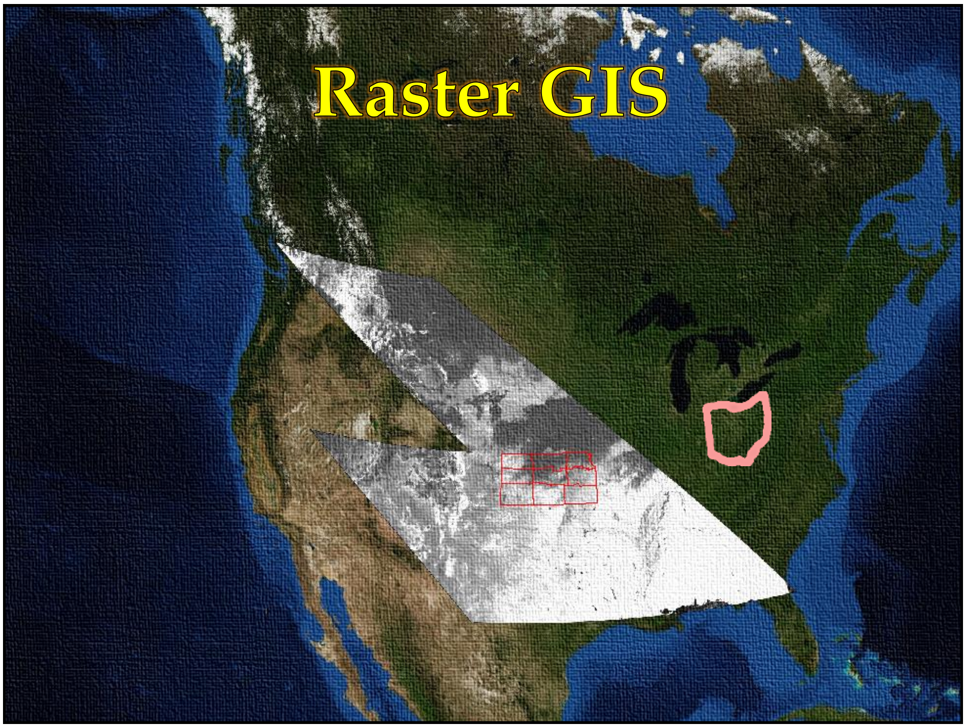


Data Type in programming

http://searchmicroservices.techtarget.com/definition/data-type

- a classification that specifies which type of value a variable has and what type of mathematical, relational or logical operations can be applied to it without causing an error
  - ✓ a string, for example, is a data type that is used to classify text and an integer is a data type used to classify whole numbers
  - ✓ http://desktop.arcgis.com/en/arcmap/10.3/manage-data/geodatabases/arcgis-field-data-types.htm
- to prevent errors, save spaces, …
  - ✓ it is logical to ask the computer to multiply a float by an integer (1.5 x 5), it is illogical to ask the computer to multiply a float by a string (1.5 x Alice)

Definition from Campbell, p. 6

- Remote sensing is the practice of deriving information about the Earth' s land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the Earth' s surface.

images

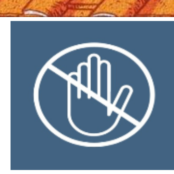
overhead perspective

Electromagnetic radiation / spectrum

reflected or emitted

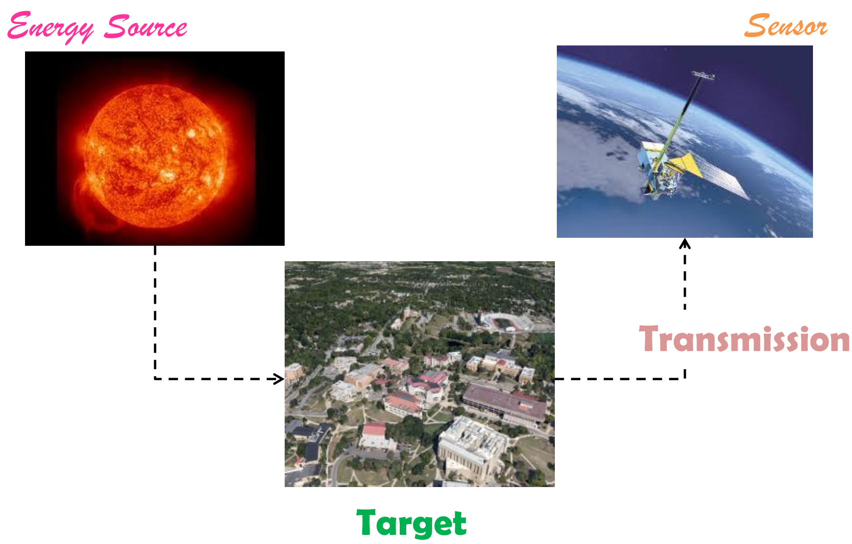
So, RS is . . .

- Eyes observing the Earth, but



touch me not!

Components of RS System

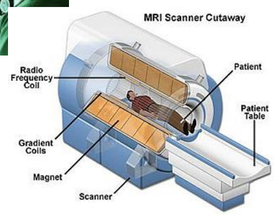


Example: Weather S. Image

- *target: Earth's surface*
  - *energy: travels through the atmosphere and space and reaches the sensor*
    - *sensor: measures, records the energy to depict the differences in temp. across the planet's surface*

Other Examples: not limited to …

Astronomy & Cosmology:
birth, life, and death of stars



Medical Applications: X-ray, MRI…

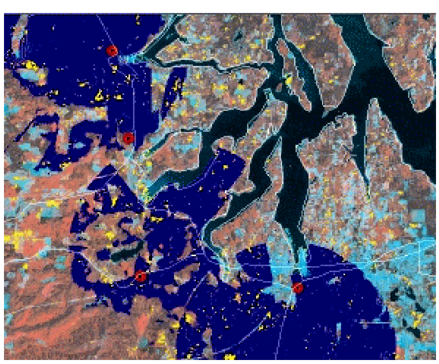
As an integral part of mapping & GIS

- Updating Databases
- Categorizing Land Cover and Characterizing Sites
- Identifying and Summarizing Natural Hazard Damage
- Identifying and Monitoring Urban Growth and Changes
- Extracting Features Automatically
- Assessing Vegetation Stress

As an integral part of mapping & GIS

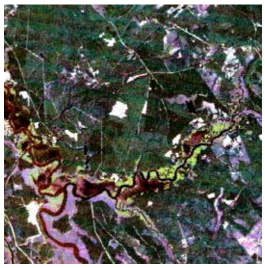
- *Updating Databases*
  : use imagery to identify changes and make revisions and corrections to geographic database

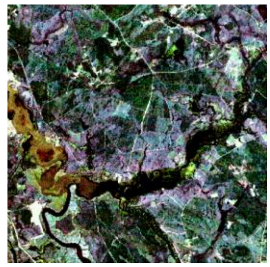
As an integral part of mapping & GIS

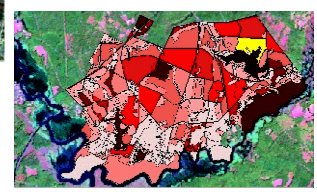


- *Categorizing Land Cover and Characterizing Sites*
  : categorize images into land cover classes to help identify suitable locations

As an integral part of mapping & GIS







- *Identifying and Summarizing Natural Hazard Damage*

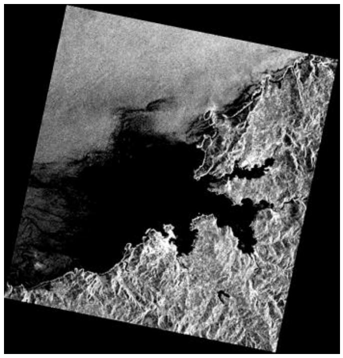
  : before & after Hurricane,

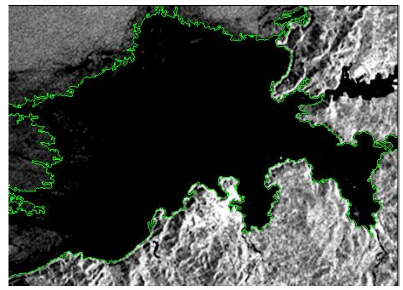
  identifies the forest boundary for comparison

As an integral part of mapping & GIS

Urban Growth in Columbus, Ohio
Sensor: L5 TM, L8 OLI
Acquisition Date: August 13, 1986, August 10, 2014
Path/Row: 19/32
Lat/Long: 40.300/-82.600
Pop.: 600,000 to 820,000

As an integral part of mapping & GIS

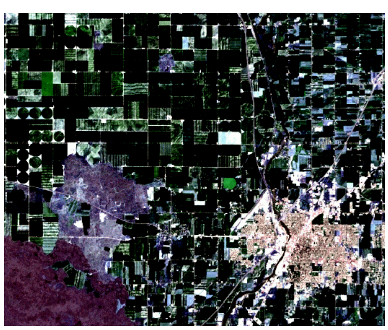


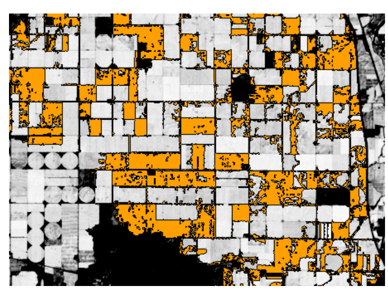


- *Extracting Features Automatically*

  : mapping the extent of an oil spill as part of a rapid response effort

As an integral part of mapping & GIS

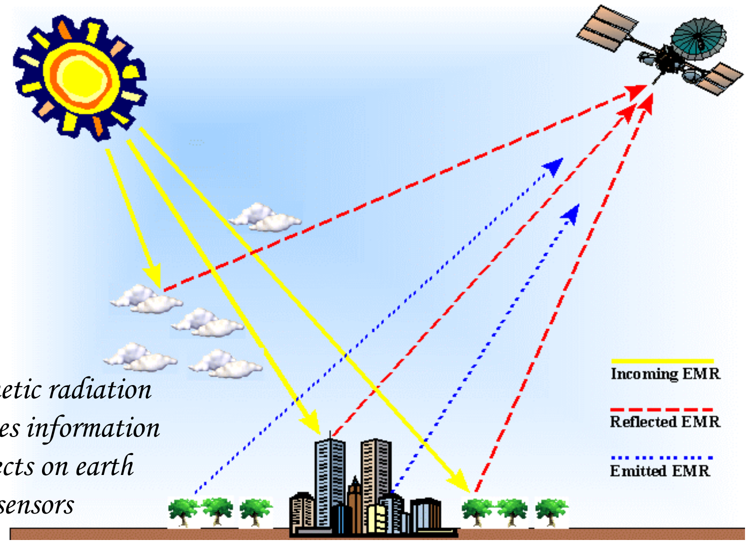




Assessing Vegetation Stress

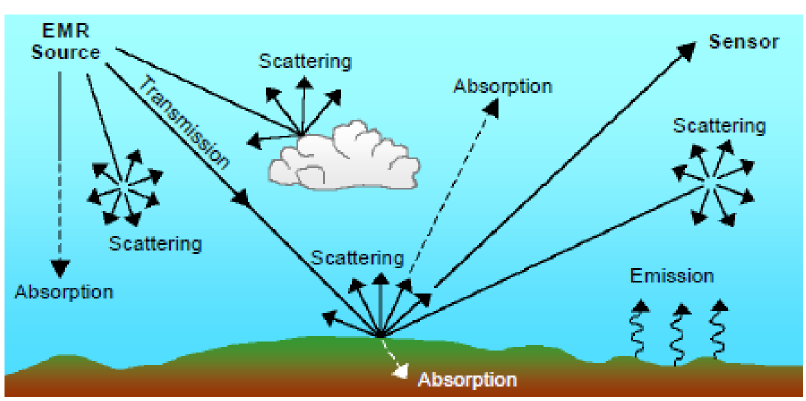
: identify and monitor a crop's health

How Does Remote Sensing Work?



Electromagnetic radiation (EMR) carries information between objects on earth surface and sensors

Interaction Processes in RS

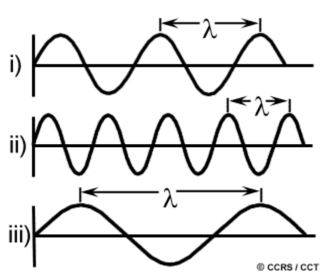


Electromagnetic Radiation

With the exception of objects at absolute zero, all objects emit **electromagnetic radiation**. Objects also reflect radiation that has been emitted by other objects. By recording emitted or reflected radiation, and applying a knowledge of its behavior as it passes through the earth's atmosphere and interacts with objects, remote sensing analysts develop a knowledge of the character of features such as vegetation, structures, soils, rock, or water bodies on the earth's surface. Interpretation of remote sensing imagery depends on a sound understanding of electromagnetic radiation and its interaction with surfaces and the atmosphere.

- Campbell, p. 31

Wavelength & Frequency



$c = \lambda v$

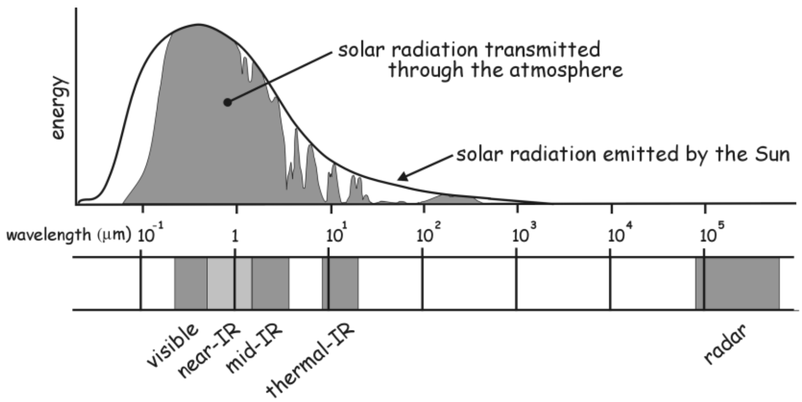
where:

λ = wavelength (m)
v = frequency (cycles per second, Hz)
c = speed of light (3×10^8 m/s)

- *Inversely related to each other*

  : The shorter the wavelength, the higher the frequency.
  : The longer the wavelength, the lower the frequency.

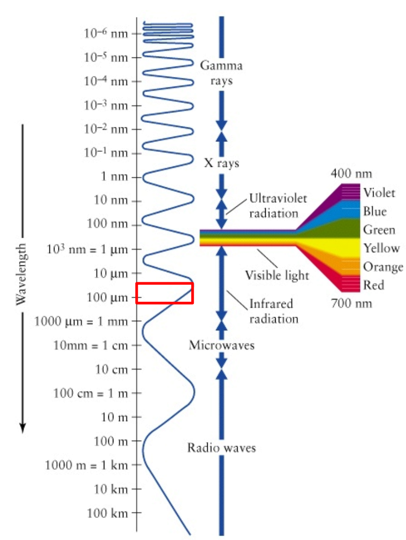
Electromagnetic Spectrum



- *Human eyes perceive light in the visible portion of the spectrum between 0.4 and 0.7μm.*
- *Specific bands of wavelengths are used for remote sensing.*
  : Reflected IR & Emitted (or Thermal) IR
  : Near-IR (0.7~1.3μm), Mid-IR (1.3~3.0μm), Far IR (7.0~1,000μm)

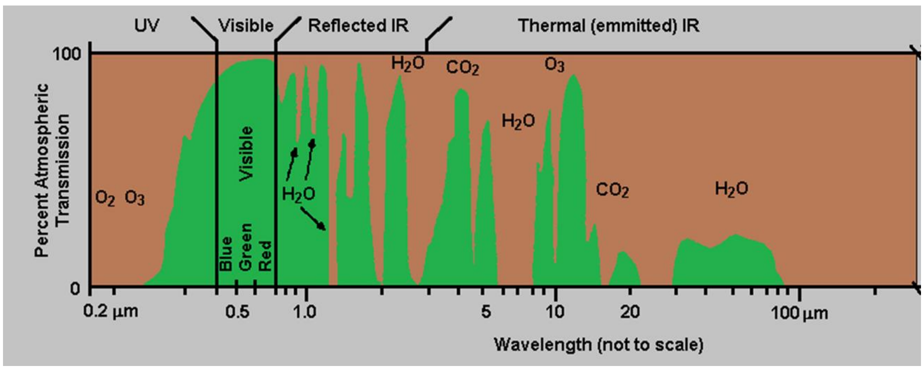
TIR Radiation

- Radiation at wavelengths between *3 - 14 μm*
- The earth with its ambient temperature of ca. 300 K has its peak energy emission in the thermal infrared region at around *9.7 μm*.

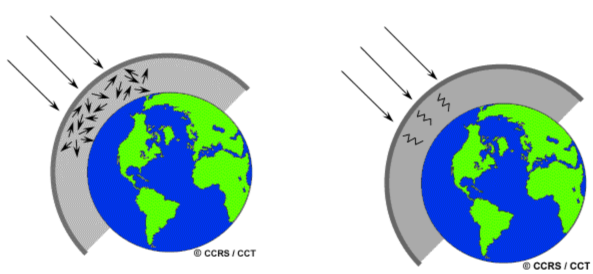


Atmospheric Windows in the Thermal IR Region

- situated between *3 - 5 μm* and *8 - 14 μm*
  - ✓ an excellent atmospheric window lies between *8-14 μm*
  - ✓ note the narrow absorption band from 9 to 10 μm caused by ozone which is omitted by most thermal IR satellite sensors



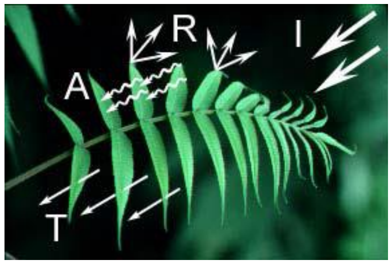
Interactions with Atmosphere



- *Scattering: particles or large gas molecules interact with and cause the electromagnetic radiation to be redirected*

- *Absorption: causes molecules in the atmosphere to absorb energy at various wavelengths*

Interactions with Target



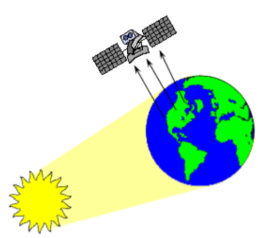
- Absorption (A)
- Transmission (T)
- Reflection (R)

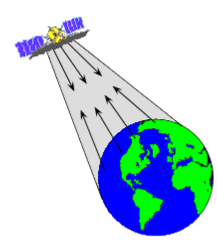
Leaves

: A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths.

: Leaves appear "greenest" to us in the summer, when chlorophyll content is at its maximum.

Passive and Active Sensors





- *Passive*
  : detect energy when the naturally occurring energy is available
  : visible, near-infrared and thermal imaging sensors
- *Active*
  : provide their own energy source for illumination
  : microwave (Radar) sensors

Spectral Signatures

- Experimental studies in field, in the laboratory, and experience with multi-spectral satellite imagery have shown that the spectral information (curve) is useful in identifying and distinguishing targets
- Because spectral responses measured by remote sensors over various features often permit an assessment of the type and/or condition of the features, these responses have often referred to as *spectral signatures*
- Other information for indentifying targets
  - ✓Spatial clues (pattern, size, shape, texture)
  - ✓Temporal (phenology)

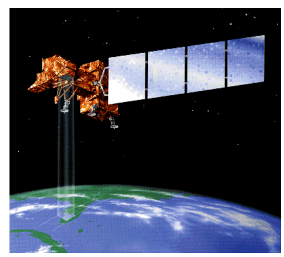
Sensor and Platform

- **A remote sensing platform is designed** with a relatively narrow set of purposes in mind. Many important decisions must be made when designing a remote sensing technology. The *type of sensor and its capabilities* must be defined. The *platform* on which the sensors will be mounted must be determined. The *means* by which the remotely-sensed data is received, transmitted, and processed before delivery to its end user must be designed. All of these decisions are made *based on knowledge of the target and the information about the target* that is in demand, balanced by other factors such as cost, availability of resources, and time constraints.

Two Major Platforms

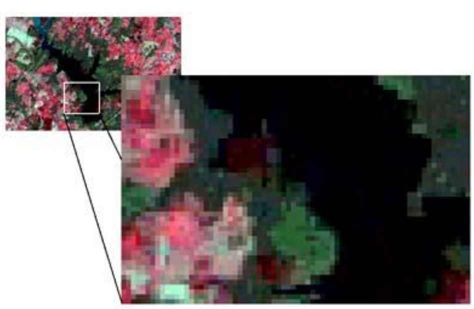
Aerial Photographs
- small area coverage
- severe distortion
- high spatial resolution
- flexibile on image acquisition

Satellite Images
- large area coverage
- geometrically accurate
- low spatial resolution
- limited flexibility on image acquisition



Digital Image

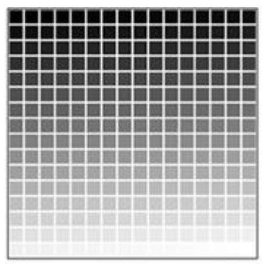
- Sensor measures the intensity of EMR
  - this detected energy level is converted into a digital value known as Digital Number (DN, or brightness value)
  - pixel (short for "picture element") is a single dot that contains the numerical value



- *So digital image is a collection of numeric data that is capable of being displayed as an image.*

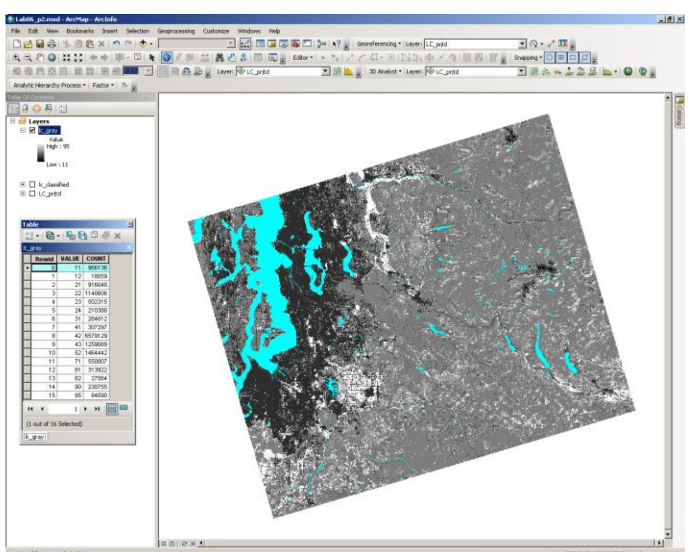
Gray Scale

- Most raw unprocessed satellite imagery is stored in a gray scale format
  - a gray scale is a color scale that ranges from black to white, with varying intermediate shades of gray
  - a commonly used 256 shade gray scale, where a value of 0 represents a pure black color, the value of 255 represents pure white, and each value in between represents a progressively darker shade of gray



- *256 level gray scale*

Gray Scale



Enhancing Image Data

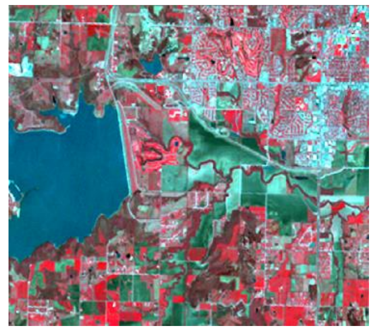
- The human eye can only distinguish between about 16 shades of gray in an image
  - ✓ however it is able to distinguish between millions of different colors
  - ✓ thus, a common image enhancement technique is to assign specific DN values to specific colors, thereby increasing the contrast of particular DN values with the surrounding pixels in an image

True color and False color

- A true color image is one for which the colors have been assigned to DN values that represent the actual spectral range of the colors used in the image
  - ✓ blue features appear blue, green features appear green, red features appear red
  - ✓ a photograph is an example of a true color image

- False color is a technique by which colors are assigned to spectral bands that do not equate to the spectral range of the selected color
  - ✓ this allows an analyst to highlight particular features of interest using a color scheme that makes the features stand out

Displaying Multiple Band Images



- *Band: 3, 2, 1*
- ***Natural** color*

- *Band: 4, 3, 2*
- ***NIR** false color*

Multiple Bands

- Humans cannot see light past the visible spectrum, but satellites are able to detect wavelengths into the ultraviolet and infrared
- Satellite instruments are able to obtain many images of the same location, at the same time
- Each image highlights a different part of the electromagnetic spectrum, called a ***band***
- The Landsat 7 satellite uses an instrument that collects seven images (+1 panchromatic image) at once

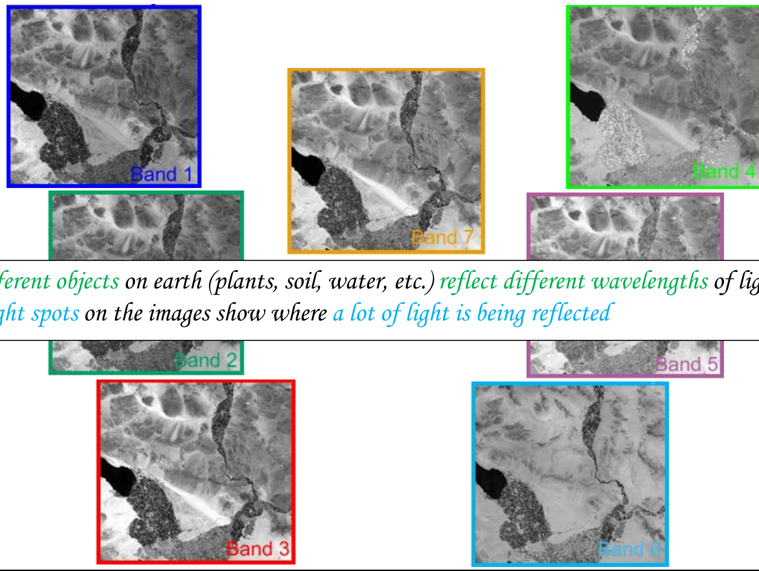
Multiple Bands

Sensor Name	Number of Channels	Spectral Range	Spectral Resolution	Spatial Resolution	Dynamic Range
GeoEye-1	3-V 1-NIR 1-pan	0.450–0.510 μm (B) 0.510–0.580 μm (G) 0.655–0.690 μm (R) 0.780–0.920 μm (NIR) 0.450–0.800 μm (pan)	35–140 nm (VNIR) 350 nm (pan)	1.65 m (VNIR) 0.41m (pan) at nadir	11 bits
LANDSAT-7	3-V 1-NIR 2-SWIR 1-TIR 1-pan	0.450–0.515 μm (B) 0.525–0.605 μm (G) 0.630–0.690 μm (R) 0.750–0.900 μm (NIR) 1.55–1.75 μm (SWIR) 2.08–2.35 μm (SWIR) 10.40–12.50 μm (TIR) 0.520–0.900 μm (pan)	60–150 nm (VNIR) 200–270 nm (SWIR) 2100 nm (TIR) 380 nm (pan)	30 m (XS) 60 m (TIR) 15m (pan)	8 bits
SPOT-5	2-V 1-NIR 1-SWIR 1-pan	0.500-0.590 μm (G) 0.610–0.680 μm (R) 0.780–0.890 μm (NIR) 1.58–1.75 μm (SWIR) 0.480–0.710 μm (pan)	70–110 nm (VNIR) 170 nm (SWIR) 380 nm (pan)	10 m (XS) 20m (SWIR) 2.5m (pan)	8 bits

Landsat 7, the Enhanced Thematic Mapper Plus (ETM+)

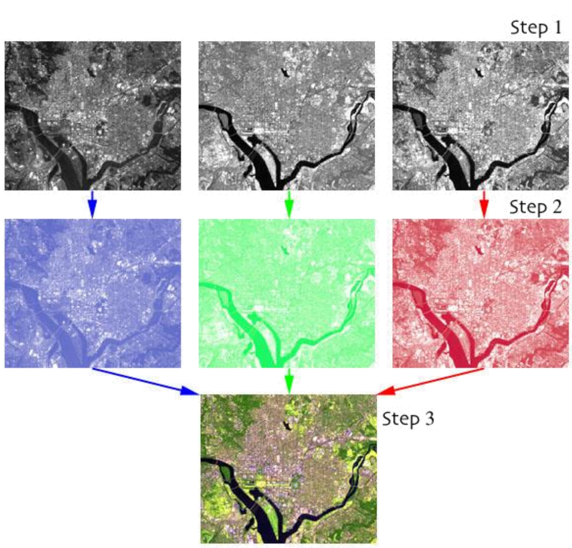
Band	Name	Band Width (λ, μm)	Spatial Resolution
1	Blue	0.45-0.515	30 m
2	Green	0.525-0.605	30 m
3	Red	0.63-0.69	30 m
4	Near Infrared	0.75-0.90	30 m
5	Shortwave IR-1	1.55-1.75	30 m
6	Thermal IR	10.4-12.5	60 m / 120 m*
7	Shortwave IR-2	2.09-2.35	30 m
8*	Panchromatic	0.52-0.9	15 m

Multiple Bands of Landsat 7



- different objects on earth (plants, soil, water, etc.) reflect different wavelengths of light
- bright spots on the images show where a lot of light is being reflected

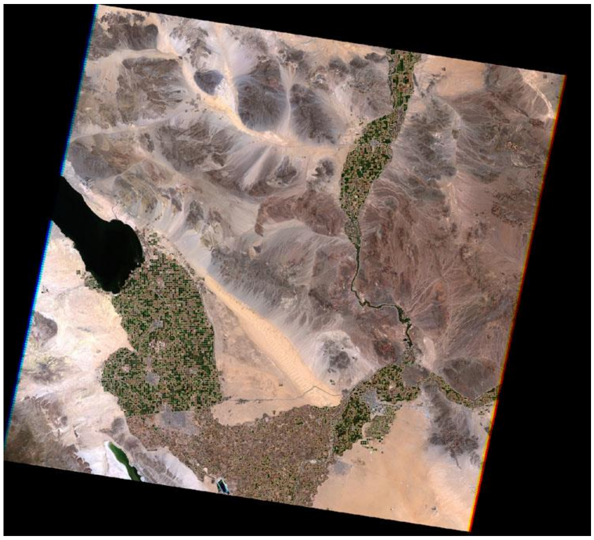
Band Combinations



- **Step 2**

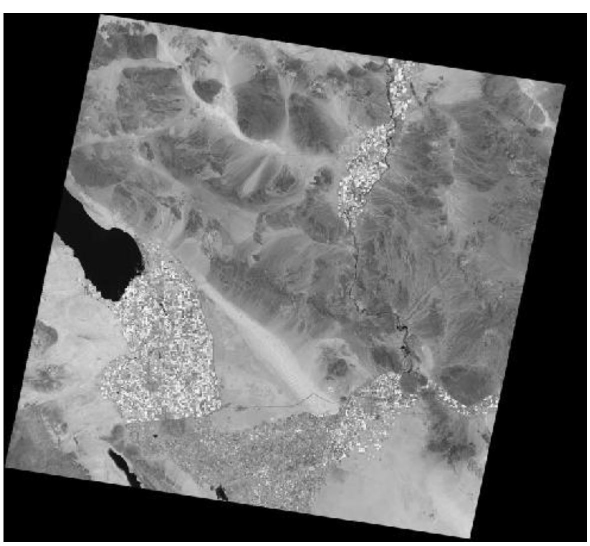
- ... different contrast (light and dark areas)

Sample Images: Landsat 7



- *"true color" image of the desert around the Salton Sea and Imperial Valley in Southern California*

Sample Images: Landsat 7



- *Band 4 image : 0.76 and 0.90μm*
- *What do you think the light areas are?*

- *The light areas are vegetation.*
- *In band 4 (NIR), vegetation is highly reflective.*

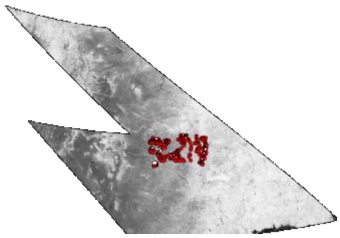
Vegetation Indexes - NDVI

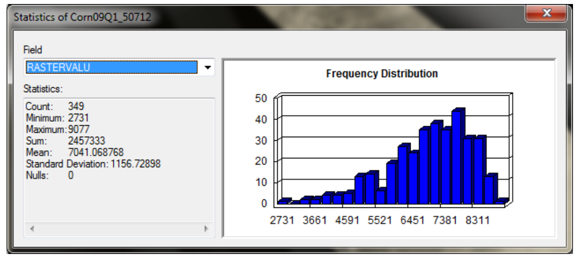
- Importance of vegetation monitoring on a regular basis
  - ✓ crop progress
  - ✓ grassland condition
  - ✓ forest (fire fuel, condition, deforestation)
- An early goal was to develop a single numerical index to create a new image that would correspond to specific canopy measurements: green biomass, LAI, % vegetative ground cover
- Based on the relationships among the bands
- Note the spectral curves and relationships – e.g., what happens to the vegetation curve when it goes from actively growing green vegetation to dying or dead vegetation.
- Some vegetation indices have been single bands, but most have been ratios of bands.
- NDVI (Rouse, et al., '73) - developed it initially with MSS data
- NDVI is far and away the most common vegetation index.

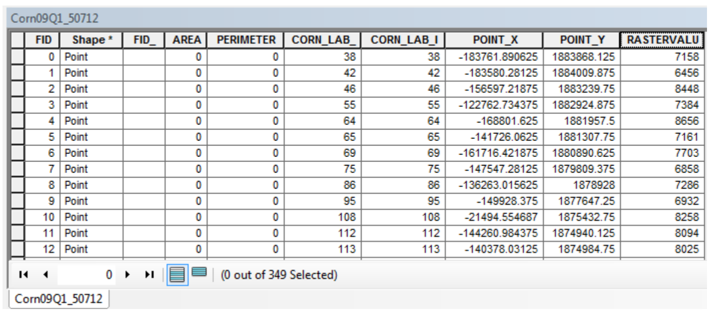
Vegetation Indexes - NDVI

- Formula: (NIR – Red) / (NIR + Red)
- Potential values range from -1.0 to +1.0
  - ✓ low values (around .20 or less) have little or no green vegetation
  - ✓ higher values (around .30 or greater) have increasing amounts of green vegetation
- What bands would be used for calculating NDVI using TM?
- NIR = 24, Red = 20, NDVI = ?
- NIR = 34, Red = 12, NDVI = ?

MODIS NDVI





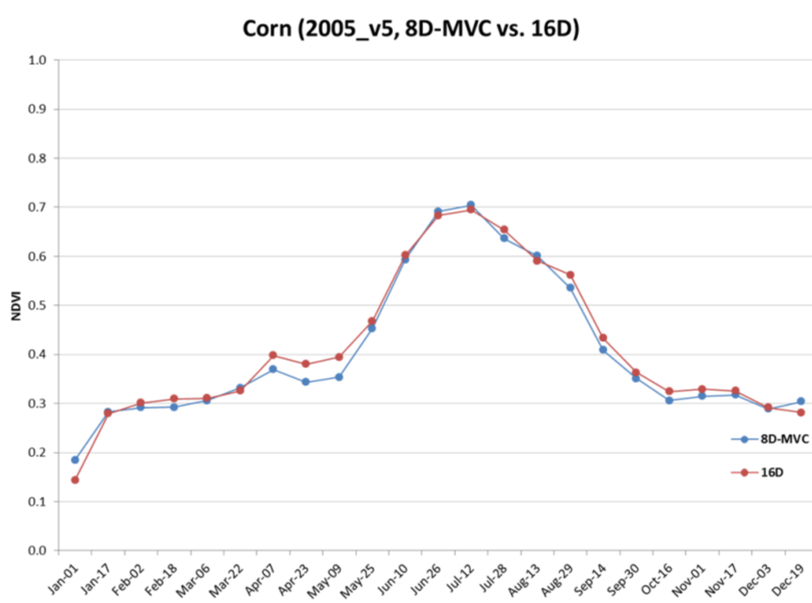


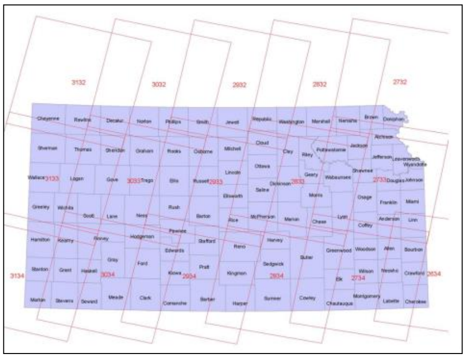
Corn09Q1_50712

FID	Shape *	FID_	AREA	PERIMETER	CORN_LAB_	CORN_LAB_I	POINT_X	POINT_Y	RASTERVALU
0	Point		0	0	38	38	-183761.890625	1883868.125	7158
1	Point		0	0	42	42	-183580.28125	1884009.875	6456
2	Point		0	0	46	46	-156597.21875	1883239.75	8448
3	Point		0	0	55	55	-122762.734375	1882924.875	7384
4	Point		0	0	64	64	-168801.625	1881957.5	8656
5	Point		0	0	65	65	-141726.0625	1881307.75	7161
6	Point		0	0	69	69	-161716.421875	1880890.625	7703
7	Point		0	0	75	75	-147547.28125	1879809.375	6858
8	Point		0	0	86	86	-136263.015625	1878928	7286
9	Point		0	0	95	95	-149928.375	1877647.25	6932
10	Point		0	0	108	108	-21494.554687	1875432.75	8258
11	Point		0	0	112	112	-144260.984375	1874940.125	8094
12	Point		0	0	113	113	-140378.03125	1874984.75	8025

0 (0 out of 349 Selected)

Corn09Q1_50712





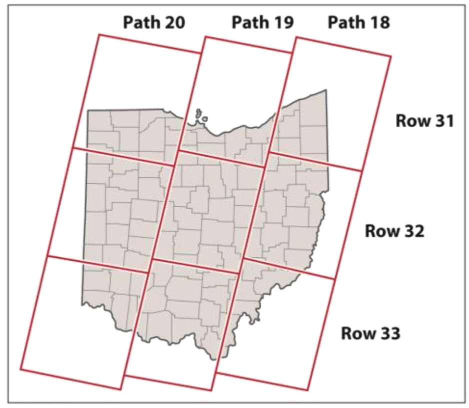


Figure 11.10
Introduction to Geospatial Technologies, Second Edition

82,277 mi²

44,825 mi²

ASCII to Raster

- ASCII2Grid.txt
  - ✓ Conversion Tools > To Raster > ASCII to Raster

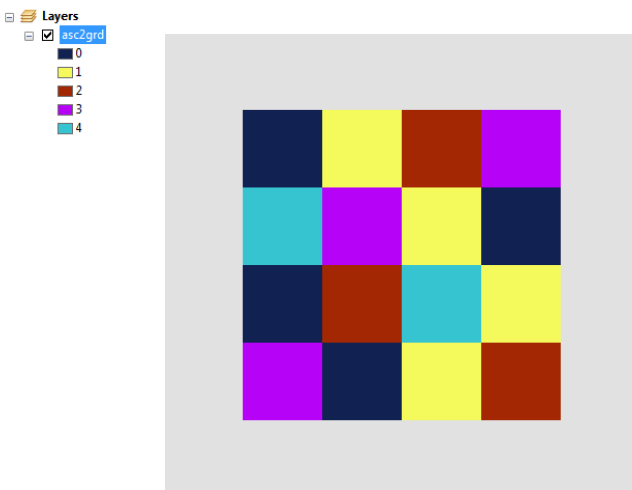
```
ncols 6
nrows 6
xllcorner 0
yllcorner 0
cellsize 10
nodata_value -9999
-9999 -9999 -9999 -9999 -9999 -9999
-9999 0 1 2 3 -9999
-9999 4 3 1 0 -9999
-9999 0 2 4 1 -9999
-9999 3 0 1 2 -9999
-9999 -9999 -9999 -9999 -9999 -9999
```

Layer Properties

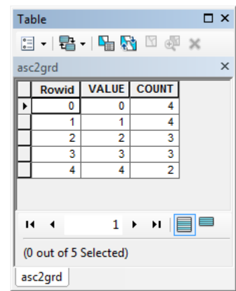
General | Source | Key Metadata | Extent | Display | Symbology

Property	Value
Raster Information	
Columns and Rows	6, 6
Number of Bands	1
Cell Size (X, Y)	10, 10
Uncompressed Size	144 B
Format	GRID
Source Type	Generic
Pixel Type	unsigned integer
Pixel Depth	8 Bit

How many cells?



- What is the number of cells of which **VALUE** is **3** in the layer?

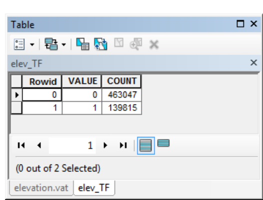


Rowid	VALUE	COUNT
0	0	4
1	1	4
2	2	3
3	3	3
4	4	2

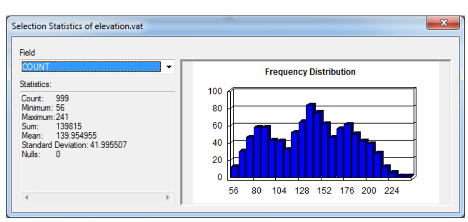
True or False

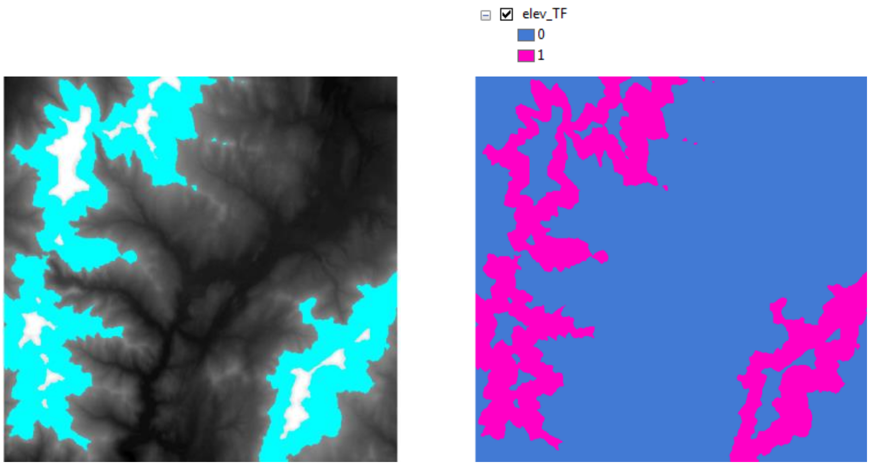
- ("elevation" > 2000) & ("elevation" < 3000)
- ("VALUE" > 2000) AND("VALUE" < 3000)

Rowid	VALUE *	COUNT
1559	2001	225
1560	2002	202
1561	2003	207
1562	2004	205
1563	2005	207
1564	2006	219
1565	2007	241
1566	2008	206
1567	2009	209
1568	2010	209
1569	2011	218
1570	2012	203
1571	2013	223
1572	2014	214
1573	2015	203
1574	2016	191
1575	2017	211
1576	2018	204
1577	2019	216
1578	2020	192
1579	2021	212
1580	2022	238
1581	2023	195
1582	2024	205
1583	2025	172
1584	2026	208
1585	2027	187
1586	2028	220
1587	2029	208



Rowid	VALUE	COUNT
0	0	463047
1	1	139815





Querying across multiple grid layers

- **([depth] < 20) & ([slope] > 5) & ([salinity] < 0.015**)
- What's the benefit?
  - ✓ In a typical tabular query, the query is performed on a single table.
  - ✓ In the case presented above, the query simultaneously finds cells that match the value of several raster grids (not just values in a single table).
  - ✓ The cell *locations* are determined by the spatial referencing framework, but the *values* are determined by different values across multiple raster grids.

Executing tools in Map Algebra

- Create a Slope
- Average of the max. temp. from 1995 through 1999