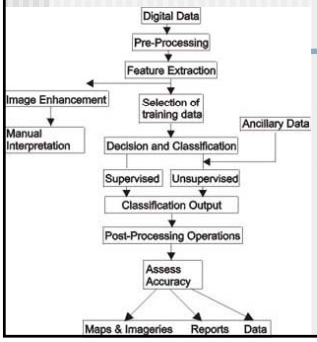
Introduction to Digital Image Processing and Analysis



Digital Image Processing

- Satellite image and many airborne data types are captured directly in a digital form
- Hardcopy imagery (e.g. air photos) can be scanned into digital form
- Digital image data in gridded (raster) form
- Digital procedures are complementary to analog techniques
- In many cases, most efficient for mapping and analysis
- Most efficient for processing images

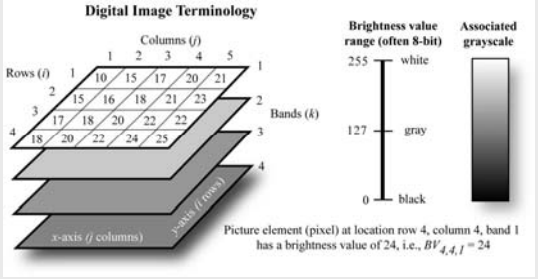
Manual vs. Digital Image Processing

- Advantages of Digital Processing
  - Ability to **quantify** brightness levels
  - Greater standardization
  - Can achieve greater efficiency
  - Restore image fidelity
  - Enhance earth surface features;
  - improves interpretability

Manual vs. Digital Image Processing

- Disadvantages of Digital Processing
  - Generally, lower interpretation accuracy (without human experiences)
  - Cost (more expensive and information dependent)
  - More sophisticated **equipment** and training requirements

Remote Sensing Raster (Matrix) Data Format



Jensen, 2004

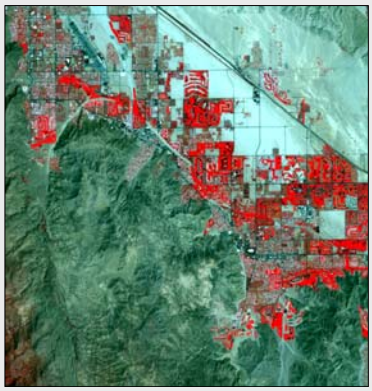
Data Acquisition

- Image Digitization
  - Optical Mechanical (Scanner) – Flatbed and Rotating Drum
    - Densitometer measures average density of small area of photo, transparency, or print
    - Offers high spatial and radiometric accuracy but slow and difficult to maintain
  - Video Digitizing (camcorder), – sense image through video camera and perform analog-to-digital conversion
  - Linear and Area Array CCD (digital camera) – newer technology, quality higher than video

Litton Emerge Spatial, Inc., CIR image (RGB = NIR,R,G) of Dunkirk, NY, at 1 x 1 m obtained on December 12, 1998

Natural color image (RGB = RGB) of a N.Y. Power Authority lake at 1 x 1 ft obtained on October 13, 1997

Jensen, 2000



Landsat 7 Enhance Thematic Mapper Plus (ETM+) Image of Palm Spring, CA 30 x 30 m (bands 4,3,2 = RGB)

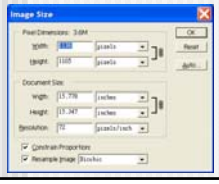
Jensen, 2000

Image Processing Flow

- Data Ingest
  - Obtain data via tape, CD, Internet
  - Convert data to system format
  - Create header or lineage file
    - Date
    - Source
    - Projection
    - Processing applied
    - Size parameters
    - Resolution

Image Processing Flow

- Image Assessment and Statistics
  - Generate and review image statistics
  - Display and view image
  - Preliminary assessment regarding pre-processing, enhancements



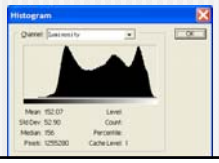


Image Processing Flow

- Restoration and Pre-processing
  - Correct imagery for distortions/degradations
  - Geometric and radiometric
  - Calibration
  - Convert types (e.g., byte to float)

Image Processing Flow

- Enhancements
  - Visual or digital analysis
  - Contrast
    - Stretches
    - Linear features
    - Band ratioing
  - Spatial convolutions
  - Other transforms

Image Processing Flow

- Feature Extraction and/or Calibration
  - Band selection
  - Signatures/training sets
    - Selection and assessment
  - Relate ground phenomena to image data

Image Processing Flow

- Image Classification or Quantification
  - Stratification
  - Classifier decision rule
  - Clustering
  - Calculation of biophysical parameter

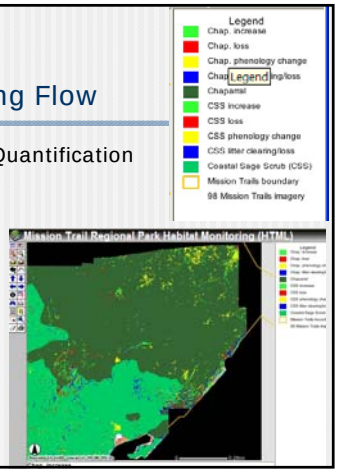


Image Processing Flow

- Output of Map or Derivative Image
  - Biophysical map
  - Thematic map
  - Statistics
  - Graphics

Ice Type (Norway)

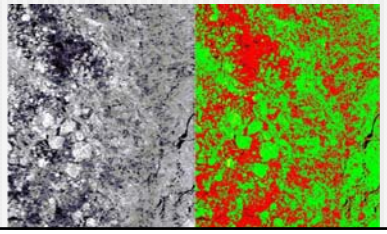


Image Processing Flow

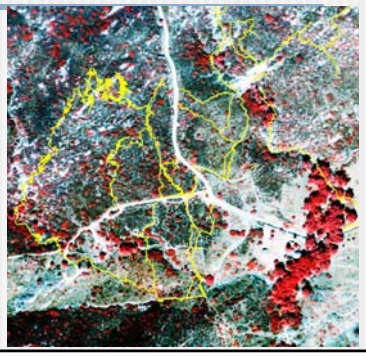
- Validation/Accuracy Assessment
  - Pre-defined criteria
  - Thematic accuracy
  - Locational accuracy
  - Quantitative (biophysical parameters)

On-screen Interpretation and "Heads-Up" Digitizing

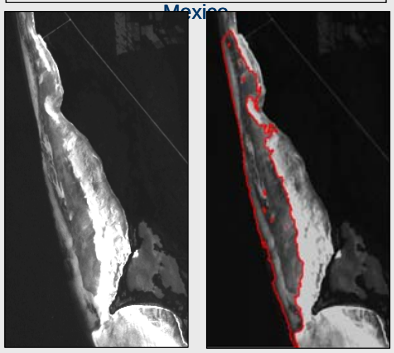
- Display
- Enhancement
- Interpretation
- Vector digitizing
- Attribute coding
- Editing
- Final product generation

On-screen Interpretation and "Heads-Up" Digitizing

(Manual)



Columbia Reef on Cozumel Island, Mexico



Courtesy of SPOT Image, Inc.

Jensen, 2000

SPOT XS Band 1
(0.50 - 0.59 μm) April 19, 1988

Perimeter = 80,880 ha
Area = 398 m^2

Land Use / Land Cover Applications

Introduction

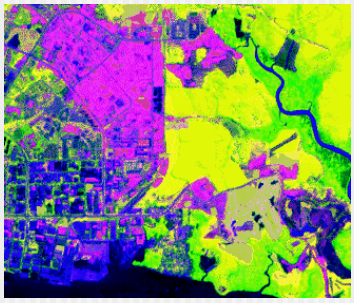
- Land Cover
  - Types of features/materials present on **Earth's surface** e.g. trees, crops, buildings, roads, rocks, water, ice
- Land Use
  - **Human activity** associated with a piece of land e.g. agriculture, forestry, urban, transportation
- Remote Sensing of Land Use vs. Land Cover (LU/LC)
  - Land use is not recorded directly by remotely sensed data
  - Use elements of **interpretation** to **derive LU/LC information**

Introduction (cont.)

- LU/LC data
  - Needed for many applications
    - urban planning
    - resource management
    - global change, etc.
  - One of most common types of spatial/GIS data derived from remotely sensed imagery
    - **Inventory** of land use/land cover
    - **Detect/identify changes** in land use/land cover

LU/LC – Classification Procedure

- Involves classifying areas in imagery into homogeneous units
- Label each LU/LC type

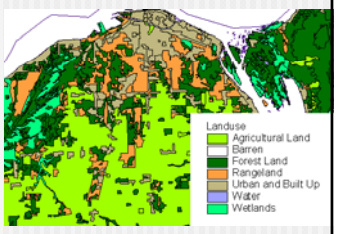


LU/LC – Classification Procedure (cont.)

- Subjective categorization
  - Where to draw boundaries
  - Level of generalization
  - Assignment of label
- Image interpretation considerations
  - Indirect, based on LU/LC recorded on image
  - Viewing only tops of objects
  - Interpreter differences

USGS - Level I Categories

- Suitable for use with moderate and coarse resolution satellite imagery
  - 1 - Urban or Built-up Land
  - 2 - Agricultural Land
  - 3 - Rangeland
  - 4 - Forest Land
  - 5 - Water
  - 6 - Wetland
  - 7 - Barren Land
  - 8 - Tundra
  - 9 - Perennial Ice or Snow



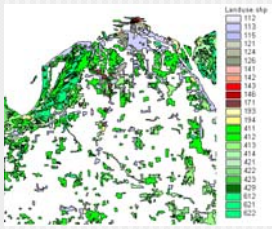
USGS - Level I - IV Categories

4 Forest Land (Level I)

42 Coniferous Forest (Level II)

421 Upland conifers (Level III)
- **4211 White pine predominates** (Level IV)
- **4212 Red pine predominates** (Level IV)
- **4213 Jack pine predominates** (Level IV)
- **4214 Scotch pine predominates** (Level IV)
- **4215 White spruce predominates** (Level IV)
- **4219 Other** (Level IV)

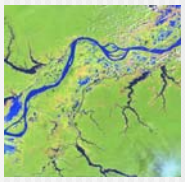
422 Lowland conifers (Level III)
- **4221 Cedar predominates** (Level IV)
- **4222 Black spruce predominates** (Level IV)
- **4223 Tamarack Predominates** (Level IV)
- **4224 Balsam fir-white spruce predominates** (Level IV)
- **4225 Balsam fir predominates** (Level IV)
- **4229 Other** (Level IV)



Resolution/Image Scale – LU/LC

Level I Landsat MSS

Level II Landsat TM or SPOT-XS, NAPP
(Scale 1:60,000 -> 1:120,000)



Resolution/Image Scale – USGS LU/LC

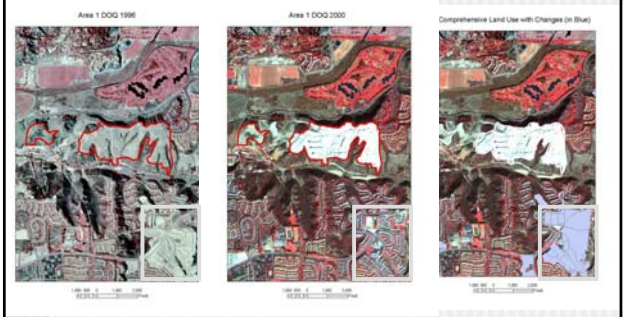
Level III IRS Pan, IKONOS, QuickBird,
SPOT-PAN, Med.-scale aerial photography
(Scale Range 1:20,000 -> 1:60,000)

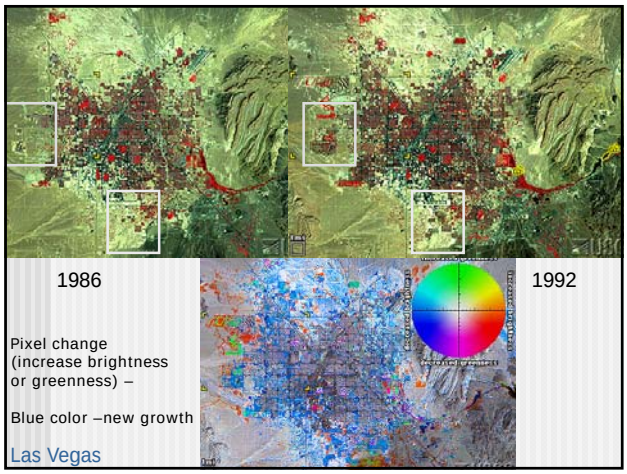
Level IV Low altitude aerial photography
(Scale < 1:20,000)

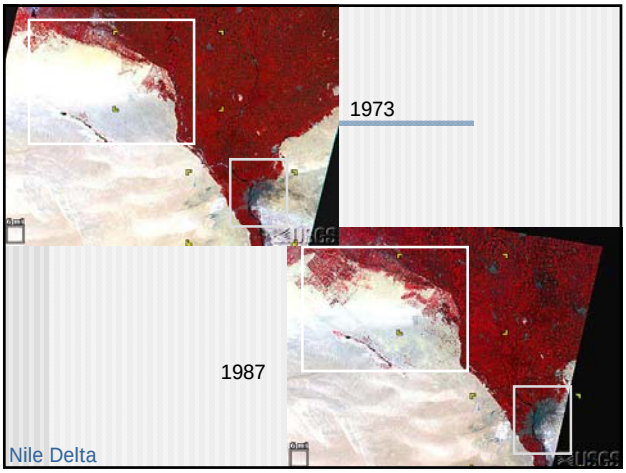
LU/LC – Change Detection

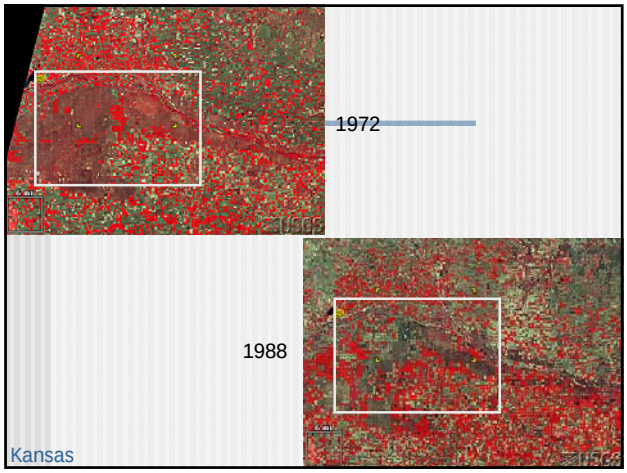
- Update LU/LC maps/data
  - Urban and regional planning
  - Resource management
- Major use of remotely sensed data
- Procedures
  - Detect change (**binary** decision)
  - Identify **type of change** (higher order -- "from--to")
- Comparisons
  - Map to image
  - Image to image

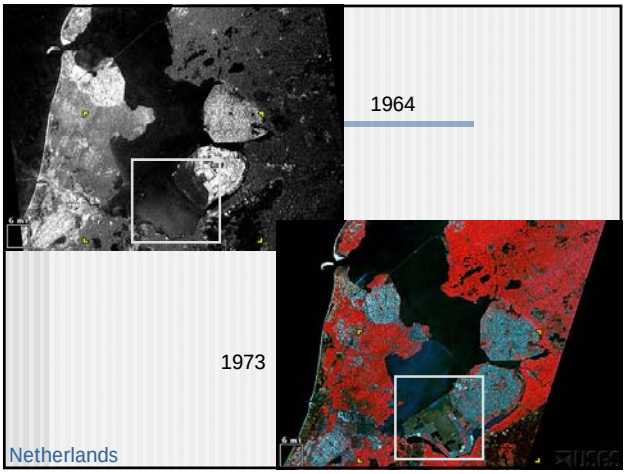
Change Detection – Example (image vs. Maps)

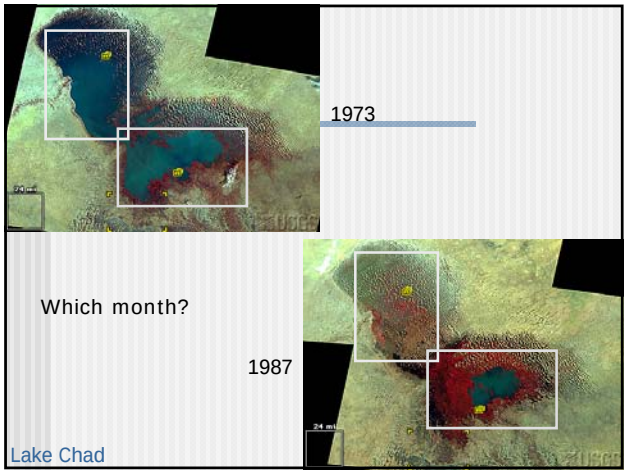


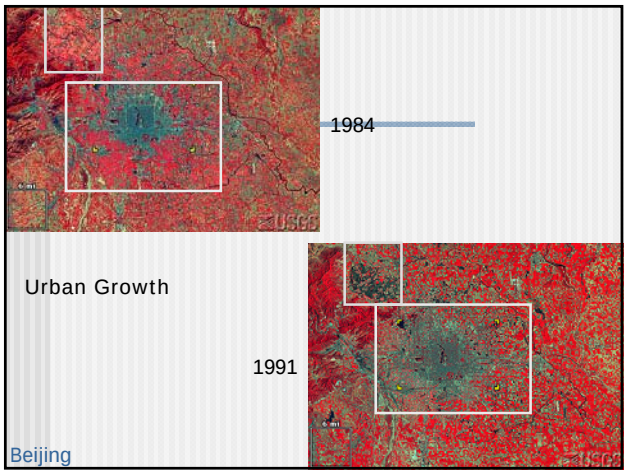








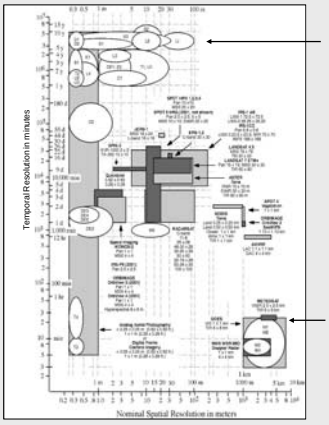




Remote Sensing for Urban Applications

Urban Remote Sensing Uses

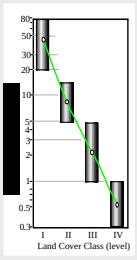
- Zoning regulation
- Commerce and economic development
- Tax assessor
- Transportation and utilities
- Parks, recreation, and tourism
- Emergency management
- Real estate and development
- Urban populations assessment
- Socio-economic conditions



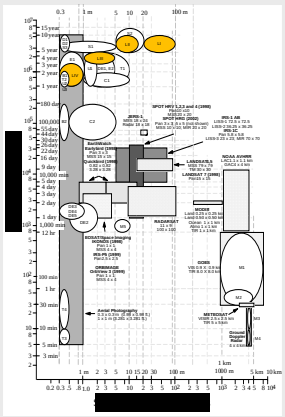
Clear polygons represent the spatial and temporal characteristics of selected *urban attributes*

Gray boxes depict the spatial and temporal characteristics of the *remote sensing systems* that may be used to extract the required urban information

Land Use /Land Cover



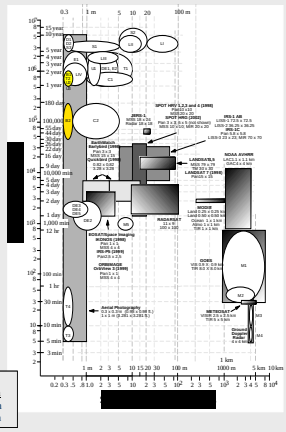
Relationship between sensor system spatial resolution and land use/land cover class



	Temporal Resolution	Spatial Resolution
L1 - USGS Level I	5 - 10 years	20 - 100 m
L2 - USGS Level II	5 - 10 years	5 - 15 m
L3 - USGS Level III	3 - 5 years	1 - 5 m
L4 - USGS Level IV	1 - 3 years	0.3 - 1 m

Building and Cadastral (Property Line) Infrastructure

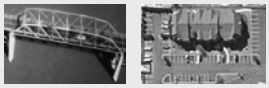
Derived from 0.3 x 0.3 m (1 x 1 ft.) spatial resolution stereoscopic, panchromatic aerial photography



	Temporal Resolution	Spatial Resolution
B1 - building perimeter, area, volume, height	1 - 2 years	0.3 - 0.5 m
B2 - cadastral mapping (property lines)	1 - 6 mo	0.3 - 0.5 m

Transportation Infrastructure

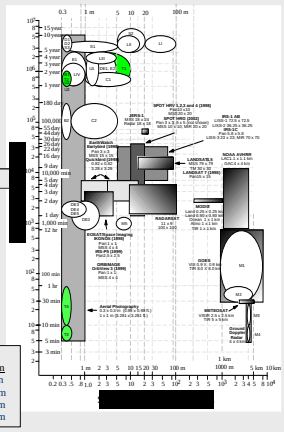
Irmo, S.C. TIGER road network updated using SPOT 10 x 10 m data



Bridge assessment using high resolution oblique photography

Parking/traffic studies require high spatial/temporal resolution

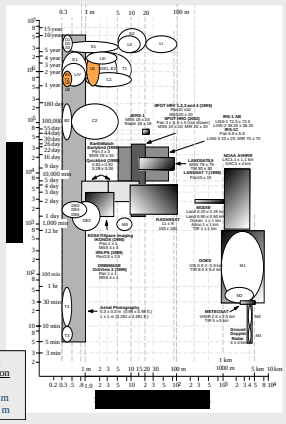
	Temporal Resolution	Spatial Resolution
T1 - general road centerline	1 - 5 years	1 - 10 m
T2 - precise road width	1 - 2 years	0.3 - 0.5 m
T3 - traffic count studies (cars, planes etc.)	5 - 10 min	0.3 - 0.5 m
T4 - parking studies	10 - 60 min	0.3 - 0.5 m



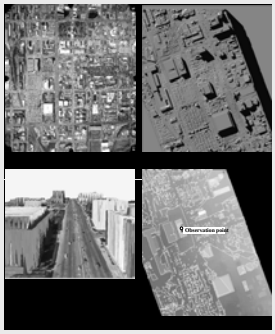
Utility Infrastructure

West Berlin, Germany (1:3,000). Utility companies often digitize the location of every pole, manhole, transmission line and the facilities associated with each.

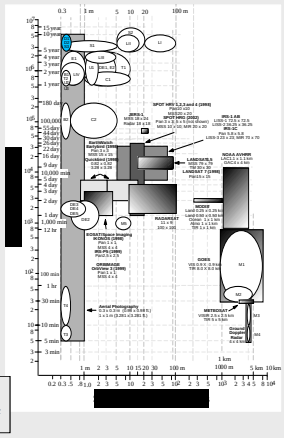
	Temporal Resolution	Spatial Resolution
U1 - general utility centerline	1 - 5 years	1 - 2 m
U2 - precise utility line width	1 - 2 years	0.3 - 0.6 m
U3 - locate poles, manholes, substations	1 - 2 years	0.3 - 0.6 m



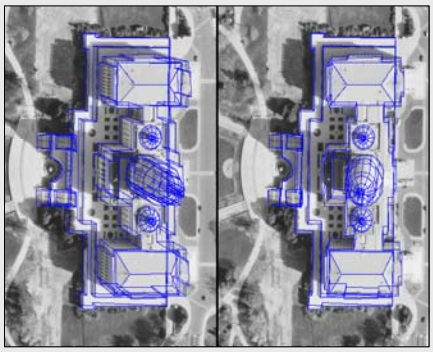
Digital Elevation Model Creation



Urban DEMs are usually created from high spatial resolution data. The DEM and orthophoto of Columbia, SC were produced from 1:6,000 stereoscopic photography using soft-copy photogrammetric techniques.



Extraction of Building Infrastructure Using Soft-Copy Photogrammetric Techniques



Urban Infrastructure of Rosslyn, Virginia Derived Using Soft-Copy Photogrammetric Techniques

Remote Sensing Assisted Population Estimation

Population estimates can be made at the local, regional, and national level based on (Lo, 1995; Haack et al., 1997):

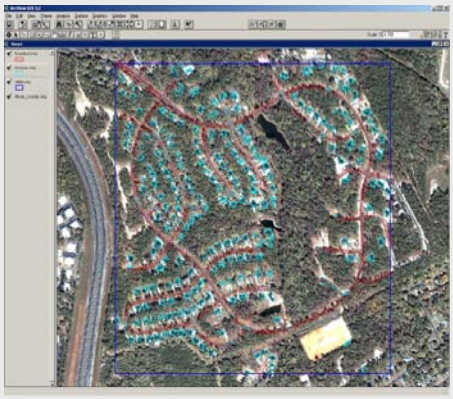
- counts of individual dwelling units,
- measurement of land areas, and
- land use classification.

Remote Sensing Assisted Population Estimation

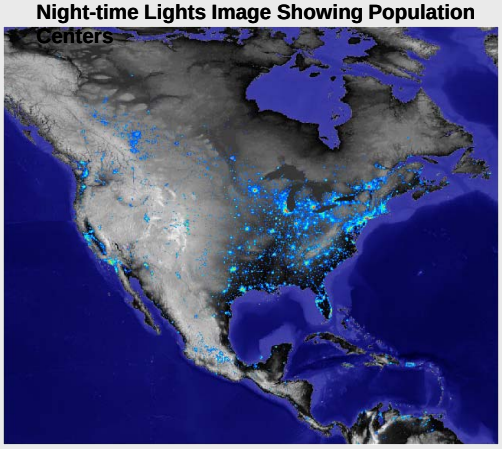
Dwelling Unit Estimation Technique Assumptions (Lo, 1986; 1995; Haack et al., 1997):

- imagery must be of sufficient spatial resolution (0.3 - 5 m) to identify individual structures even through tree cover and whether they are residential, commercial, or industrial buildings;
- some estimate of the average number of persons per dwelling unit must be available, and
- it is assumed that all dwelling units are occupied.

Automated building counts



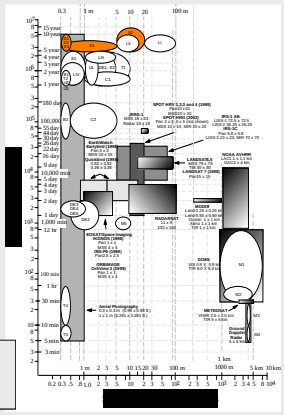
Night-time Lights Image Showing Population Centers



Socioeconomic Characteristics

Single and multiple family residences in Columbia, S. C.

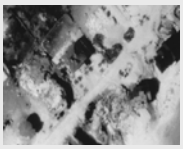
Konso village in southern Ethiopia



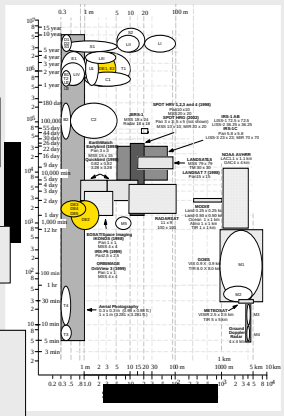
	Temporal Resolution	Spatial Resolution
S1 - local population estimation	5 - 7 years	0.3 - 5 m
S2 - regional/national population estimation	5 - 15 years	5 - 20 m
S3 - quality of life indicators	5 - 10 years	0.3 - 0.5 m

Disaster Emergency Response

Pre-Hurricane Hugo
Sullivans Is., S.C.
July 15, 1988
1 x 1 m
panchromatic



Post-Hurricane Hugo
Oct. 23, 1989
1 x 1 m
panchromatic

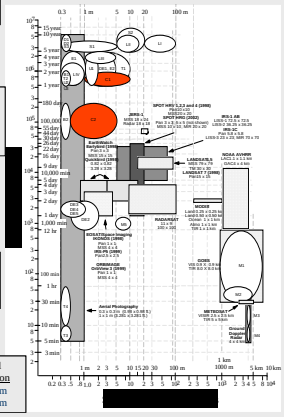


	Temporal Resolution	Spatial Resolution
DE1 - pre-emergency imagery	1 - 5 years	1 - 5 m
DE2 - post-emergency imagery	12 hr - 2 days	0.5 - 2 m
DE3 - damaged housing stock		1 - 2 days
0.3 - 1 m		
DE4 - damaged transportation	1 - 2 days	0.3 - 1 m
DE5 - damaged utilities	1 - 2 days	0.3 - 1 m

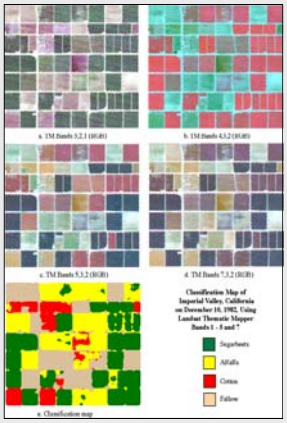
Critical Environmental Area Assessment

Sun City, S.C.
Digitized NAPP
Jan. 22, 1994
2.5 x 2.5 m
(0.7 - 0.9 µm)

CAMS Band 6
Sept. 23, 1996
2.5 x 2.5 m
(0.7 - 0.69 µm)



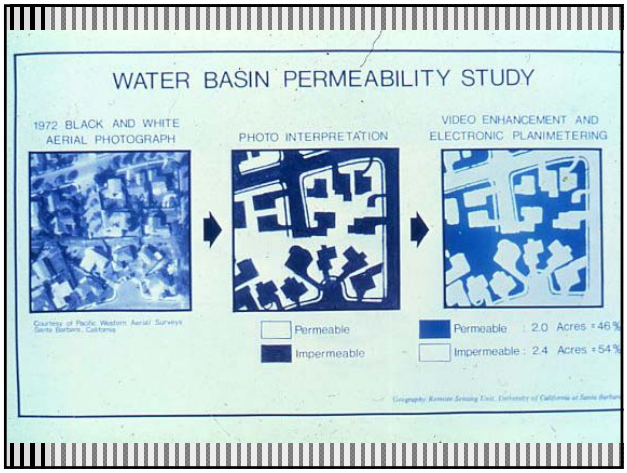
	Temporal Resolution	Spatial Resolution
C1 - stable sensitive environments	1 - 2 years	1 - 10 m
C2 - dynamic sensitive environments	1 - 6 months	0.5 - 5 m

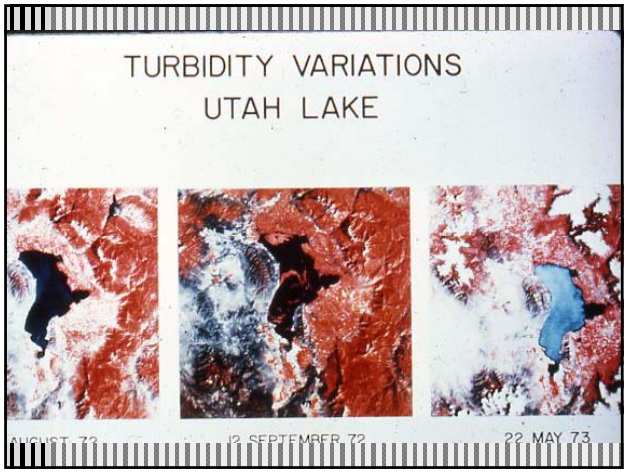


Landsat Thematic Mapper Color Composites and Classification Map of a Portion of the Imperial Valley, California

Jensen, 2000

- Water Resource Applications
  - Hydrologic monitoring
    - Primarily surface
    - Vegetation as surrogate/indicator for depth of ground-water
    - Mapping and assessment of watershed characteristics
  - Flood Monitoring
    - Extent – IR is good to discriminate land/water boundary
  - Snow Mapping
    - Areal extent
    - May be related to ground measurements to predict water content and depth
  - Wetland Mapping
    - Important environmentally as interface between terrestrial and ocean systems

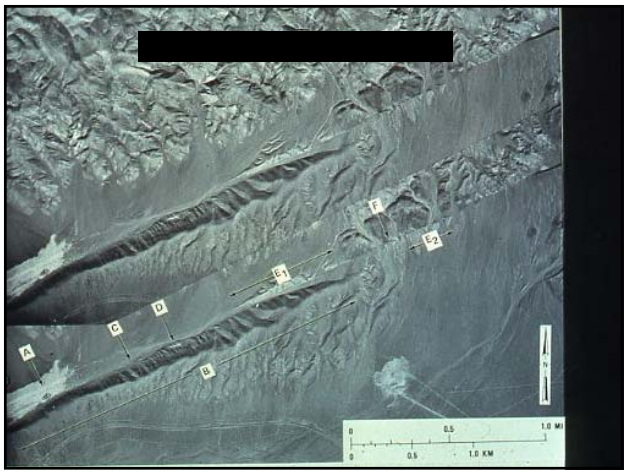


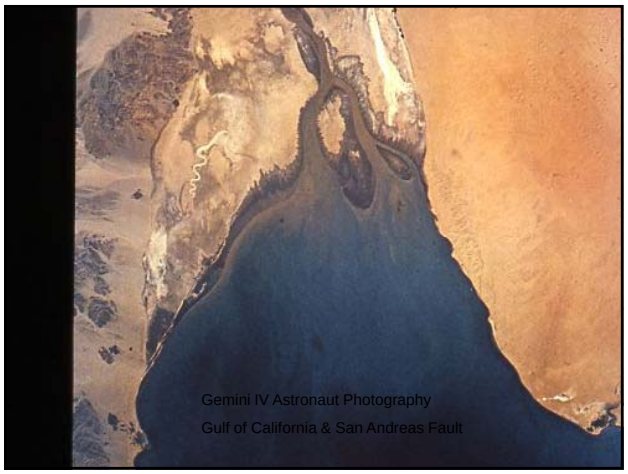


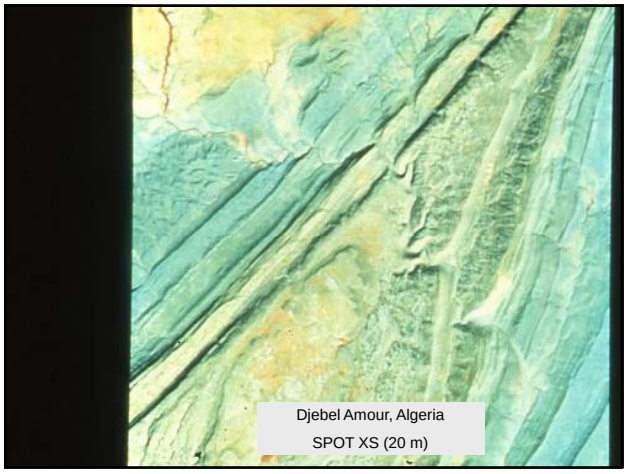
Geologic Applications

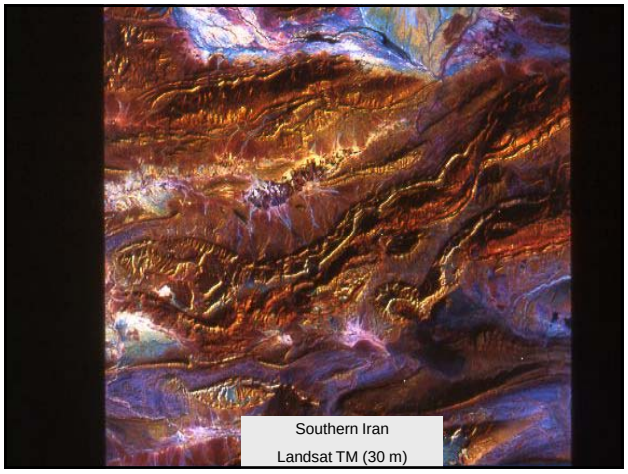
Applications

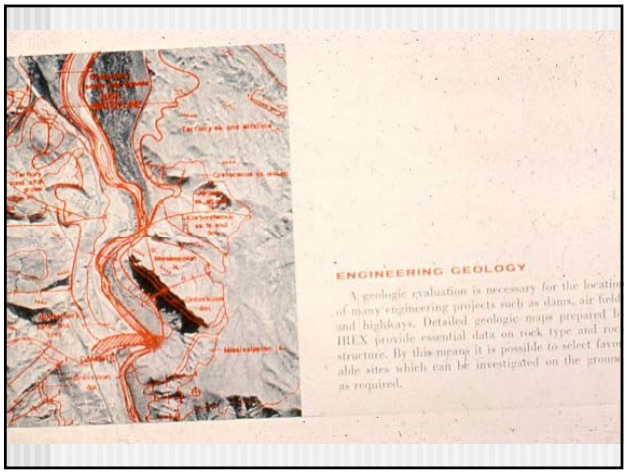
- Landform analysis and mapping
- Geologic engineering and hazards assessment
- Lithology/rock unit mapping
- Structural mapping
- Mineral/petroleum/geophysical exploration



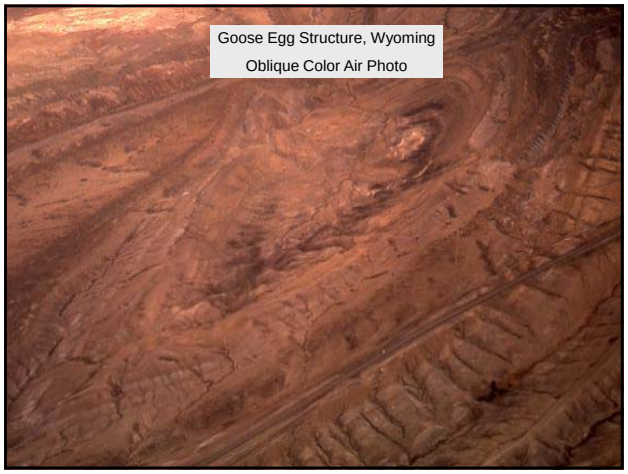

Gemini IV Astronaut Photography
Gulf of California & San Andreas Fault


Djebel Amour, Algeria
SPOT XS (20 m)


Southern Iran
Landsat TM (30 m)


ENGINEERING GEOLOGY

A geologic evaluation is necessary for the locatio
of many engineering projects such as dams, air fiel
and highways. Detailed geologic maps prepared b
HREX provide essential data on rock type and roc
structure. By this means it is possible to select favo
able sites which can be investigated on the groun
as required.


Goose Egg Structure, Wyoming
Oblique Color Air Photo

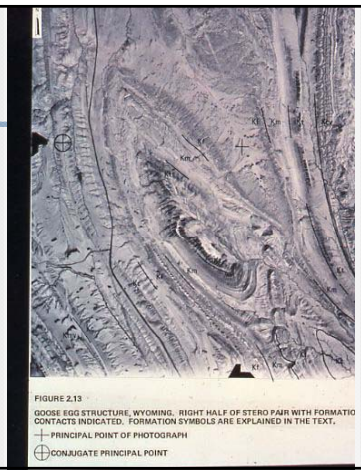


FIGURE 2.13
GOOSE EGG STRUCTURE, WYOMING. RIGHT HALF OF STERO PAIR WITH FORMATIO CONTACTS INDICATED. FORMATION SYMBOLS ARE EXPLAINED IN THE TEXT.
PRINCIPAL POINT OF PHOTOGRAPH
CONJUGATE PRINCIPAL POINT

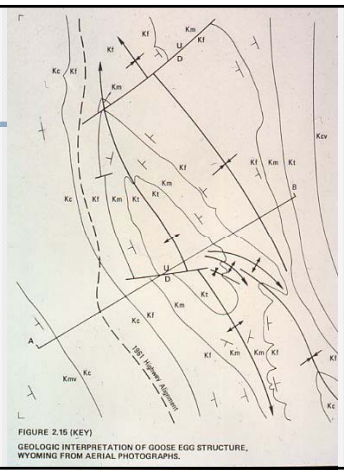
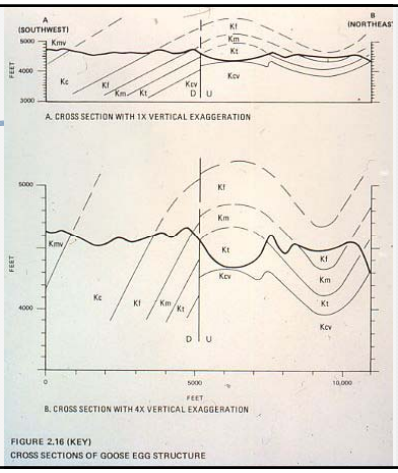


FIGURE 2.15 (KEY)
GEOLOGIC INTERPRETATION OF GOOSE EGG STRUCTURE, WYOMING FROM AERIAL PHOTOGRAPHS.



A. CROSS SECTION WITH 1X VERTICAL EXAGGERATION

B. CROSS SECTION WITH 4X VERTICAL EXAGGERATION

FIGURE 2.16 (KEY)
CROSS SECTIONS OF GOOSE EGG STRUCTURE

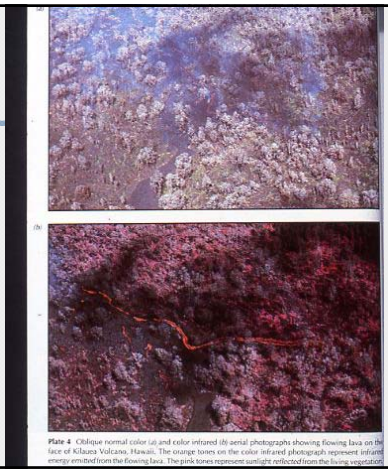
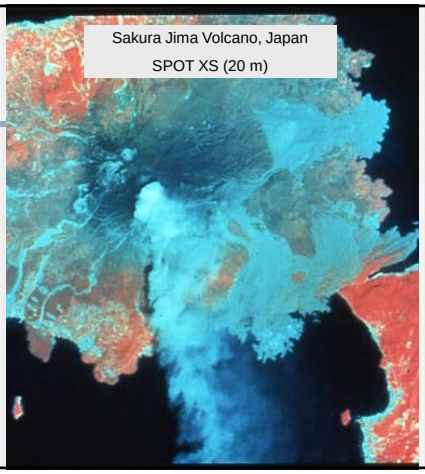
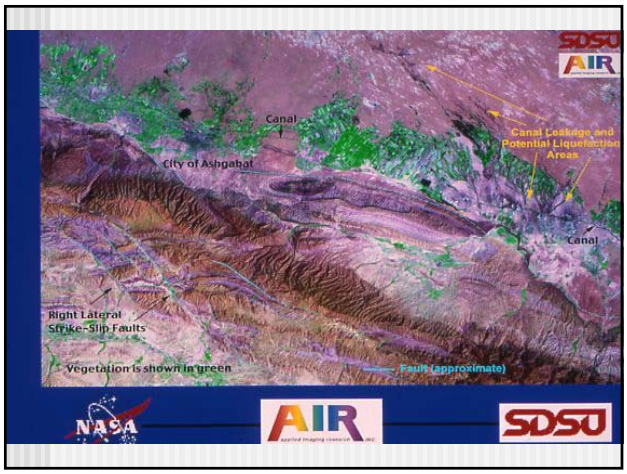


Plate 4 Oblique normal color (a) and color infrared (b) aerial photographs showing flowing lava on the face of Kilauea Volcano, Hawaii. The orange tones on the color infrared photograph represent infrared energy emitted from the flowing lava. The pink tones represent sunlight reflected from the living vegetation



Sakura Jima Volcano, Japan
SPOT XS (20 m)

IGURE 1.25
hematic Mapper image of Mt. St. Helens, created on July 19, 1984. The mountain and he destruction caused by the eruption are clearly visible. Healthy vegetation appears n red, while areas lacking vegetation are evident by their shades of gray-to-white. Wa er bodies are black, such as Spirit Lake, just north of Mt. St. Helens. The yellowish reas in the north end of the lake are debris resulting from the eruption, mostly floating ree trunks. Most of the patchwork patterns east of Mt. St. Helens are areas that have een timbered. (Earth Observation Satellite Company)



Applications – Coastal and Marine

Introduction

- Importance of coastal zone
- Coastal land vs. water
- In relation to oceanography
- Scale requirements