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Department of Geography

Managing uncertainty when aggregating from pixels to parcels: context sensitive mapping and possibility theory

Dr Lex Comber
ajc36@le.ac.uk

www.le.ac.uk/gg/staff/academic_comber.htm

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Managing uncertainty when aggregating from pixels to parcels: object-oriented classification and land use implications

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Overview

- Land use from remote sensing
  - Classification of remote sensing data
  - Confusion with land cover
  - Why the distinction is important
- Object object-oriented classification of remote sensing data
  - Mapping using eCognition
  - Aggregating from higher level (fine) objects to lower level (coarse) objects
- Try to summarise and draw some conclusions

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My background and bone fides

- 1st Degree in Plant Science
- PhD in Computer Science
  - At the Macaulay Land Use Research Institute
  - Modelling vegetation, land cover and land use
  - Developed approaches to represent human image interpretation heuristics
    - Linking expert systems, remote sensing, GIS
  - Automated monitoring systems as input to land use decision support systems
- Maybe I am not a geographer . . .!
- …perspective on how I tackle this issue

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Part 1: Land use from remote sensing

- Land Use or Land Cover?
  - Land cover / land use - illogical but commonplace paradigm
  - In the literature, in reporting, in international programmes
  - They are not the same thing . . .
- Confused in every major, national & international dataset from remote sensing
- Instructive to review their characteristics
- First some examples

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USGS Land use and Land cover classification (after Anderson *et al.*, 1976)

Level 1			Level 2		
2	**Agricultural land**	**Use**	21	Cropland and pasture	**Use**
			22	Orchards, groves, vineyards, nurseries, and ornamental horticultural areas	**Use**
			23	Confined feeding areas	**Use**
			24	Other agricultural land	**Use**
3	**Rangeland**	**Cover**	31	Herbaceous rangeland	**Cover**
			32	Scrub and brush rangeland	**Cover**
			33	Mixed rangeland	**Cover**
5	**Water**	**Cover**	51	Streams and canals	**Cover**
			52	Lakes	**Cover**
			53	Reservoirs	**Use**
			54	Bays and estuaries	**Cover**
7	**Barren land**	**Use**	71	Dry salt flats	**Cover**
			72	Beaches	**Cover**
			73	Sandy areas other than beaches	**Cover**
			74	Bare exposed rock	**Cover**
			75	Strip mines, quarries and gravel pits	**Use**

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The CORINE Land cover classification (EEA, 2001)

Level 1			Level 2			Level 3		
1	Artificial Surfaces	Cover	11	Urban fabric	Cover	111	Continuous urban fabric	Cover
						112	Discontinuous urban fabric	Cover
			12	Industrial, commercial and transport units	Use	121	Industrial or commercial units	Use
						122	Road and rail networks and associated land	Use
						123	Port areas	Use
						124	Airports	Use
			13	Mine, dump and construction sites	Use	131	Mineral extraction sites	Use
						132	Dump sites	Use
						133	Construction sites	Use
			14	Artificial, non-agricultural vegetated sites	Cover	141	Green urban areas	Cover
						142	Sport and leisure facilities	Use

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Definitions

- Land cover defined by the physical matter that is observed
  - There may be variation in what is observed (different data, sensors, classification algorithms and operators)
  - But land cover is agreed to be a single phenomenon at any given point in time
- Land use is defined by human activity any given place
  - This may be single, simultaneous or alternate
    - Activity can be multi-dimensional: Forestry used for recreation, (hunting, hiking), grazing & timber
    - Activity can vary seasonally: Reservoir: flood control in the spring, hydro-electric power in the winter, fishing in season and boating all year round

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Land use: influenced by cultural factors

- Bibby and Shepherd (1999) say that land use objects
  - *"are best regarded as objects by convention, that is, they are objects by virtue of the fact that they are held to be so"*
  - and that such objects are *"grounded in discourse and projected onto the physical world" (p584)*
  - Land use class hierarchies reflect different economic and social organizations
- *c.f.* land cover which is concerned with pre-existing physical matter
- Examples: Robbins (2001), Hoeschele (2000)

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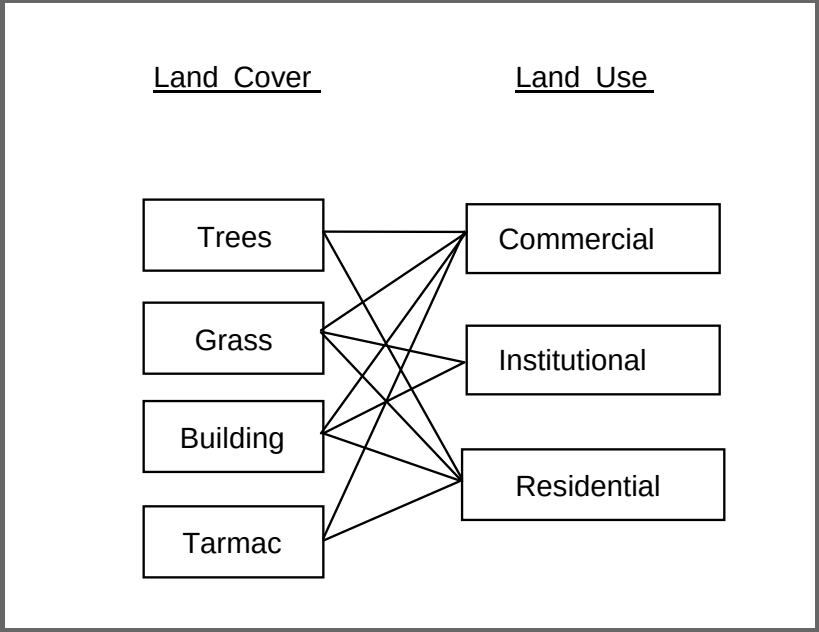
Land cover / use: not directly compatible

- Rarely have a one-to-one relationship
  - Usually 1:Many or Many:1
- Examples:
  - 'Grass' cover may occur in many uses (sports grounds, urban parks, residential land, pasture)
  - 'Residential' use may have many covers (trees, grass, buildings, asphalt)



Many to Many relations of Land cover and Land use

- Land use has no intrinsic relation to physical matter
  - Remote sensing → Physical matter (land cover)
  - Remote sensing ~~→~~ Activity (land use)
- Land use cannot be measured directly only inferred

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Why does all this matter?

- Land cover & land use distinction is important
- They support very different objectives
  - Land cover for physical environmental models
  - Land use for policy and planning purposes
- Their confusion makes data from remote sensing difficult to use systematically
  - Climate change models
  - Land use decision simulations

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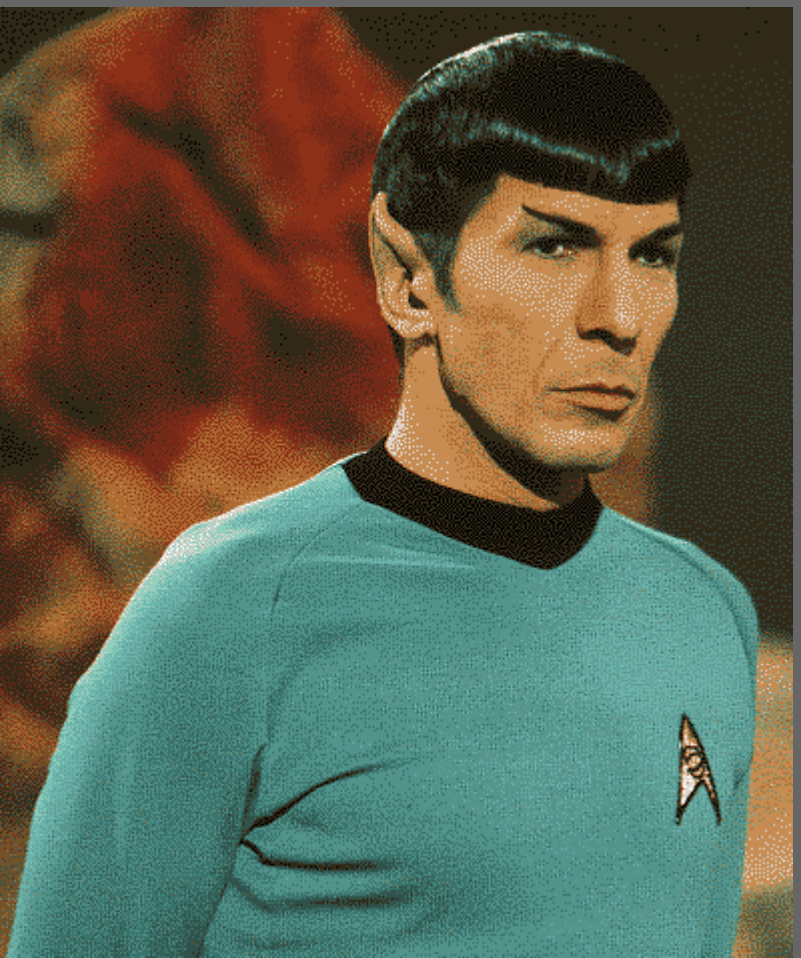
Land cover / land use: their conflation together is illogical so we should not do it



I recently edited a special issue of the Journal of Land Use Science on this topic

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Part 2: Object object-oriented classifications of remote sensing data

- Outline object classification in eCognition
  - Compare with traditional remote sensing
- Objects and how they are managed
  - Uncertainties when moving from low level (fine) objects to high level (coarse) objects
- Title: "Managing uncertainty when aggregating from pixels to parcels: object-oriented classification and land use implications"

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Object-Oriented classification

- Traditional remote sensing techniques
  - *Generally* treat each pixel in the same way
  - Classification done simultaneously
  - Class allocation on by clustering or distance
    - Unsupervised and Supervised
  - Classification based only on image properties
  - Problematic in heterogeneous environments
    - Uplands, semi-natural, moorlands etc
    - Makes the poor relationship between land cover and land use even more difficult

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Object-Oriented classification

- Object-oriented classification overcome some of these problems
  - Objects in imagery identified
  - Rules in a knowledge base in eCognition
  - Rules used to classify objects
  - Different from continuous division of space as per pixel / raster model

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Object-Oriented classification in eCognition

- In eCognition / Definiens Developer
- Can incorporate other Spectral & Spatial data
  - Proximity to scene features (e.g. GIS layers)
  - Landscape ecology metrics (e.g. agricultural patterns)
  - Human activity (e.g. census or survey data)
  - Encoded as class rules in knowledge base
- Provides contextual information for classification
- This might be very appropriate for land use

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Object-Oriented classification in eCognition

- Advantages
  - Heuristic: identifies objects in the same way as human surveyors (field and API)
  - Uses knowledge base and rules to classify objects
  - Sequential to give control: classification can be done in stages
    - Areas already identified as Class A are not considered when trying to identify areas of Class B
- Disadvantages
  - Requires a lot of knowledge
  - Expert – Ecologist, Social Geographer

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Objects

- Image divided into contiguous clusters by segmentation
  - Objects are the unit of analysis
- Segment attributes used in classification include
  - Spectral properties
  - Texture, Shape, Proximity, etc
- Different segmentations give different results
- Defines the spatial characteristics of the output

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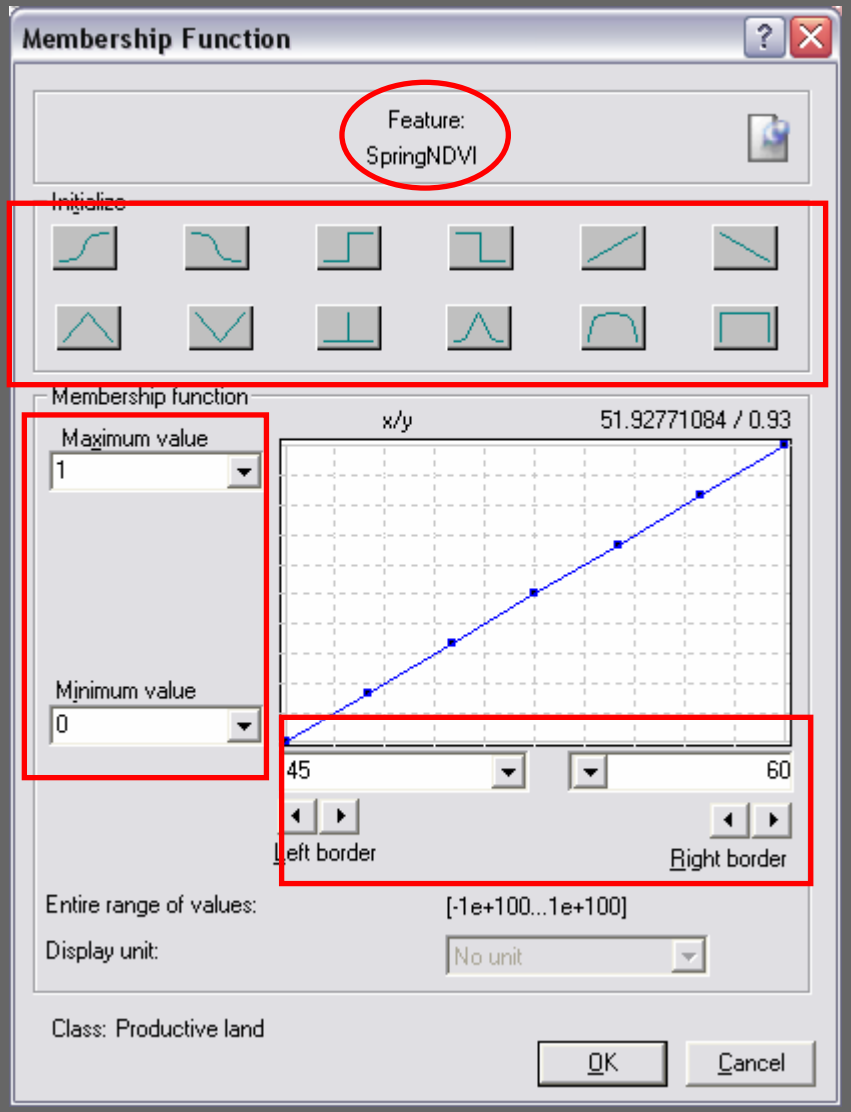
Classification

- Example of spectral rule
- Rule defines
  - Function
  - membership (i.e. fuzzy value)
- Could be another rule related to proximity
- But there are function choices



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Classification

- Classes identified by rules in knowledge base
- Sequence of rule application determined by process tree
- Each rule contributes to the overall belief in that object
  - Membership to the fuzzy set
- Result is fuzzy objects

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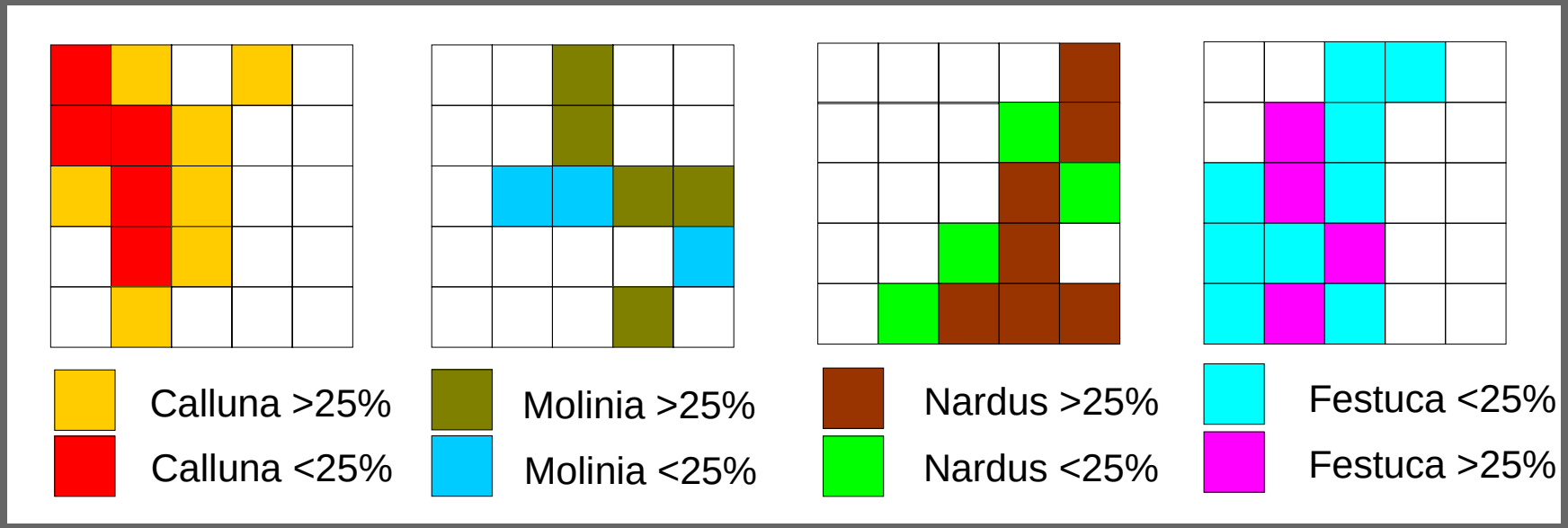
Classified Objects: habitat example



Overlap in space

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Low level to high level

- Low level objects in hierarchy
  - "data primitives" or "end members"
  - Building blocks for reporting classes
  - Bottom of the hierarchy tree
- Low level objects are combined to generate higher level class
  - Reporting purposes e.g. policy
- Example from habitats

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Low level to high level: Example habitats

Reporting Objects → / Detailed Objects ↓	D.1.1 Dry Acid Heath		D.2 Wet Heath		E.1.6.1 Blanket Bog		E.1.6.2 Raised Bog	
	AND (max)	OR (min)	AND (max)	OR (min)	AND (max)	OR (min)	AND (max)	OR (min)
Blanket Bog						>=0.1		
Bog Moss	<=0.05					>=0.1		
Bogs			<=0.1			>=0.25		>=0.1
Calluna		>=0.25		>=0.25				>=0.1
Cotton Grass	<=0.05					>=0.1		>=0.1
Festuca-Agrostis			<=0.01					
Heathy bog	<=0.05		>=0.25			>=0.25		>=0.1
Jsq-nardus				>=0.1				
Molina	<=0.25	>=0.1			<=0.1		<=0.25	
Mossy Fescue			<=0.01					
Vaccinium		>=0.25						

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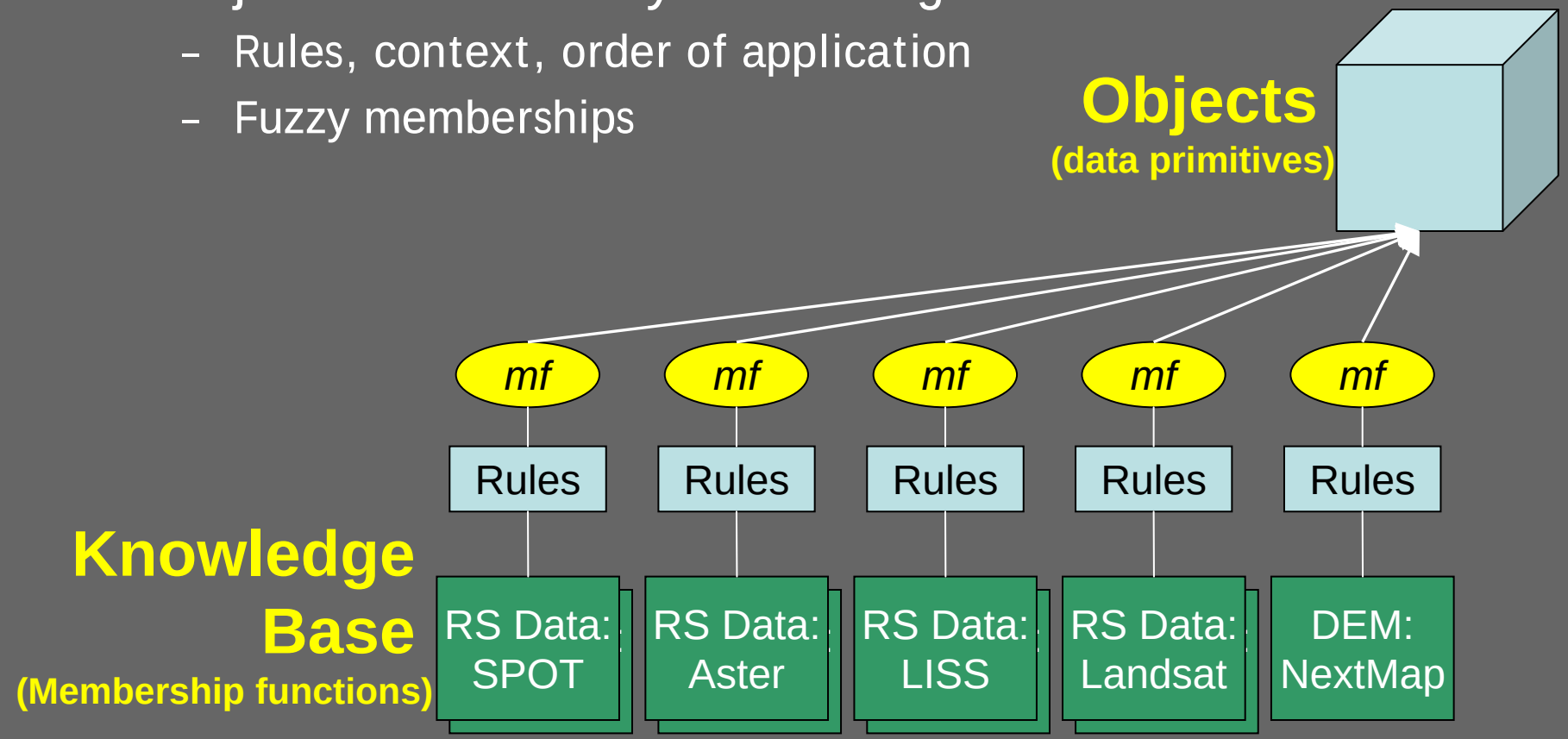
Low level to high level: Example habitats

- Segmentation → objects - low Level, detailed
- Objects classified by 'knowledge base'
  - Rules, context, order of application
  - Fuzzy memberships



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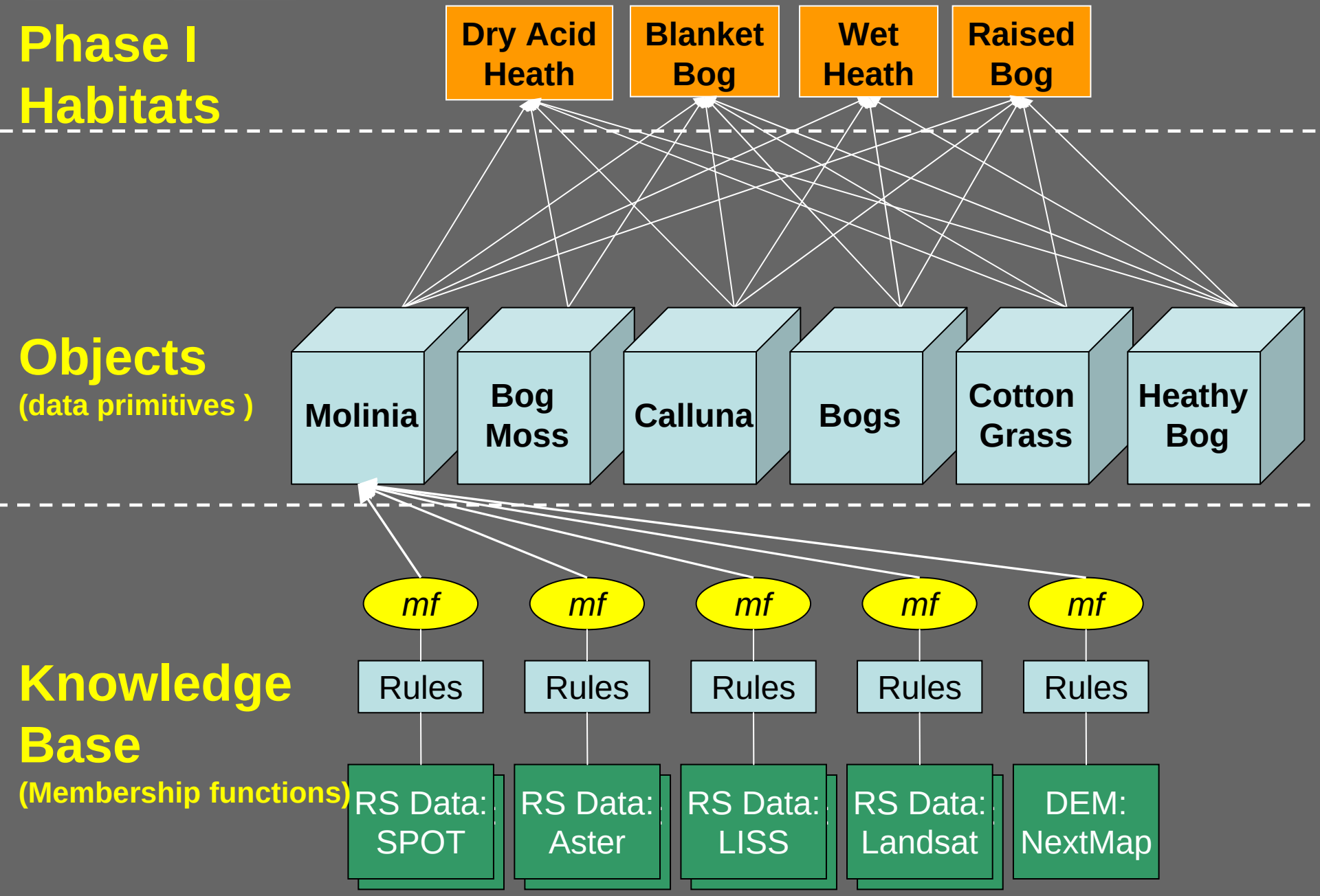
Phase I Habitats



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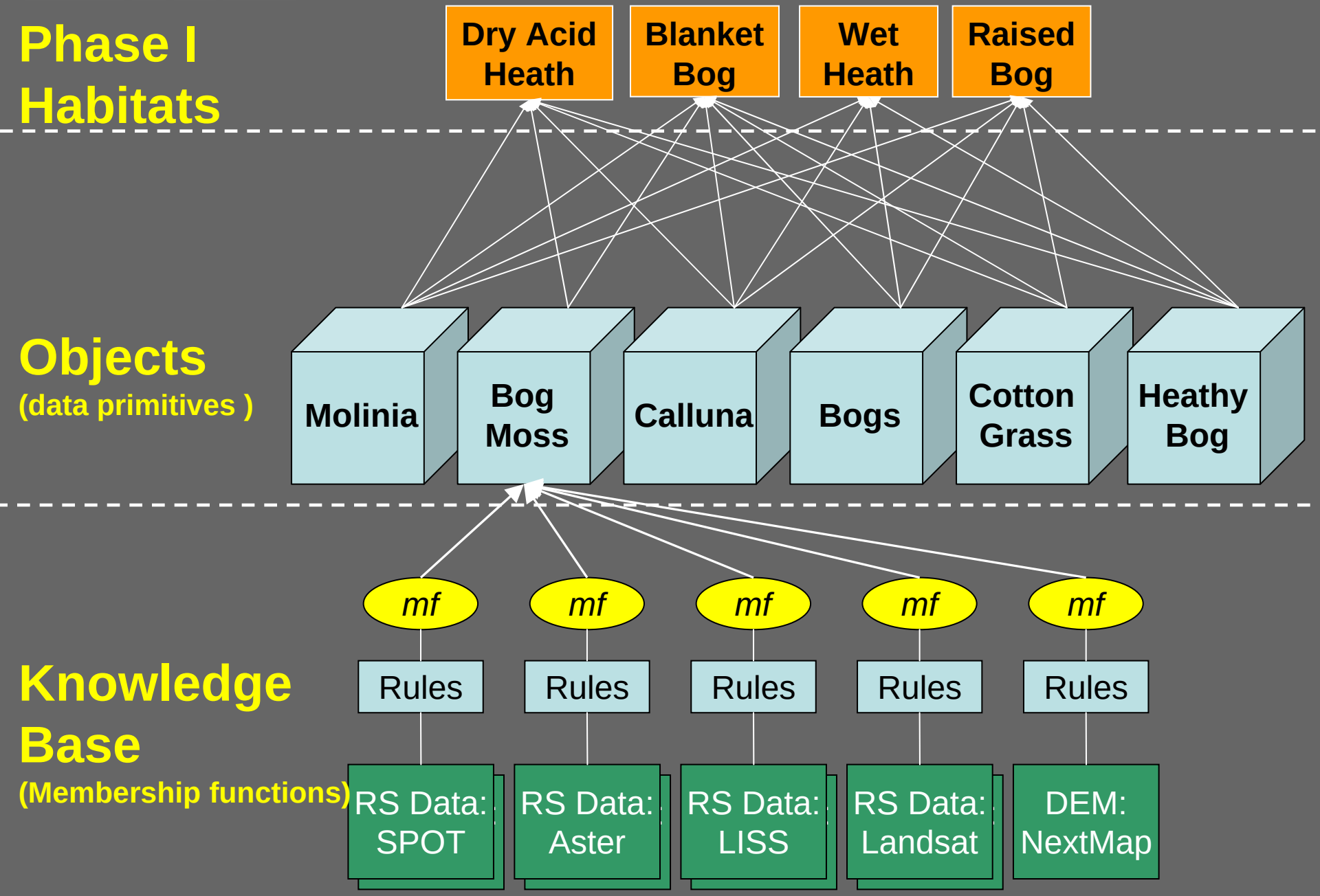
Phase I Habitats



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Phase I Habitats

Dry Acid Heath | Blanket Bog | Wet Heath | Raised Bog

Objects
(data primitives)

Molinia | Bog Moss | Calluna | Bogs | Cotton Grass | Heathy Bog

Knowledge Base
(Membership functions)

mf → Rules → RS Data: SPOT

mf → Rules → RS Data: Aster

mf → Rules → RS Data: LISS

mf → Rules → RS Data: Landsat

mf → Rules → DEM: NextMap

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Phase I Habitats

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(data primitives)

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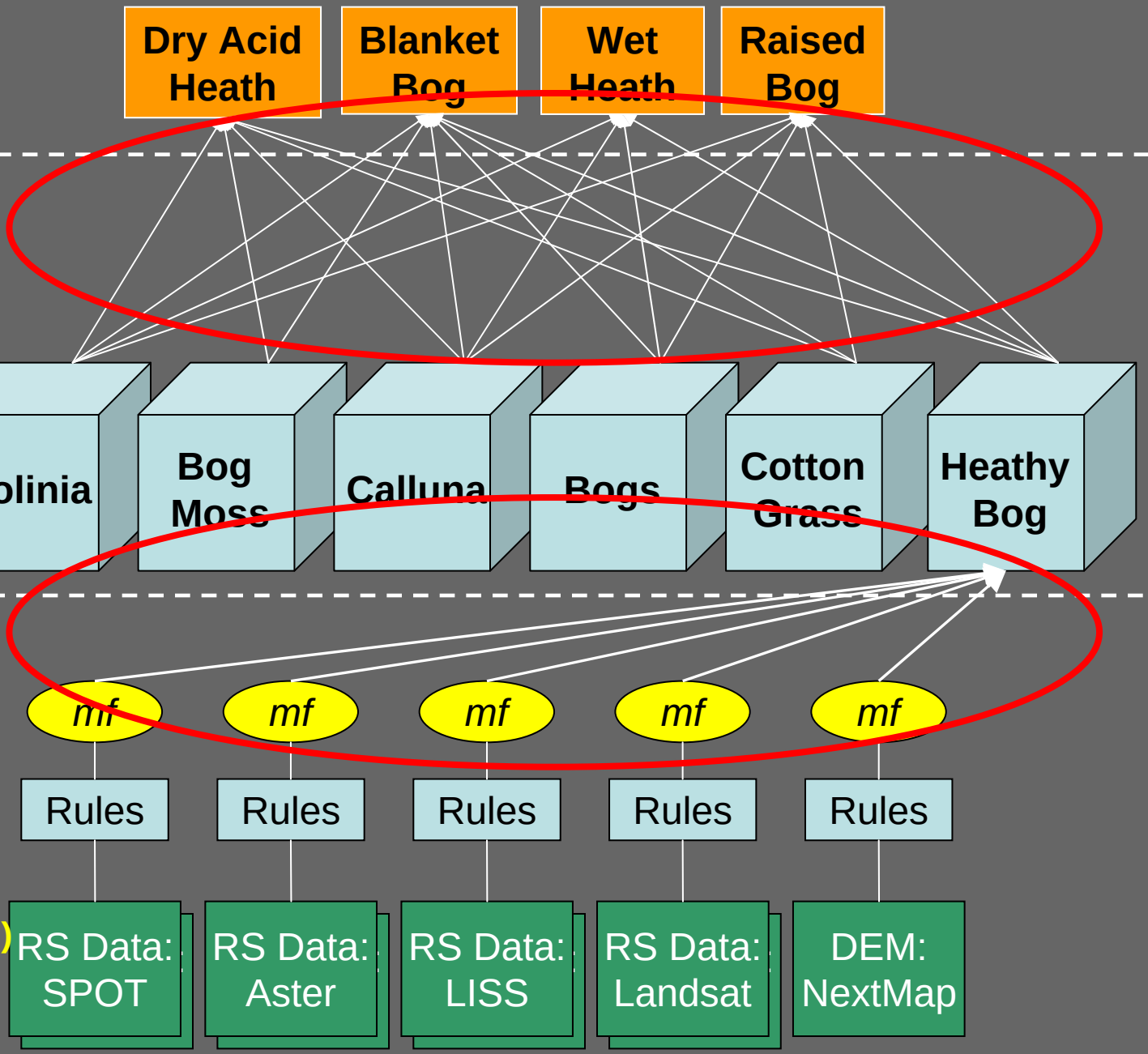

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Low level to high level: Example habitats

- In eCognition ONLY fuzzy min function used
  - most supported higher level class → what is there!
  - Good for policy
- But conservation
  - interested in what could be there, what has happened there
    - Restoration, Monitoring
  - Interested in the full fuzzy model range of uncertainties
- There are a range of fuzzy operators that are not accommodated in eCognition
    - Weighted Linear Combination (WLC)
    - Ordered Weighted Averaging (OWA)
    - Analytical Hierarchy Process (AHP)
- Tradeoff, factors and weights commonly used in GIS MCE analyses

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Summary: land use vs land cover

- Land cover / land use confused in data
- They have different conceptual basis
  - Land cover: pre-existing physical matter
  - Land use: human activity
- Land use cannot be directly measured from space
- Land Use cannot be inferred from each land cover directly (very little 1:1)
- Implication: you need to be careful with land use from remote sensing data

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Summary: object-oriented classification

- Object-oriented classification (eCognition) is very different
  - uses a knowledge base: Rules and ancillary data, Contextual information
- Offers good potential for land use compared to traditional remote sensing approaches
- BUT . . . high & low level objects from rules
- With little flexibility in how uncertainty is managed
  - Only a fuzzy MIN (AND) operator
- For some analyses other operators may be better
  - Other fuzzy approaches, allowing tradeoff
  - Possibility Theory (Dubois and Prade, 2001) allows more flexibility in aggregation (Comber et al, 2008)

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Some References

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Thank You!

Please contact me:

ajc36@le.ac.uk