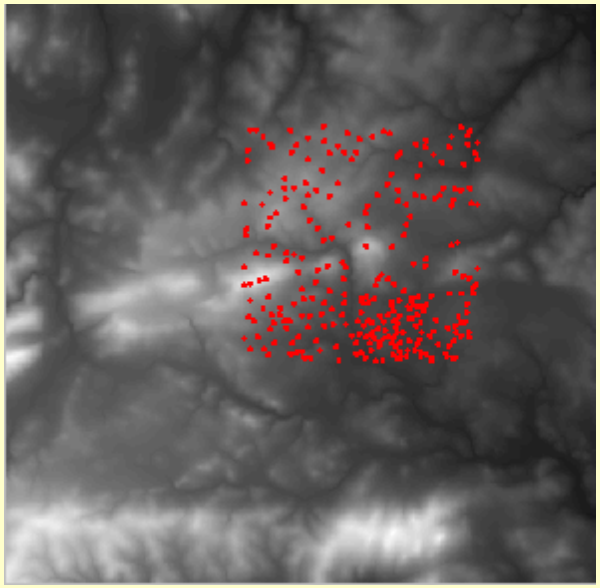
This is different from Higher order probablistic uncertainty

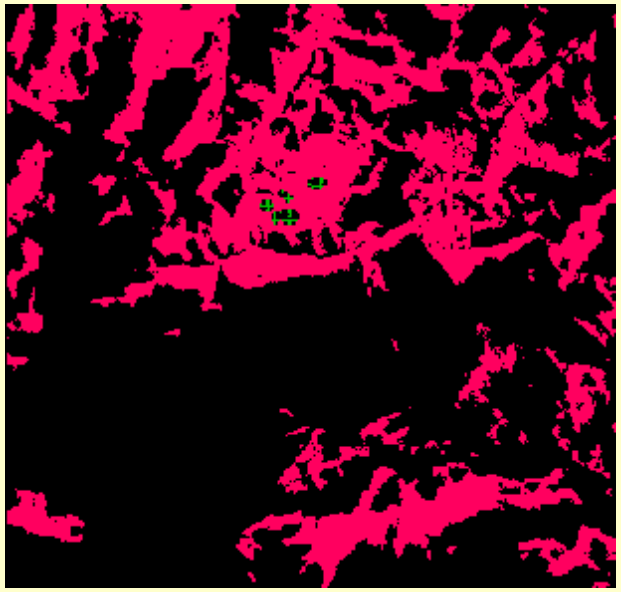


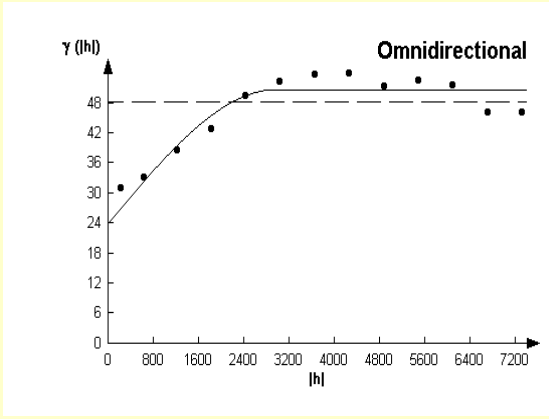
Probable Viewshed










γ (|h|)
Omnidirectional
48
42
36
30
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18
12
6
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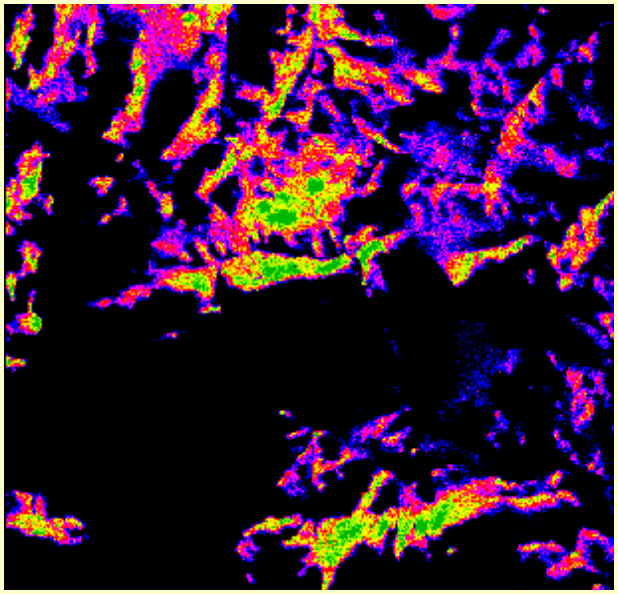
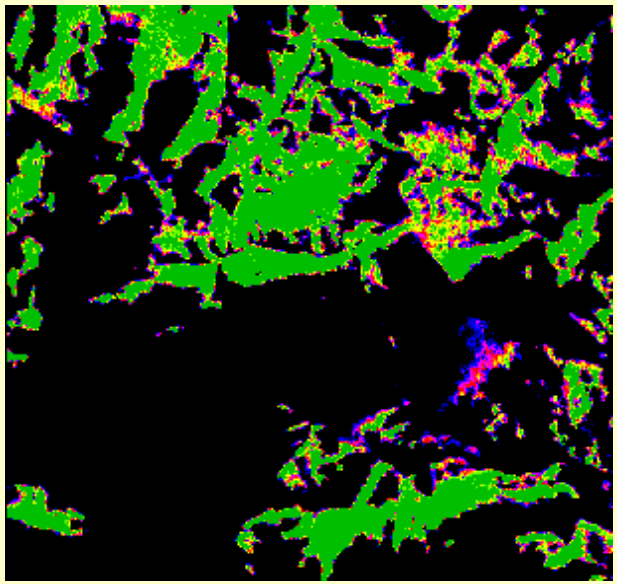
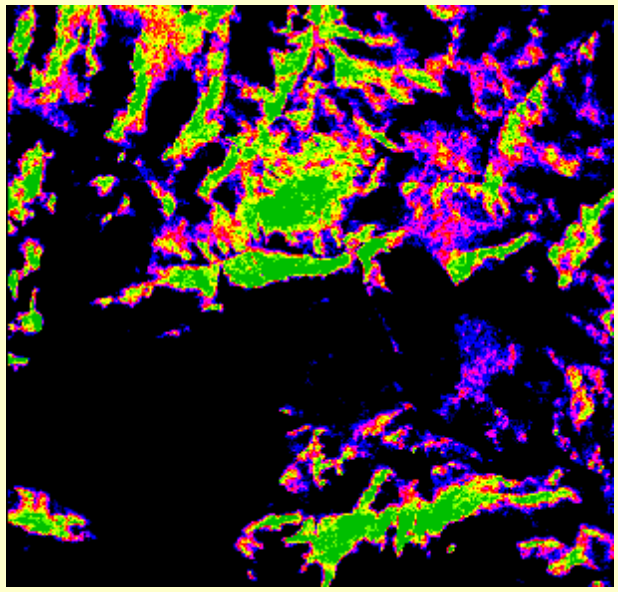
0
800
1600
2400
3200
4000
4800
5600
6400
7200
|h|







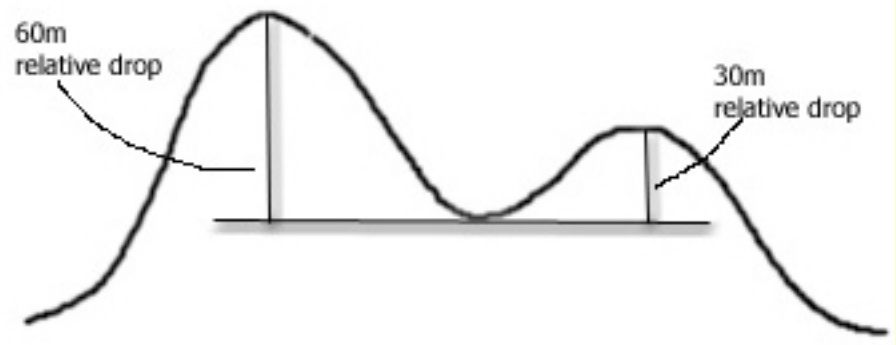
Semantic Uncertainty - Ambiguity

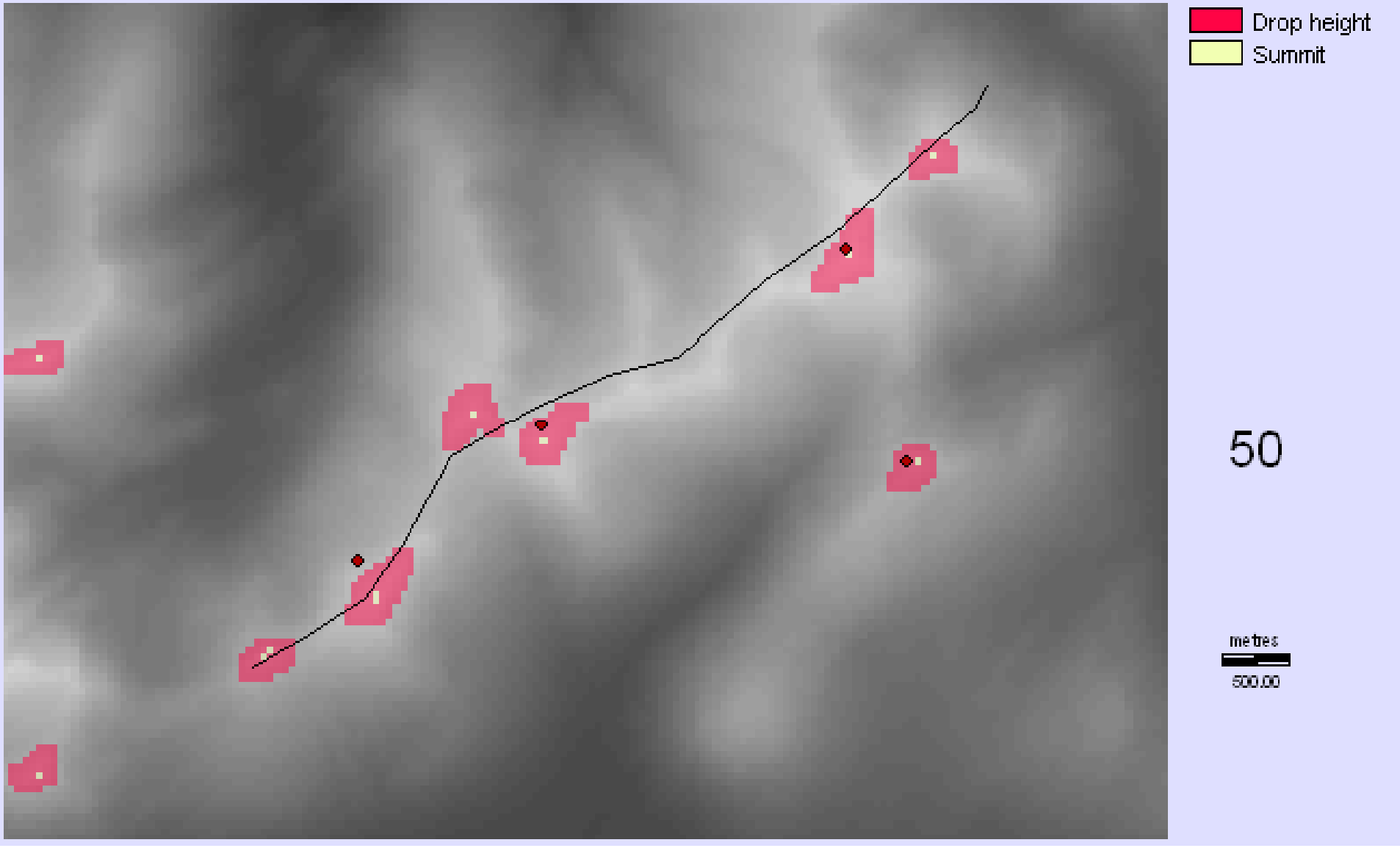
- What if we call the same thing different things?
- Or call two things we are agree are different the same?

OR DISCORD

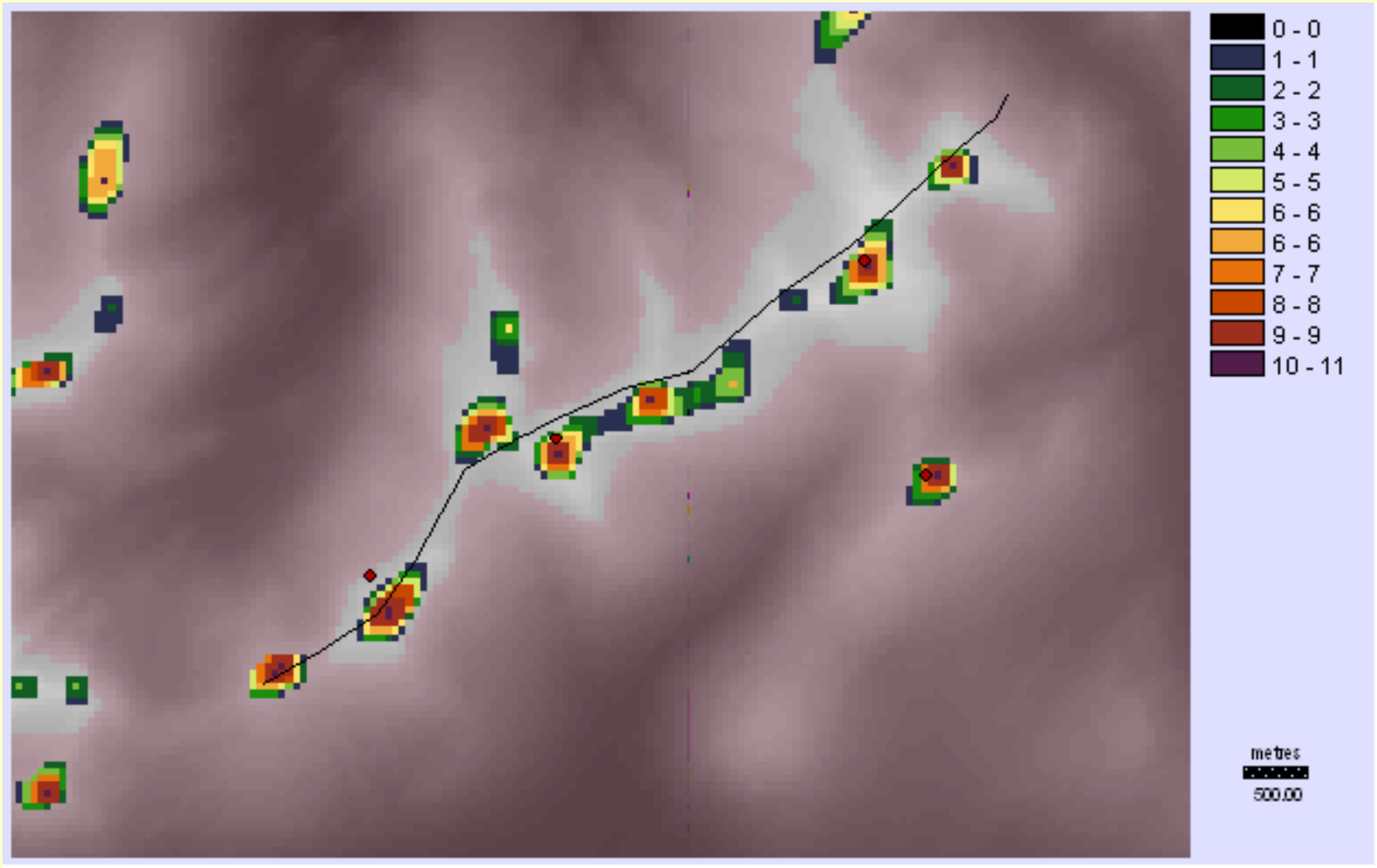
Reflection

- Peakness is problematic (moving peaks)
- Therefore we redefine precise summits on the basis of relative drop from the highest point




Drop height
Summit
50
metres
500.00

Summits and 50m Drops

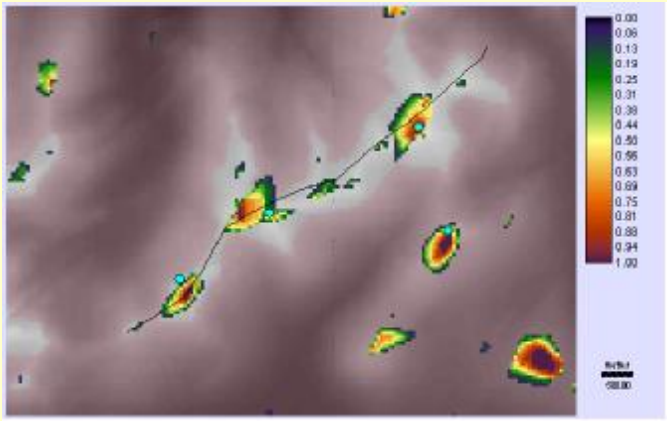


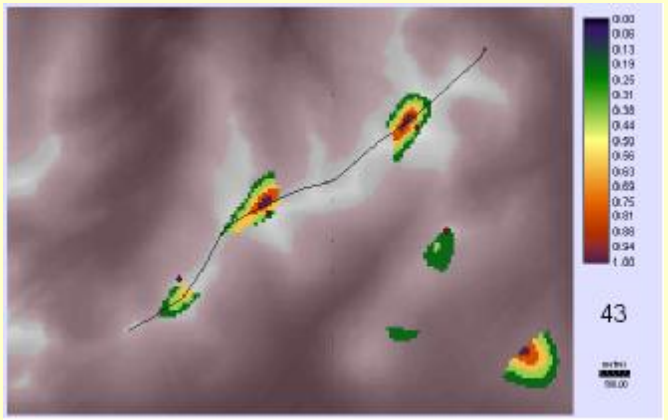
Alternative Algorithmic Semantics

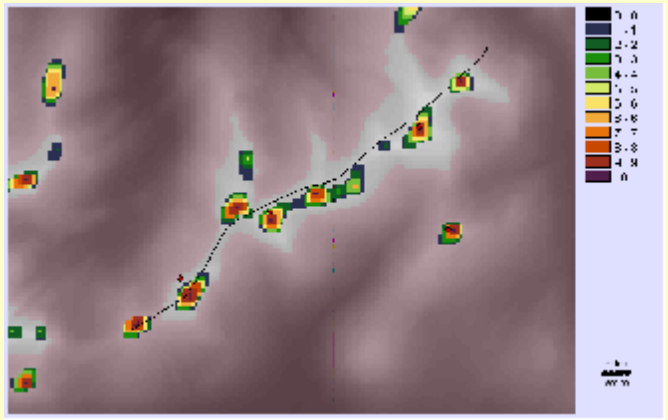
- Peaks
  - Resolution
  - Slope Threshold
- Drop height

- Inverted Watersheds?
- Further definitions

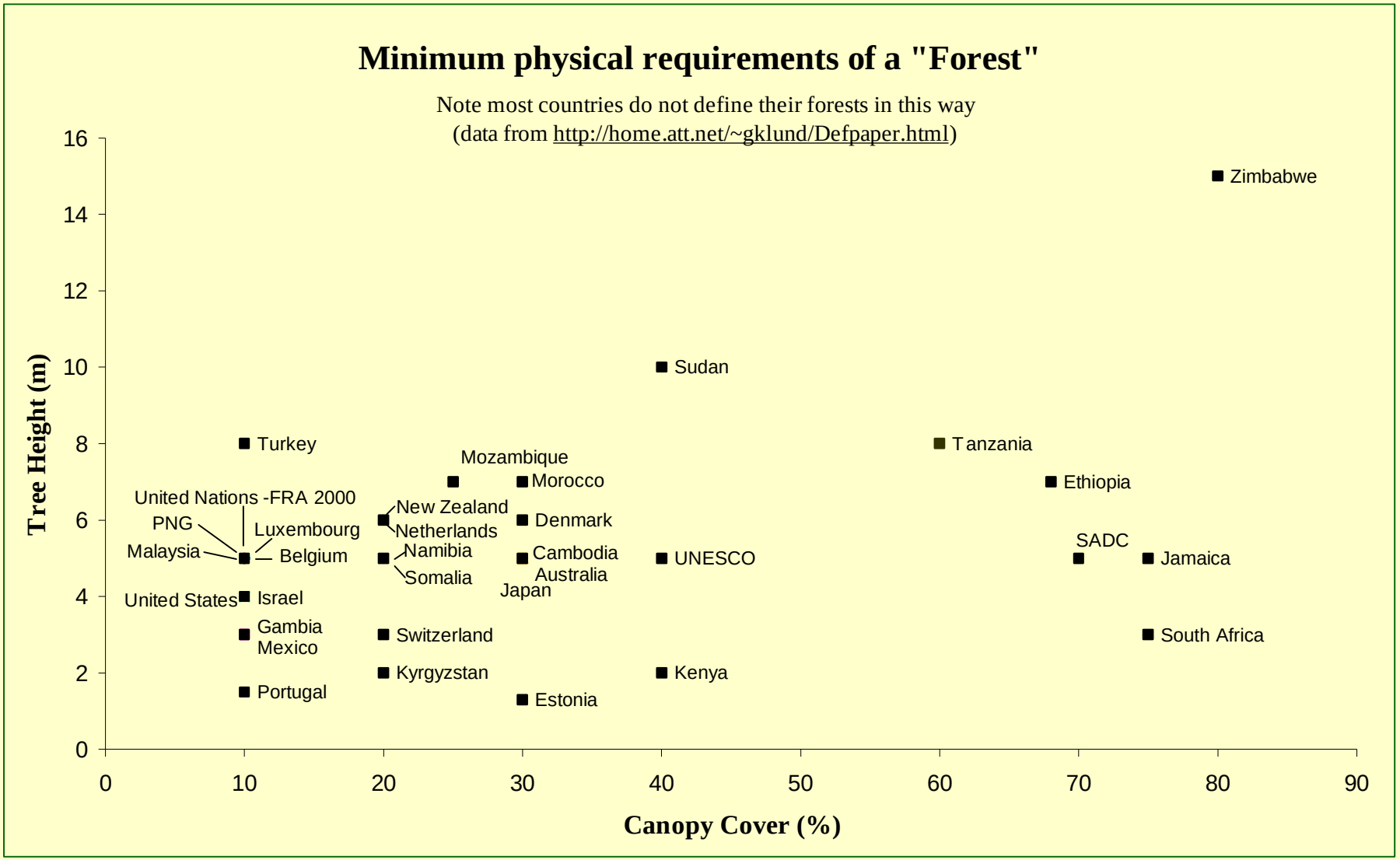
- All discordant vague definitions







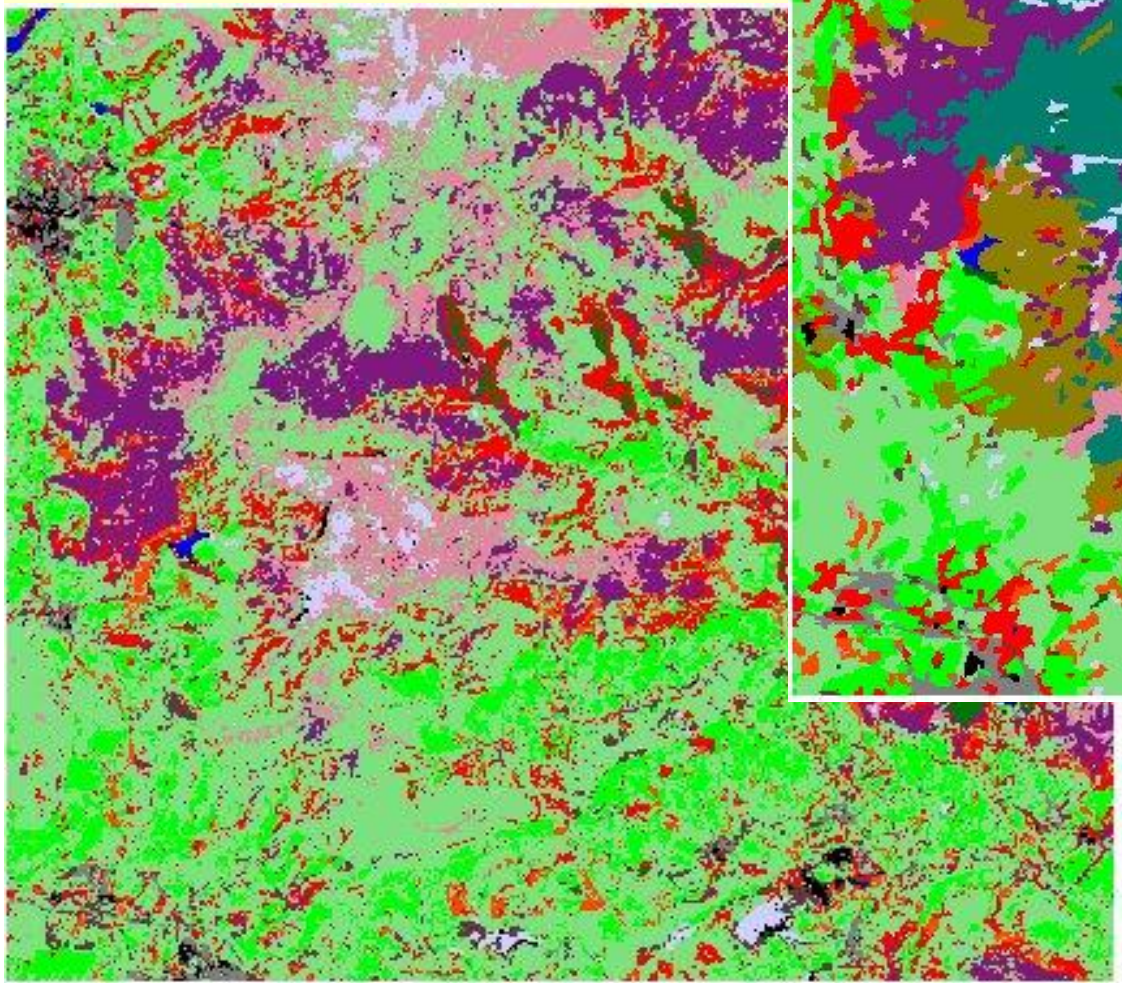
Other Semantic or Ontological Confusions

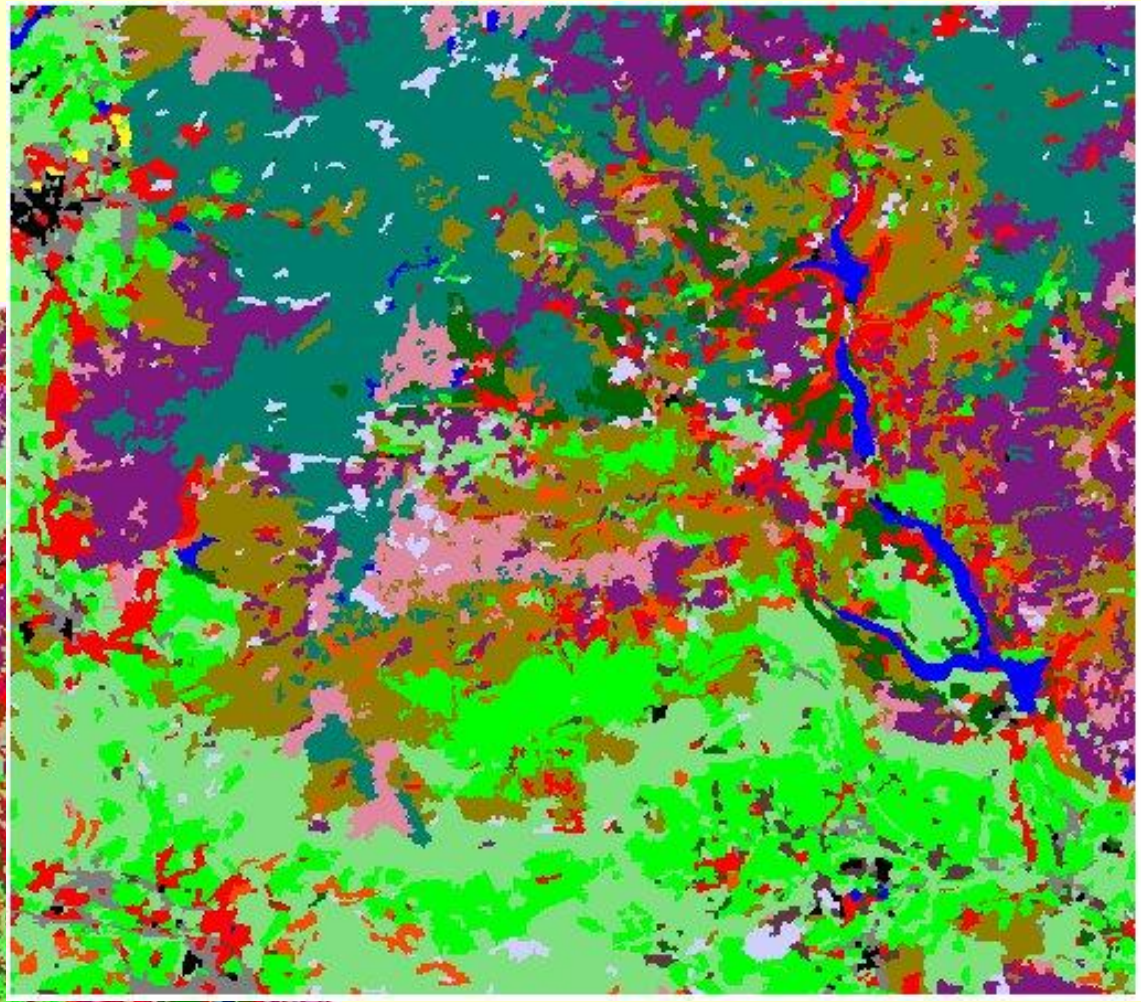


Land Cover Mapping

- Within EU funded REVIGIS project
- 1990 LCMGB vs LCM2000:
    - Landsat TM, Centre for Ecology & Hydrology
- Same phenomenon but changes:
    - Representation (raster vs. parcel structures)
    - Conceptualisation eg Classification
        - 1990: 25 Target classes
        - 2000: 26 Broad Habitats
    - Technology (LCM2000: extensive object level meta-data)
    - Objectives (Science and Policy)
- Endemic problem
    - USGS-LCDS / MODIS / GLC
    - National soil classifications ….
- This is a problem if you are trying to map change in the landscape

LCMGB 1990



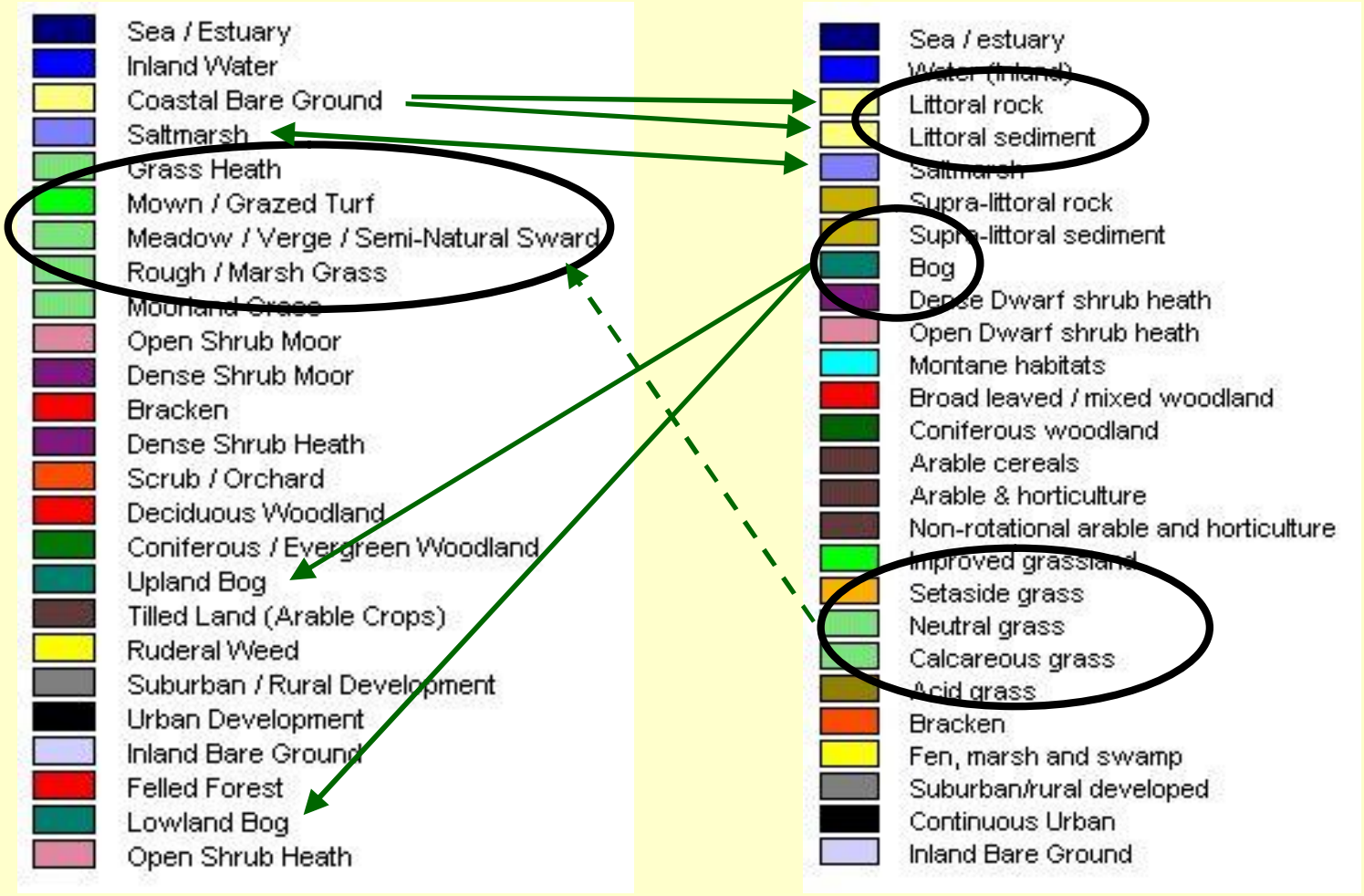


LCM 2000

But what is a “bog?”

- LCMGB
  - 12 pixels (<1 ha) in SK tile
    - permanent waterlogging, resulting in depositions of acidic peat
    - mostly herbaceous communities of wetlands with permanent or temporary standing water
    - Lowland Bogs: carry most of the species of upland bogs, but in an obviously lowland context, with Myrica gale and Eriophorum spp. being highly characteristic.
    - Upland bogs: have many of the species of grass and dwarf shrub heaths
    - characterised by water-logging, perhaps with surface water, especially in winter. species such as bog myrtle *(Myrica gale)* and cotton grass (*Eriophorum* spp.) in addition to the species of grass and dwarf shrub moorlands.
- LCM2000
  - 120728 pixels (75 km^2) in SK tile
    - Bogs include ericaceous, herbaceous and mossy vegetation in areas with peat >0.5 m deep; ericaceous bogs are distinguished at subclass level. Inclusion of Ericaceous bogs contrasts with LCMGB 1990 where bogs were herbaceous or mossy in seasonal standing water

Concepts



LCMGB 1990

LCM 2000

Remaining Problems

- Formalising the different natures of uncertainty is fundamental
- Visual clues for the types of uncertainty
  - Object level
  - Uncertainty taxonomy
  - Unaddressed
- Visualising higher dimensions of uncertainty
- Visualising discord and semantic uncertainty