Chapter 2. Mapping GIS Data

Objectives:

- Understanding **map scales** and GIS data scaling issues
- Knowing **types of attribute data** and the maps created from each
- Understanding how to **classify** numeric data
- **Displaying** raster images
- Understanding how **map documents** save and represent data

What is a Map?

Definition of Maps:

•A graphic depiction on a flat medium of all or part of a geographic realm in which real world features have been replaced with symbols in their correct spatial location **at a reduced scale**.

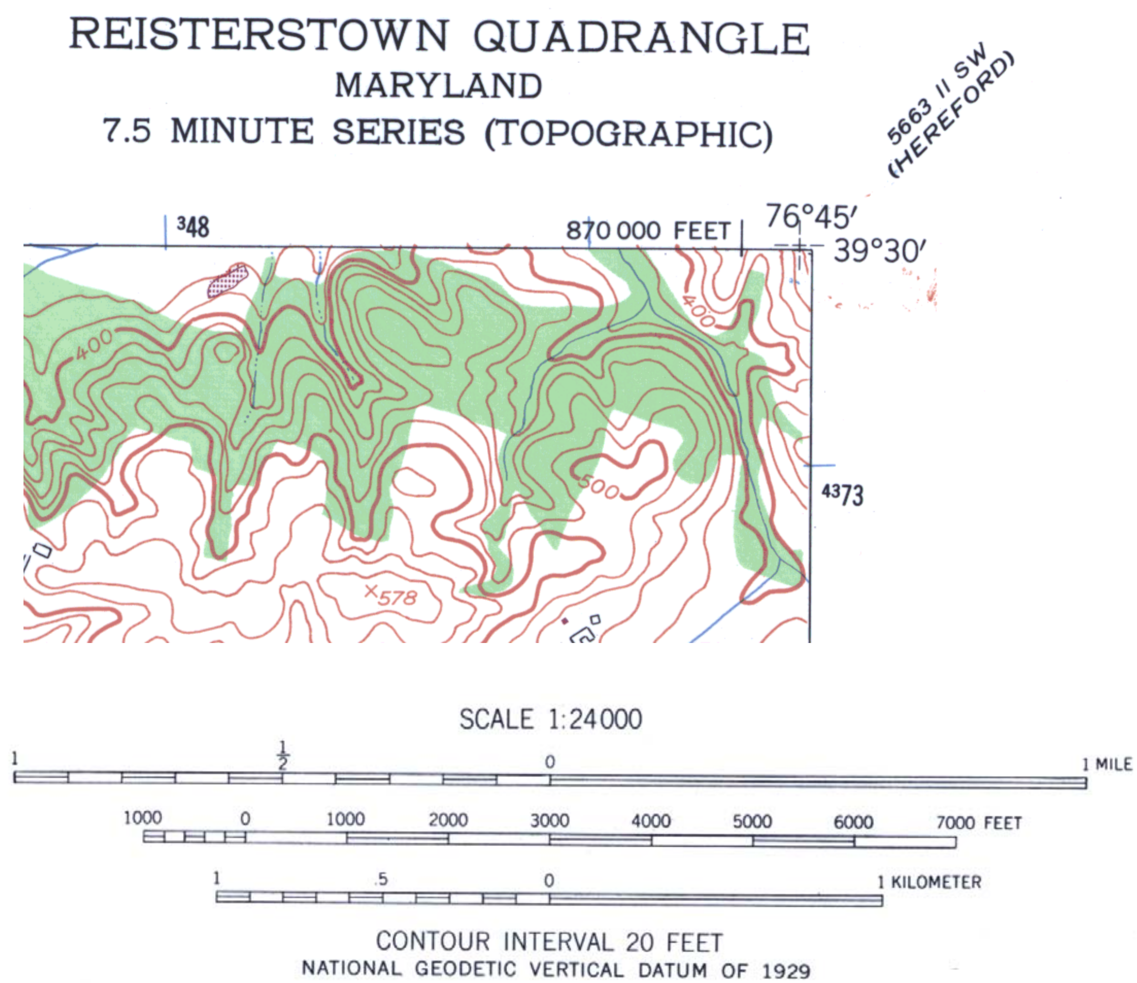
•To map is to transform information from one form to another --- Mathematics

•Earth surface —map→ Paper --- Geography

Scale

- Scale is a way to **quantify** the **size relationship** between the real world and the map
- But the notion of scale goes beyond simply the issue of the size at which features are portrayed, and is one of the most important concepts in geography because of its **effects on analysis**
  - It affects nearly **all aspects** of geographic data and GIS
  - A GIS is **scaleless** in the sense that maps can be **enlarged and reduced** and plotted at many scales other than that of the original data.
  - To **compare** maps in a GIS, **both** maps **MUST** be at the **same scale** and have the **same extent**.

USGS Topo Map Title and Scale



Representing Scale on Maps

Definition:

The scale of a map is **ratio** between distances on the map and the corresponding distances in the real world.

Scale representation on the map:

- Representative fraction (RF): 1:100,000, 1 to 100,000, or 1/100,000
- Verbal: 1 inch is equal to 50 miles
- Graphic: Scale bar   10 miles

Purpose (or a kind of question that scale can answer):

- Scale information allows us to answer questions like: 1 inch on a 1:24000 map represents what distance on the surface of the Earth?   (2000 feet)

General Classification of Scale

- Remember that the notions of small and large are **reversed** from our conventional thinking when we talk about scale → **large scale** refers to looking at a **smaller area** in detail, and this makes sense because the **representative fractions** are larger:
  - – Large scale → 1:400 to 1:50,000
  - – Intermediate scale → 1:50,000 to 1:250,000
  - – Small scale → 1:250,000 and beyond
- Even these are just guidelines … we might refer to large or small scale **in a given context** (the categories given above are for the full range of mapping, from local to global), or we might use these terms in a relative sense

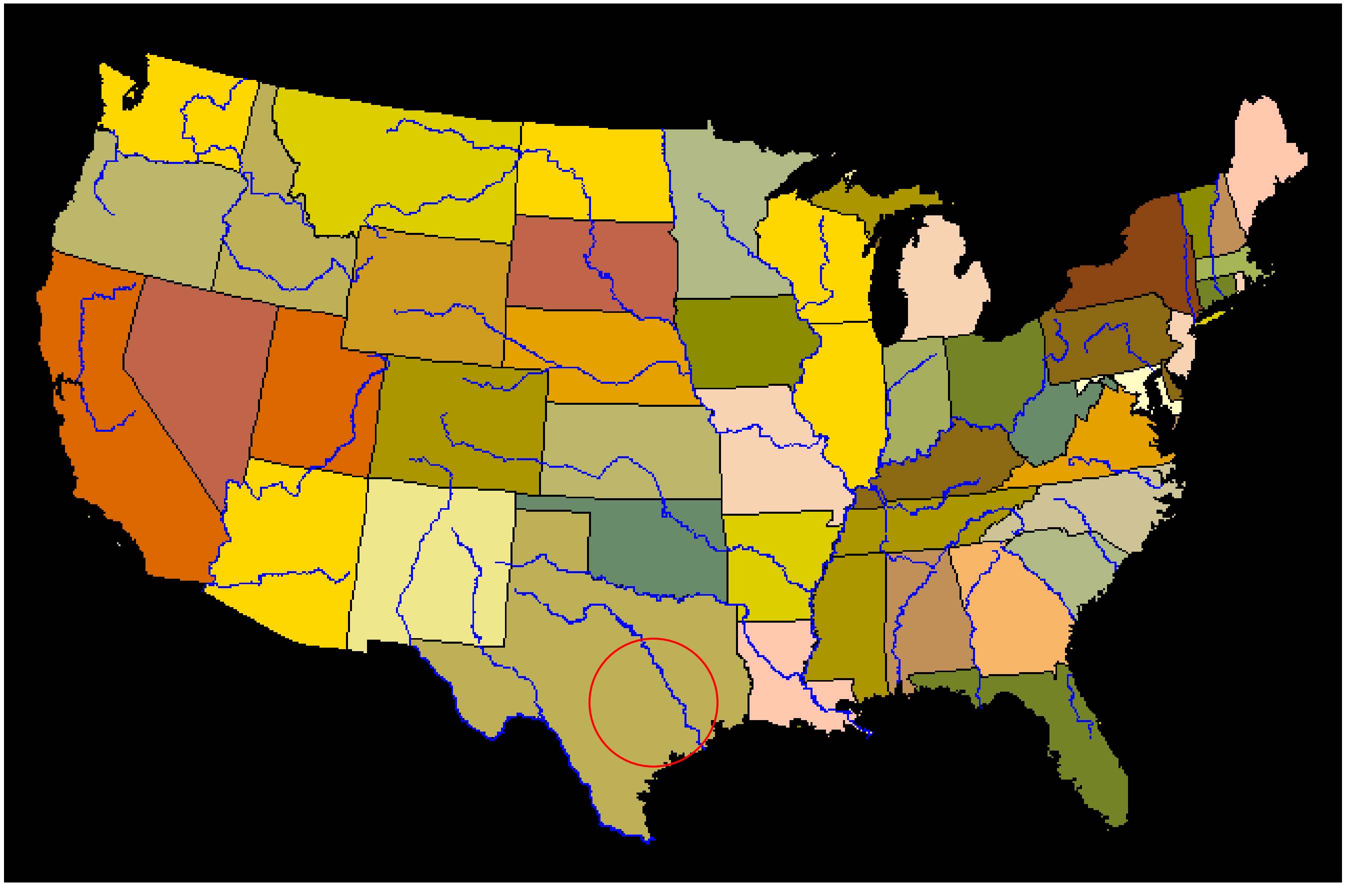
Map Scale and GIS

- GIS is **scaleless**, in the sense that the onscreen representation of a GIS is **far less limited** by the considerations associated with map representations (i.e. you can resize your *View* to any scale you'd like, although there are resolution limitations imposed by the minimum unit of display, a pixel)
- Thus, data captured at a certain scale can be **scaled** (multiplied up or reduced down) **freely** in a GIS, potentially **not respecting** the **limitations** associated with the scale at which the data was created

Map Scale and GIS

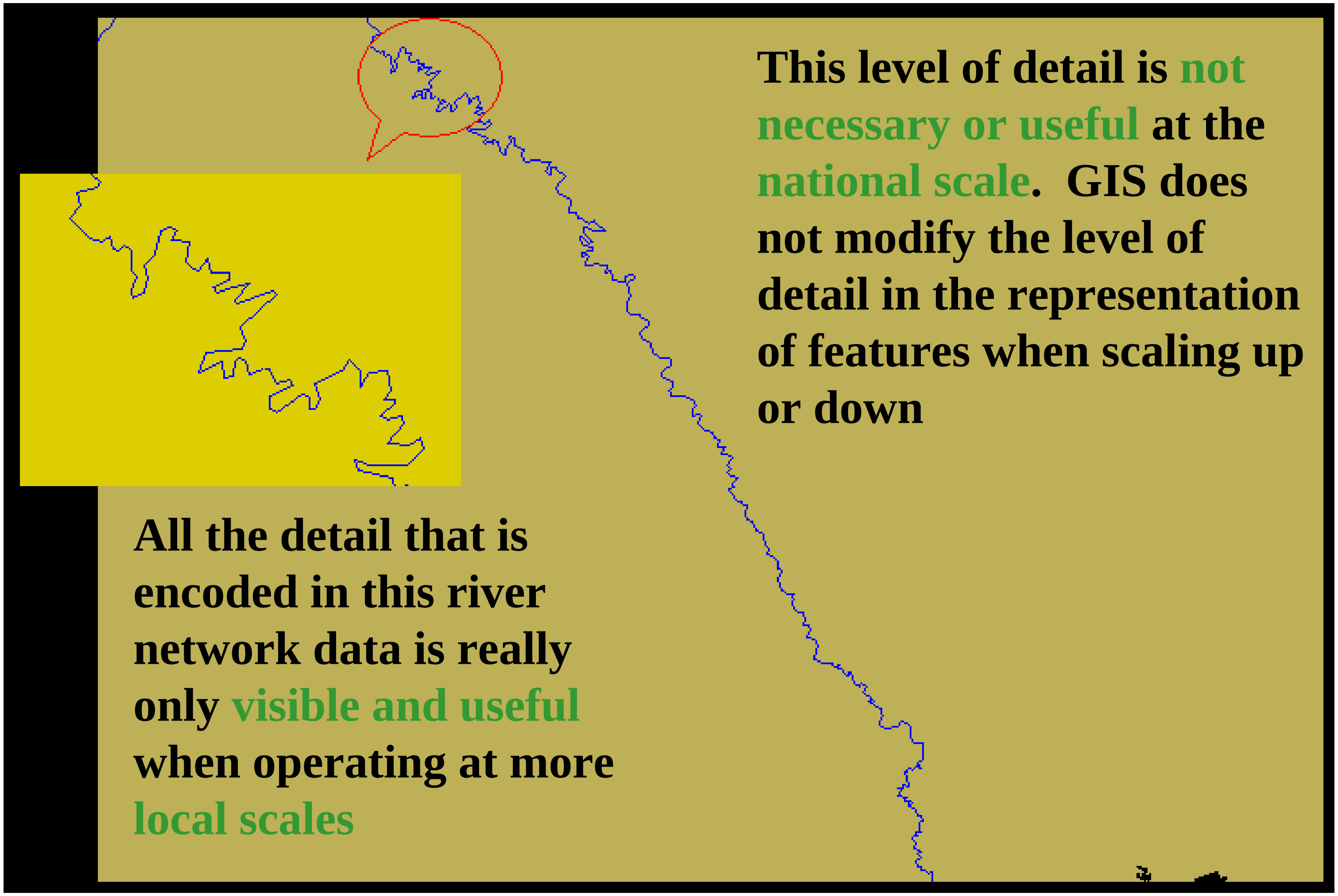
- When we **freely scale data** captured at a certain scale in a GIS, we can run into **problems** if we go **too far in either direction**:
- If we **reduce** a map's scale too much, the map becomes **too information-dense** to be useful, because the detail can no longer be displayed
- If we **enlarge** a map produced at a small scale too much, we can see the **lack of detail** as a result of the data's **scale of production**
- Representation of data at an **appropriate scale** is one the most important goals of cartography

Maps and GIS - Scaling Up



- The river network shown here on a national scale was produced at a **much larger scale**, and it contains a great deal of **detail** that **cannot be seen here** … zooming in …

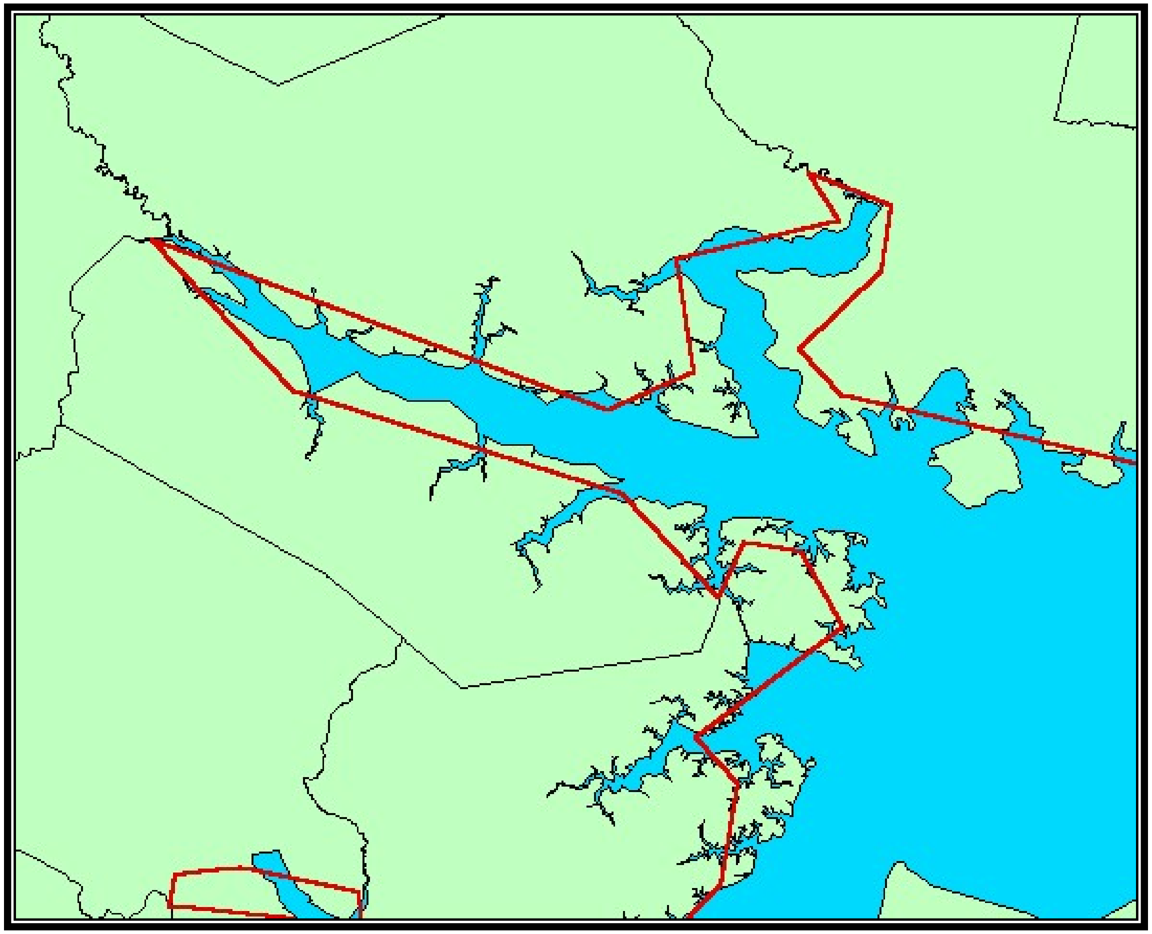
Maps and GIS - Scaling Up



Maps and GIS - Scaling Down

- Scale affects both the precision and accuracy of geographic information's representation of reality
- The **scale** at which data is collected / produced at affects the amount of **generalization** inherent in vector data objects' representation
- **Large-scale** data contains **more detail** than small-scale data
- When using **small-scale data** at an extent or for a purpose that is **larger-scale** than it was intended for can reveal a different kind of problem …

Maps and GIS - Scaling Down



- Here we can see a national scale coastline (shown in red) superimposed over local scale data, we can clearly see the **generalization** and **lack of detail**

Choosing a Map Type

- Cartographers have designed **hundreds of map types**: methods of cartographic representation.
- Not all GISs **allow** all types.
- Most have a set of **basic** types
- Depends heavily on the **dimension of the data** to be shown in the map figure.

Choosing Map Types

- **Check** the data
  - Continuous vs. Discrete
  - Accuracy & Precision
  - Reliability
- **Dimension** (Point, Line, Area, Volume)
- **Scale of Measurement** (Nominal etc.)
- What types is your GIS **capable** of creating
- May need to **supplement** GIS software

Scales of Measurement

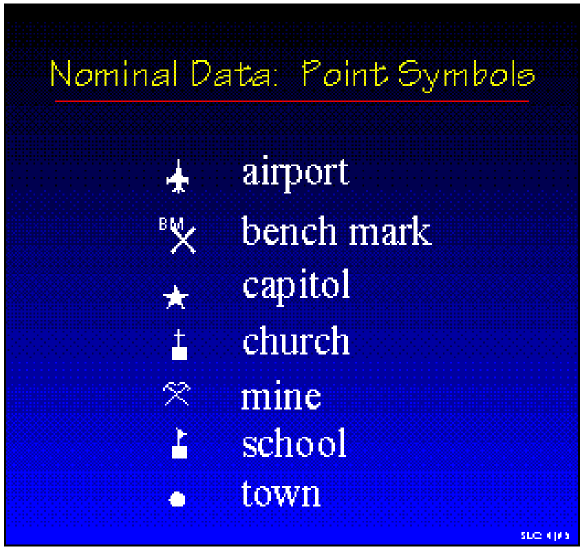
- **Thematic data** can be divided into four types

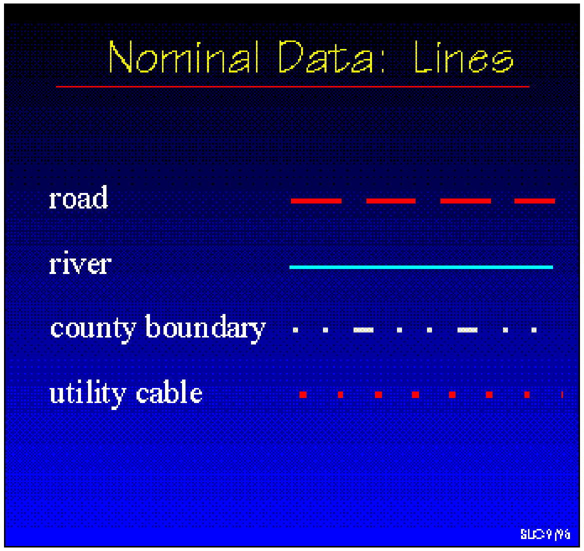
1. The Categorical Scale
2. The Ordinal Scale
3. The Interval Scale
4. The Ratio Scale

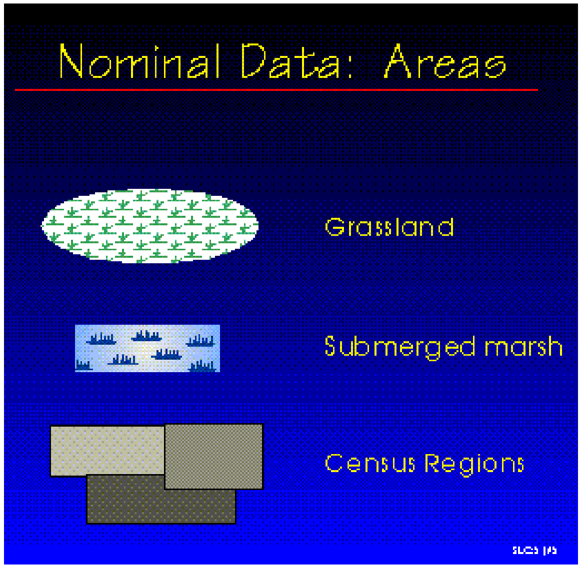
As we progress through these scales, the types of data they describe have increasing information content

The Categorical Scale

- **Categorical data** - information that is simply grouped into categories on the basis of qualitative considerations
  - Example: Place names

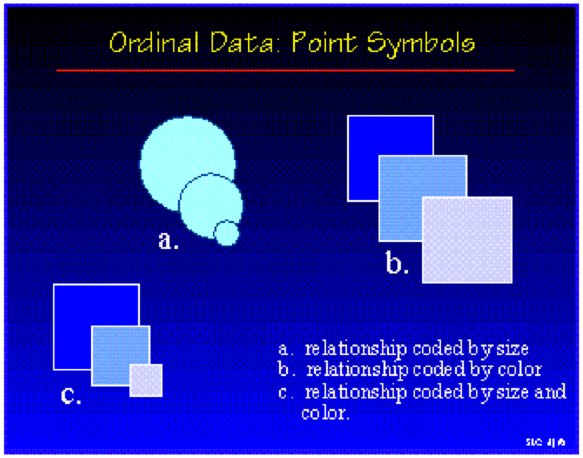


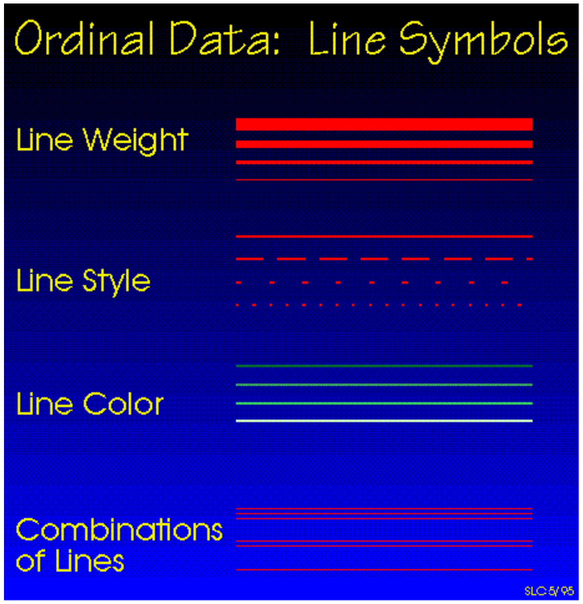


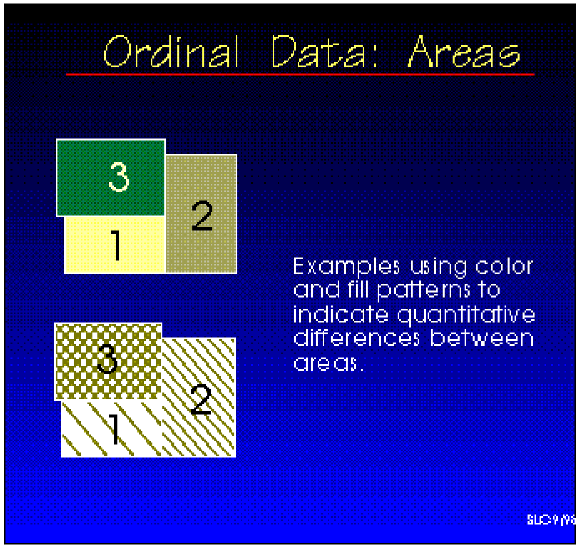


The Ordinal Scale

- **Ordinal data** - grouped by rank on the basis of some quantitative measure
  - Example: Small, medium and large towns







The Interval Scale

- **Interval data** - information that can be arranged using a standard scale along which operations of addition and subtraction have meaning
  - Example: Temperature is an interval measure

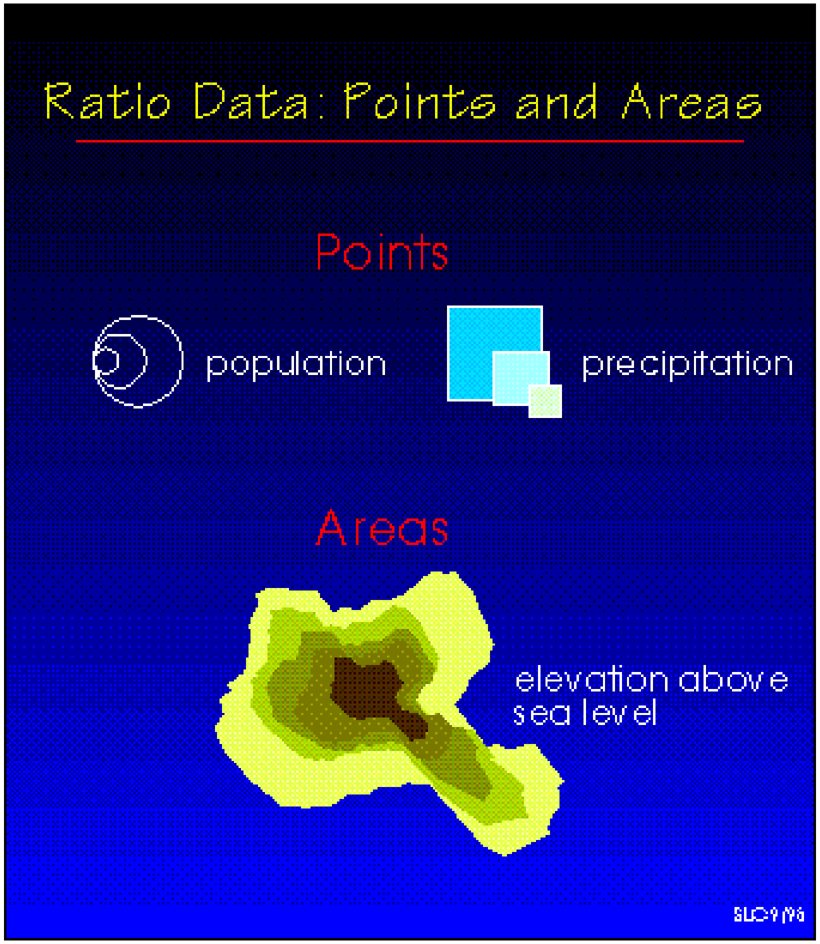
- Interval data is one type of continuous data

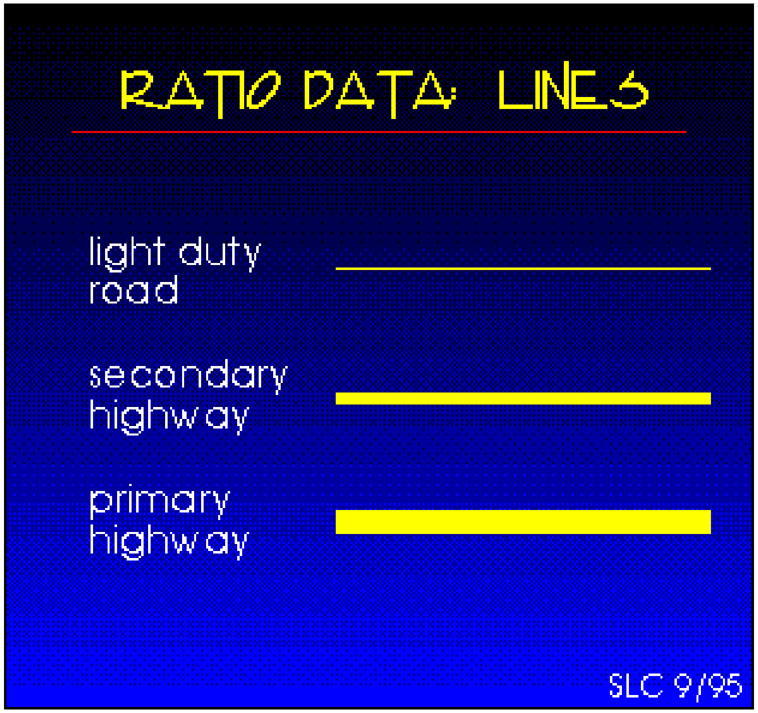
The Ratio Scale

- **Ratio data** - other type of continuous data that can be arranged along a scale but, in addition, the scale begins at a non-arbitrary zero point
  - At the zero point, no features are present
  - Multiplication and division can be employed with ratio data to consider proportions and magnitudes
  - Examples: Elevation above sea level, precipitation, population

The Ratio Scale

- **Ratio data**

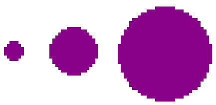




Data Symbolization

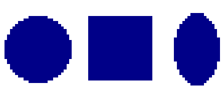
- There are a number of characteristics of symbols that we can use of to make **visual distinctions** in **thematic information** (Jacques Bertin's **Visual Variables**):
  - Size
  - Shape
  - Color Hue (color)
  - Color Value (intensity)
  - (Texture)
  - (Orientation)
  - (Arrangement)

Data Symbolization



Size → Graduated & proportional symbol maps

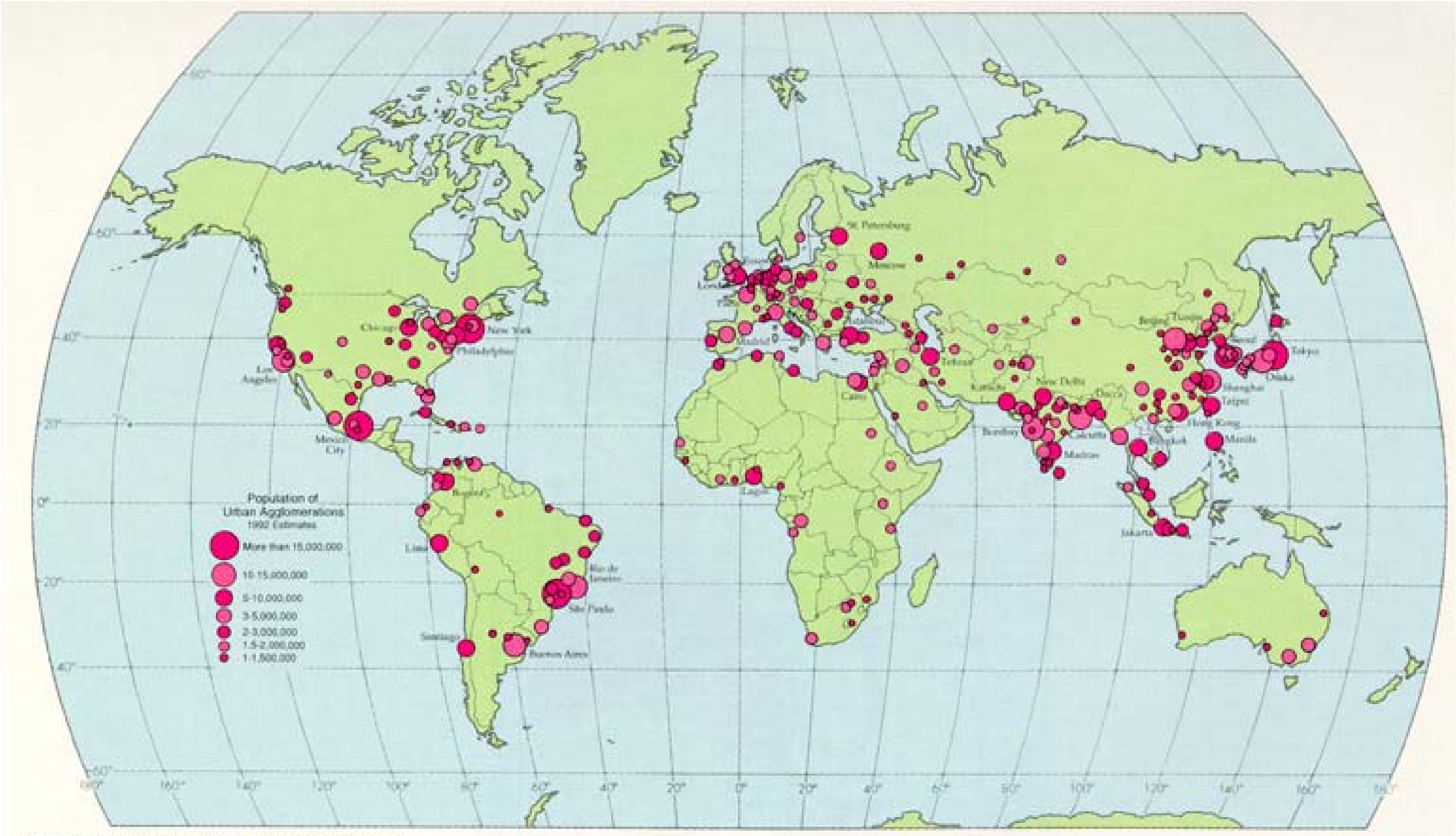
- difference in dimensions of symbols
- useful for ordinal, interval, & ratio data; bad for categorical
- convention: larger size = greater quantity



Shape

- differences in forms of symbols can be abstract and "geometric", or iconographic
- useful for categorical data; bad for for ordinal, interval, & ratio
- too many shapes = cluttered & difficult for map reader to discriminate

Graduated Symbol Maps



World Metropolitan Areas of 1 Million or More
Figure 12.3

Data Symbolization

Color Hue (color) → Area-class Maps

- differences in wavelengths of light reflected (or emitted, in the case of computer monitors)
- useful for categorical data, can be used for ordinal & interval/ratio data but is tricky
- perceptual difficulties for some map readers is a problem (e.g. 6-8% males color-blind)

Color Value (intensity) → Choropleth Maps

- relative lightness or darkness of symbols
- useful for ordinal, interval, & ratio data
- convention: darker = higher numerical values
- difficult for map readers to perceive more than four or five values

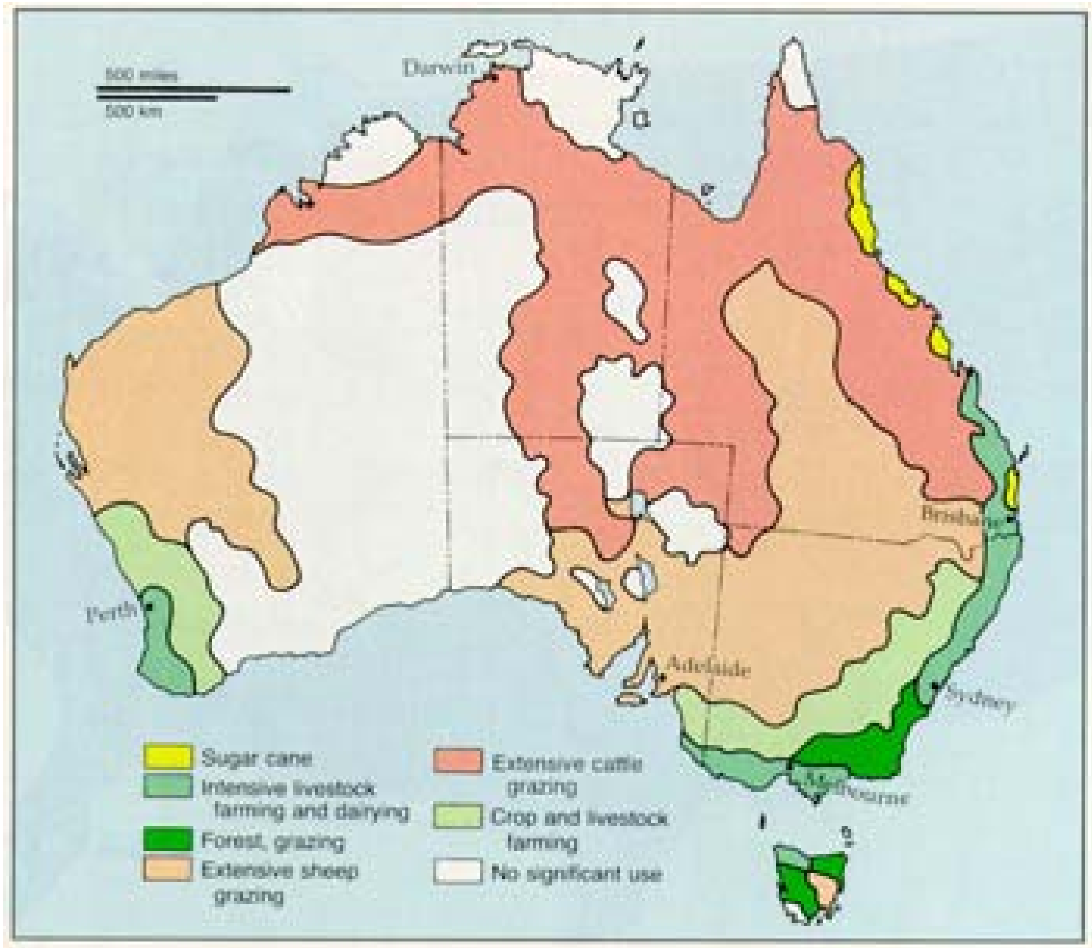
Area-class Maps

- Represent **continuous areas of attribute data**

Some **examples** of such data include:

- landuse
- vegetation
- climate zones

-Boundaries determined **by variation of the attribute** being mapped



Formal Regions
Figure 1.11

Area-class Maps

- Represent **continuous areas of attribute data**

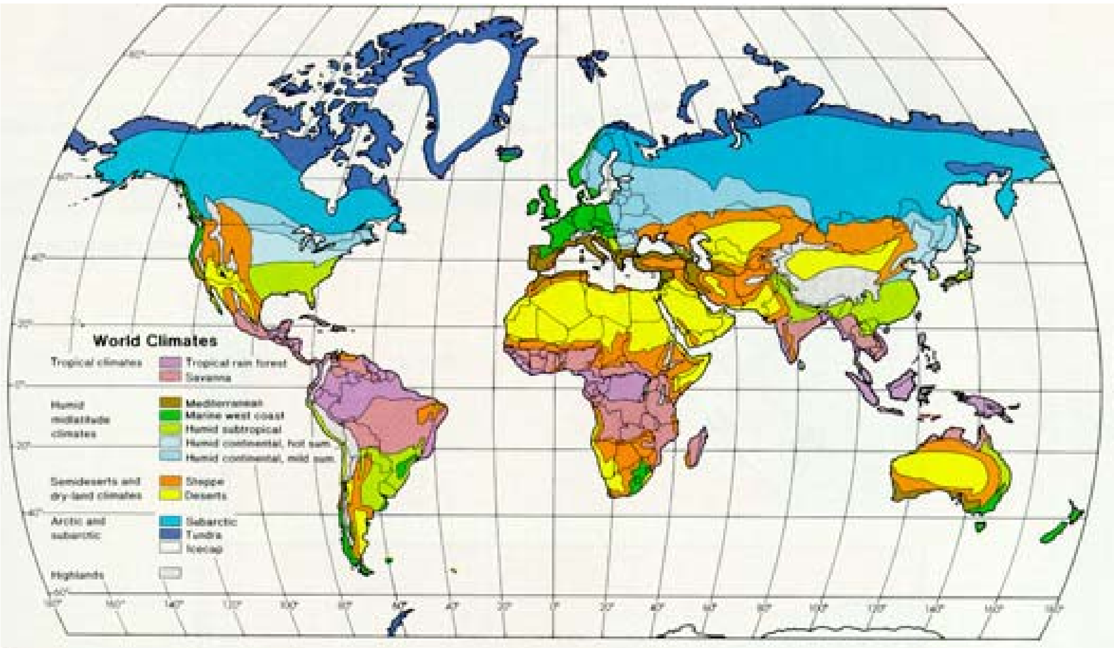
Some **examples** of such data include:

• landuse

• vegetation

• climate zones

-Boundaries determined **by variation of the attribute** being mapped



Climates of the World
Figure 4.29

Choropleth Maps

- Use of **reporting zones** (areal units)

- Zones are **independent** of data

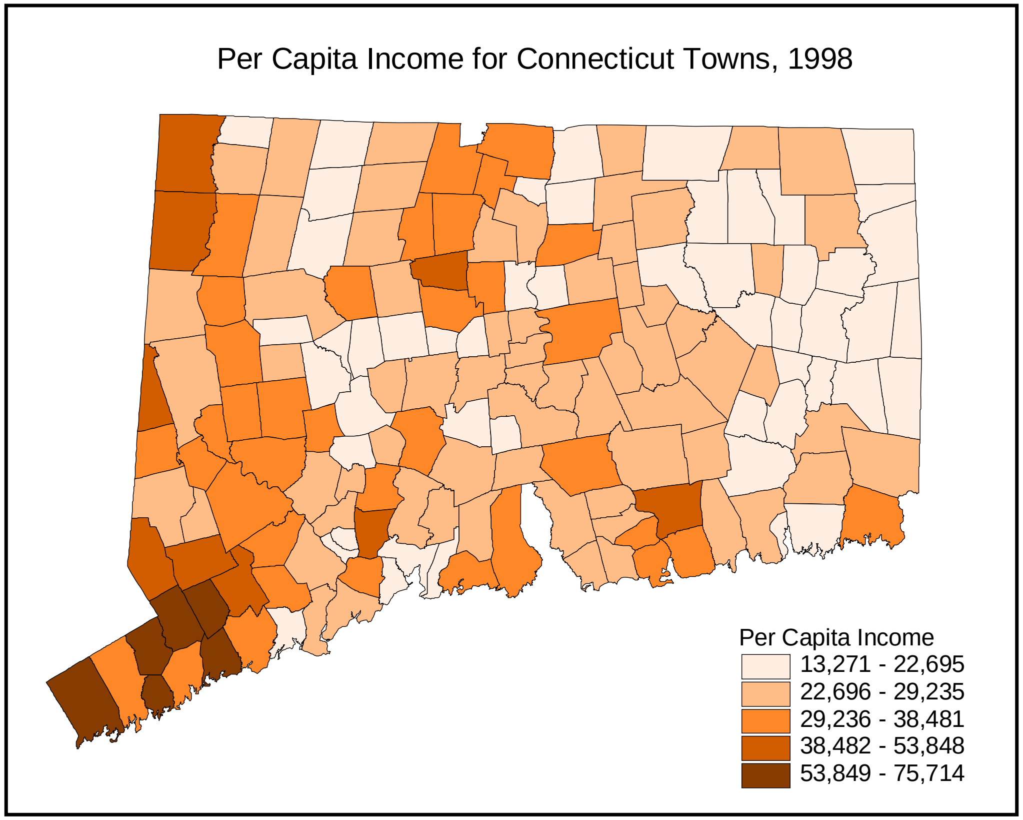
- Types of attributes:

• population density

• mortality rates

• average income

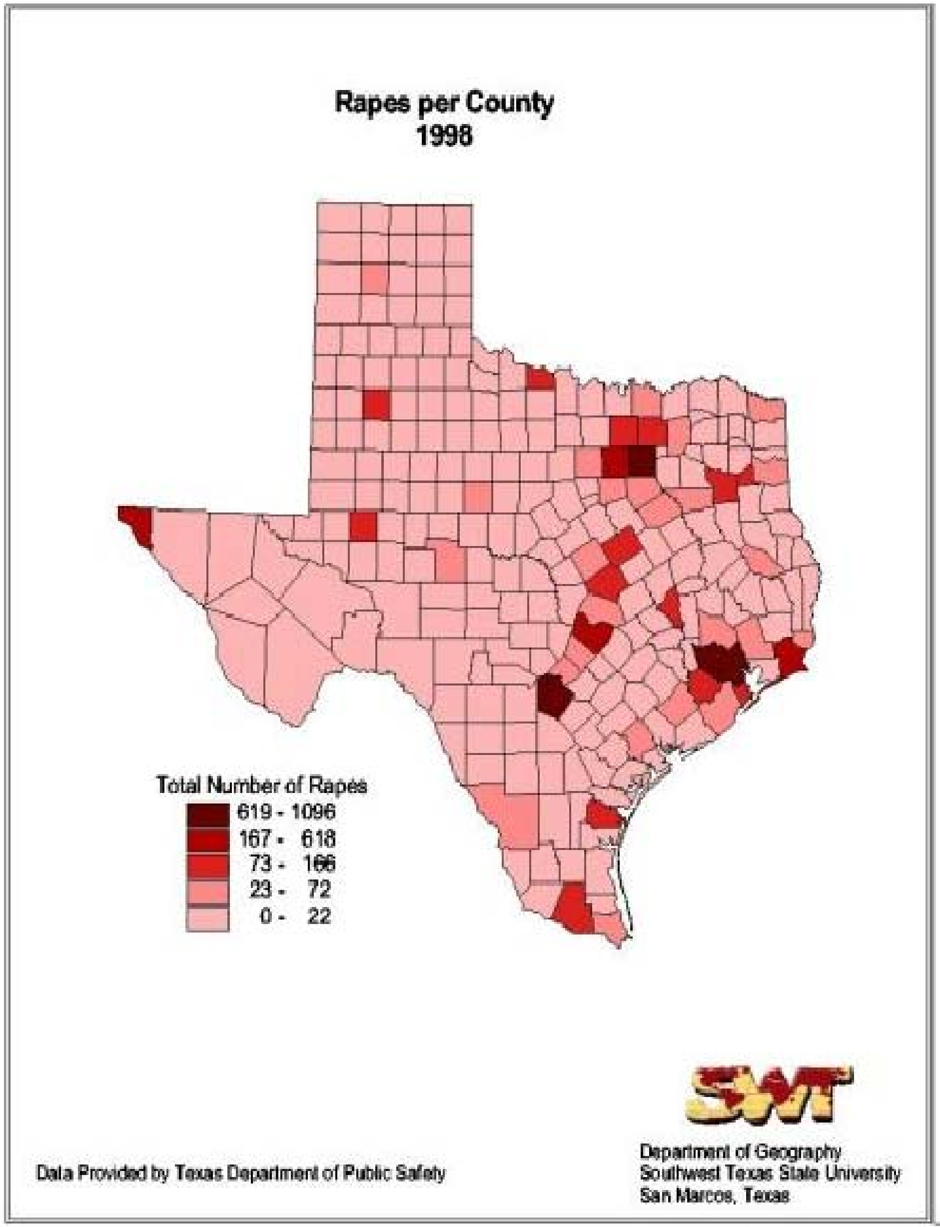
*** Absolute counts **are not suitable** (i.e. total population)

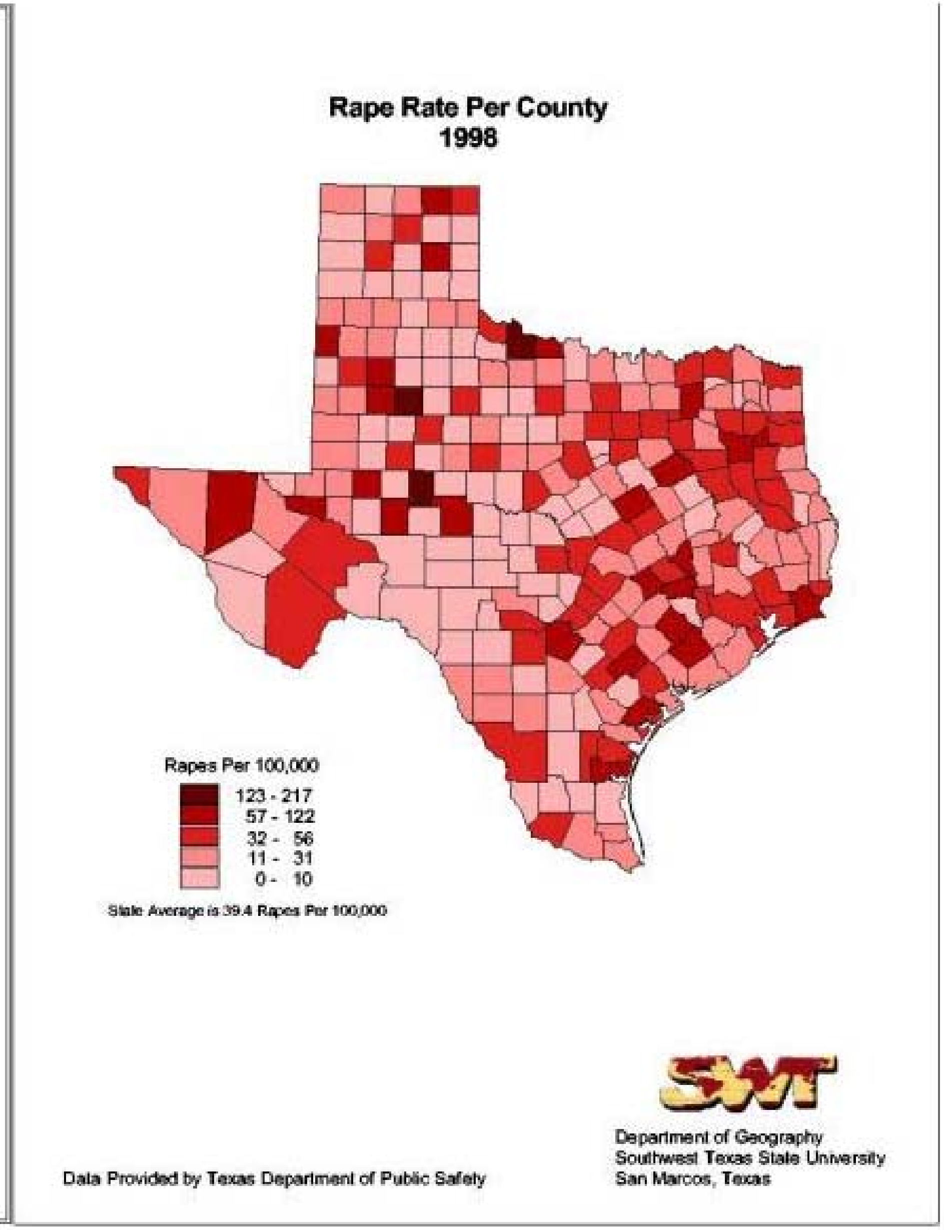


Choropleth Maps

- Greek: choros (place) + plethos (filled)
- These are used to map categorical and quantitative data over defined areas
  - **polygonal enumeration units**

    e.g. census tract, counties, watersheds, etc.
- Data values are generally **classified** into ranges
  - allow map reader to readily interpret the map
- Polygons can produce **misleading** impressions
  - area/size of polygon vs. quantity of thematic data value


Rapes per County
1998
Total Number of Rapes
619 - 1096
167 - 618
73 - 166
23 - 72
0 - 22
Department of Geography
Southwest Texas State University
San Marcos, Texas
Data Provided by Texas Department of Public Safety

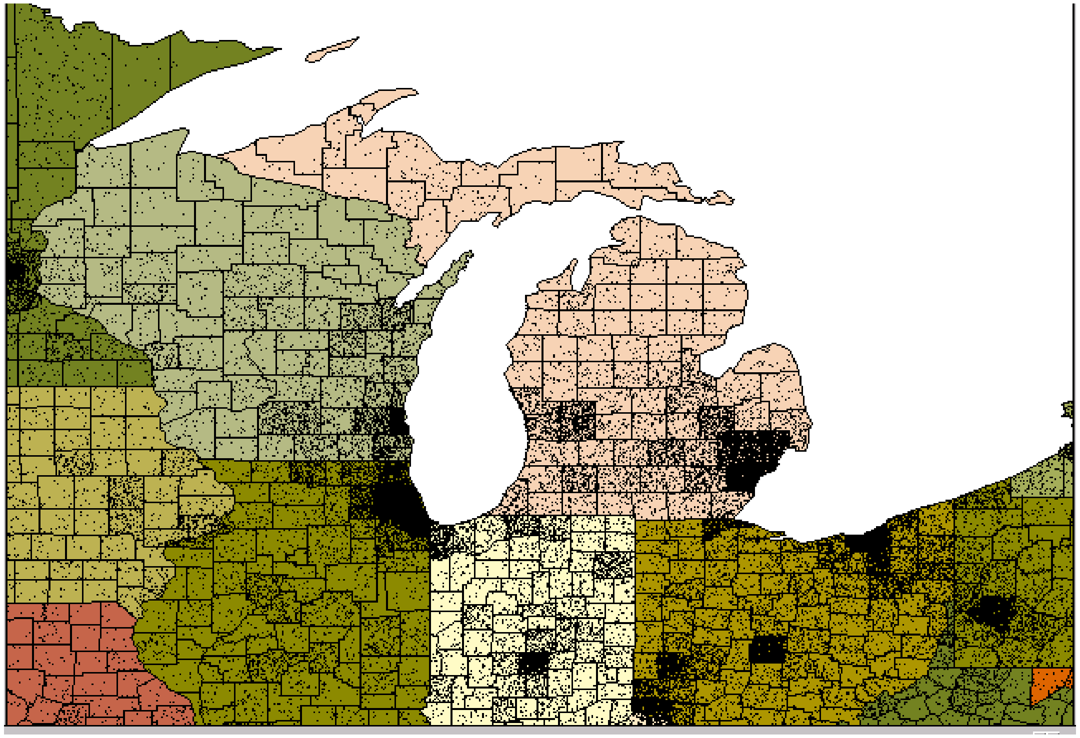

Rape Rate Per County
1998
Rapes Per 100,000
123 - 217
57 - 122
32 - 56
11 - 31
0 - 10
State Average is 39.4 Rapes Per 100,000
Department of Geography
Southwest Texas State University
San Marcos, Texas
Data Provided by Texas Department of Public Safety

Dot Density Maps

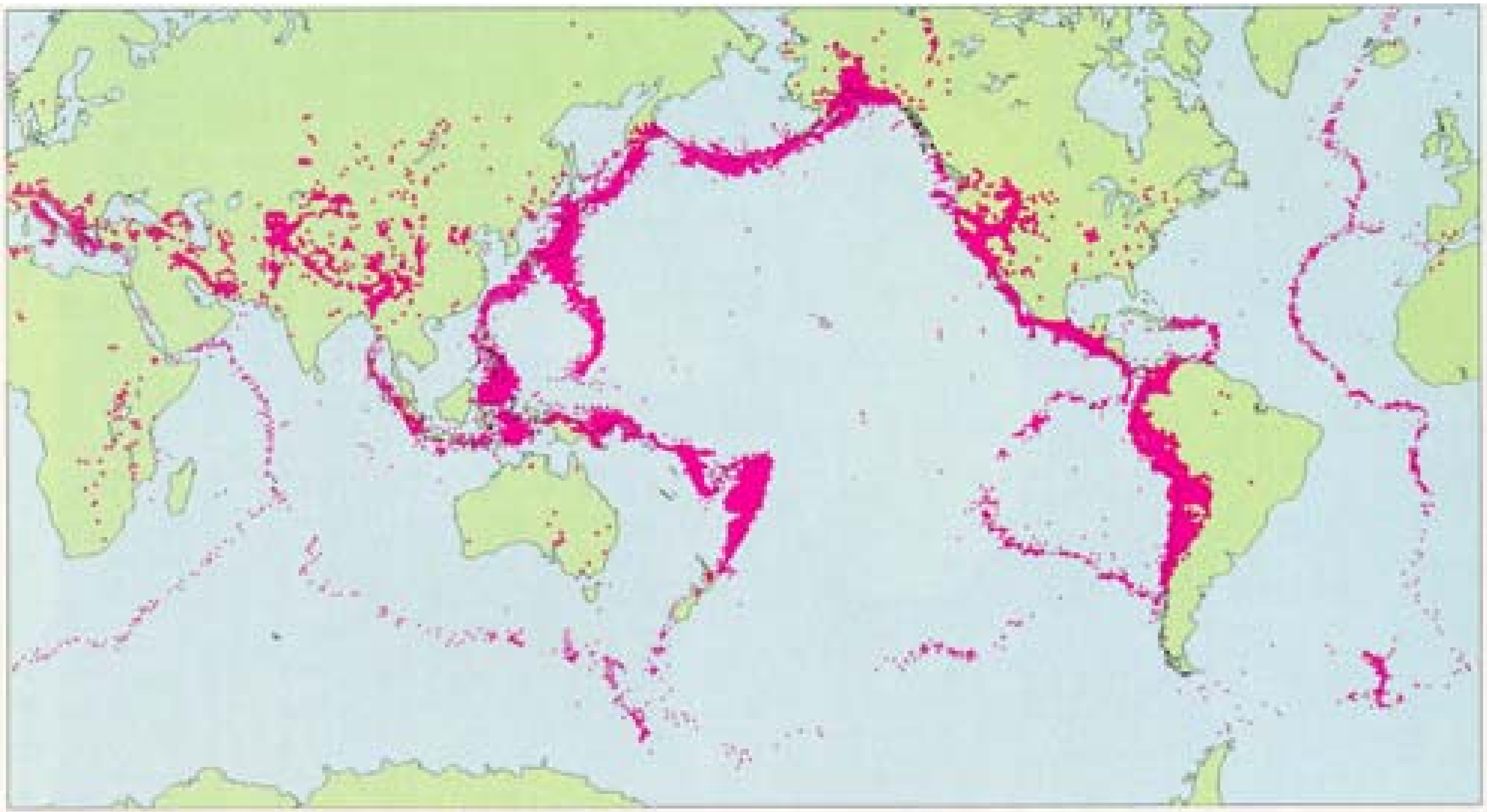
- Data is **represented as dots**

- Dots usually **represent a certain quantity** of something (1 dot = 100 persons)

- Dots **do not necessarily represent exact locations** of the data being represented



Dot Density Maps



World Earthquake Epicenters
Figure 3.6

Classifying Thematic Data

- Data values are **classified into ranges** for many thematic maps (especially choropleth)
  - This aids the reader's **interpretation** of map
- Trade-off:
  - presenting the underlying data **accurately**

    <u>vs.</u>
  - **generalizing** data using classes
- Goal is to **meaningfully classify** the data
  - **group features** with similar values
  - assign them the **same symbol**
- But how to **meaningfully** classify the data?

Creating Classes

- **How many** classes should we use?
  - too few - **obscures** patterns
  - too many - **confuses** map reader
    - difficult to recognize more than **seven** classes
- How do we **create** the classes?
  - assign classes **manually**: create meaningful classes, such as population above / below poverty level
  - **equal intervals**: This ignores the data distribution, which can be misleading too!

Creating Classes

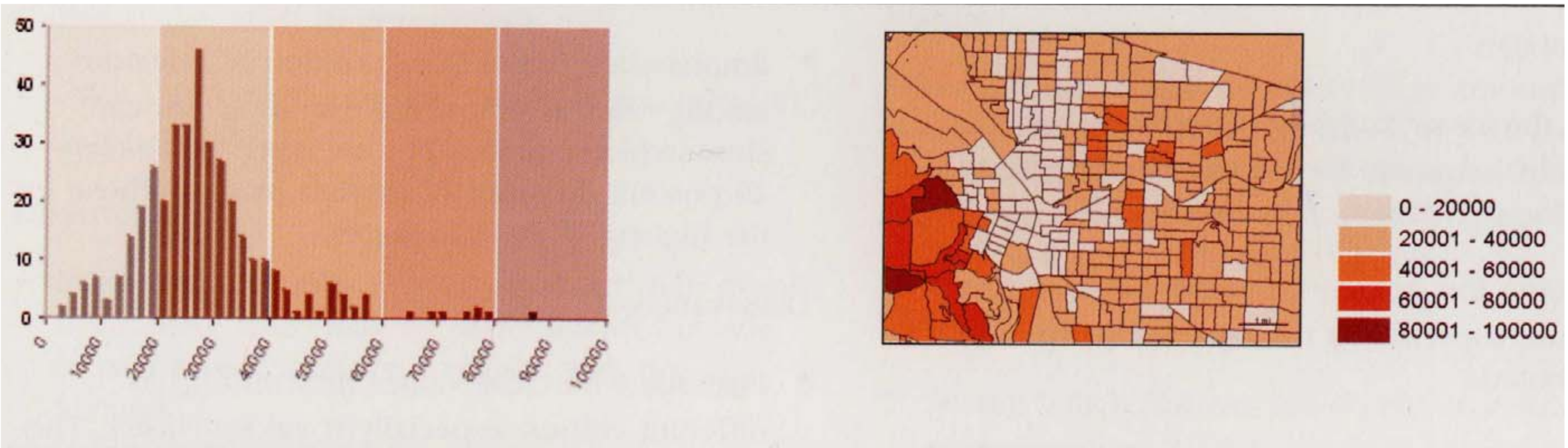
- How do we create the classes (cont.)
  - **"natural" breaks** based on data distribution: minimize within-class variation and maximize between-class variation
  - **quartiles**: top 25%, 25% above middle, 25% below middle, bottom 25% (quintiles uses 20%)
  - **standard deviation**: mean+1s, mean-1s, mean+2s, mean-2s, …

The Effect of Classification

- **Four common ways** to display continuous data in ArcGIS (i.e. these are options in Symbolization):
  - Equal Interval
  - Quantiles
  - Natural Breaks
  - Standard Deviation

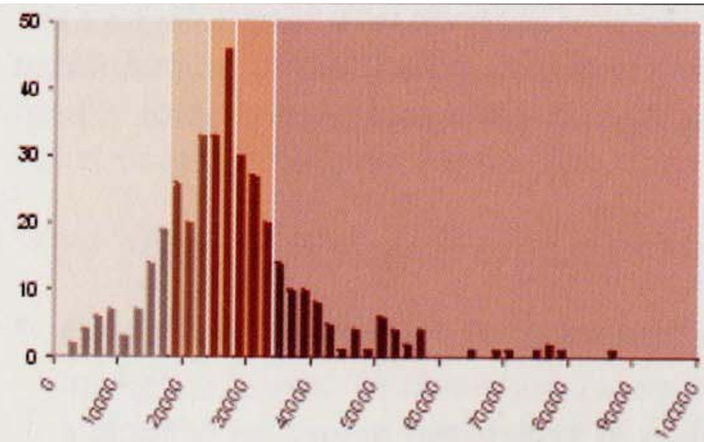
The Effect of Classification

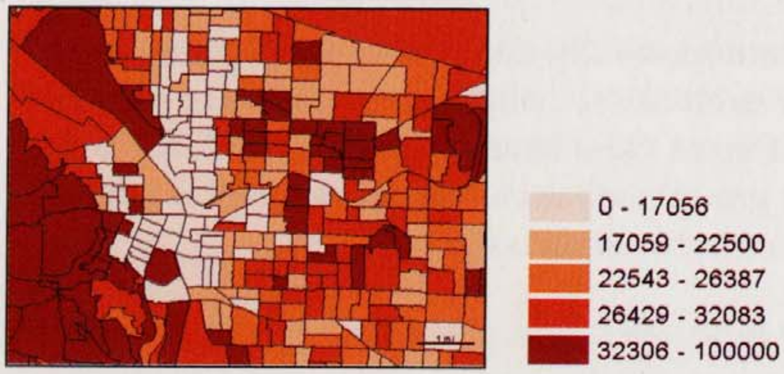
- **Equal Interval**
  - Splits data into user-specified number of classes of **equal width**
  - Each class has a **different** number of observations



The Effect of Classification

- **Quantiles**
  - Data divided so that there are an **equal number of observations** are in each class
  - Some classes can have quite **narrow** intervals





The Effect of Classification

- **Natural Breaks**
  – Splits data into classes based on **natural breaks** represented in the data histogram

The Effect of Classification

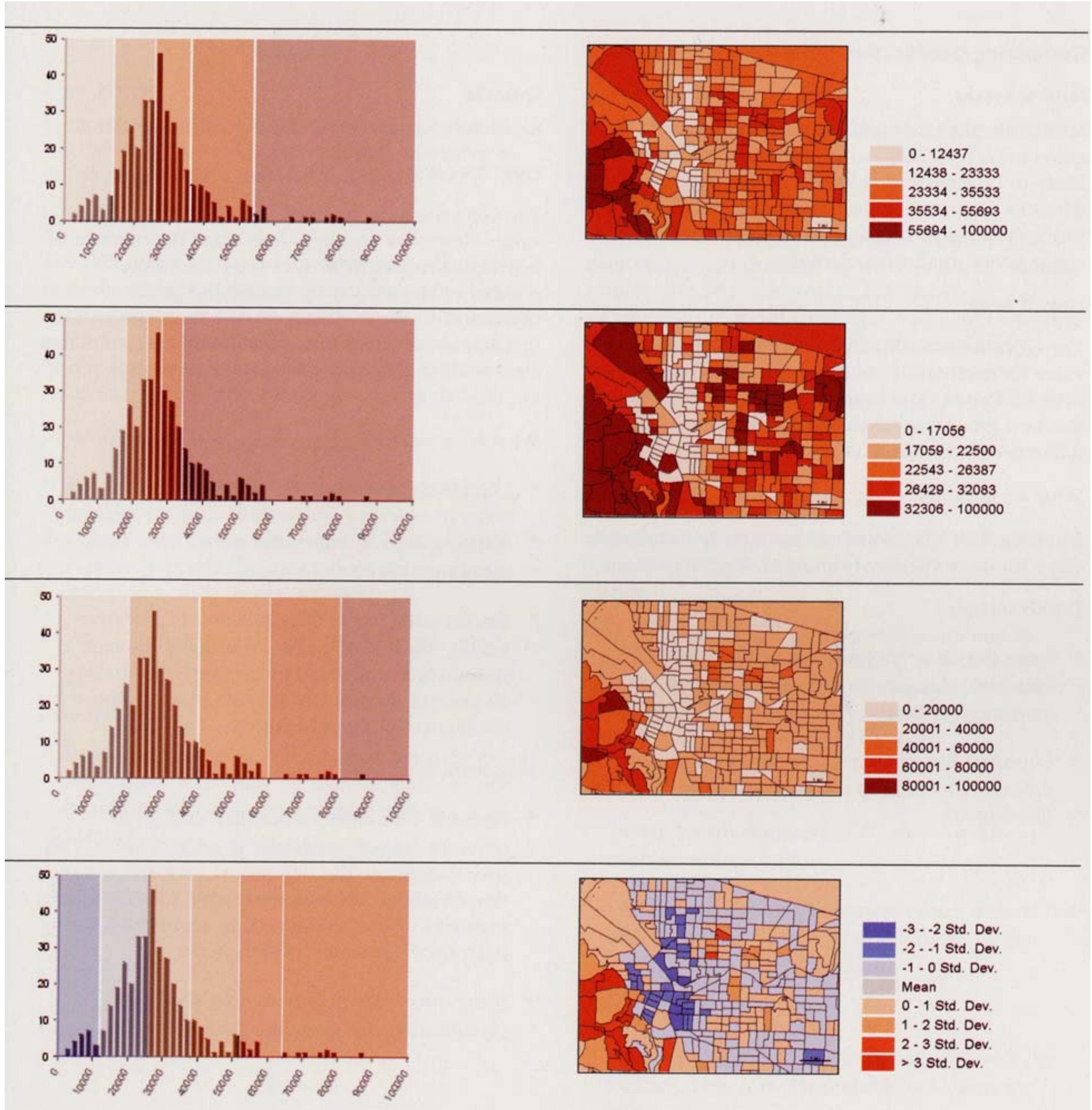
- **Standard Deviation**
  - Splits data into classes that represent values close to the mean and **increments of standard deviations** above and below the mean

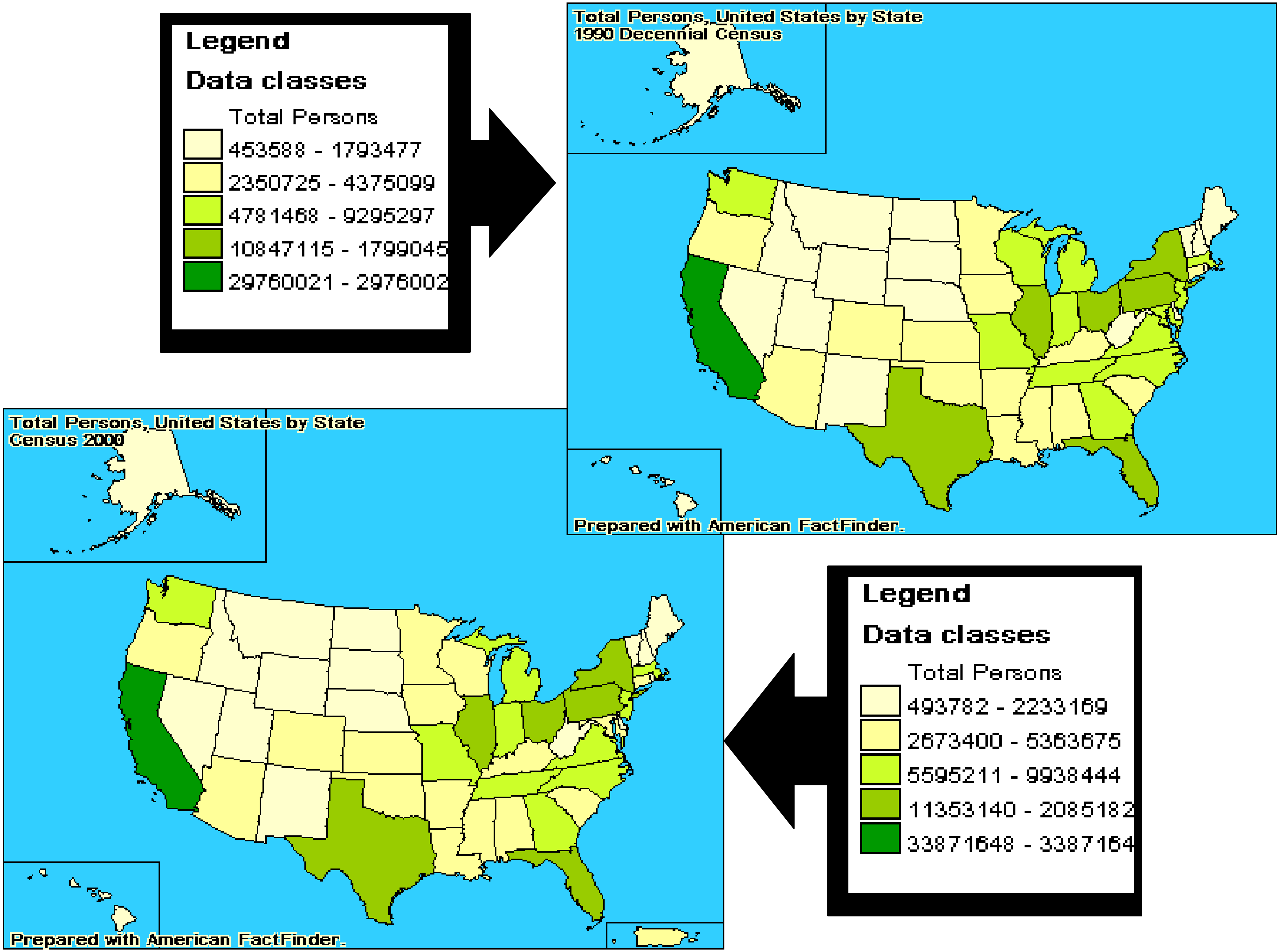
Natural Breaks

Quantiles

Equal Interval

Standard Deviation





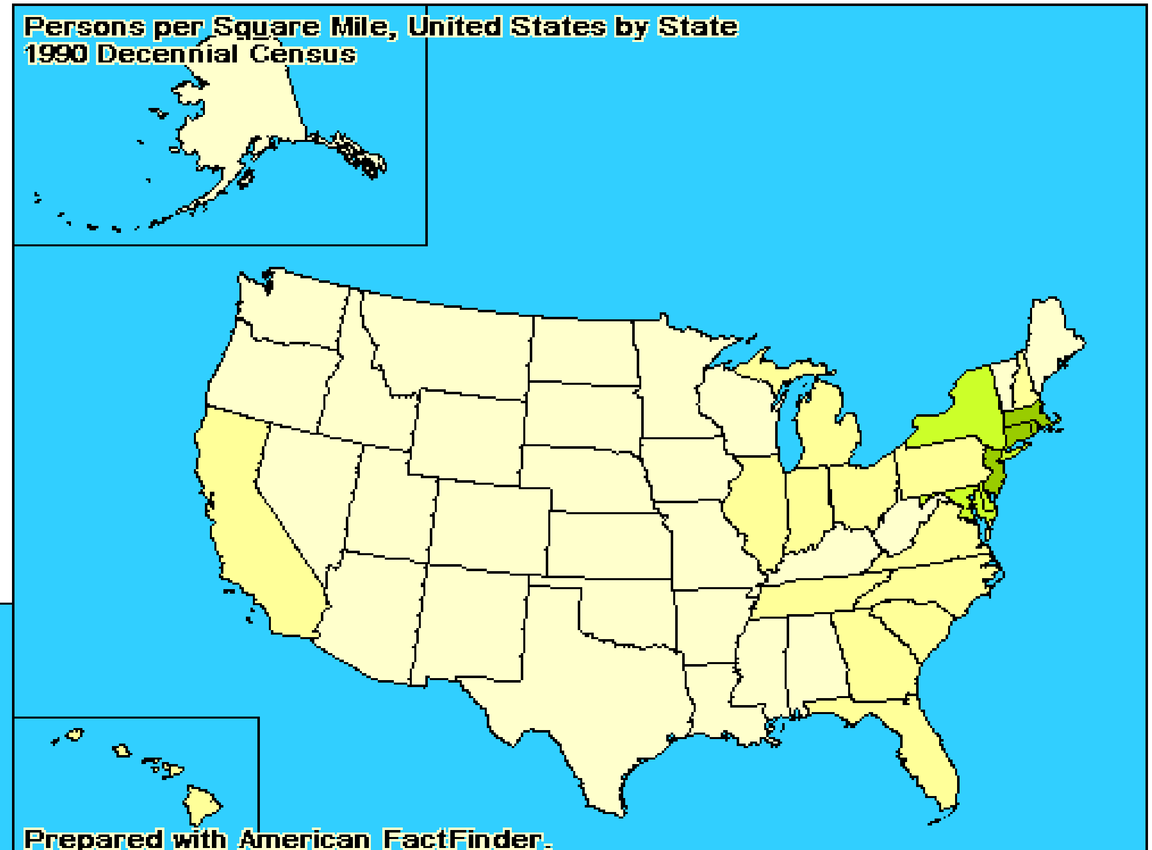
Legend
Data classes
Total Persons
453588 - 1793477
2350725 - 4375099
4781468 - 9295297
10847115 - 1799045
29760021 - 2976002
Total Persons, United States by State
1990 Decennial Census
Prepared with American FactFinder.
Total Persons, United States by State
Census 2000
Prepared with American FactFinder.
Legend
Data classes
Total Persons
493782 - 2233169
2673400 - 5363675
5595211 - 9938444
11353140 - 2085182
33871648 - 3387164

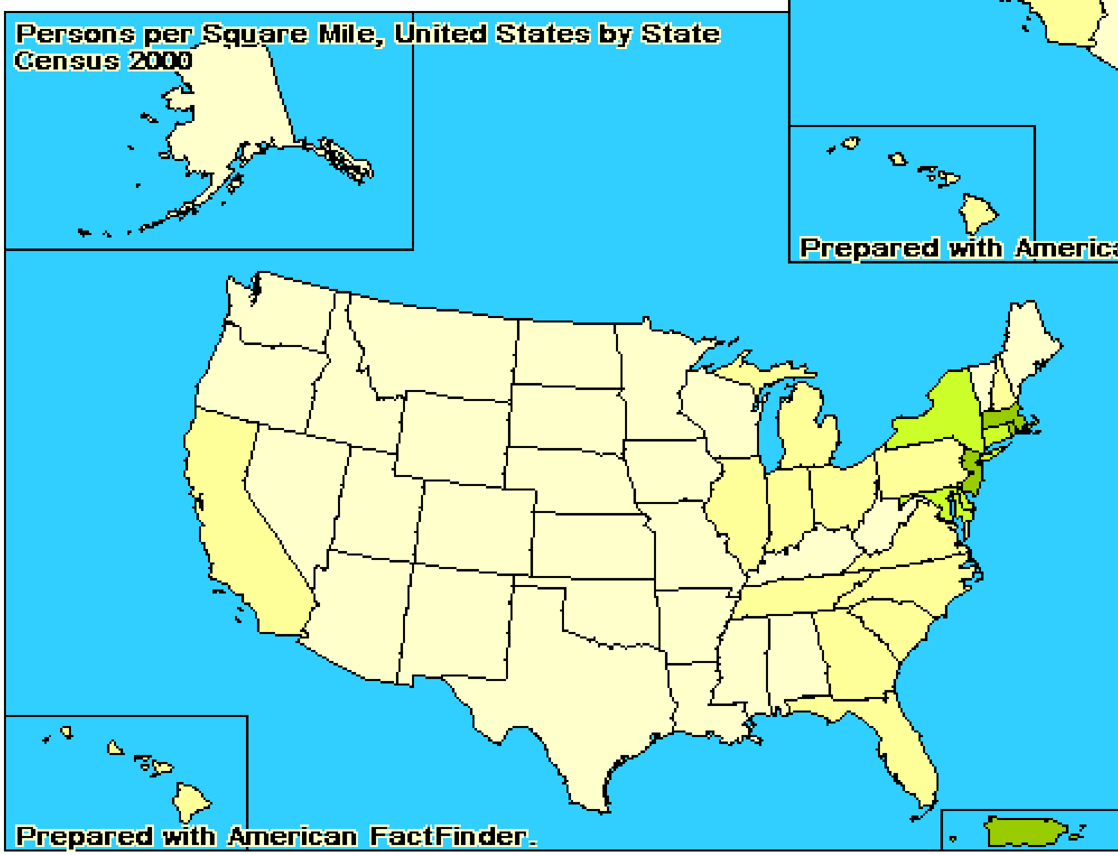
Legend

Data classes

Persons/Sq Mile

- 1 - 97
- 112 - 265
- 341 - 489
678 - 1042
9883 - 9883





Legend

Data classes

Persons/Sq Mile

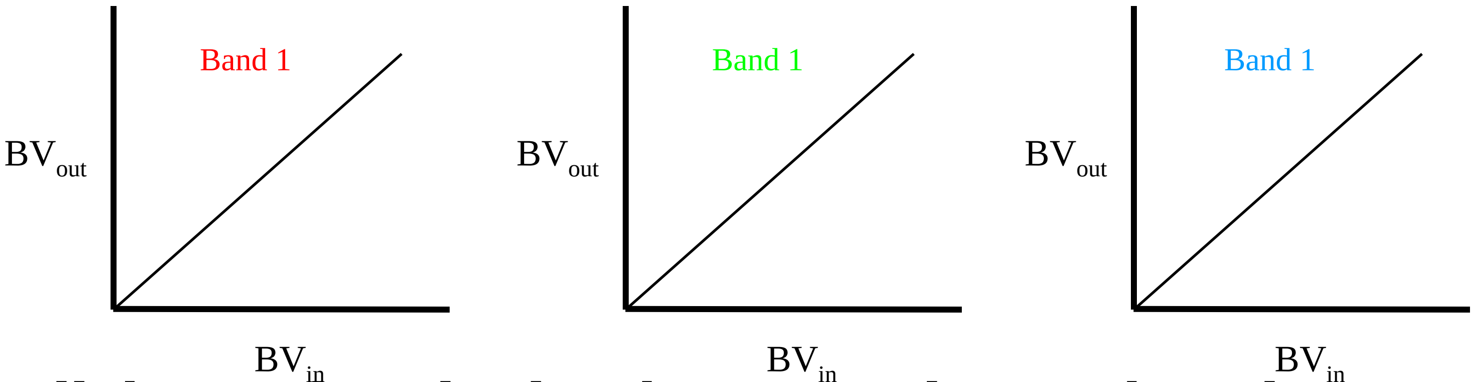
- 1 - 103
- 133 - 296
- 401 - 703
- 810 - 1134
- 9316 - 9316

Displaying Rasters

- **Two types** of raster data sets:
  - **Thematic rasters** → represent **quantities** like land use or rainfall, can be further subdivided into:
    - **Discrete thematic rasters** → **coded** values (cf. categorical data, area-class maps, displayed ideally using unique values)
    - **Continuous thematic rasters** → values that change **continuously** (cf. interval or ratio data, choropleth maps, displayed using either classified methods or stretched)
  - **Image rasters** → from aerial photography and satellite imagery, pixels represent **brightness** (displayed using a stretched or RGB composite method)

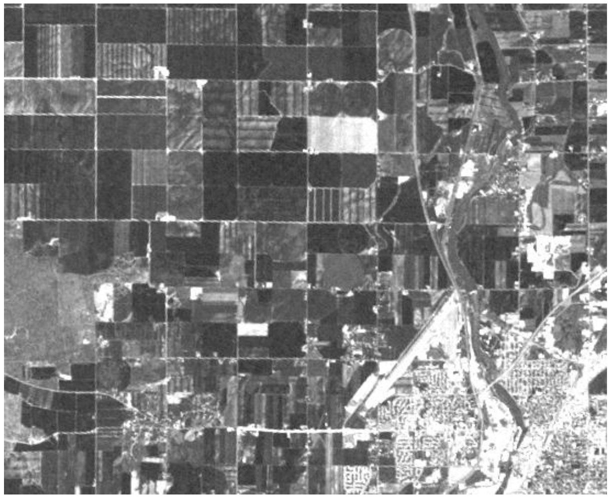
Image Raster Display - Stretched

- Assume that the In and Out brightness values are equal
- For a single band, the resultant color will be grayscale



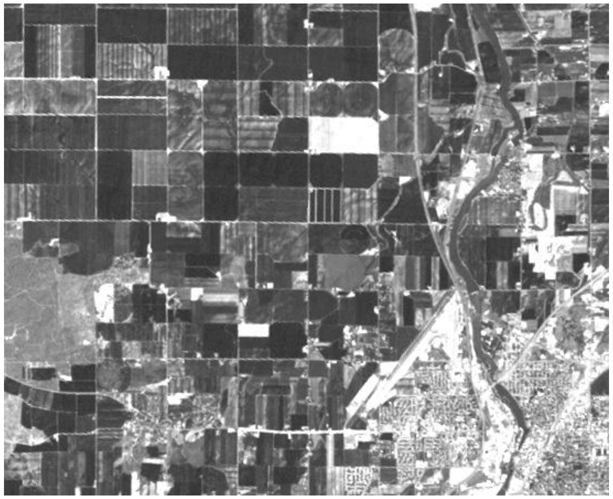
- All three colors display the same value, so the colors are shades of gray

Image Raster Display - Stretched



Band 1 - Blue

Band 2 - Green



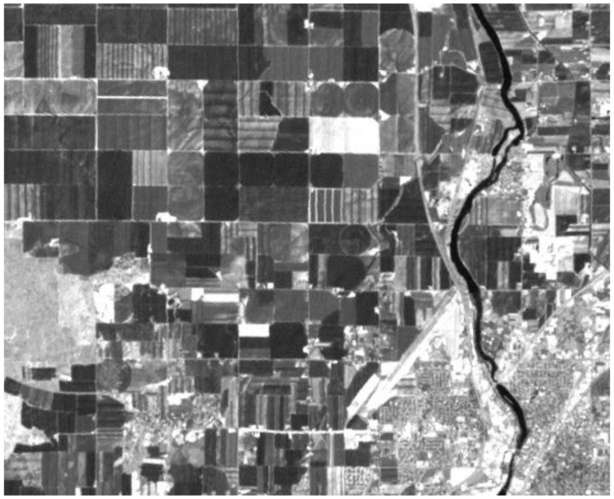
Band 3 - Red

Band 4 - NIR

Image Raster Display - Stretched

Band 5 - IR

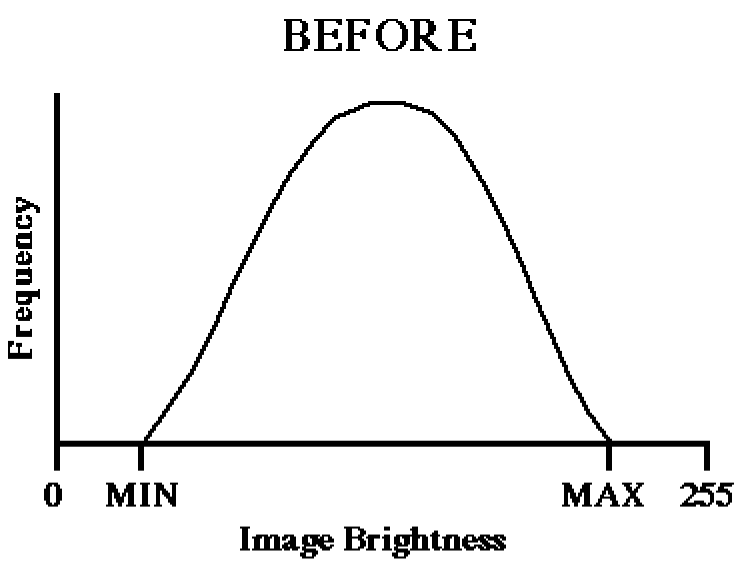
Band 6 - TIR



Band 7 - FIR

Image Raster Display - Stretched

- Contrast Enhancement - **"stretching"** all or part of the input BVs from the image data to the full 0-255 screen output range for better visual performance (i.e. we **maximize** the contrast so we can see the differences better)



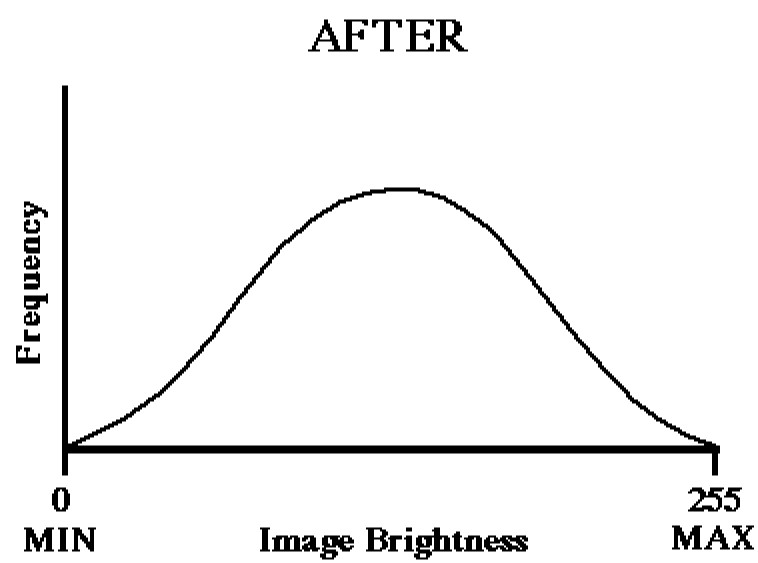


Image Raster Display - Stretched

- A **linear stretch** is one of the most common types of contrast enhancement
- The minimum BV is remapped to 0
- The maximum BV is remapped to 255
- E.g. given a certain band histogram:

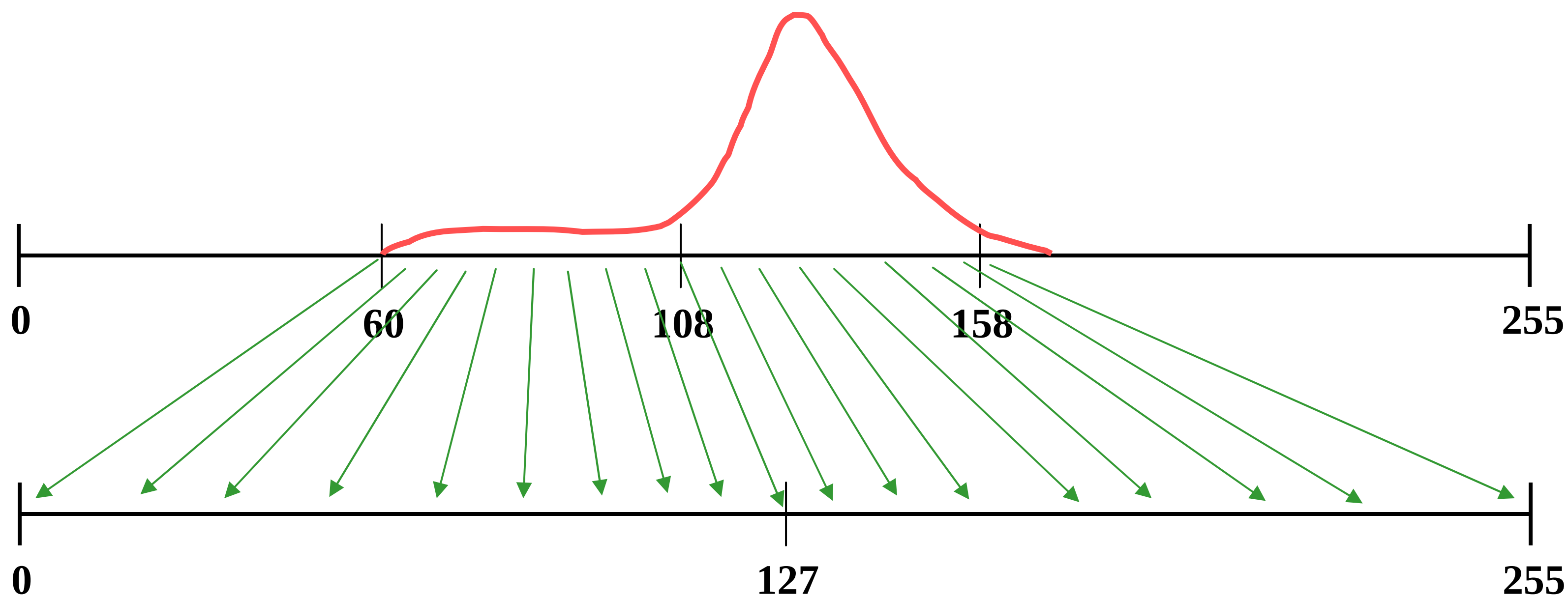
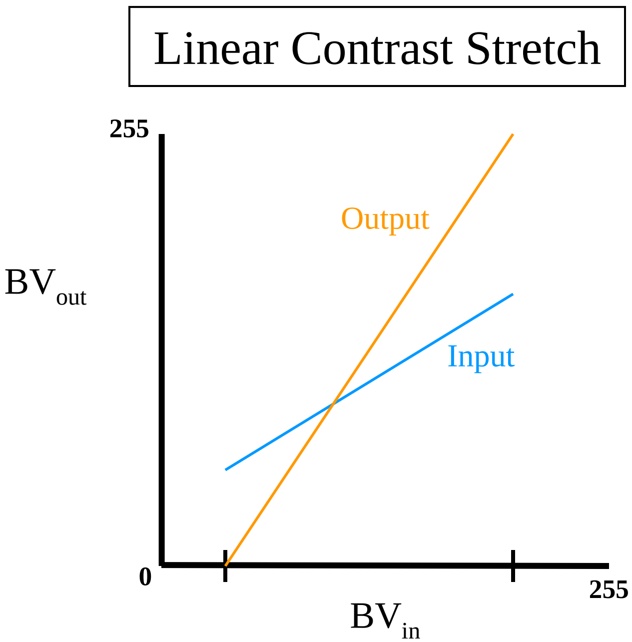
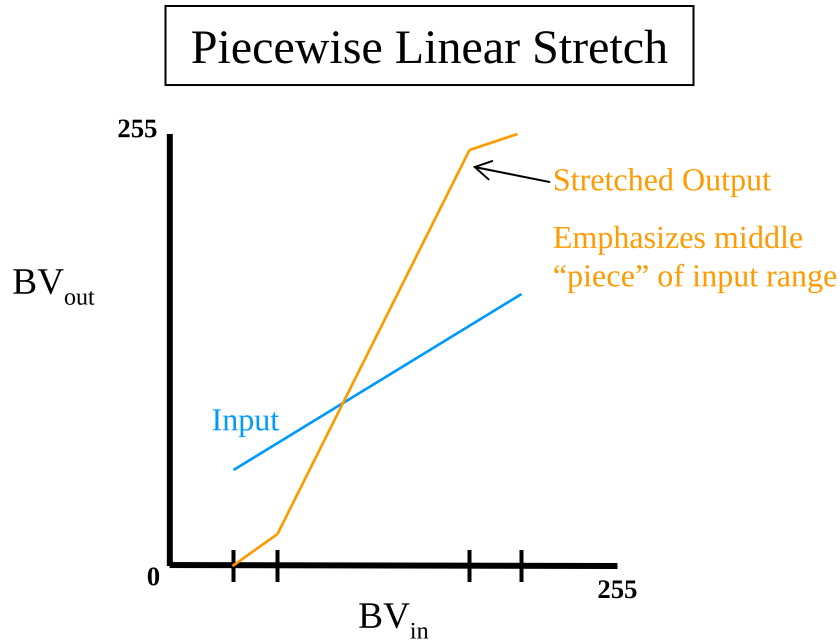
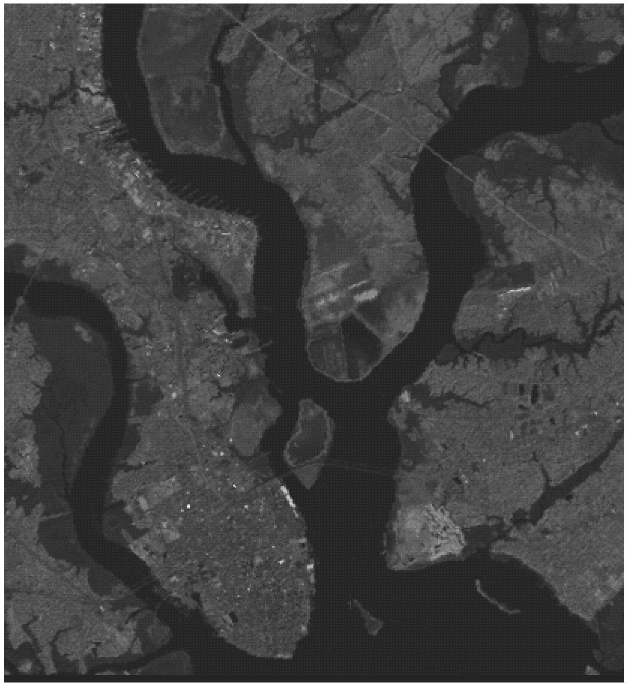


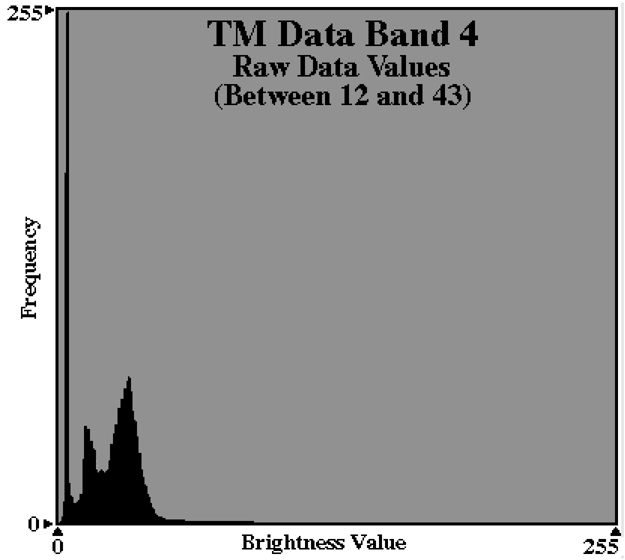
Image Raster Display - Stretched

- Two types of linear stretches:
  - The basic **linear contrast** stretch
  - A **piecewise linear** stretch








TM Data Band 4
Raw Data Values
(Between 12 and 43)
255
Frequency
0
0
Brightness Value
255

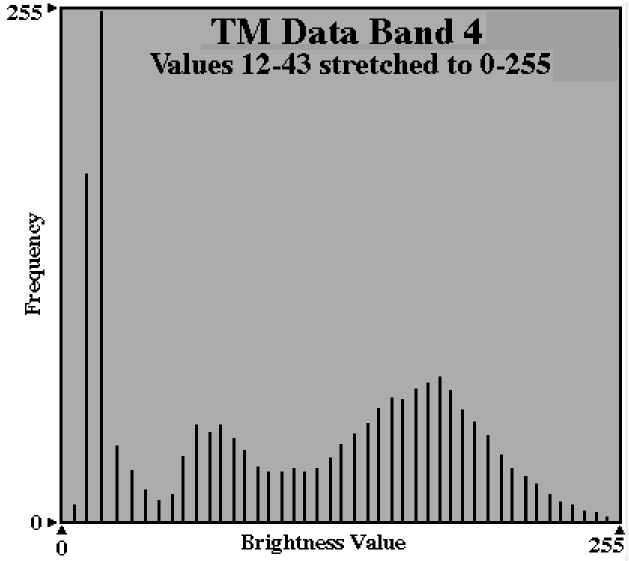
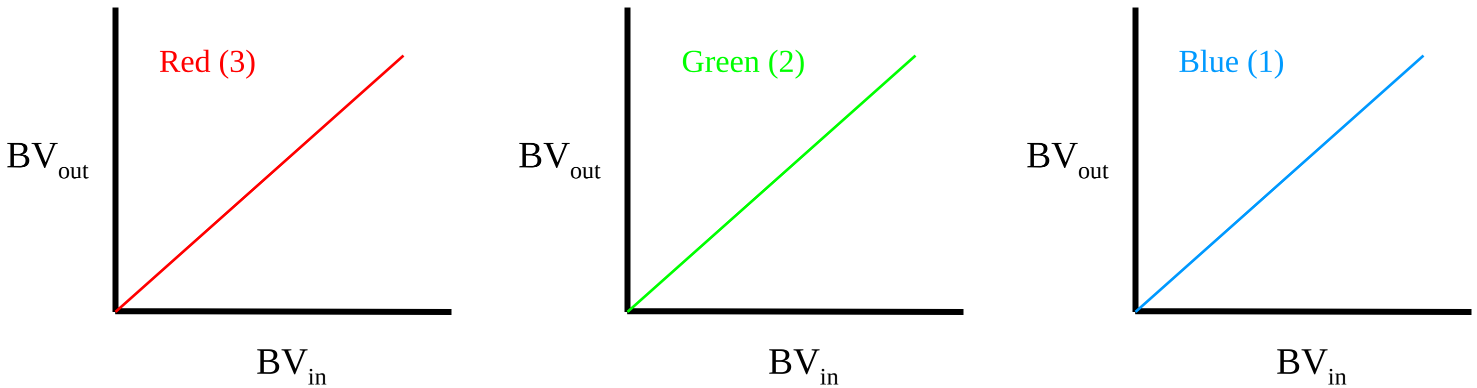

TM Data Band 4
Values 12-43 stretched to 0-255
255
Frequency
0
0
Brightness Value
255

Image Raster Display – RGB Composite

- For a multi-band image, the resultant color will depend on which bands are assigned to which color guns

True Color Composite

(321)



False Color Composite

(432)

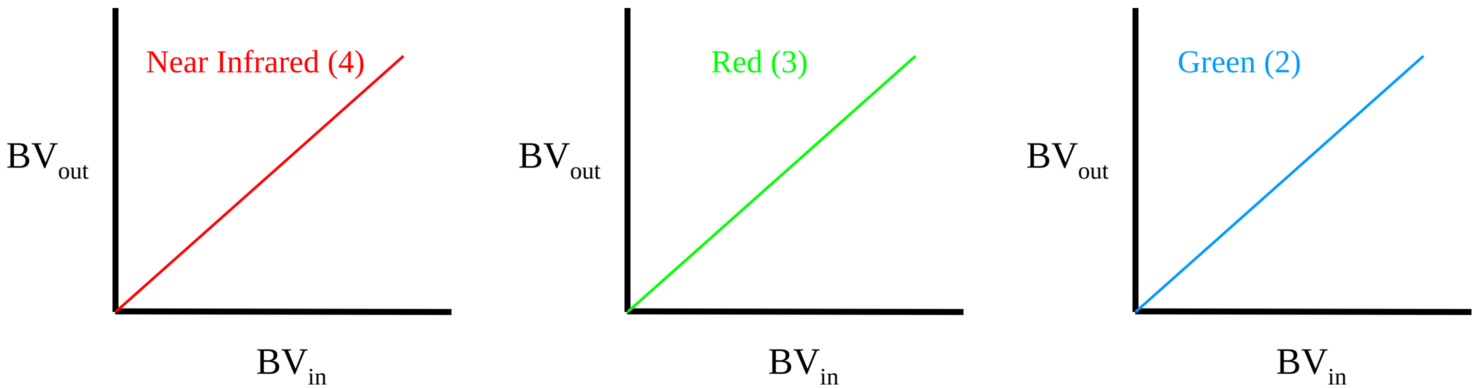


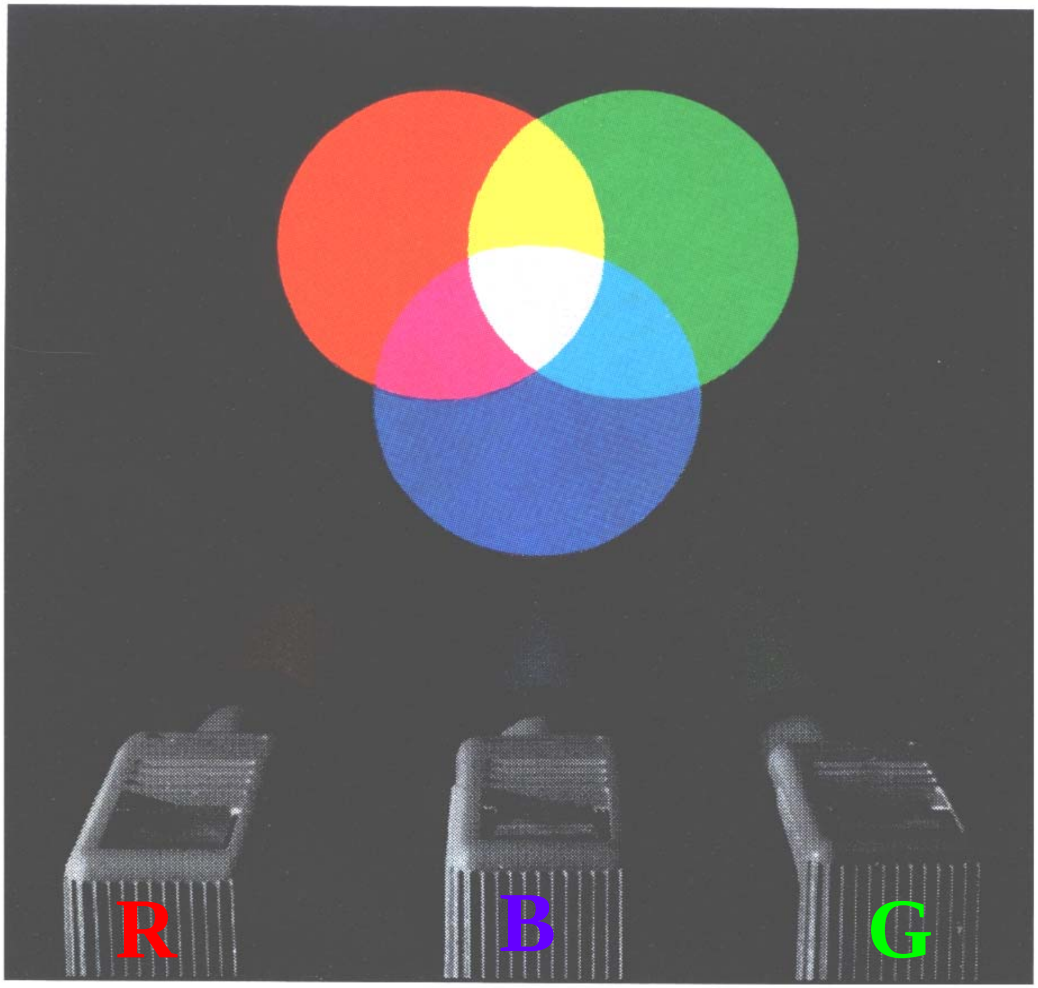
Image Raster Display – RGB Composite

1. We put the **digital numbers** into the color guns of computer display so that the **level of intensity** for the color corresponds to the **size of the number** (i.e. brightness values are equal)

2. If we put the **same digital numbers** into all three color guns on a computer, we will get a **black and white** picture. We call this an image

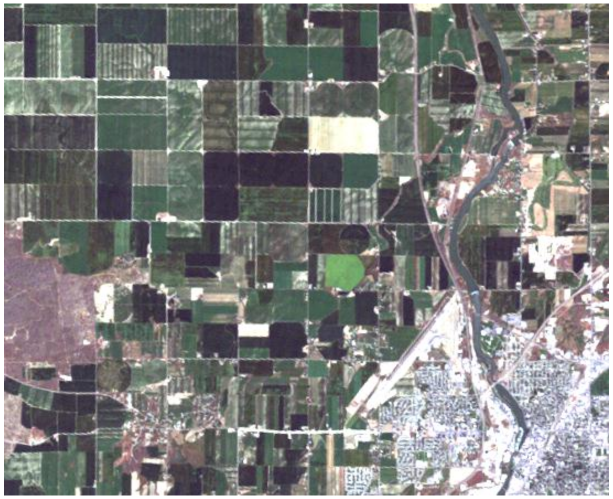
3. If we put the digital number for red light in red gun, and the digital numbers for blue light in blue gun, and the digital numbers for green light in green gun, we will have a **true color image**. Otherwise mappings we call **false color images** (all are RGB composites)

Color Arithmetic

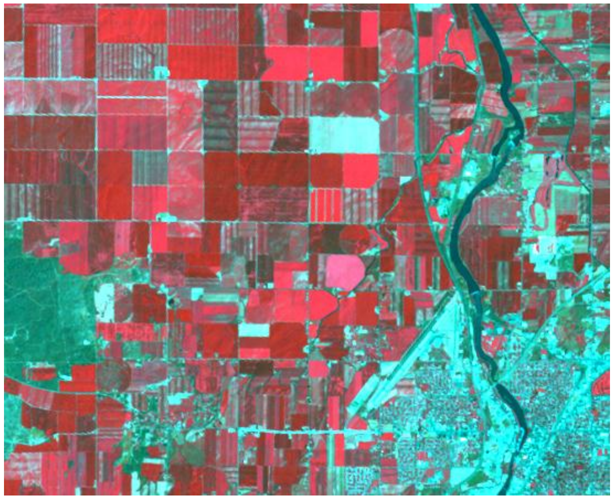


red + green = yellow
green + blue = cyan
red + blue = magenta

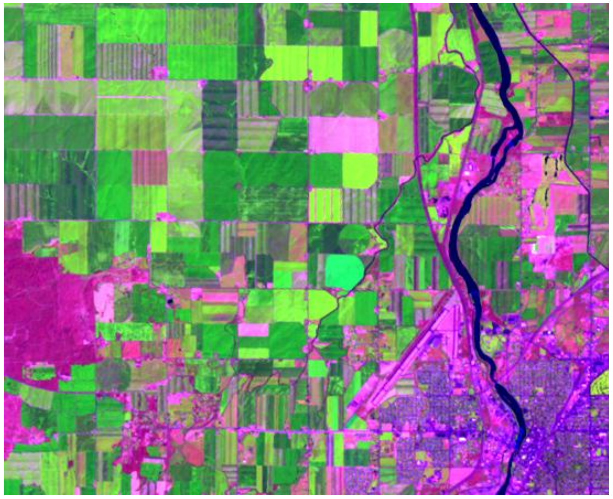
Image Raster Display – RGB Composite



321



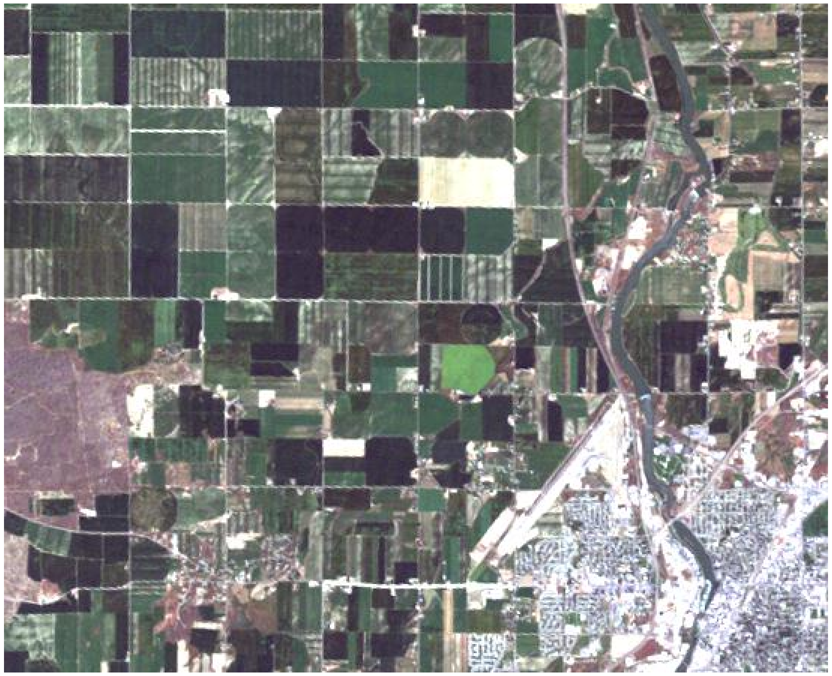
432



543

True-Color 321 Image

No stretch applied



True-Color 321 Image

Linear Contrast Stretch

Next Topic:

Coordinate Systems