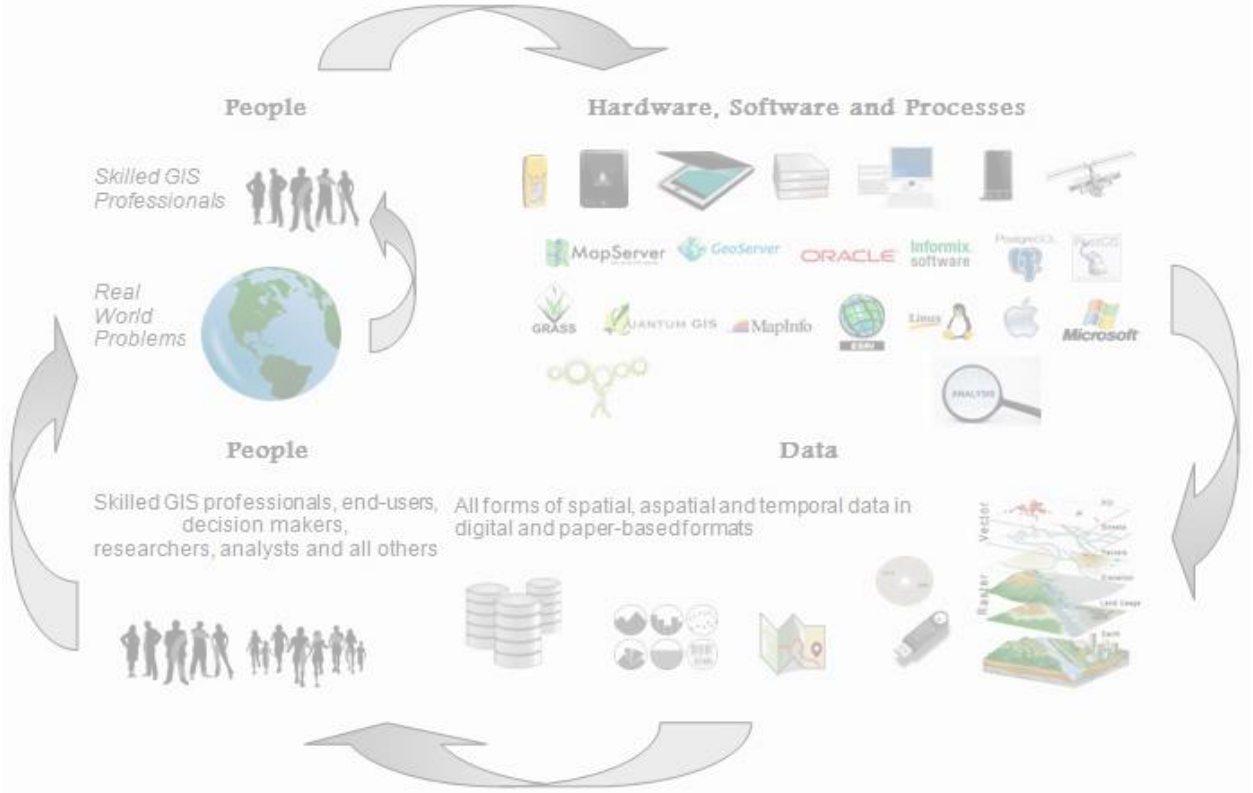


Introduction to Geographical Information Systems

MedCof Training Workshop, 2015, Madrid, Spain

Presenter: Grahame Niles **October 2015**

Introduction to GIS

Discussion Topics

1. What are Geographical Information Systems?

2. Exploration of GIS Data Types

3. Key components for visualization of GIS Data

What are Geographical Information Systems?

Three Key Words:

1. **GEOGRAPHICAL**

+

2. **INFORMATION**

+

3. **SYSTEM**

What do these words mean???

What are Geographical Information Systems?

1. "GEOGRAPHICAL"

*"**Geography** of or relating to the natural features of the earth's surface"* ***(Collins English Dictionary, 2014)***

Geography is at the root of all things "Geographical"

But what is Geography???

Geography - *"The study of the physical features of the earth and its atmosphere, and of human activity as it affects and is affected by these…"* ***(Oxford Dictionaries, 2014)***

What are Geographical Information Systems?

What are Geographical Information Systems?

2. "Information"

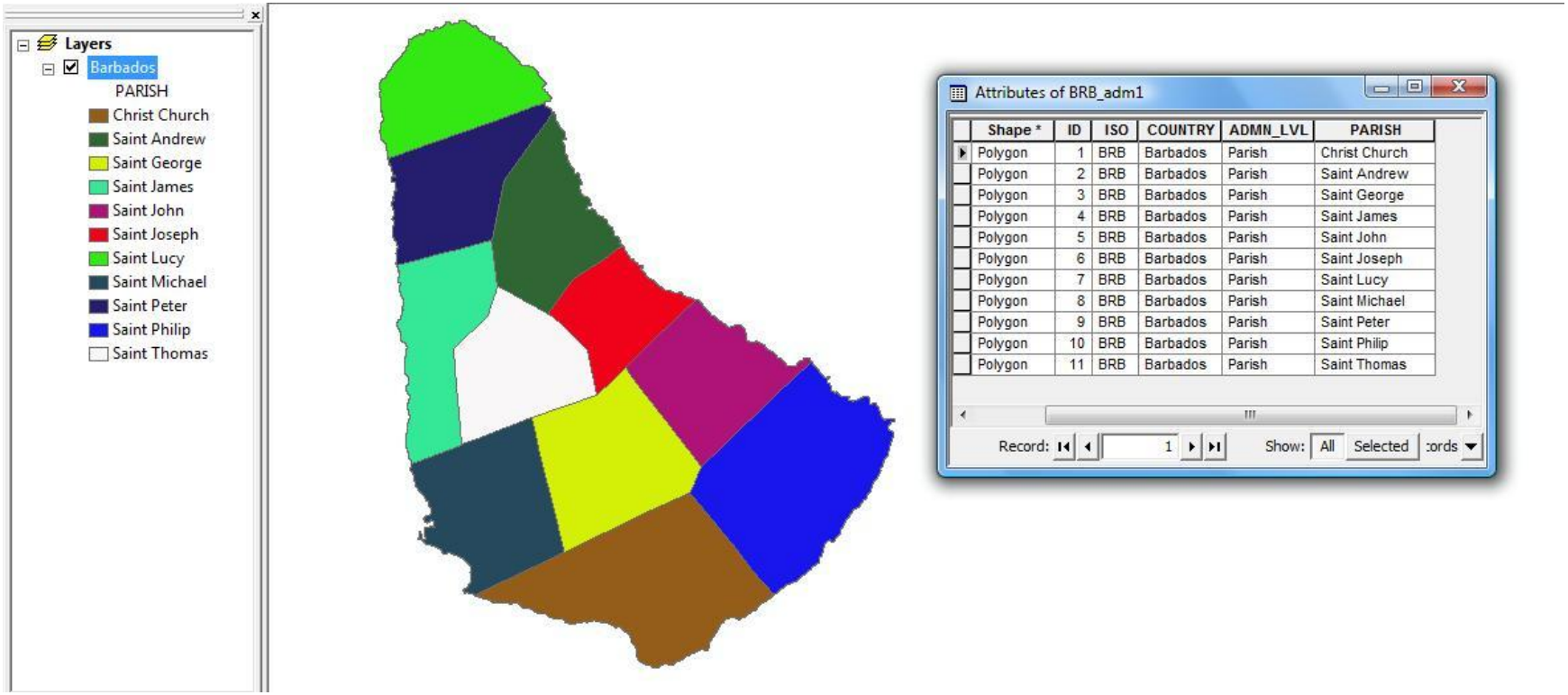
Data are at the core of Information

But what are Data???

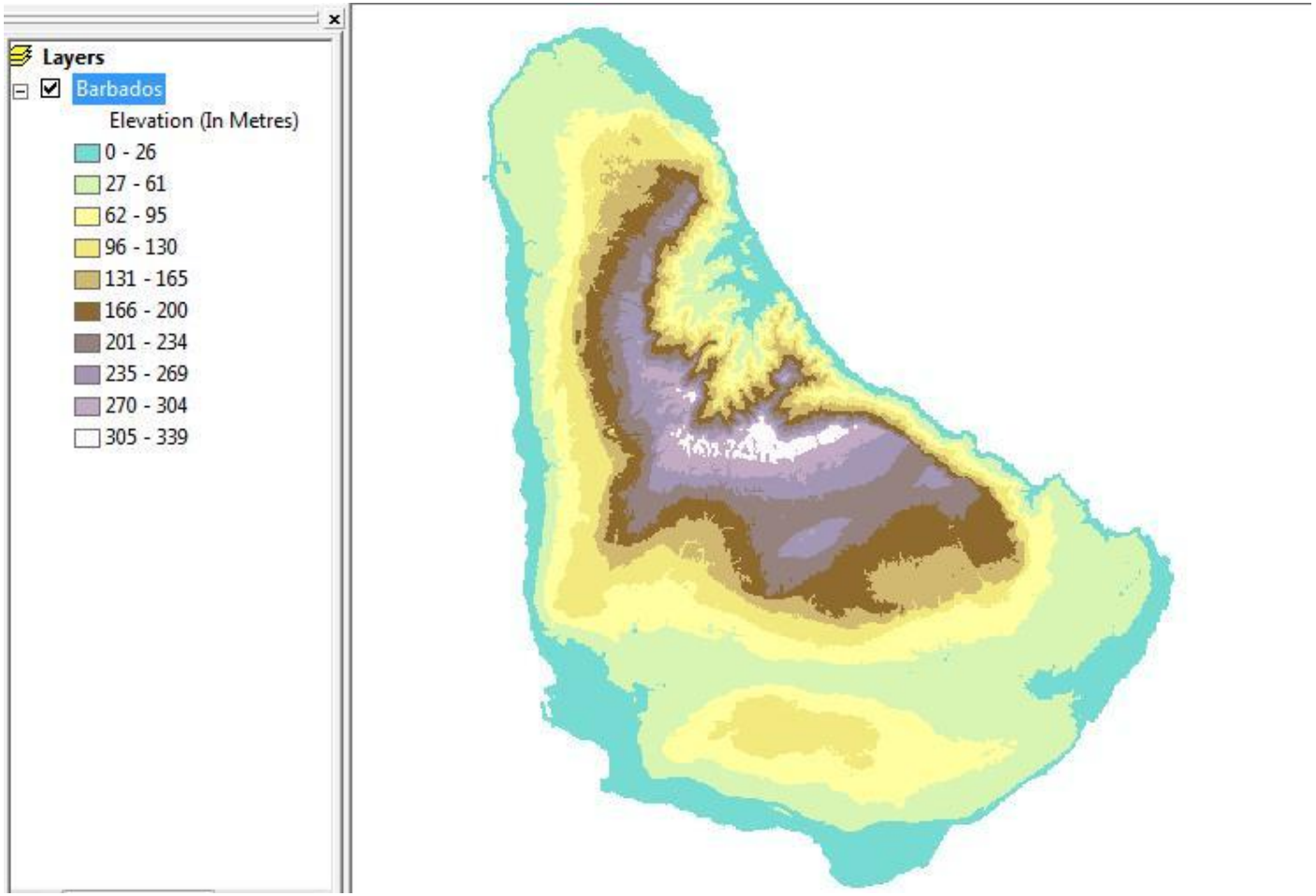
Data - raw, unorganized or unstructured facts

Information* is -** *"Data that are (1)* ***accurate and timely*, (2)* ***specific*** *and* ***organised*** *for a purpose, (3)* ***presented within a context*** *that gives it meaning and relevance, and (4) can lead to an* ***increase in understanding*** *and* ***decrease in uncertainty****."* ***(Business Dictionary.com, 2014)***

What are Geographical Information Systems?

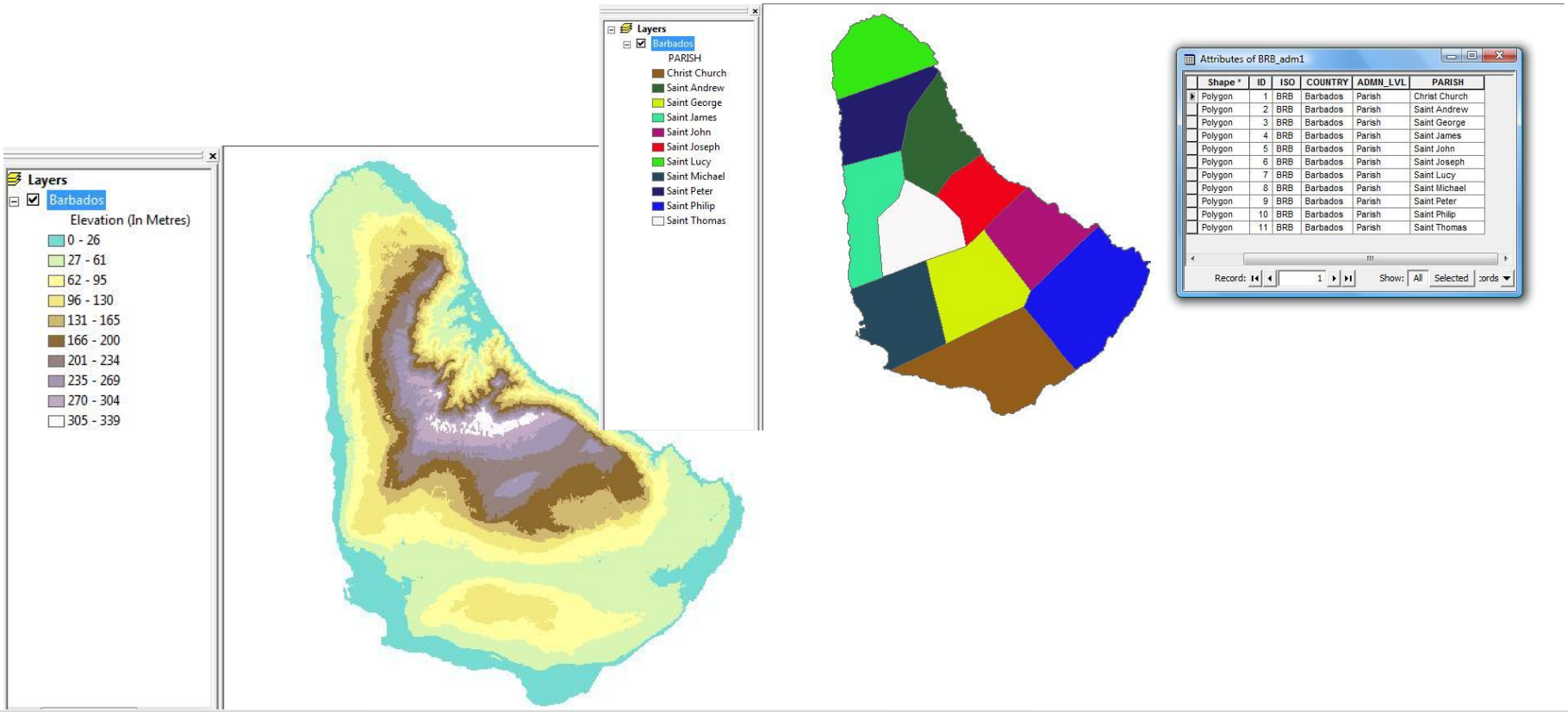


What are Geographical Information Systems?



What are Geographical Information Systems?

In which parishes of Barbados can the highest elevations be found?



What are Geographical Information Systems?

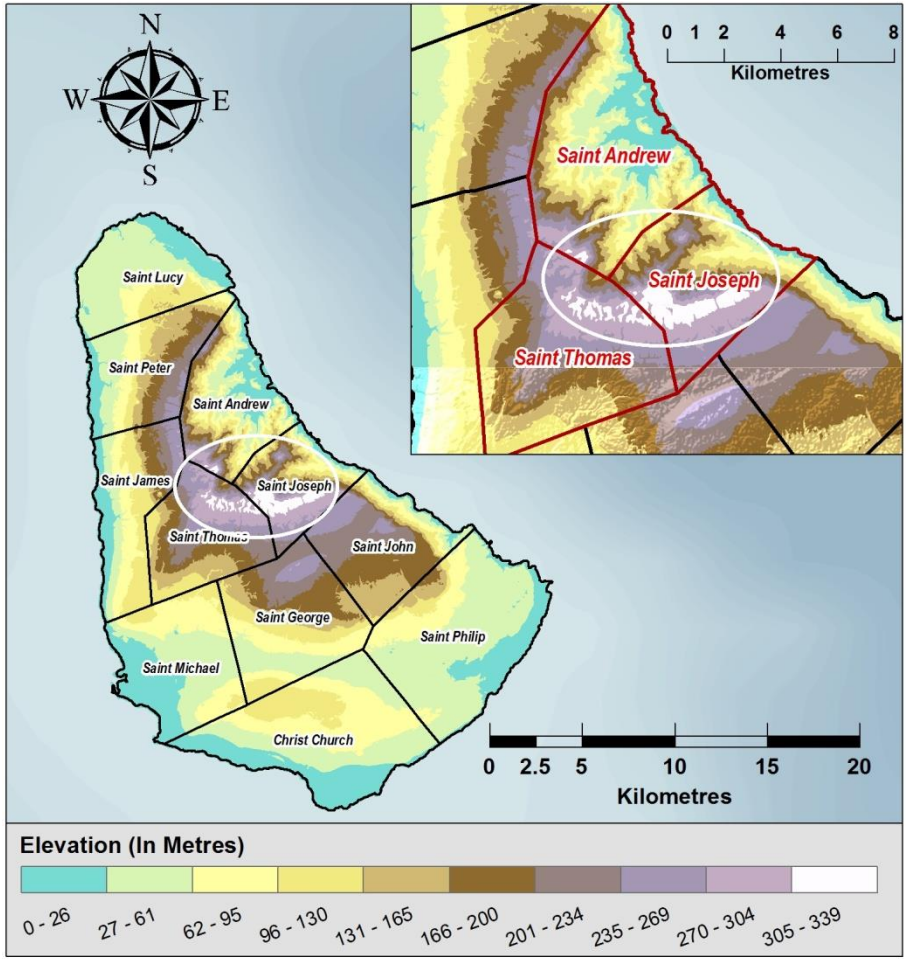


Figure 1 – Map showing parishes with the highest elevations in Barbados

By processing and organizing the elevation and administrative data for Barbados, we may now convey meaningful or useful information.

What are Geographical Information Systems?

3. "System"

What is a System?

"A set of things working together as parts of a mechanism or an interconnecting network; a complex whole..." *(Oxford Dictionaries, 2014)*

"A set of connected things that work together for a particular purpose" *(Macmillan Dictionary, 2014)*

What are Geographical Information Systems?

The "System" in GIS is made up of the following:

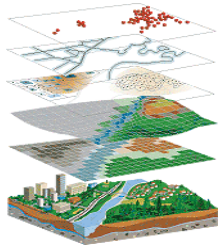
1 - People

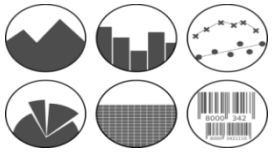
2 - Software

3 - Hardware

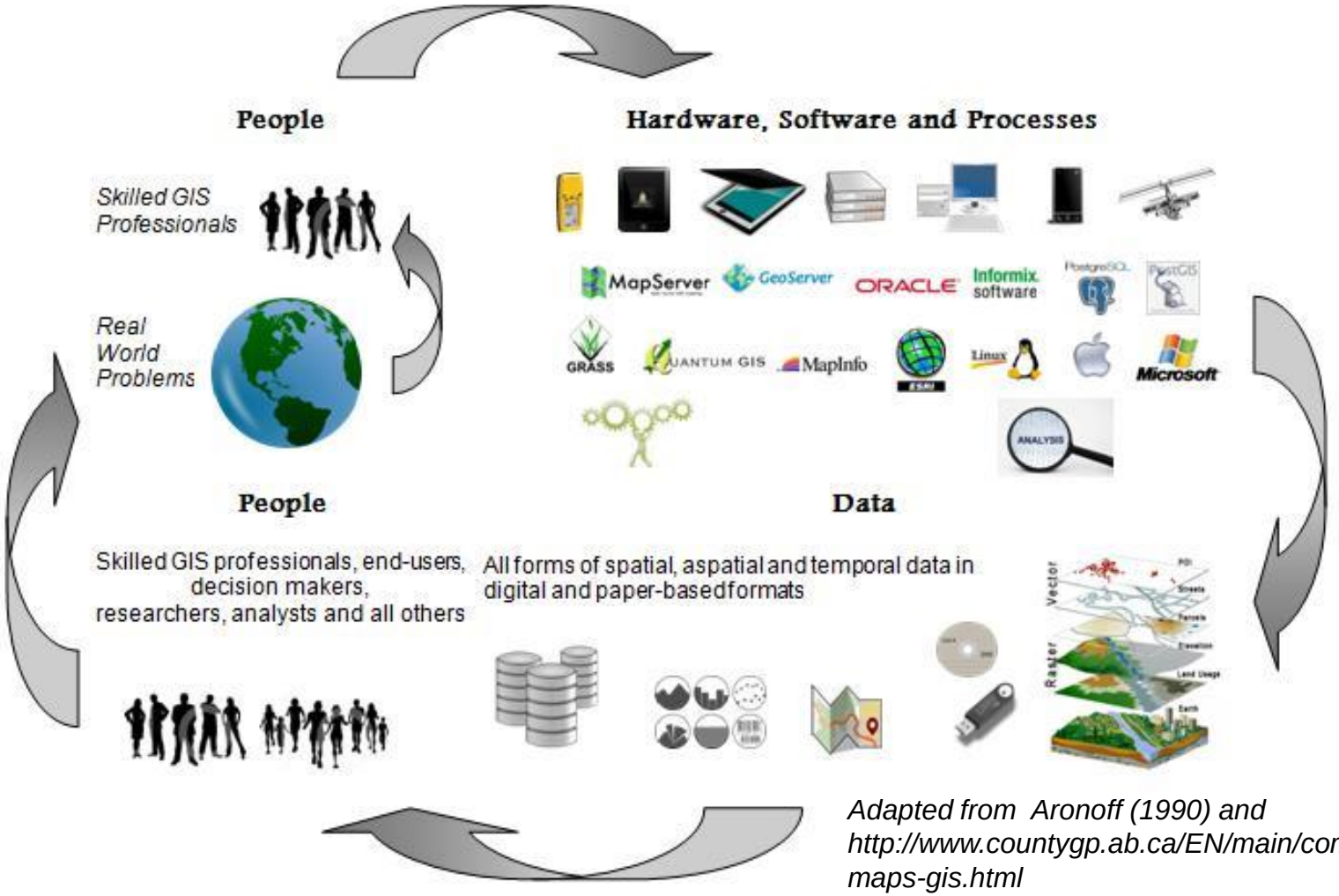
4 - Processes

5 - Data





What are Geographical Information Systems?



Adapted from Aronoff (1990) and http://www.countygp.ab.ca/EN/main/community/maps-gis.html

What are Geographical Information Systems?

Geographical + Information + System

***Geographical Information Systems** (GIS) are connected components (consisting of **PEOPLE, HARDWARE, SOFTWARE, PROCESSES and DATA**) that work together to aid knowledge and understanding through accurate, timely, organised and contextualised data.*

Knowledge and understanding gained from GIS are generally related to the physical features of the earth, the atmosphere and any related human activities that may impact these (i.e. earth's physical features and its atmosphere).

What are Geographical Information Systems?

Geographical Information Systems *(GIS) are used to study and solve earthly problems through* ***CAPTURE, STORAGE, PROCESSING, VISUALIZATION, ANALYSIS*** *and* ***DISTRIBUTION*** *of data (spatial and non-spatial) to support decision making.*

What are Geographical Information Systems?

Exploring GIS Data Types

Spatial Data Models

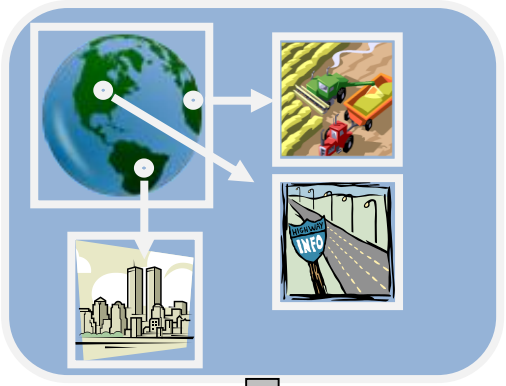
One of the primary objectives sought by Geographical Information Systems (GIS) is to accurately model phenomena of the real world.

3 categories of interrelated data models are used to represent earthly objects and phenomena.

- **Conceptual Data Models**
- **Logical Data Models**
- **Physical Data Models**

Exploring GIS Data Types

Spatial Data Models



Conceptual Models
Describe the world using abstract two and three dimensional concepts

→ **Field & Object Based Concepts**

Logical Models
Use logical and mathematical constructs to represent abstract concepts

→ **Vectors and Rasters**

Physical Models
Implement logical models on a computer system

→ **Physical implementation of vectors and rasters in memory**

Exploring GIS Data Types

Spatial Data Models

Conceptual Modelling - **There are two paths to conceptual modelling**

1. The Field Based Approach

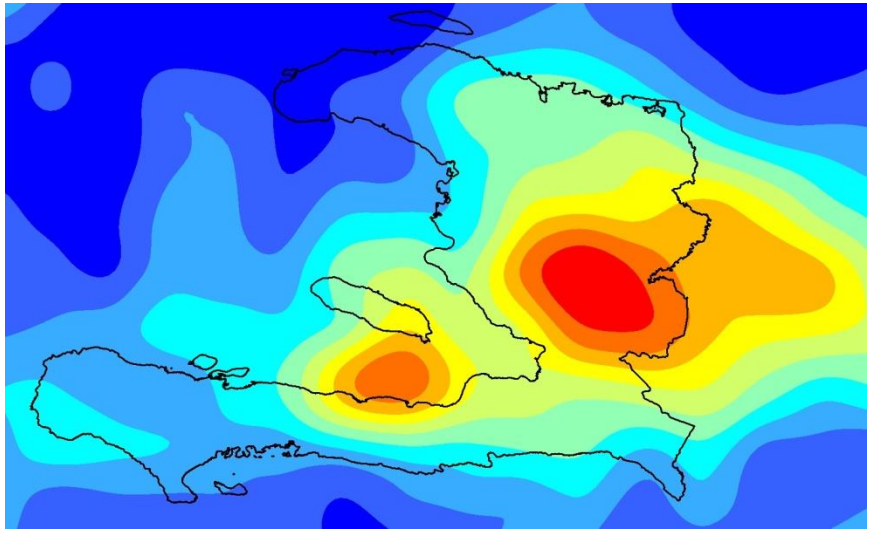
- **Represents the variations in the spatial distribution of earthly phenomena as finite tessellations of space**
- **Uses as two or three-dimensional surfaces covering a finite area, with no gaps or overlaps**

2. The Object Based Approach

- **Earthly phenomena are conceptualised as discrete entities in space with distinct locations and/or boundaries**

Exploring GIS Data Types

Spatial Data Models



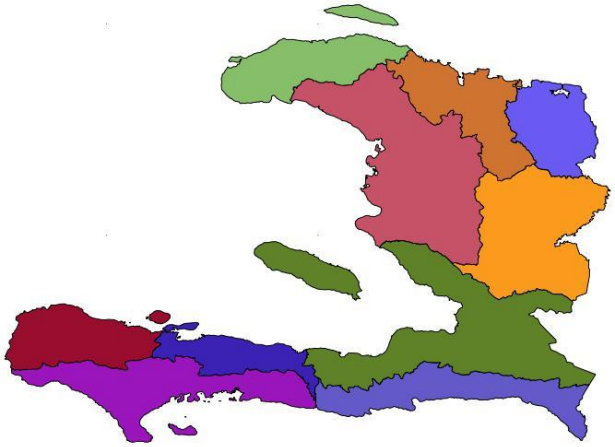
FIELD BASED EXAMPLE

Accumulated rainfall levels for a finite region conceptualised as a continuous surface with regularised intervals

- **Intervals represent localized rainfall values**
- **Variations in the spatial distribution of rainfall for temperature can be represented with this concept**

Exploring GIS Data Types

Spatial Data Models



OBJECT BASED EXAMPLE

A set of parishes or provinces in a country, such that each division is conceptualised as a discrete object occupying a unique portion of Space.

- **Physical configurations of parish boundaries and spatial relationships (in reality) can be captured by the use of discrete objects**

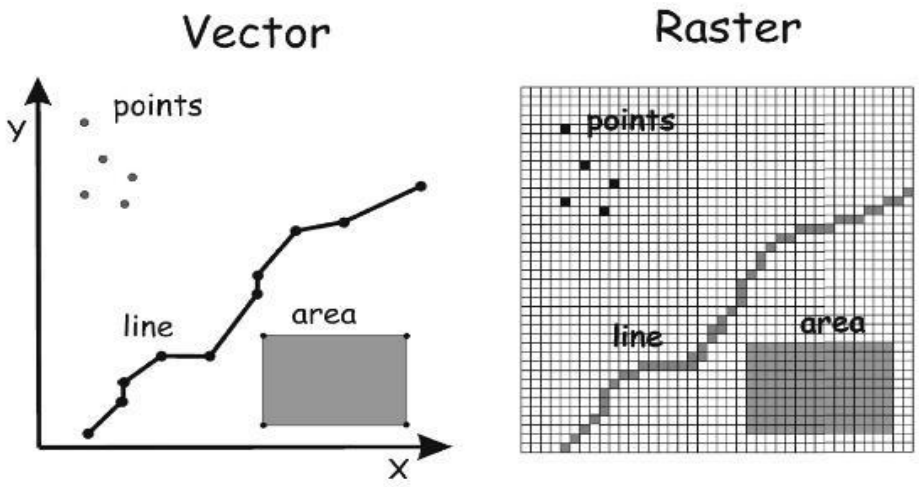
- **Each object would be readily distinguishable from another by location**

Exploring GIS Data Types

Spatial Data Models

- Earthly objects/phenomena of all categories may be described as having **point**, **linear** or **area**-based characteristics.

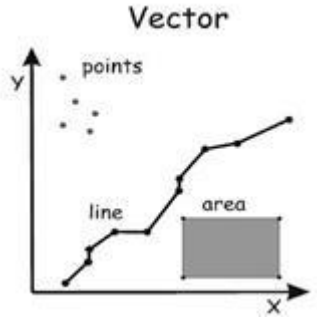
- GIS use **vectors** and **rasters** to represent these conceptual characteristics as logical constructs



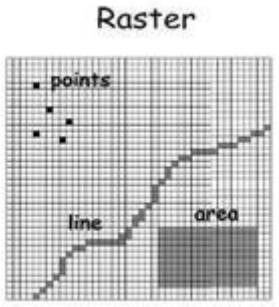
(Bolstad, 2002)

Exploring GIS Data Types

Spatial Data Models



- **Vectors**
  - Logical Models
  - Discrete geometric constructs
  - Best used to model object-based phenomena (discrete)



- **Rasters**
  - Logical Models
  - Grid/surface based constructs
  - Best used for modelling field- based concepts (finite continuous phenomena)

Exploring GIS Data Types

Spatial Data Models

Examples of abstract and physical entities modelled by Vectors and Rasters

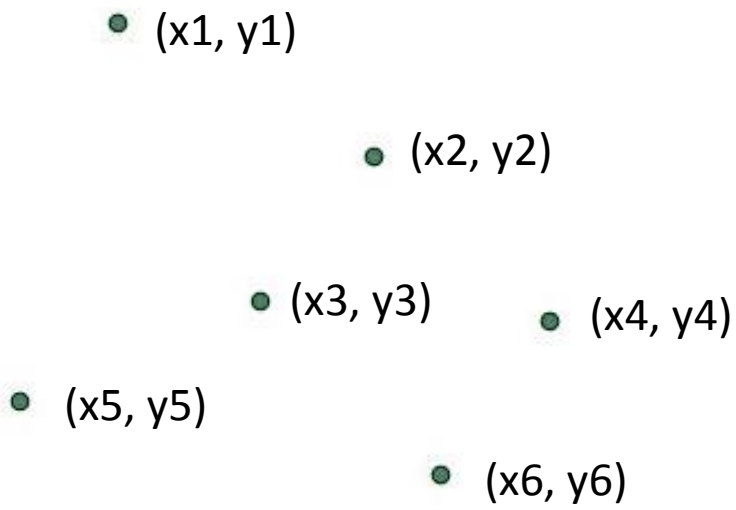
Point/Location features	Linear features	Area-based features
Locations of cities	Streams	Geo-political boundaries
Population density	Rivers	Water bodies (lakes, lagoons, ponds, etc.)
Weather station locations	Roads	Agricultural land parcels
Locations of wells	Network paths	Flood zones
Storm intervals	Storm trajectories	Temperature and Precipitation distribution

Exploring GIS Data Types

Vectors

- ***Points*** *are the most basic form of* ***vectors***

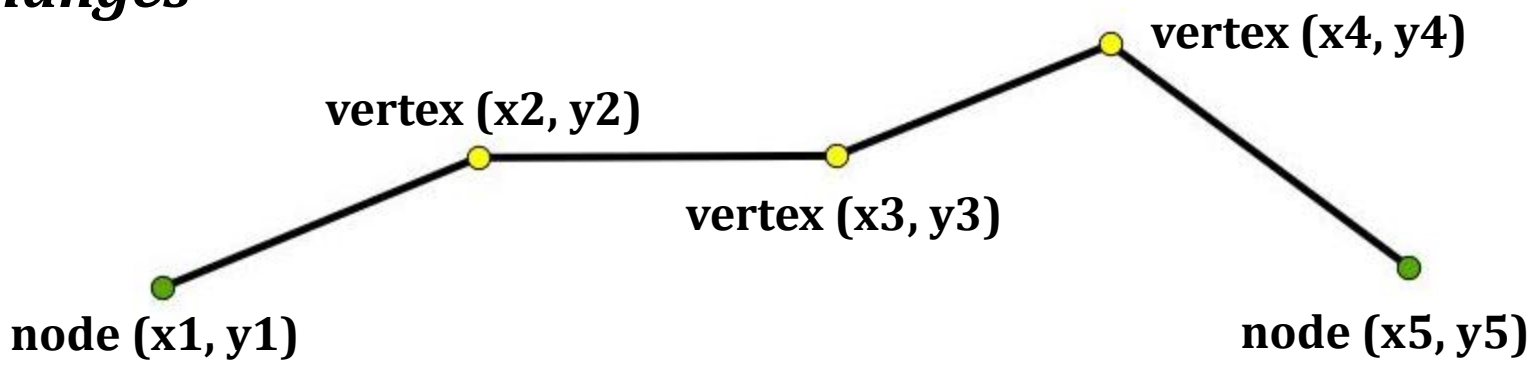
- ***Points*** *are synonymous with discrete locations (Cartesian coordinate pairs) in GIS*



Exploring GIS Data Types

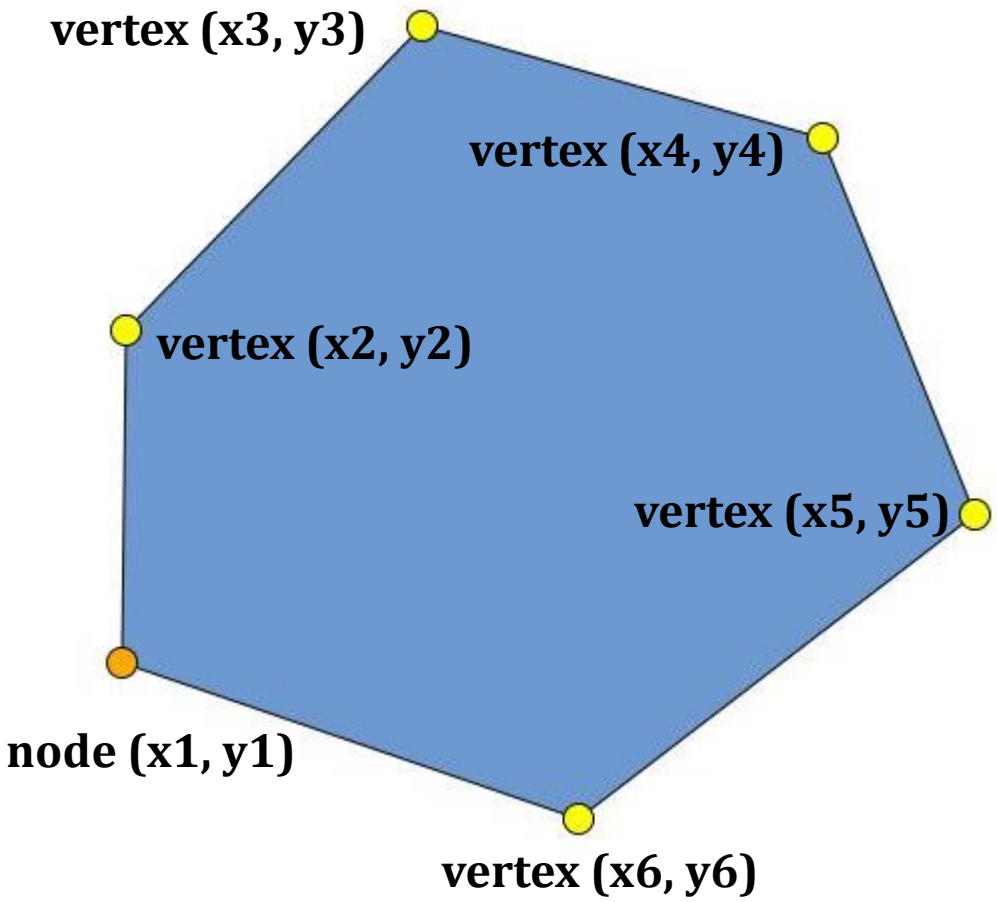
Vectors

- *In a GIS **linear** features are stored as a list of **nodes** and **vertices***
- ***Nodes** are the locations that represent the start and end of a feature*
- ***Vertices** are the locations at which the path of the feature changes*



Exploring GIS Data Types

Vectors



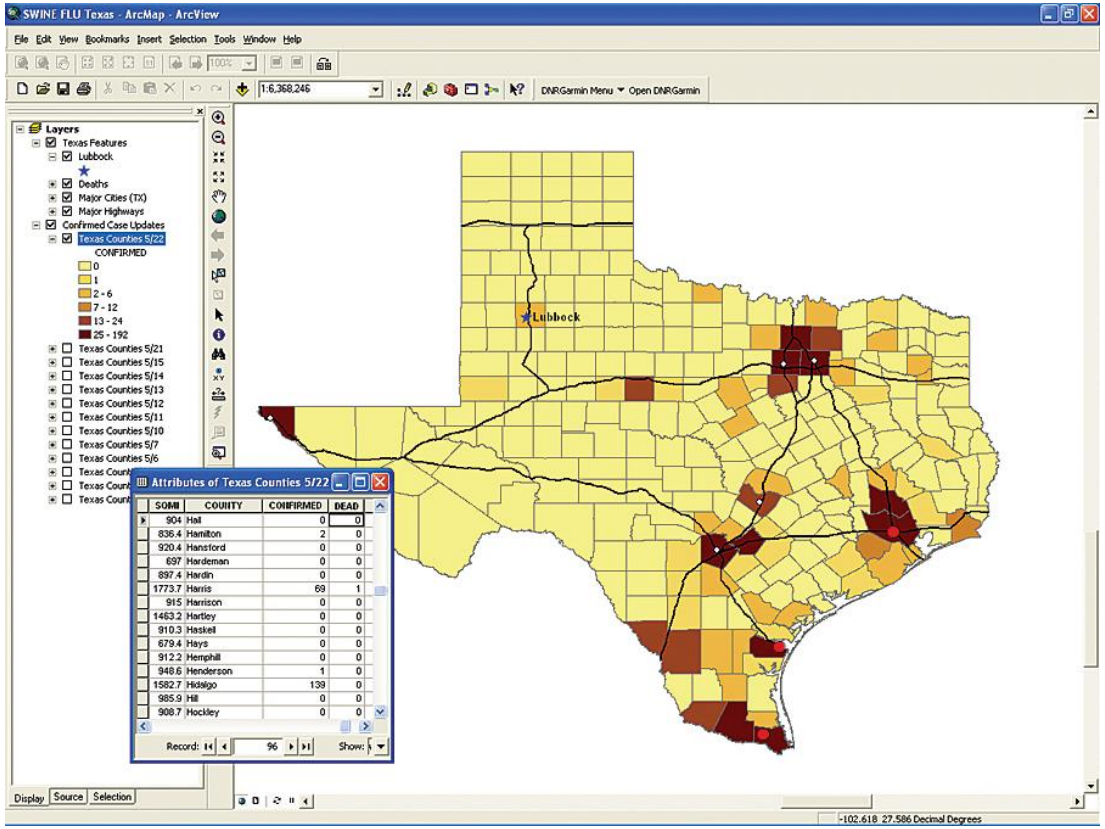
In a GIS polygons are a list of nodes and vertices

Polygons are closed objects – so the start and end nodes are always at the same location

Exploring GIS Data Types

Vectors

Tables provide a valuable means of interaction with vector data in GIS.

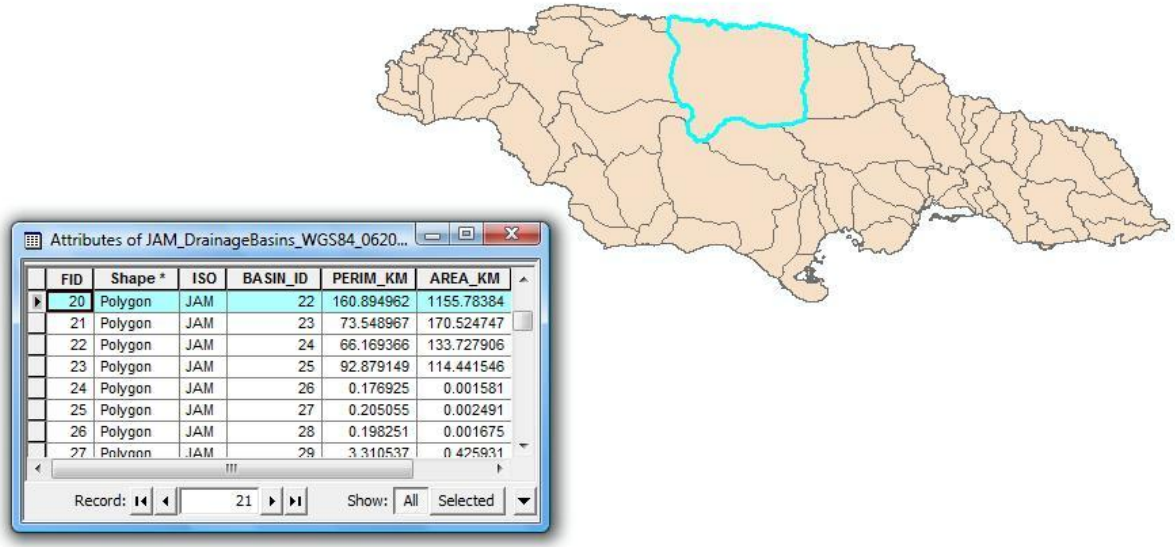


Exploring GIS Data Types

Vectors

- The characteristics or attributes associated with **vector** objects are listed in tabular columns

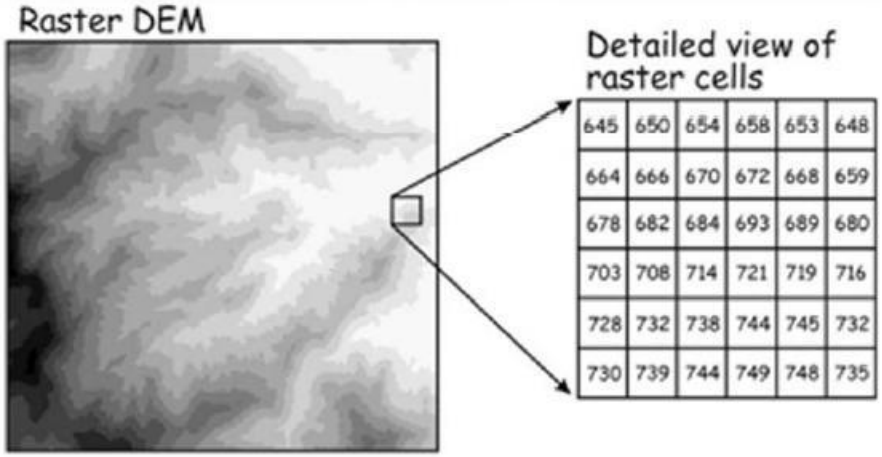
- Each row in the table represents a unique spatial feature within the **vector** data set



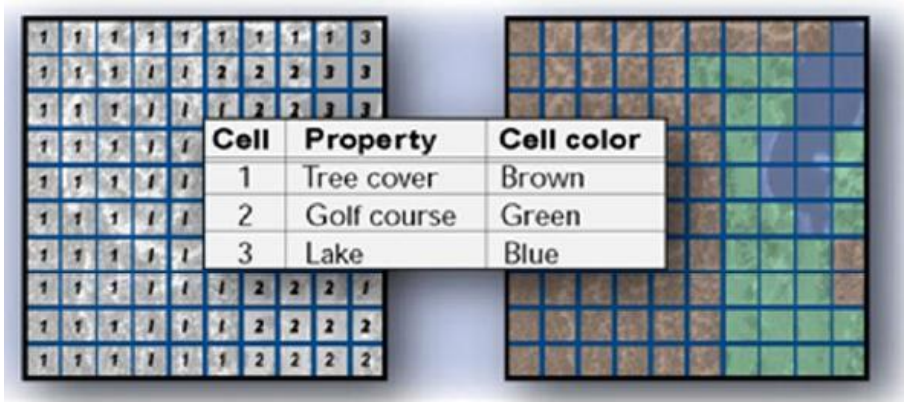
Exploring GIS Data Types

Rasters

- ***A Raster is a grid-based construct, consisting of a finite number of rows and columns, that can graphically convey real-world phenomena***



Source: Bolstad (2002)

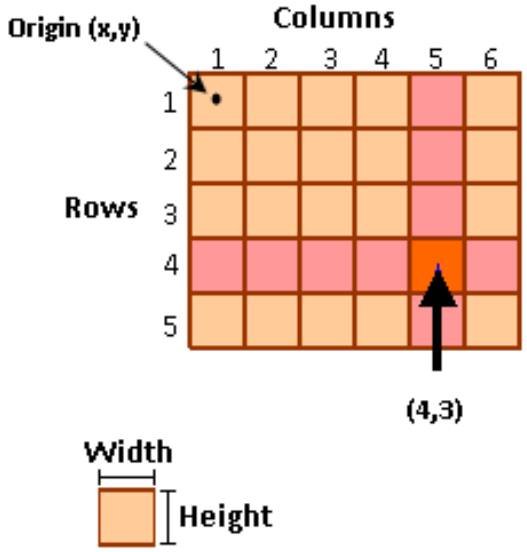


- ***Rasters store information in a matrix-like structure. This information is translated into colours and/or shades for visualisation purposes***

Exploring GIS Data Types

Rasters

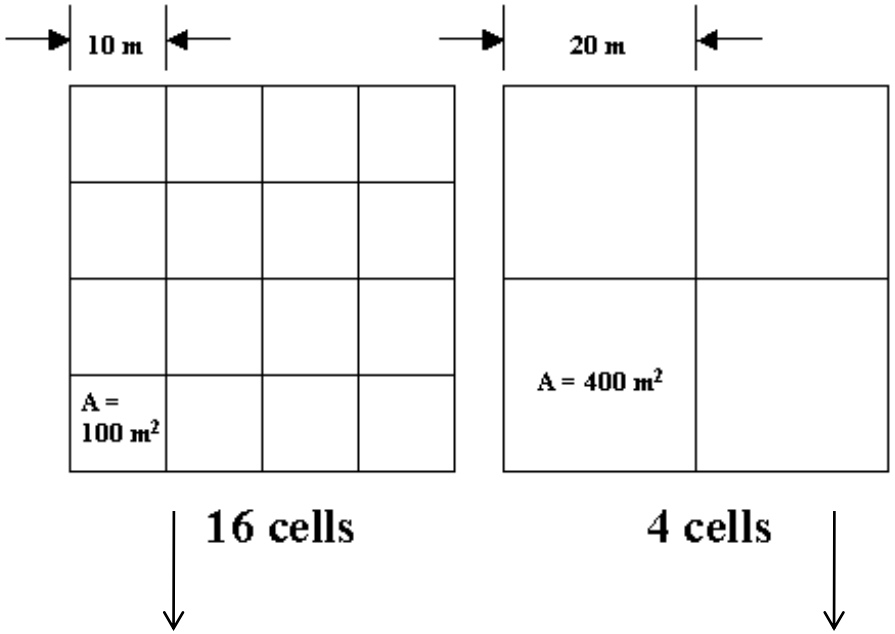
- Attribute data are held within the cells of **rasters**
- Each **raster** cell may be referenced to a location defined by Cartesian coordinates in space
- **Rasters** are not implemented in GIS by storing the locations of every cell



- Cell locations are referenced implicitly by checking their position in the matrix relative to the origin, whose position is known.

Exploring GIS Data Types

Rasters



Cell Spacing is defined as the dimensions of the portion of the ground represented by a raster cell.

Spatial resolution is defined as the size or dimensions of the smallest resolvable object on the earth's surface

➢**Smaller cell size**	➢ **Larger cell size**
➢**Higher resolution**	➢**Lower resolution**
➢Higher spatial accuracy	➢Lower spatial accuracy
➢Slower processing	➢Faster processing
➢Slower rendering	➢Faster rendering
➢Larger file size	➢Smaller file size

Exploring GIS Data Types

Rasters

- The data within the cells of a raster's grid structure are categorized or layered in what are called **"Bands".**

- **Bands** are dimensions within a raster, that associate each cell with one or more categories of data values.

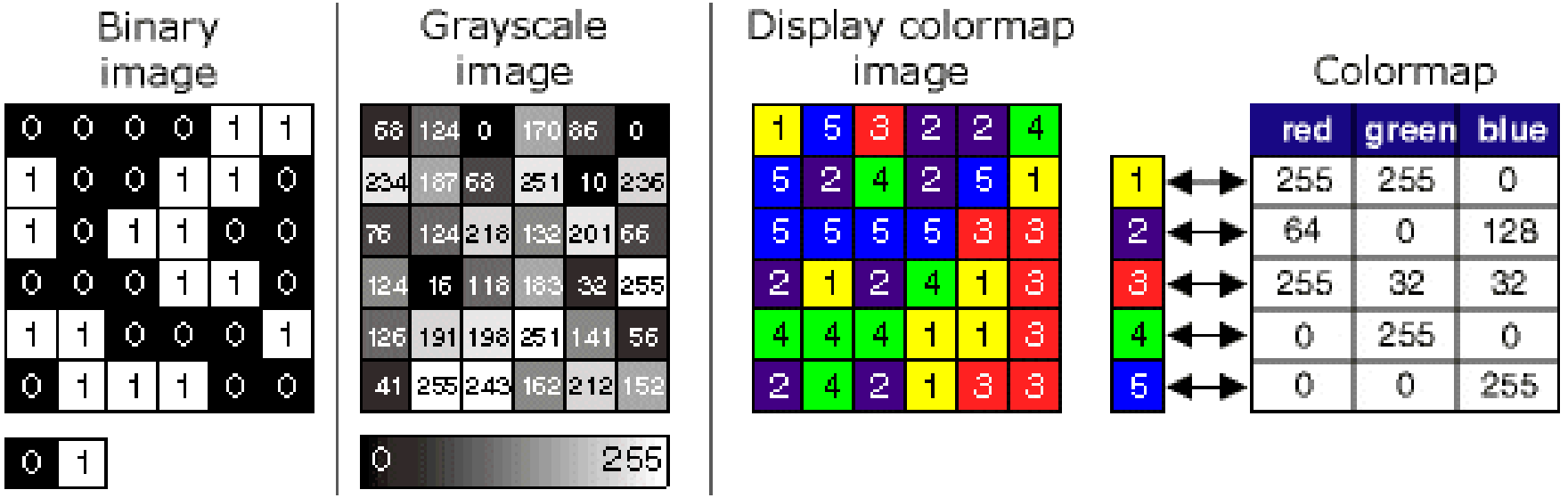
- Single-band rasters contain one category of data

- Multiple-band rasters assign two or more categories of data to each cell

Exploring GIS Data Types

Rasters

- **Single-Band rasters may be illustrated in a GIS using three methods:**

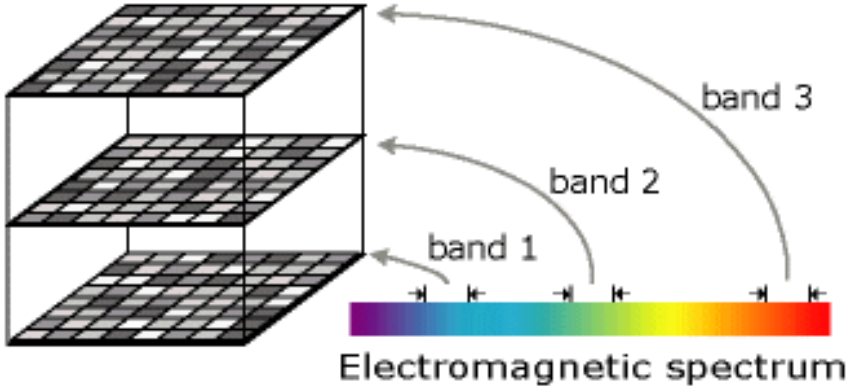


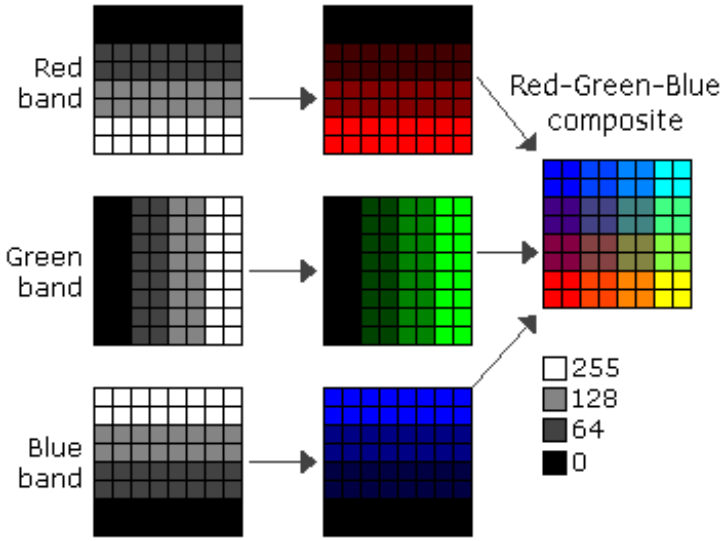
(Source: ESRI)

Exploring GIS Data Types

Rasters

➢ **The cells of a multi-band raster provides two or more categories or layers of information at each cell location**





(Source: ESRI)

Exploring GIS Data Types

Vectors versus Rasters

Category	Vector	Raster
Structural Complexity	➢ Geometrical composition makes vectors complex ➢Nodes and vertices must all be stored and referenced explicitly	➢Matrix composition is structurally simpler ➢Cells are stored and referenced implicitly
Storage Requirements	➢Stored as a list of coordinates with instructions ➢Smaller requirements	➢Memory required for each cell ➢Larger storage requirements

Exploring GIS Data Types

Vectors versus Rasters

Category	Vector	Raster
Spatial Accuracy	➢Usually higher ➢Limited only by positional measurements	➢Usually less reliable ➢Positional generalisation occurs in low resolution rasters
Suited Applications	➢Can model continuous phenomena ➢Best suited for discrete data	➢Can model discrete data ➢Best suited for continuous data

Exploring GIS Data Types

Vectors versus Rasters

Category	Vector	Raster
Speed of Analysis	➢High structural complexity and storage constraints impact speed ➢Generally slower than rasters	➢Generally faster
Quality of Visualisation	➢Good aesthetics at high and low resolutions ➢Unaffected by map scale ➢Generally better than rasters	➢Good aesthetics only at high resolutions ➢Affected by map scale ➢Generally weaker

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- **Before Vector and Raster data can be processed in a GIS, they must be rendered using:**
  - **COORDINATE SYSTEMS**
  - **DATUMS**
  - **PROJECTIONS**

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- **Maps consist of geographic data which are encoded with coordinate systems.**

- **Two types of coordinate systems used in GIS are:**

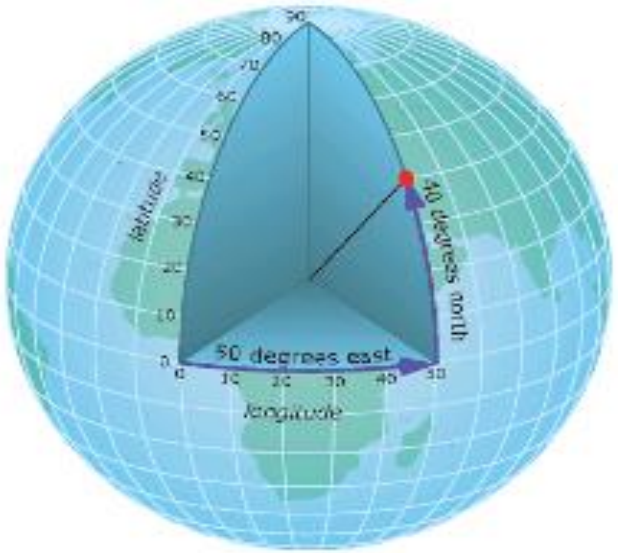
1. **Geographic Coordinate Systems**

2. **Projected Coordinate Systems**

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- A **Geographic Coordinate System** is a method for describing the position of a geographic location in angular degrees, using what are known as **"Datum".**



- A **Datum** is a system that enables the location of an object, when used with a three-dimensional earth model. Objects may be located using latitudes, longitudes and altitudes.

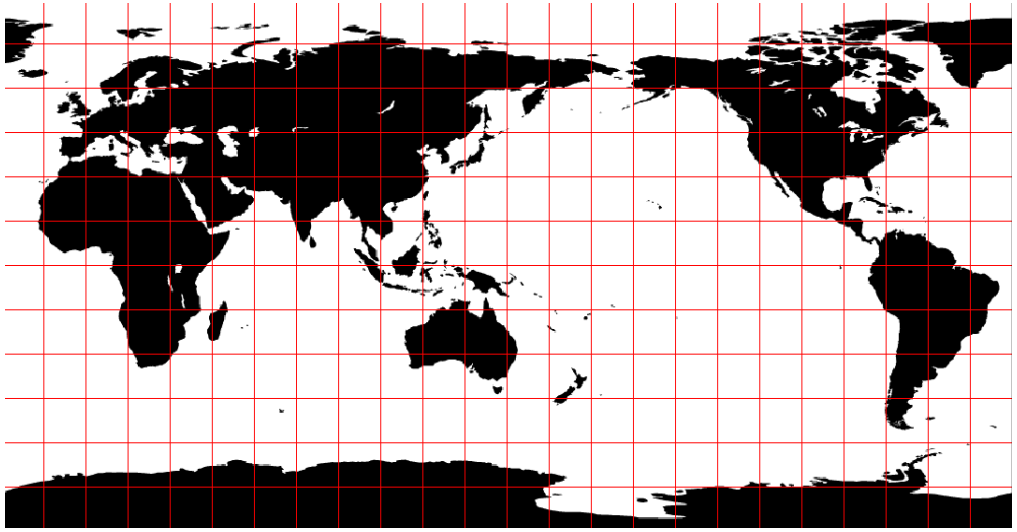
Examples: Clarke_1880, WGS 84, NAD 27 and more

Datums have been defined for most countries in the world

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- A **Projected Coordinate System** is defined in a flat, two-dimensional surface.
- It describes the location of objects using constant lengths, angles and areas across the two dimensions using metric units.



Projected Coordinate Systems are created from **Geographic Coordinate Systems**

Examples: UTM, Mercator...

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- **Visualization of geographic data is ideal when all data sets in the same map use the same coordinate system**

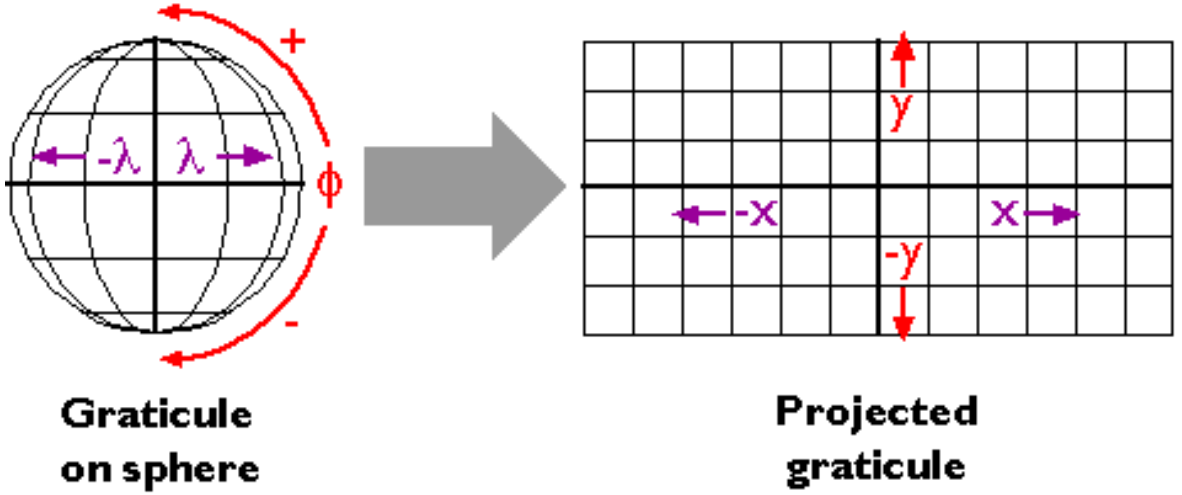
- **However, geographic datasets that use different types of coordinate systems can be easily transformed to ensure compatibility if they all use the same Datum.**

Visualization of GIS Data

Coordinate Systems, Datums and Projections

- The Earth is curved, maps are flat. 3-D →2-D

- The process of flattening the earth onto a flat piece of paper or computer screen is a mathematical process called a "Projection".



(Source: Penn State University)

- Projections can distort certain elements of the map

Visualization of GIS Data

Coordinate Systems, Datums and Projections

CONFORMALITY - Are the shapes accurate?

DISTANCE - Are the distances accurate?

AREA - Are the areas represented on the map proportional to their true area on the Earth?

DIRECTION - Are directions between points on the map accurately?

Visualization of GIS Data

Maps

- **Vector and Raster data in GIS are rendered using (Coordinate Systems, Datums and Projections)**
- **Data are processed by GIS**
- **Information deduced/extracted must then be presented in a meaningful manner**
- **Maps are powerful tools for communicating this information**

Visualization of GIS Data

Maps

- **What types of Maps are there?**

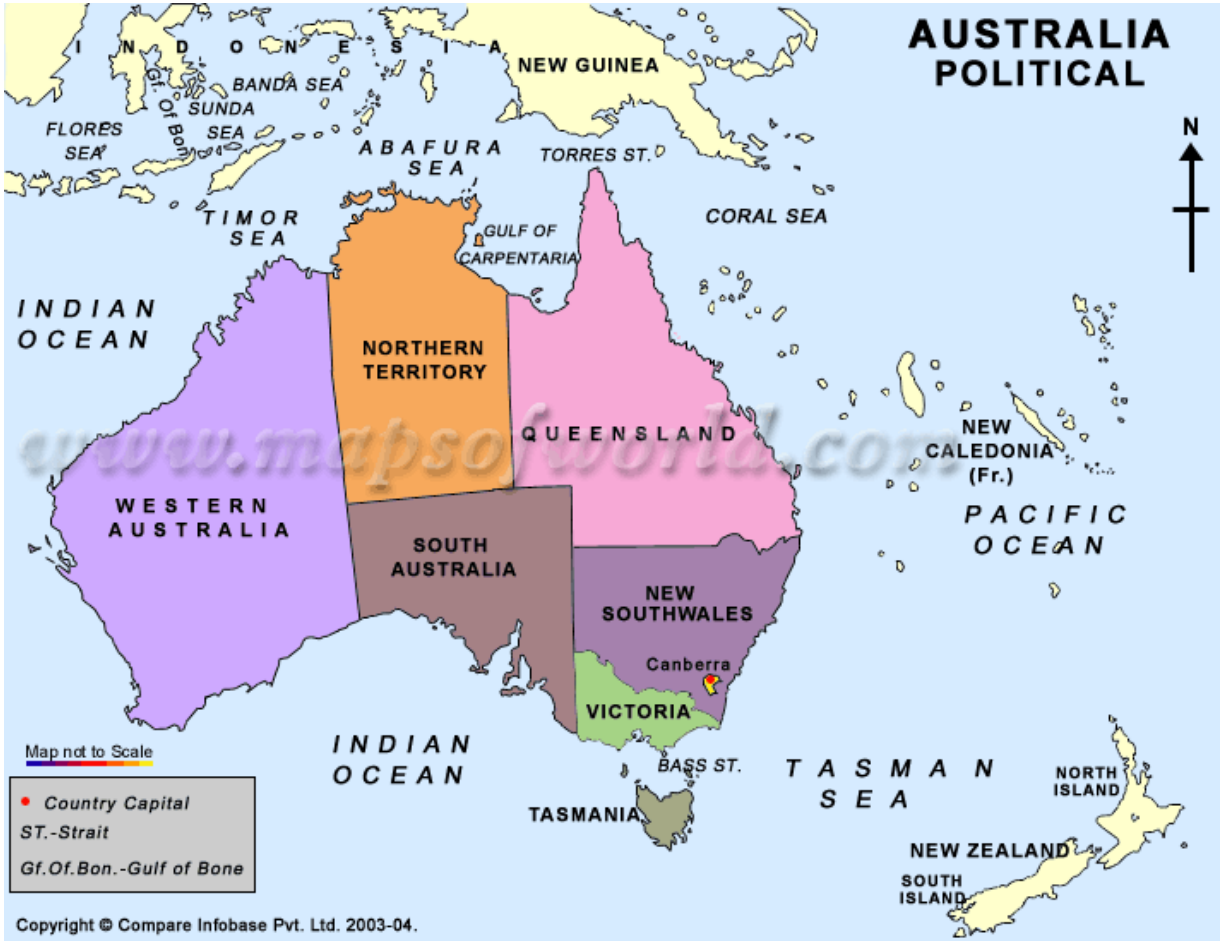
  - **Political Maps**
  - **Physical /Topographic Maps**
  - **Climate Maps**
  - **Road Maps**

  And More…

Visualization of GIS Data

Maps

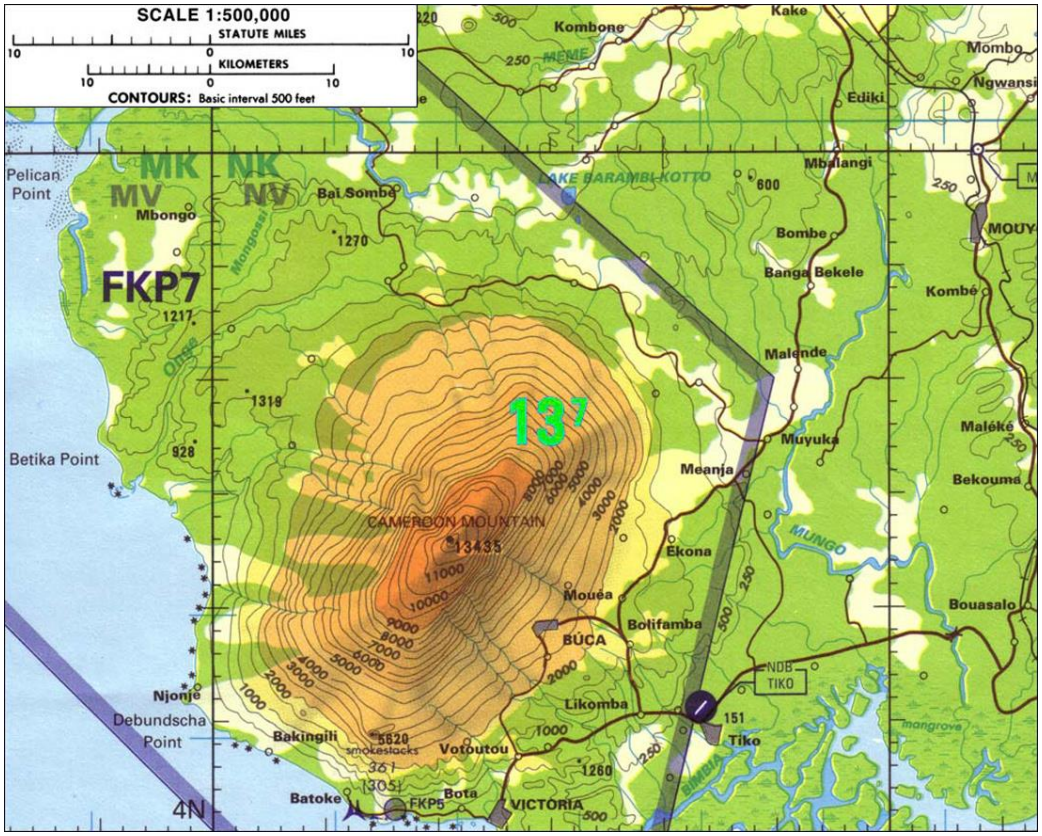
Political map of Australia ***(obtained from http://www.4shared.com)***



Visualization of GIS Data

Maps

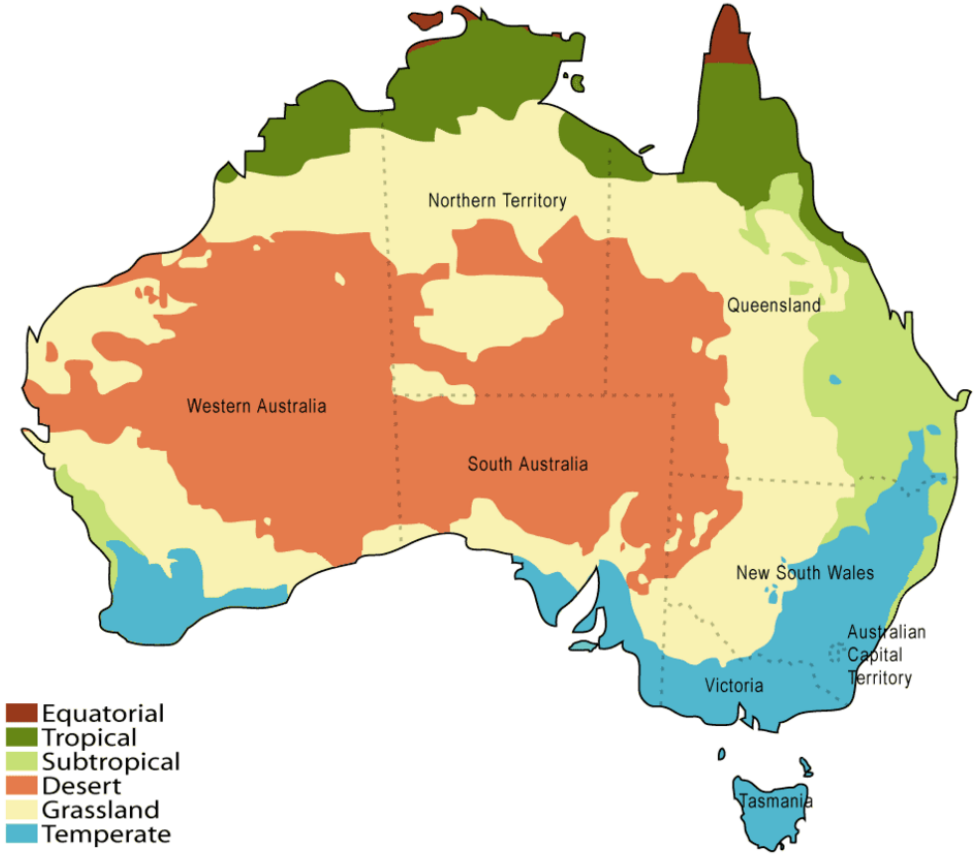
Topographic Map of Mount Cameroon ***(obtained from www.mappery.com)***



Visualization of GIS Data

Maps

Climate Map of Australia ***(obtained from https://en.wikipedia.org)***



Visualization of GIS Data

Maps

Other categorizations of Maps

- **Reference Maps**
- **Thematic Maps**

Visualization of GIS Data

Maps

Reference Maps – ex. Geographic maps

Many bits of information on one map, focusing on no specific aspect of information.

Challenges:

- ❑ **What group of information to include?**
- ❑ **What is too much information?**

Visualization of GIS Data

Maps

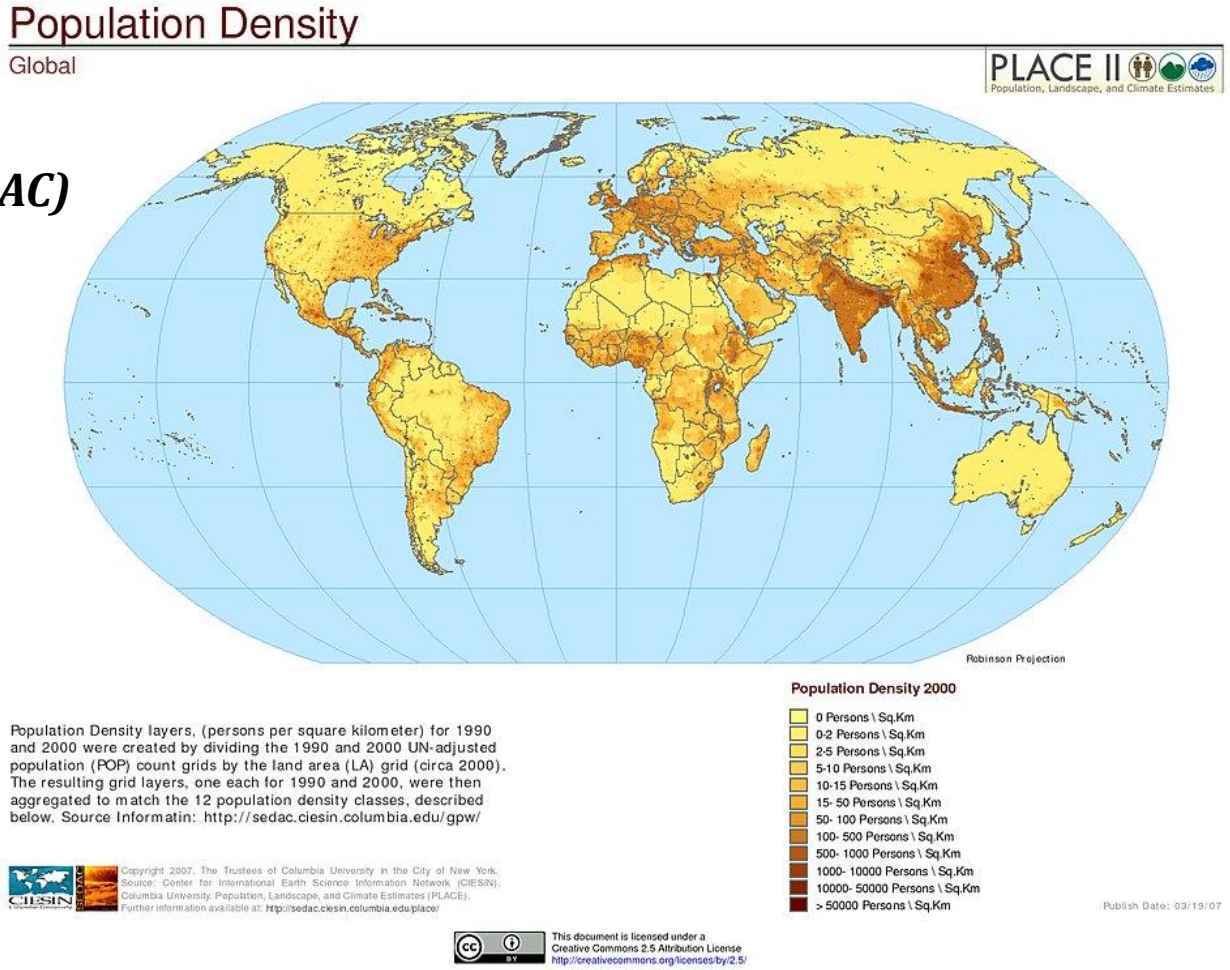
Thematic maps focus on specific aspects of information unlike **Reference maps**

- **Aim:** Tell a story that communicates a theme or concept about a geographic region
- **Goal:** Draw readers' attention to an important message
- **Challenge:** What is the most effective way to get the message across without getting lost in geographical details?

Visualization of GIS Data

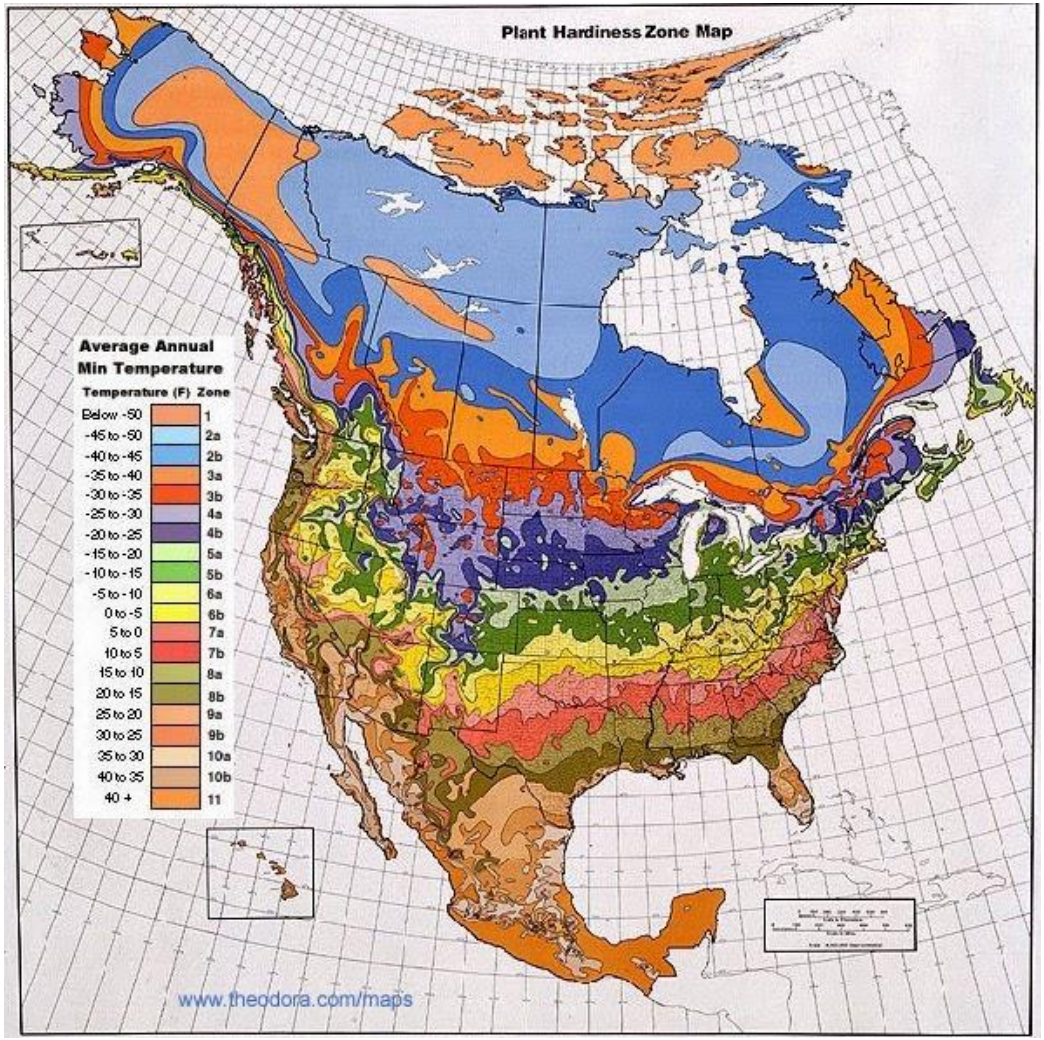
Maps

(Source: SEDAC)



Visualization of GIS Data

Maps



(obtained from www.imageboard.co)

Visualization of GIS Data

What Makes a Good Map?

- **Does the map tell a clear story?**
  - **Is there enough or too much information?**
  - **Is the information well balanced and composed on the page?**
  - **Are the map objects creating conflicts and distractions?**
- **Are your data suitable, well styled and explained?**
  - **Is the data too generalized?**
  - **Are the data symbols used appropriate?**
  - **Can the colour styles applied be easily be interpreted by all even those with colour-vision impairments?**
  - **Does the Legend clearly explain what is in the map?**

Visualization of GIS Data

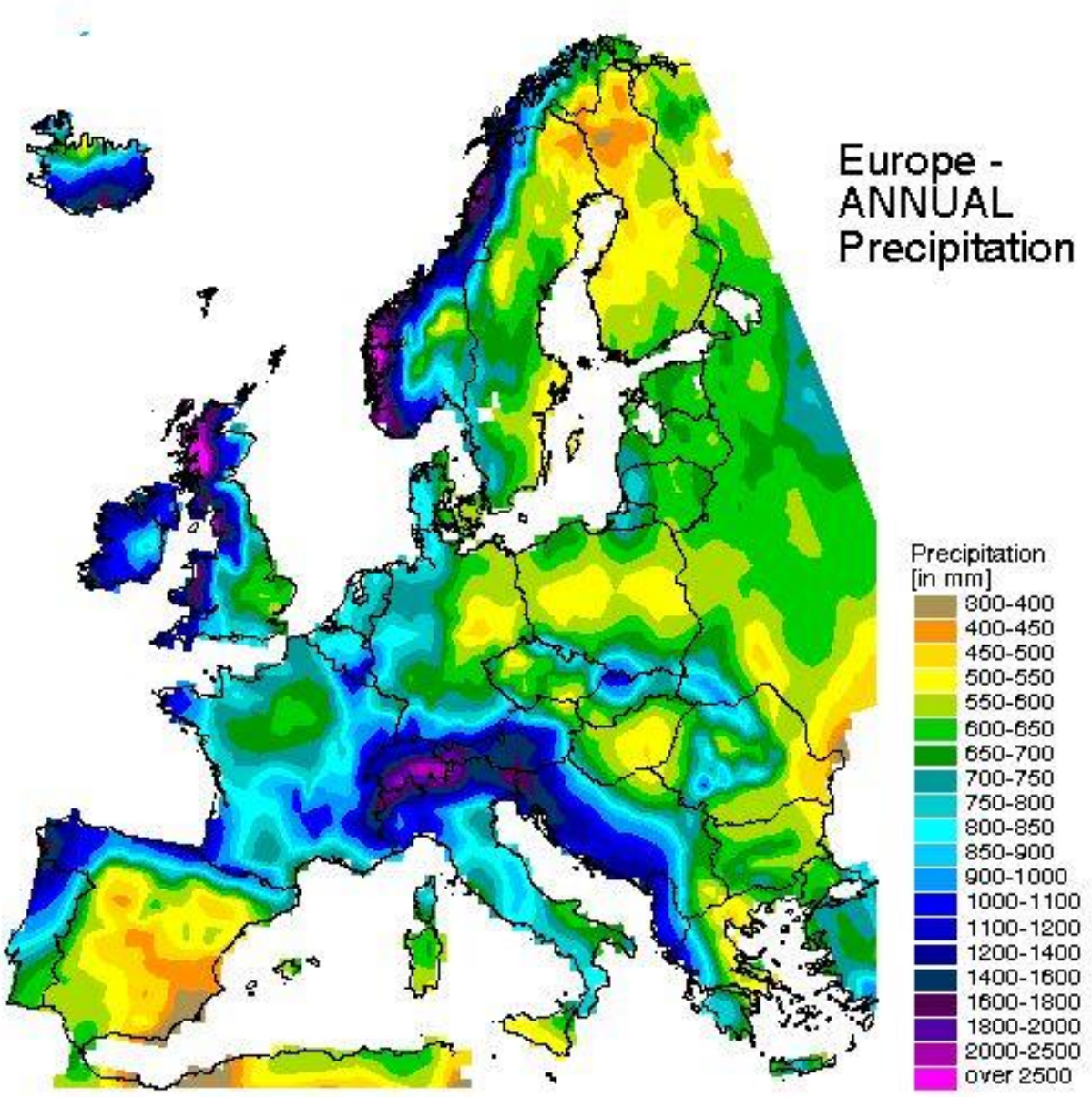
What Makes a Good Map?

What elements do a good map have?

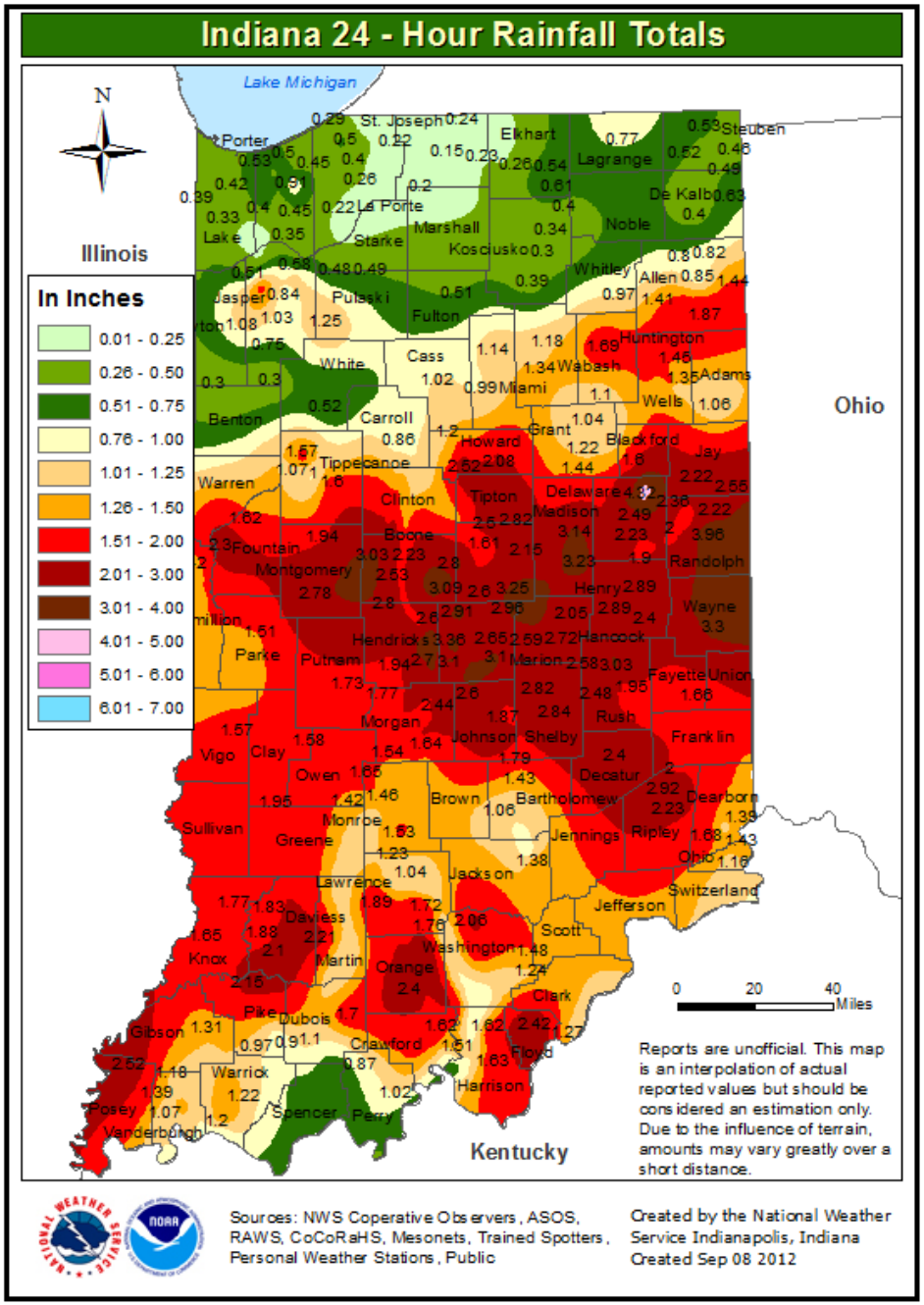
- ❑ **North Arrow**
- ❑ **Scale Bar**
- ❑ **Legend**
- ❑ **Title**
- ❑ **Text explanations (content, sources, author, etc.)**

Anything else???

Are the following images examples of good maps??

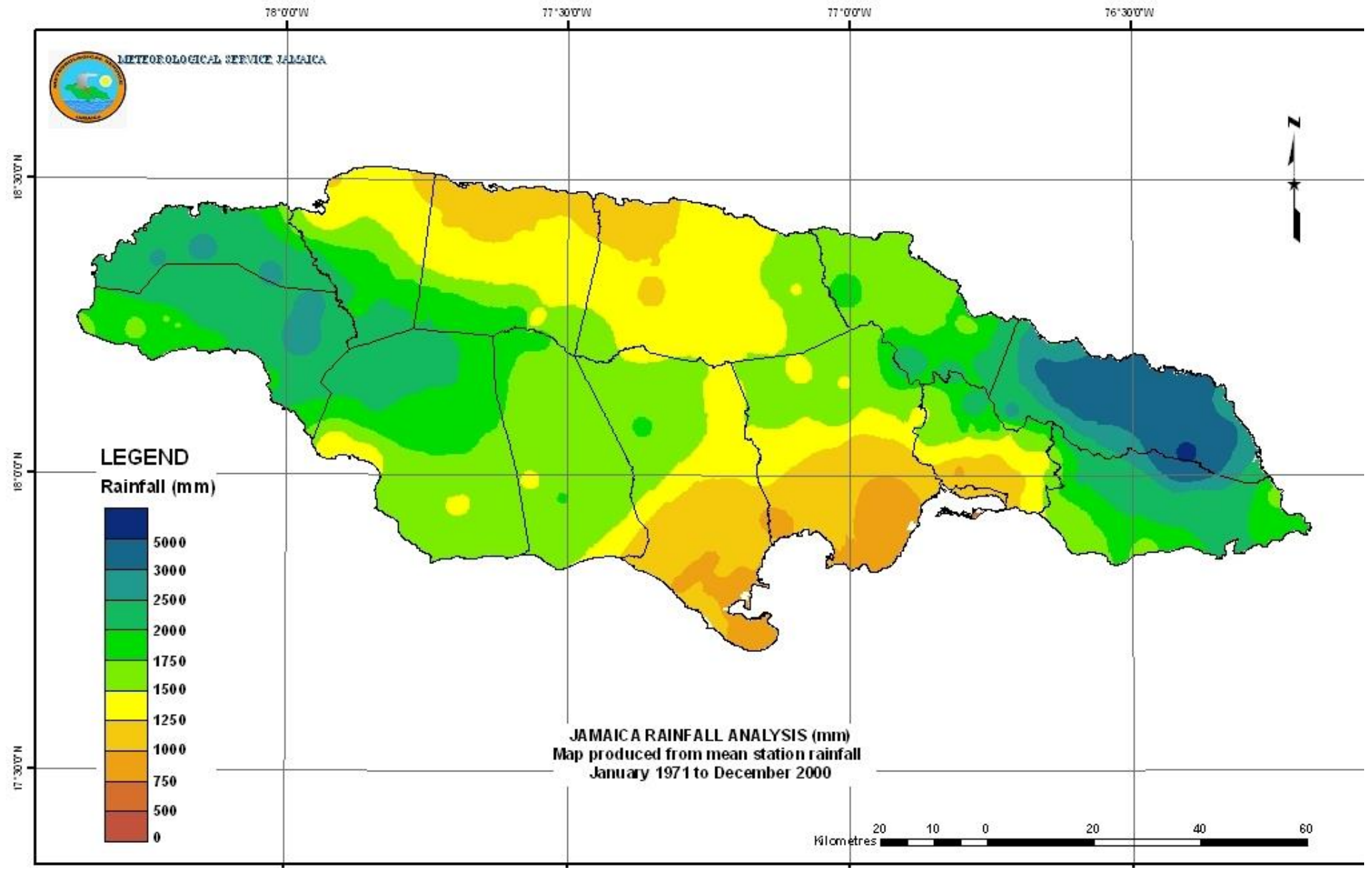


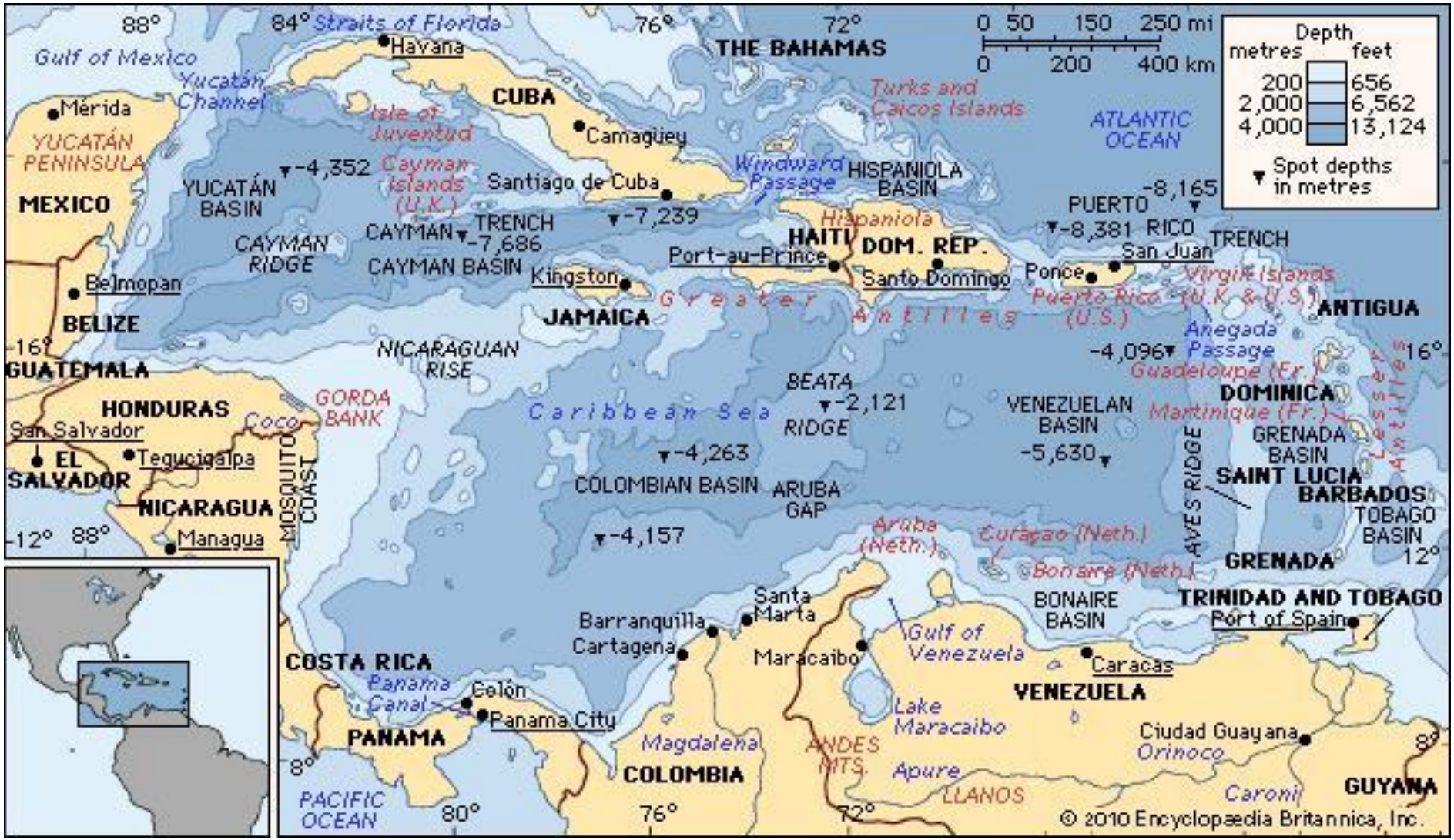
(obtained from http://norway4.wikispaces.com)



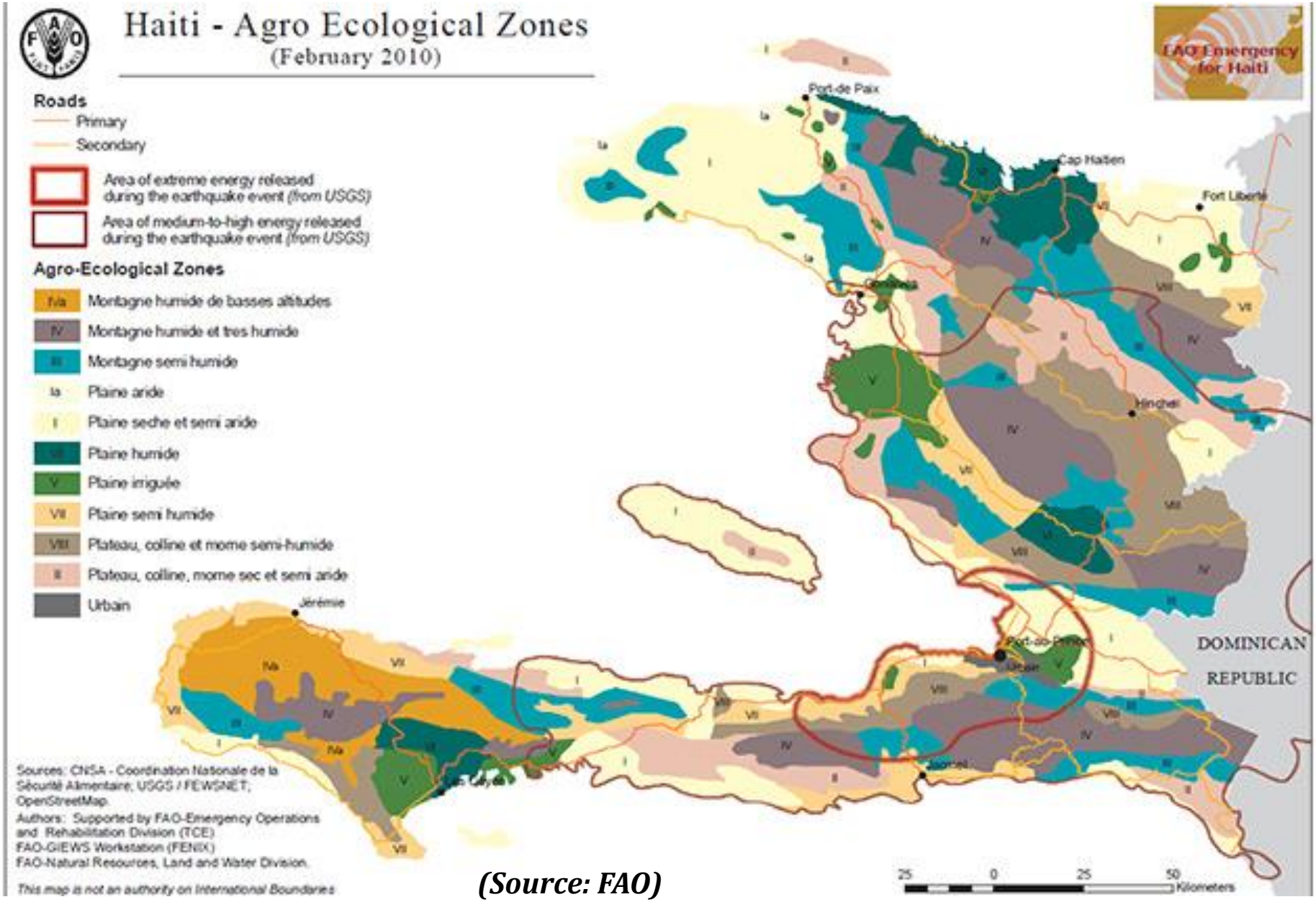
(Obtained from http://www.weather.gov)

(Obtained from http://www.jamaicaclimate.net)

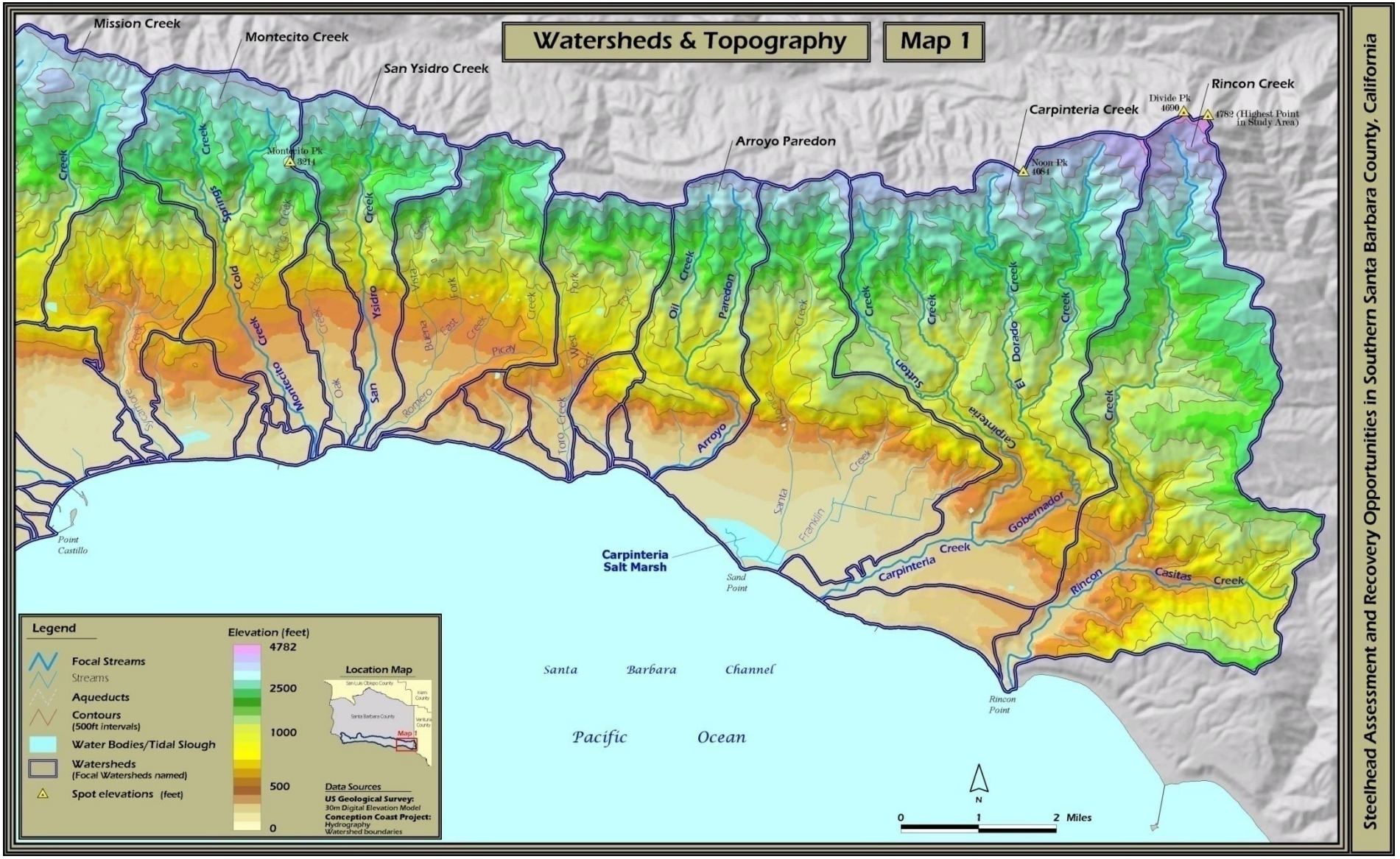




(Obtained from http://media-2.web.britannica.com)

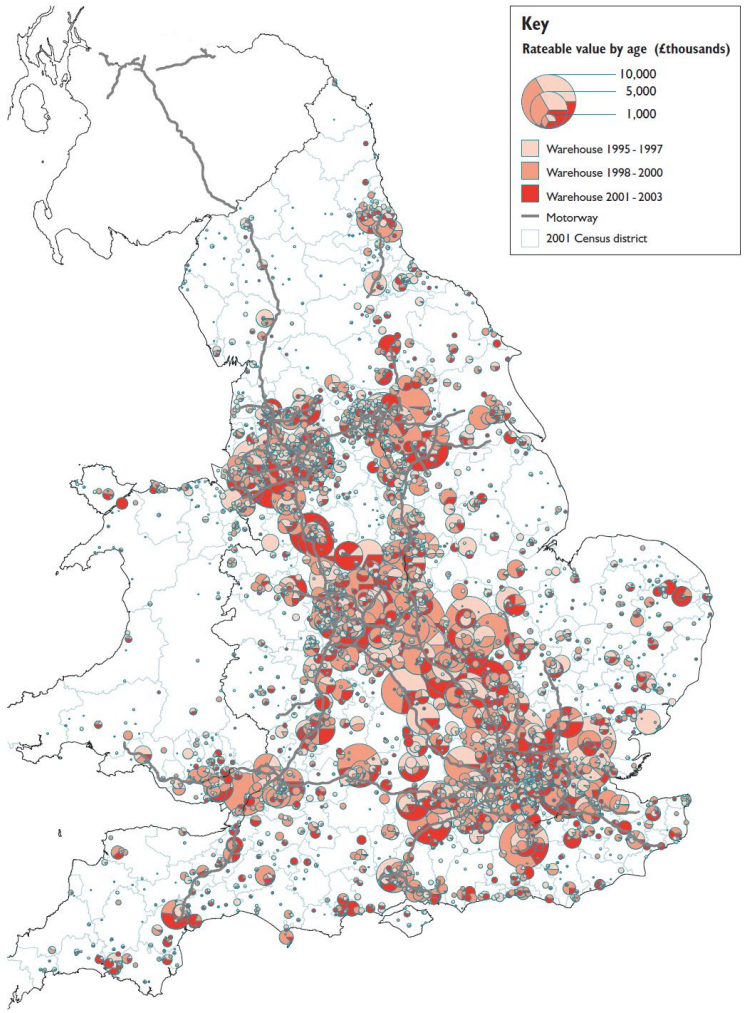

Haiti - Agro Ecological Zones
(February 2010)
FAO Emergency for Haiti
Roads
Primary
Secondary
Area of extreme energy released during the earthquake event (from USGS)
Area of medium-to-high energy released during the earthquake event (from USGS)
Agro-Ecological Zones
IVa Montagne humide de basses altitudes
IV Montagne humide et tres humide
III Montagne semi humide
Ia Plaine aride
I Plaine seche et semi aride
VI Plaine humide
V Plaine irriguée
VII Plaine semi humide
VIII Plateau, colline et morne semi-humide
II Plateau, colline, morne sec et semi aride
Urbain
Port-de Paix
Cap Haïtien
Fort Liberté
Hinche
Jérémie
Port-au-Prince
Jacmel
DOMINICAN REPUBLIC
Sources: CNSA - Coordination Nationale de la Sécurité Alimentaire; USGS / FEWSNET; OpenStreetMap
Authors: Supported by FAO-Emergency Operations and Rehabilitation Division (TCE)
FAO-GIEWS Workstation (FENIX)
FAO-Natural Resources, Land and Water Division
This map is not an authority on International Boundaries
25 0 25 50 Kilometers

(Source: FAO)



(Obtained from http://www.stoeckerecological.com)

Figure 1.17: Location of new warehouses with concentrations at motorway intersections, 1995-2003



(Obtained from http://gis.stackexchange.com)

Thank You!!

Questions???