Geography 4203 / 5203

GIS & Spatial Modeling

Class 3: Raster Data and Tesselations

Some Updates

- **Readings discussions**
- **Labs next week:**

  Monday group joins the **Wednesday** group or comes on **Friday 2-4pm**

Readings Discussions - How to…

- Prepare a **presentation** (25min max) and go on with a discussion
- **Contents of your presentations**:

  Who is/are the authors

  What is the central topic / field and the character of the paper (method./concept.)?

  What is the methodological key part / theoretical contribution?

  What is your opinion about the reading?

  Open or unsolved questions and critiques?

Readings Discussions - How to…

- **Materials and media**:

  Feel free! Whatever is useful in your eyes and makes the presentation exciting.

- **Discussion** (approx. 20 min):

  Prepare **4-5** interesting, challenging **questions** for the class

  When getting answers **insist** until you think your questions have really been thoroughly answered!

  If no one raises his/her hand – just **pick someone** out! You are the discussion leader.

- You can send me the material or come to me the day before to show and discuss the material (write me an email)

Last Lecture

- We talked about key terms in GIScience such as **spatial analysis** and **spatial modeling**
- I tried to give you an idea how to understand what people mean and which **definitions** and **taxonomies** exist
- We have seen some **examples** which (hopefully) helped to approach the problem
- So can you say what a **spatial modeler** does ad why this can be different from what an **spatial analyst** does?

Today‘s Outline

- **Tesselations** and **spatial** information **representation**
- Review and deepening knowledge of **raster datasets**, properties, structures
- Conceptual models for **geographic space**

Learning Objectives

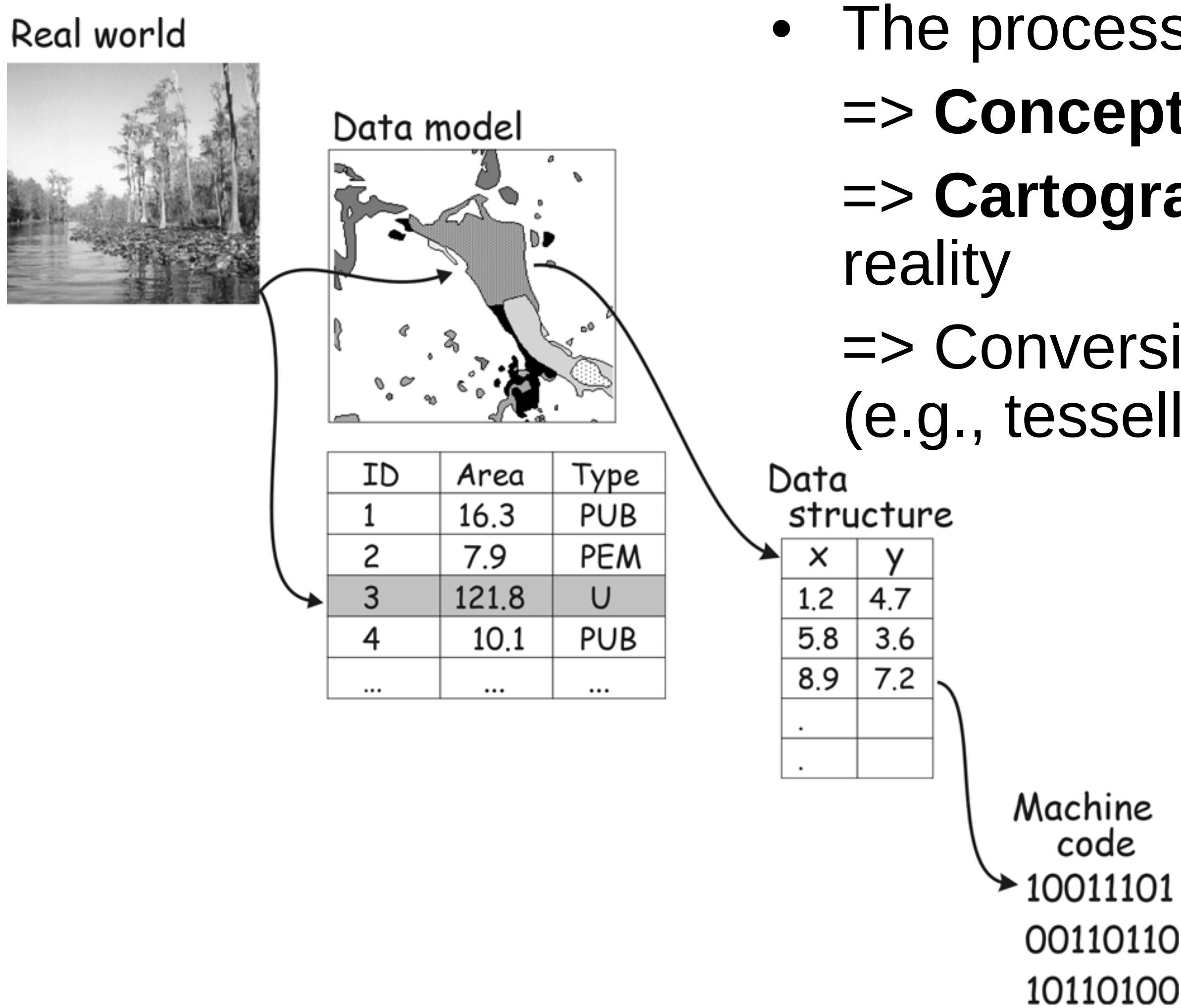
- Refreshing your knowledge of **raster datasets** and learning what **tesselations** are
- Looking at new details considering raster datasets as **tesselations**
- Understanding the **assignment** of cell values in the context of different raster **data models**
- Simply understand the data we are going to work with

Space and Tessellation

- “**tessella**” (Latin) - small cubical piece of clay, stone or glass used to make mosaics (Webster); "small square" (“**tessera**” - Greek for “four”)
- Ways of dividing our **geographic space**…
- … to represent space **computationally**
- *Boots 2005* (Perspective on boundaries vs. on interior of a region)*:*

A tessellation of d-dimensional, Euclidean space, $\Re^d$, can be defined from two different yet equivalent perspectives. It may be considered either as a subdivision of $\Re^d$ into d-dimensional, non-overlapping regions or as a set of d-dimensional regions which cover $\Re^d$ without gaps or overlaps.

Representing Space Computationally



- The process:

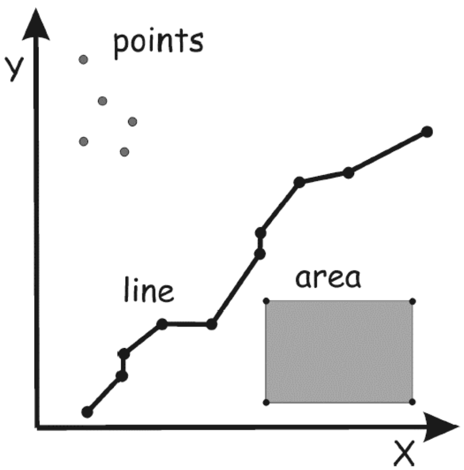
  => **Conceptualizing** the real world

  => **Cartographic abstraction** of the reality

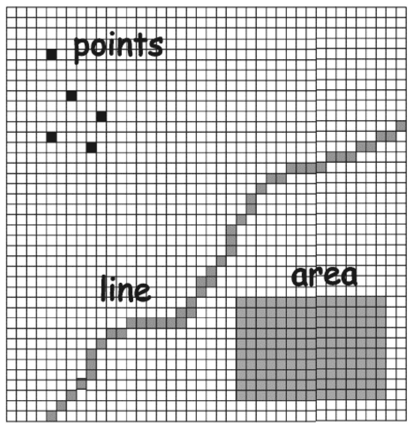
  => Conversion to **digital equivalent** (e.g., tessellation)

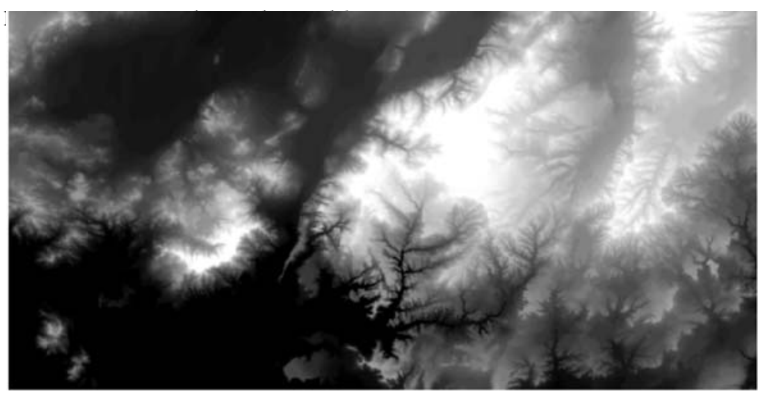
Representing Space Computationally

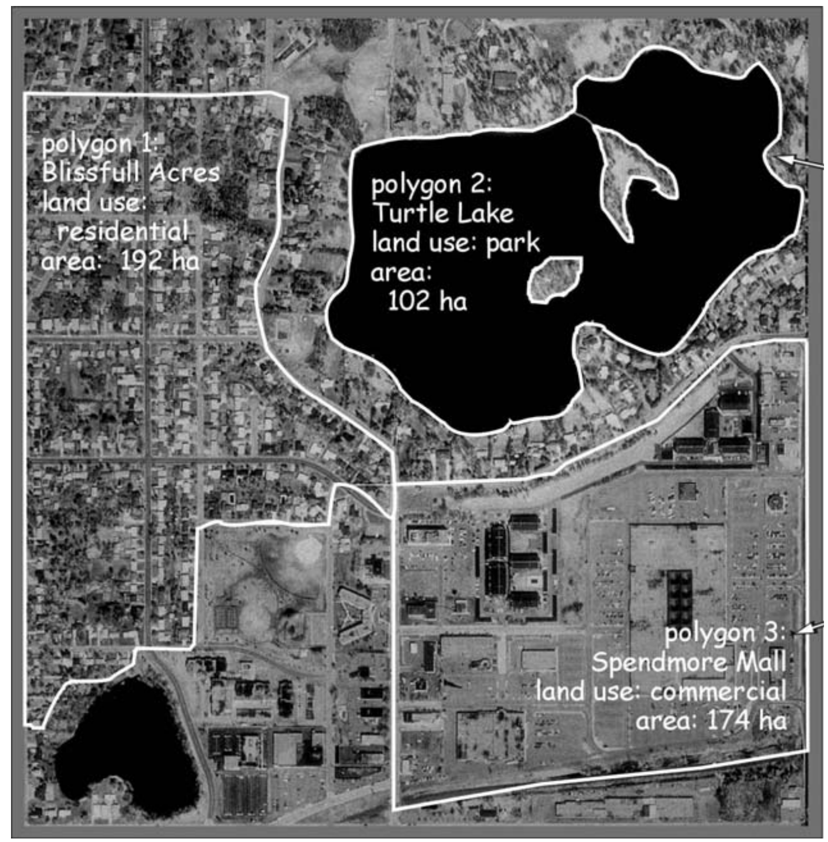
Vector



Raster







Tessellations of Geographic Space

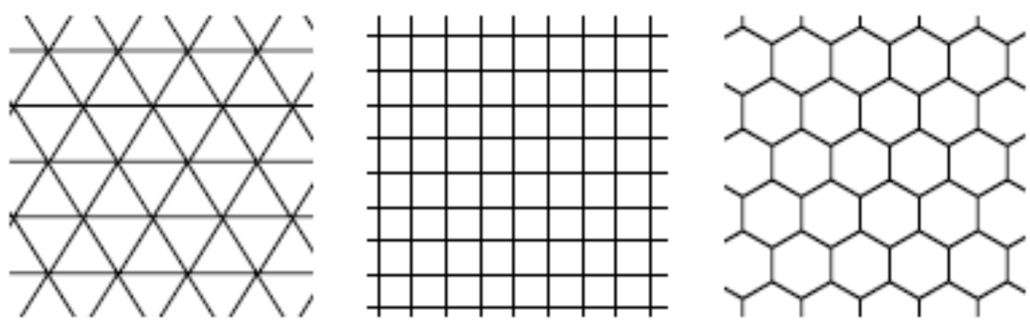
- **Quantizing space** (Kemp 1993):

  Division of geographic space into a series of discrete **“quanta”** (units), which represent real geographic data. On these quanta we perform **analytical operations** (individually or collectively).

  Continuous and discrete spatial data are converted into **discrete “units”** (this has implications, which?)

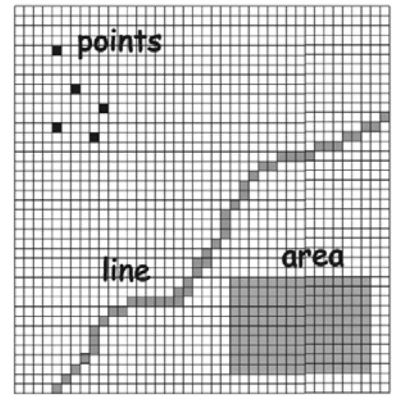
Tessellations and the "discrete" Reality

- **Uniform** storage of spatial entity information
- Mostly as **squares** (other shapes are **parallelograms**, **hexagons**, **triangles**)
- **Ease** of operation, **simplicity** of data structure
- **MAP** (Tomlin 1983) as the most common raster GIS with **squared** tessellations
- What are the consequences for analysis, geometry and neighborhoods?



Object Representation in Tesselations

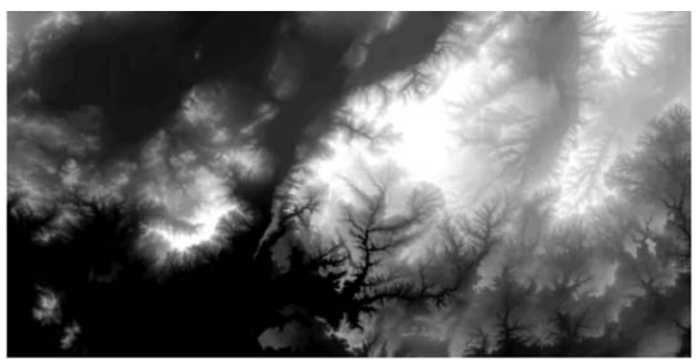
Discrete entities:



- **Points** (0D) as single grid cells
- **Lines** (1D - length as only dimension): Linear collection of grid cells
- **Areas** (2D) - groups of clustered grid cells

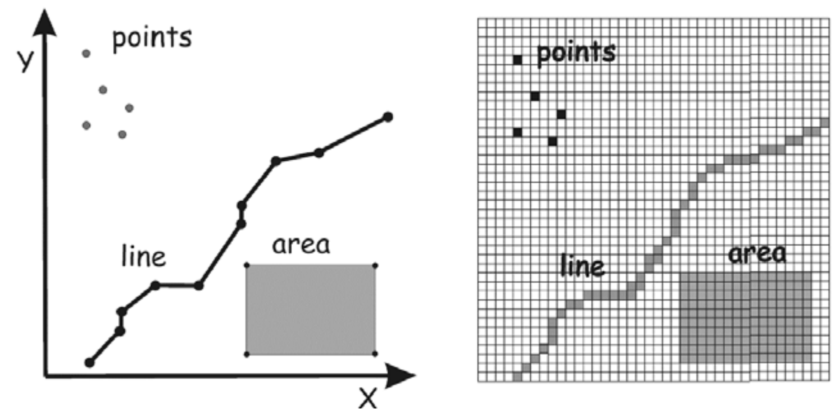
Continuous fields:

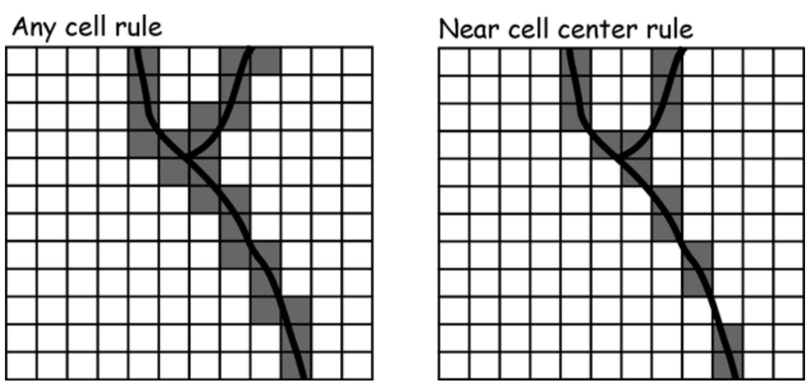
- ***Statistical surfaces***: any continuous set of data that can be measured on ordinal, interval, or ratio scale

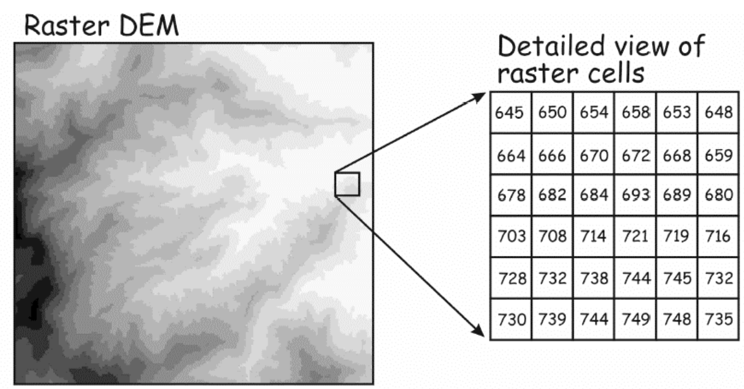


Back to Implications by Discretization

- Locational **accuracy**, dimensions, aggregation
- Relative **location** (matrix) in Cartesian space linked to geographic coordinate systems
- Mechanisms to store **descriptive** information about those objects
- Assignment if more than one category covers one pixel





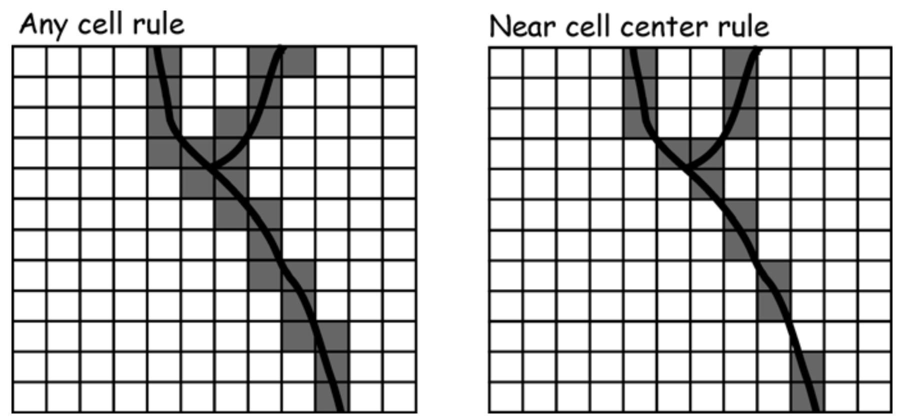


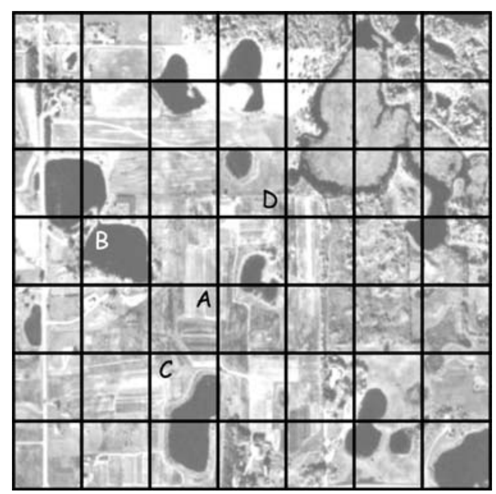
645	650	654	658	653	648
664	666	670	672	668	659
678	682	684	693	689	680
703	708	714	721	719	716
728	732	738	744	745	732
730	739	744	749	748	735

Problems in Assigning Cell Values

Cell assignment can be complex. How would you assign the following situations?

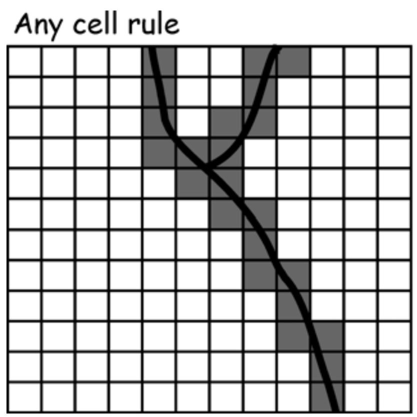
- Two point objects are located within one grid cell
- Two lines of different categories cross each other
- How to determine the cells that belong to the line?
- How to assign one land cover value to each of the large cells?

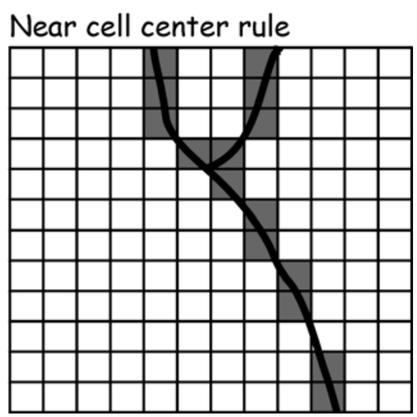


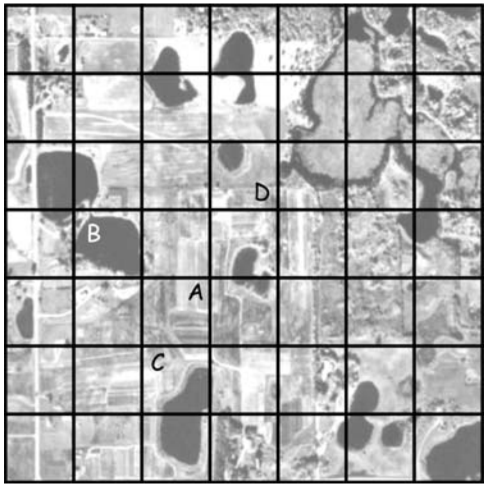


Coding Strategies…

- **Systematic**:
  Presence / absence
  Centroid of cell
  Percent occurrence
  Dominant type
- **Unsystematic**
  "most important type"
  (preference)







… and Raster Data Models

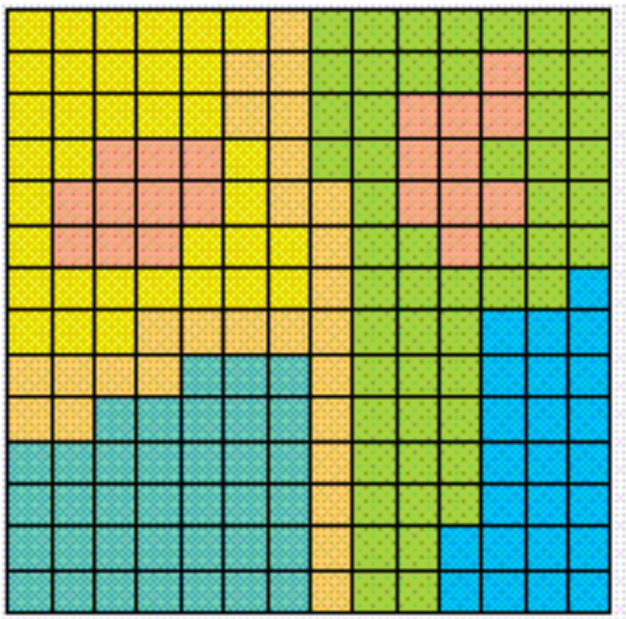
- Such cases can cause data explosions in **simple raster models** (MAGI, IMGRID, MAP) since all categories must be encoded for each cell…
- **Extended Raster:**

  Allows **multiple descriptors** for each grid cell in the attribute table (one-to-one, many-to-one, indexing)

  Problem: We loose part of the simple structure and create complex files

Raster Data

- **Matrix of cells** (pixels) organized into **rows and columns** (grid)
- Each cell contains a **value** representing information
- Digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.



What can Data in Rasters Tell us?

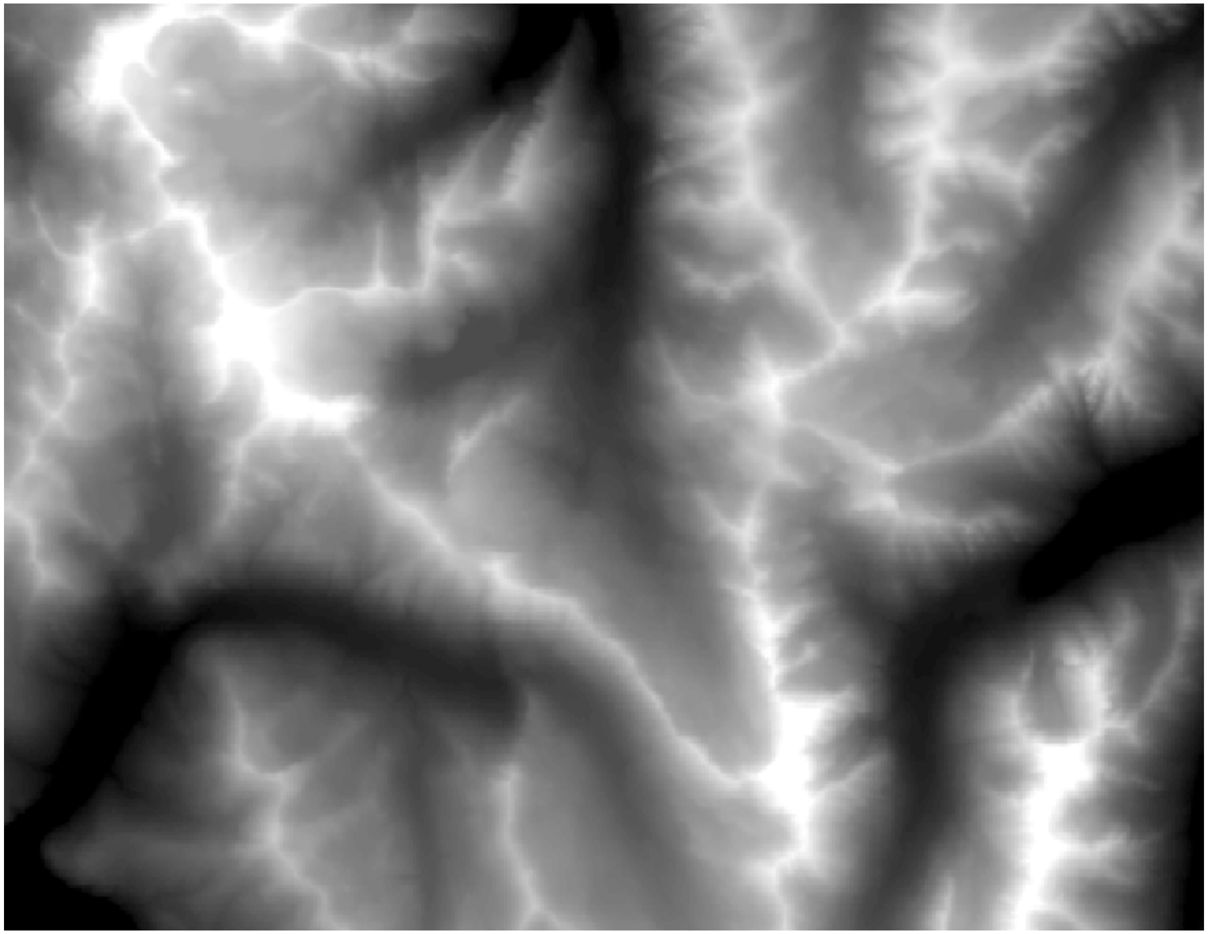
- **Thematic information** (discrete data):

  Land use, soil data
- **Continuous data (fields)**:

  Data regarding phenomena of changing degree over space on a continuous scale
- **Images / pictures**

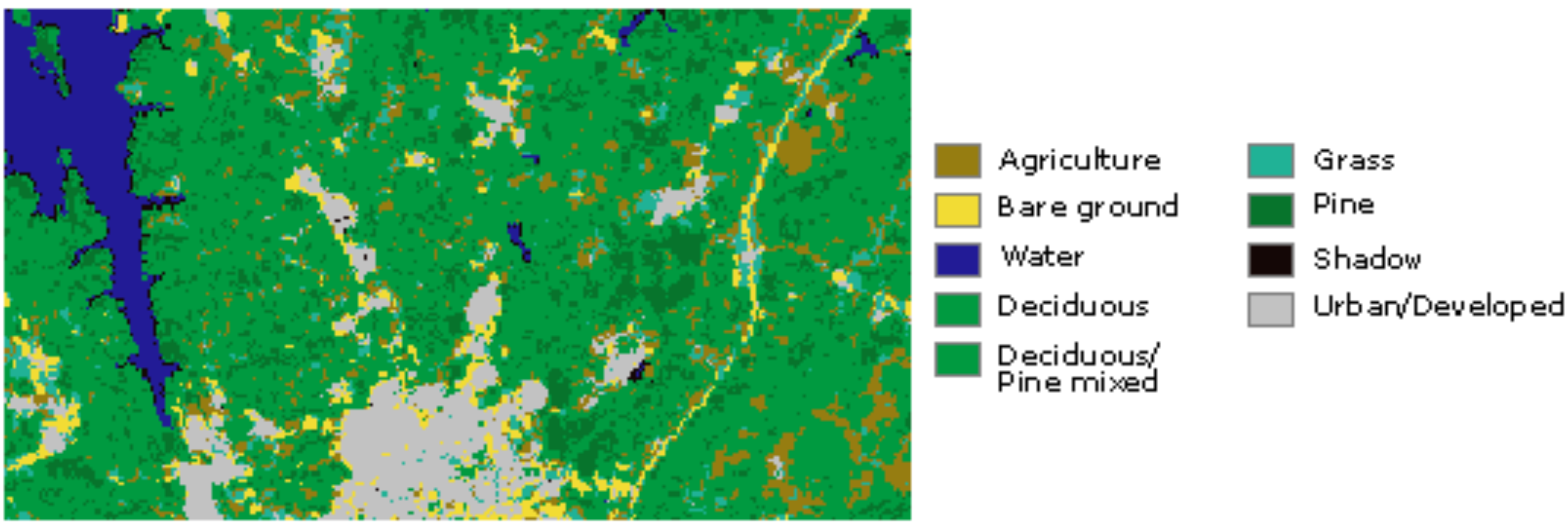
  Pixel values represent real world phenomena according to spectral range of the **sensor** and the **properties** of the objects

Surface Maps

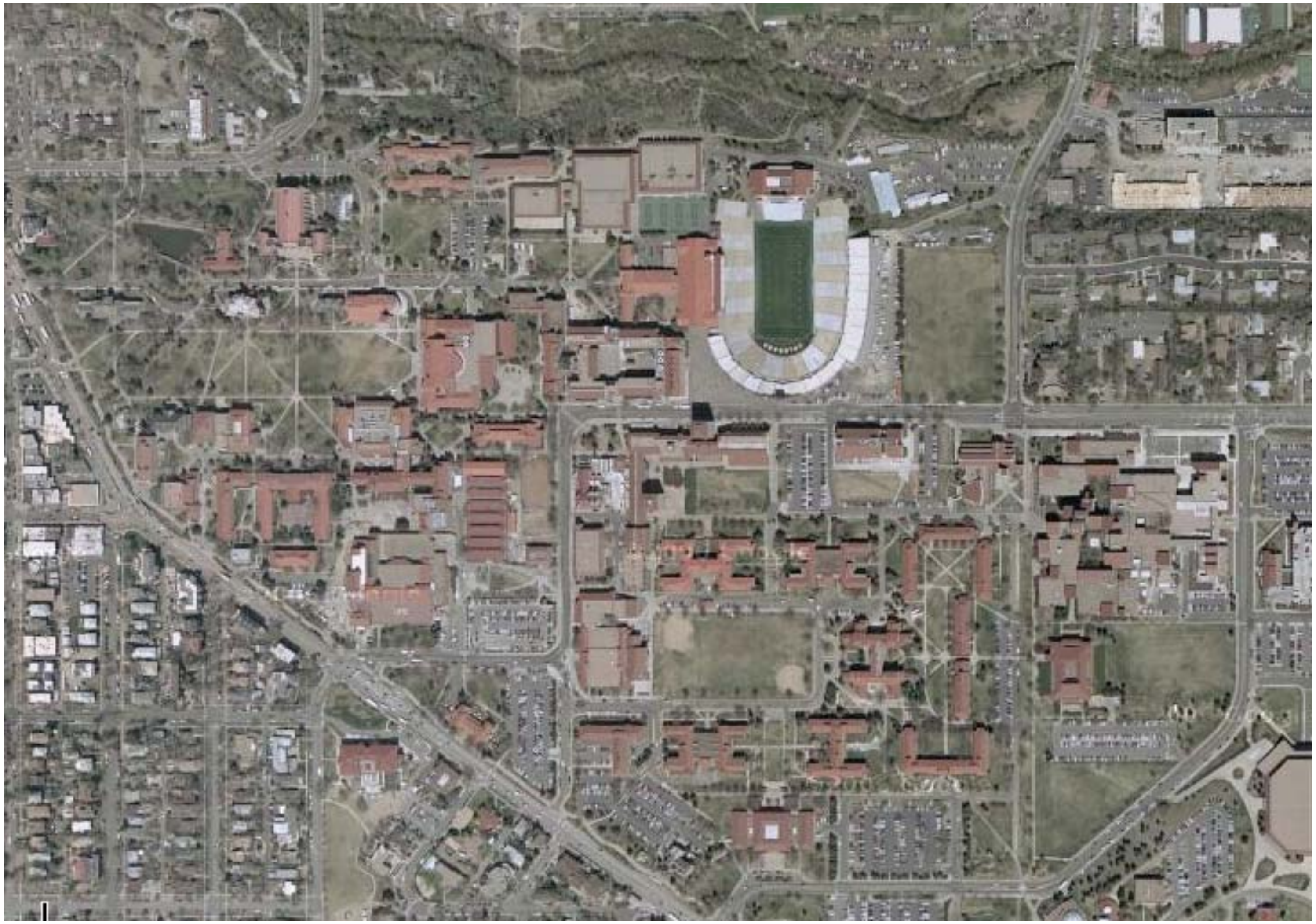


Thematic (categorical) Maps

- As results from analysis of other data
- Classifications (discrete or categorical data)
- Conversions and sharp boundaries



“Raw” Images Captured

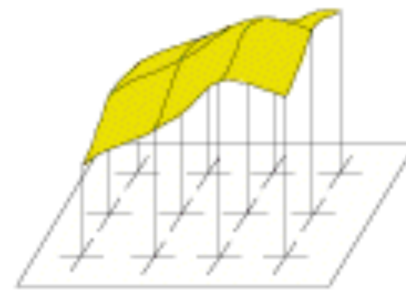


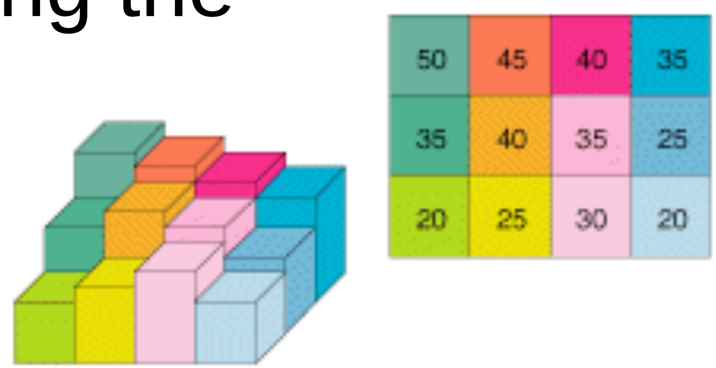
Remind Some Characteristics

- **Simple** data structure that can represent **discrete entities (“approximations”),** and **continuous values**
- **Categories** (land use), **magnitudes** (rainfall), **height** or just **spectral** values
- Values as negative/positive, **Boolean**, **Integer**, **floating point**
- Easy linking between different **overlaying** datasets
- **NoData** - absence of data
- Limitations in accuracy due to **cell sizes**
- Size of datasets/accuracy <> **resolution/cell size**

What is the Value of the Cell

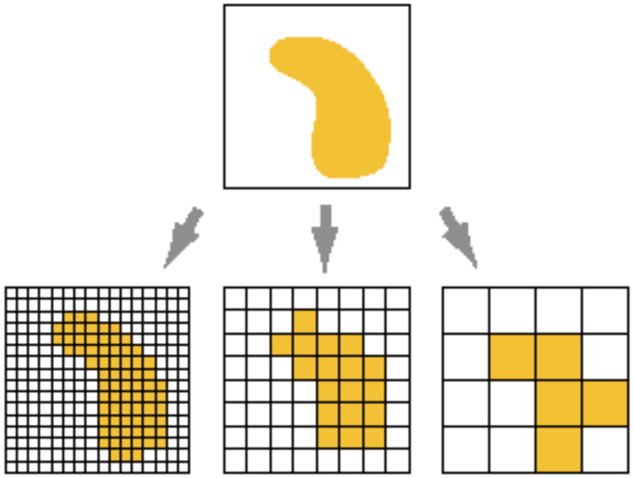
- Cell value can apply to the **center** of the pixel
- In most data the cell value refers to the **whole area** of the pixel (sampling of a phenomenon representing the **whole square**)





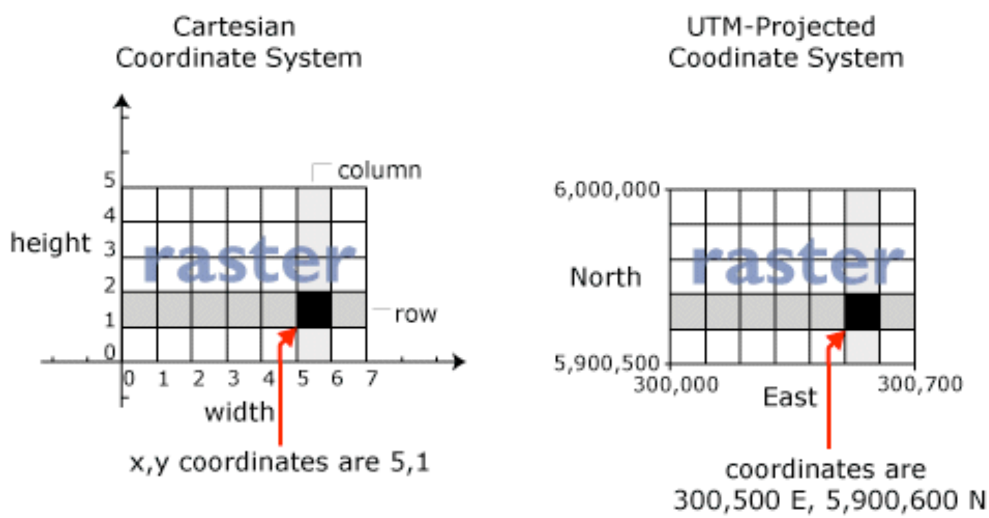
Rasters as Sets of Cells

- Uniform tesselations
- Cells have all the same **width** and **height** (**equal portions** of the surface)
- Cell **size** and **resolution** as critical elements for representing features, accuracy and file size (storage - space/resolution tradeoff)

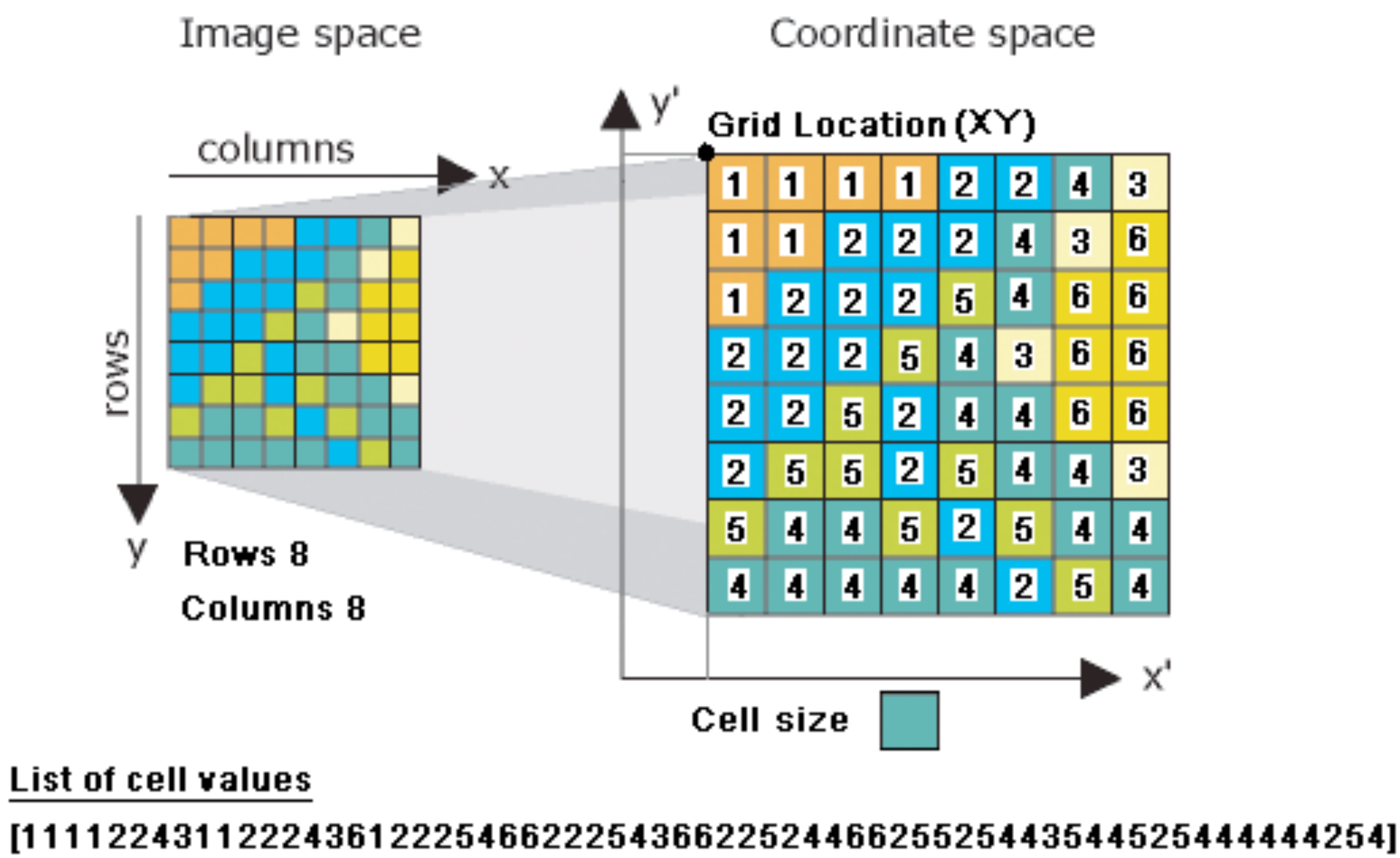


Rasters as Spatial Representations

- Locations of cells are defined by the number of **rows** and **columns** in the **matrix**
- **Cartesian** coordinate system representation (row || to x, col || to y)
- Values of **geographic coordinate systems**, accordingly



Addressing the Locations

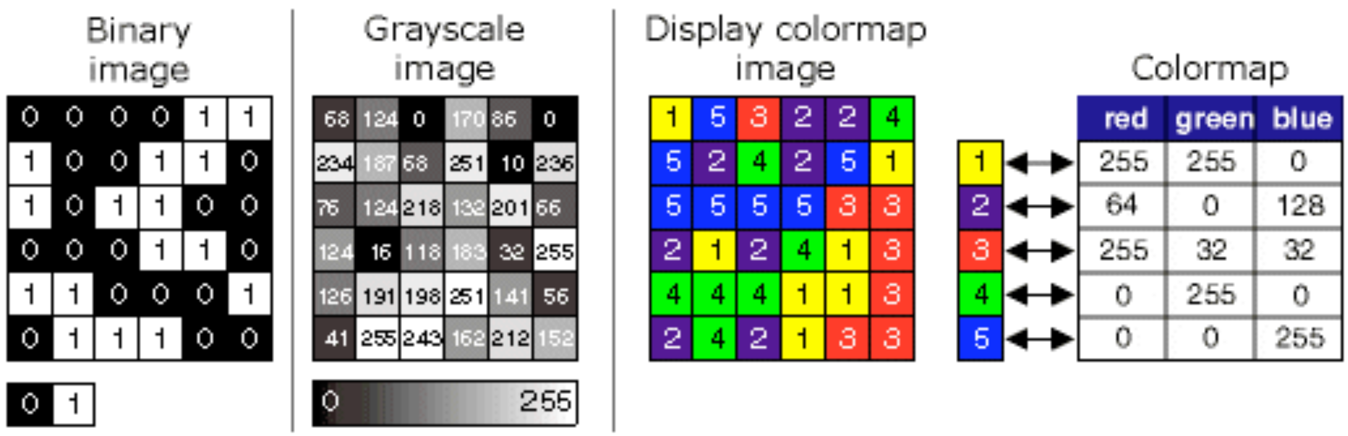


Raster Bands

- A band is represented by a single matrix of cell values
- A raster with multiple bands contains multiple **spatially coincident matrices** of cell values representing the same spatial area
- **Single-band**: DEM (each cell with only one value), orthophoto (panchromatic / grayscale)
- **Multiple bands**: Satellite imagery (values within a range of the electromagnetic spectrum in each band)

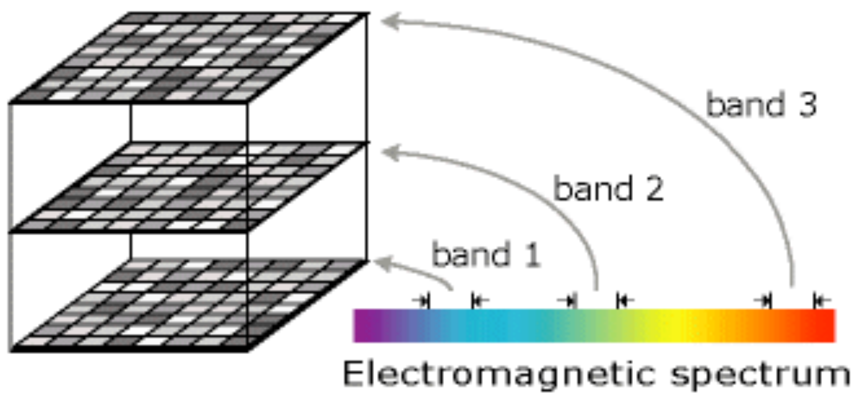
Single-Band Raster Datasets

- **Binary** images (parcel maps, results from raster queries and analysis)
- **Greyscale** images: Areal photographs
- **Color map** images (coding a set of values to match a defined set of RGB values)



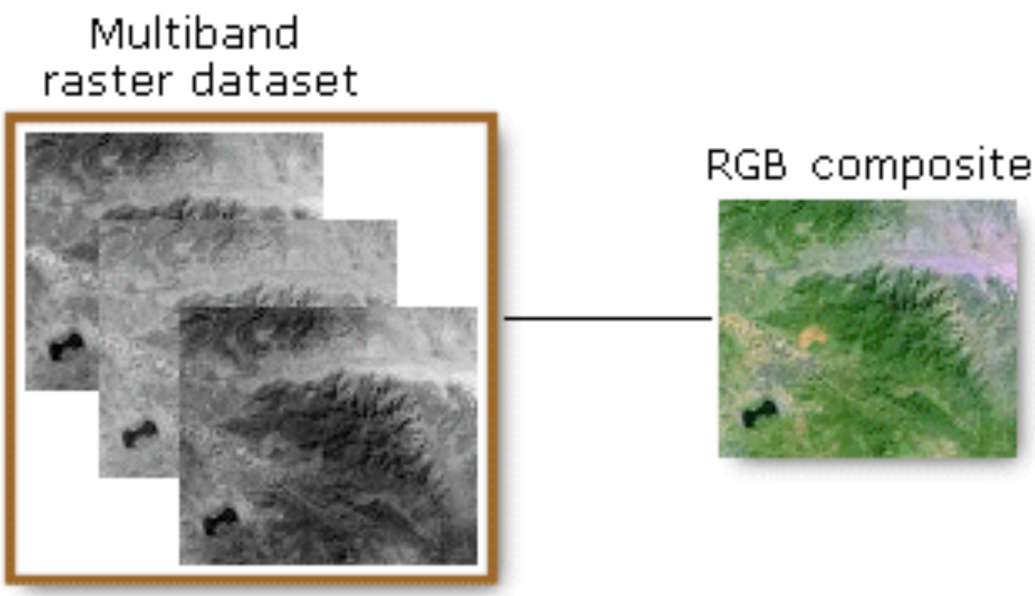
Multiple Bands

- One **cell location** has several values associated with it
- **Bands** usually represent segments of the **electromagnetic** spectrum (visible, invisible)



Multiple Bands 2

- Working with **satellite** images puts you normally in the situation to work with **multi-band** images



Types of Resolution

- **Spatial resolution:** Cell size
- **Spectral resolution:** Ability of the sensor to distinguish between wavelength intervals in the electromagnetic spectrum
- **Temporal resolution:** Frequency for data capture at the same location
- **Radiometric resolution:** Ability of a sensor to distinguish objects viewed in the same part of the electromagnetic spectrum, number of values in a band

Raster Dataset Information

- **Format**: File type for storing the raster
- **Number of bands**: Number of spatially coincident layers in the raster (min 1)
- **Data type**: Pixel type - int or float
- **Data depth**: Pixel or bit depth - possible range of values stored in each band (depth=8 stores 2**8=256 values (0 to 255); depth=16 stores 2**16=65536 values (0 to 65535)
- **Statistics**
- **Extents**: Left, right, top, and bottom coordinates
- **Projection**: Coordinate system
- **Size**: Number of rows & columns (uncompressed size)

Bit Depth

Bit depth	Range of values that each cell can contain
1 bit	0 to 1
2 bit	0 to 3
4 bit	0 to 15
Unsigned 8 bit	0 to 255
Signed 8 bit	-128 to 127
Unsigned 16 bit	0 to 65535
Signed 16 bit	-32768 to 32767
Unsigned 32 bit	0 to 4294967295
Signed 32 bit	-2147483648 to 2147483647
Floating-point 32 bit	-3.402823466e+38 to 3.402823466e+38

World Files for Georeferencing Information

- Some image formats store GI in a header of the image file (grids, img, GeoTIFF)
- Others use world (ASCII) files (.tfw)
- Origin of an image is ul (row values increase downward), of a coord system ll

```
20.17541308822119 - A
0.00000000000000 - D
0.00000000000000 - B
-20.17541308822119 - E
424178.11472601280548 - C
4313415.90726399607956 - F
```

```
A = x-scale; dimension of a pixel in map units in x direction
B, D = rotation terms
C, F = translation terms; x,y map coordinates of the center of the upper left pixel
E = negative of y-scale; dimension of a pixel in map units in y direction
```

Critical Points in Working with Raster Data

- Noise, false colors, mixed colors
- Object separation / identification
- Neighborhoods for Morphology operators
- Assignment and coding
- Edges, contours and transitions between objects and background (blurring)