Title
Unit 09 - Environmental and Natural Resource Data

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Compiled with assistance from Charles Parson, Bemidji State University and Jeffrey L. Star, University of California, Santa Barbara

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For Information that Supplements the Contents of this Unit:

[Links to the following resources have been omitted.]

- Aerial Photography and Remote Sensing (Crum/Geographer's Craft) -- Electromagnetic waves and spectrum; infrared radiation; applications of aerial photography; digital image processing; satellite imaging; radar scanning; remote sensing and GIS; etc.
- Applied Environmental GIS (AEGIS) -- Projects which address a variety of environmental issues in which GIS solutions are appropriate; sample images (e.g. fire hazard, soil permeability).
- Canada Centre for Remote Sensing -- Index and Information.
- Environment, Lands and Parks -- Studies and data on the environment; climate change; habitat, waste and water management.
- Application Areas of a GIS (Geographer's Craft) -- Natural resources management; facilities management; land management; street networks.
- GCIP Data Management Services System -- National climate data (US); Satellite Data Source Module; USGS.
- GIS/Remote Sensing Publications Online
- Environmental Protection Agency -- Access to GIS spatial data sites,including: agriculture, natural resources and US digital data.
- GEWEX Data Sets -- Defense Meteorological Satellite; NOAA/ETL radar data; World Radiation Monitoring Centre.
- Image Analysis Related Terms
- International GIS and Remote Sensing Services -- Arc/Info tutorial; Digital Land Systems Research (DLSR); Environmental Resource Information Network (ERIN); Environmental Systems Resource Institute (ESRI); European Science Foundation (GIS data program); IDRISI homepage.
- Landsat and TM (NASA) -- Program summary; Landsat program documents; information on Landsat data; access to Landsat data (including Canada).
- National Oceanic and Atmospheric Administration (NOAA) -- U.S. Environmental information services; data on: meteorology/weather, oceanography, satellite imagery.
- Samples of Remotely Sensed Images -- CFS Advanced Forest Technology Program.
- Remote sensing -- GIS and other related fields; organizations; satellite data; sites; etc.
- Remote Sensing Online Resources (Delaney)
- Index of Remote Sensing -- Glossaries and Acronyms (search).
- Resources for Geographers (U of Western Ontario) -- GIS; remote sensing; USG; other geospatial sites.

Signal and Image Analysis: Images -- Illustrated and Described: Time frequency analysis of sonar signals; texture analysis by co-occurrence matrices; image segmentation using 2 D Wigner-Ville distribution; analysis and coding of medical images.
United Nations Environment Programme (UNEP) -- Global resource information database; environmental data sets, including: biodiversity, human-related; soils; vegetation.

- NOTES

You may prefer to use a local example of a natural resources database in place of the section on the MLMIS. This section can then serve as an outline for the organization of information about your local example.

Examples of different air photos (low level, high level, oblique), satellite (natural color, false color) and radar images would be useful illustrations for this unit.

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A. INTRODUCTION

- natural resource-based GISs may be used:
  - as an inventory tool
  - to better manage the marketing of the resource
  - to protect the resource from improper development
  - to model the complex interactions between phenomena so that forecasts can be used in decision-making

Contents of environmental databases

- there are several different kinds of information needed in an environmental database
  - many of these are obvious: geology, vegetation, hydrology, soils

- however, to address a range of issues, the environmental database must include several characteristics that are not generally perceived as "natural"
  - transportation network
  - political boundaries
  - management unit boundaries

- other data may be needed for modeling, e.g. variables relating to:
  - erosion
  - groundwater flow
  - soil productivity

B. CHARACTERISTICS

- natural resource data in GIS is comparatively static
  - update can be infrequent

- spatial resolution can be relatively low
  - e.g. grid cells covering large areas

- historically, natural resource GIS have been raster-based
  - adequate for many planning and management applications
  - can provide comprehensive coverage of a jurisdiction at reasonable cost
  - could often run on existing mainframes - hardware requirements were modest

Spatial management units

- the actual management units of most natural resources in North America are pseudo-rasters
  - square, forty acre parcels are the standard building block for PLSS areas (areas surveyed under the Public Land Survey System) of the Midwest, and Western United States, and much of Canada

- "forties" are frequently broken into ten acre units, or combined into:
  - quarter sections (160 acres)
  - sections (640 acres, 1 square mile)
  - townships (6x6 miles)
- farms are managed in rectangular fields and forest resources are sold in similar acreage units

- however, natural resources do not commonly conform to PLSS grids
  - vector-based systems appear better able to accurately represent them

- on the other hand, satellite imagery, which is an important source of environmental data is raster-based

C. SOURCES OF DATA

Thematic

- thematic map series are compiled by various agencies:
  - soil maps (e.g. Soil Conservation Service)
  - land use (e.g. USGS land use series)
  - vegetation (forestry agencies, many state governments)
  - surficial geology (US and state geological surveys)

Topographic

- topographic maps can supply:
  - elevations
  - roads and railroads
  - cultural features
  - streams and lakes
  - political and administrative boundaries
  - public land survey system (PLSS) - "township and range"

- this type of data from USGS topographic maps is becoming available in digital form as DLG (digital line graph) files

- elevation data is available from the USGS in the form of DEMs, (digital elevation models) at various resolutions

  - US Geological Survey supplies 30 m resolution data for much of US

Remote sensing

- remotely sensed imagery data can be interpreted to yield many layers
  - e.g. urban/rural, vegetation, crops, surface geology, land use

- LANDSAT and TM (Thematic Mapper) are commonly used sources

D. REMOTE SENSING AND GIS

- definition of remote sensing
  - "In the broadest sense, the measurement or acquistion of information of some property of an object or phenomena, by a recording device that is not in physical or intimate contact with the object or phenomena under study" (Manual of Remote Sensing)

- aircraft and satellite platforms can be used

- selection of a platform involves balancing a number of competing goals:
  - ability to schedule the acquisition
  - atmospheric distortions vs. platform stability
  - the available suite of sensors for a given application
  - issues of coverage and scale
  - cost

- data can be captured in analog (photographs) or digital form (data, transmitted to a ground station or recorded onboard)

Wavelengths

- key issue in a remotely sensed observation is the range of wavelengths of energy that will be observed

- the human eye sees only a limited range of wavelengths
  - photographs capture visible light

- remotely sensed observations may include information in the infrared portion of the spectrum which is not visible to human eyes
  - infrared sensors allow recording of the thermal characteristics of the earth's surface

- microwave wavelengths can also be used

- Radar is a form of microwave system
  - sometimes of particular value due to the ability to penetrate clouds and carry their own source of illumination
    - i.e. radar systems generate and collect radiation - they are active sensors
  - objects with large differences in their electrical properties may be discriminated, and the size of the

    object compared to the wavelength of the radar system is also important

Scale in images

- key concern is the scale of the images, and how the scale varies within each image due to distortion

- many sources of distortion

- focal length of the optical system, viewing geometry, surface topography greatly affect the scale at each location in the image

Elevation

- information on elevation can be obtained by comparing photographs taken from different camera positions, i.e. stereographic images
- the simplest devices for viewing pairs of photographs in stereo, called stereoscopes, effectively recreate the illusion of one's eyes being in the same position as the camera lenses when the photographs were taken
  - produce the impression of 3-D images
- more complex instruments known as stereoplotters allow operators to use pairs of photographs to develop accurate topographic maps and contours
- thus, by understanding the geometrical details of the camera system and the Earth's surface, one can determine both horizontal and vertical positions of objects with high accuracy and precision
- an analytical plotter is a partially automated form of stereoplotter which obtains contours by automatically comparing photographs

Image interpretation

- the identification of objects and determination of their significance involves:

  Identification - recognizing features on the image

  Measurement - once features have been identified, can make measurements (i.e., the distance between objects, the number of features per unit area)

  Interpretation - normally based on a systematic examination of the primitive elements of the photograph, in conjunction with a wide range of ancillary data

  - primitive elements include tone, color, size, shape, texture, pattern, shadow, site, association
  - automated image analysis typically relies on only the first few primitive elements (tone, color, size)
  - ancillary data are often very diverse, may include maps, vegetation phenologies, and many kinds of information about human activities in the general area
  - human experts bring all these elements, plus their acquired skills and knowledge of related disciplines

- the best photointerpreters have expertise in such related disciplines as physical geography, geology and plant biology and ecology
- human interpretation also includes a significant perceptual or subjective component

Classification

- the information obtained from a remote sensing instrument consists of reflectance measurements, often in several different bands or parts of the electromagnetic spectrum
  - measurements are in discrete units with fixed range, e.g. 0-255

- the process of classification, an important part of image interpretation, attempts to assign each pixel to one of a number of classes based on its reflectance in one or more bands
  - e.g. vegetation types or land use classes ("urban", "pasture", "cropland", "water", "forested")

- many techniques exist for classification
  - supervised classification develops the rules for assigning reflectance measurements to classes using a "training area", based on input from the user, then applies the rules automatically to the remaining image
  - unsupervised classification develops the rules automatically

Problems in classification

- since reflectances vary with time of day, season of the year, etc., classification rules vary from image to image

- classification is often uncertain or inaccurate
  - also pixels may often contain several classes - mixed pixels

- despite this, classification assigns a single class to every pixel, ignoring uncertainty

- there is no best method of classification - successful classification is time-consuming and can be expensive

Using remotely sensed data in GIS

- often difficult or time consuming to develop systematic products of known accuracy
  - complex operations are required to force images to correspond to a known map projection and/or to have a

consistent scale
    - difficult to go from image (varying reflectance or emissivity in different wavelength bands) to interpreted features and objects

- however, since the value of a GIS is directly related to the quality and currency of its internal data
    - remote sensing offers a suite of tools for quickly creating current, consistent datasets for input to a GIS

- conversely, remotely sensed data is best interpreted when additional spatial datasets (representing other dates, other scales, other sensors, other methods for acquiring data about the earth) are employed
    - such data may be obtained from a GIS

- thus, strong links between remote sensing and GIS can improve both technologies

E. EXAMPLE DATABASE - MLMIS

Minnesota Land Management Information System (MLMIS)

- one of the most extensive natural resource databases

- a statewide inventory of layers for natural resource management and planning

- list is the result of over fifteen years of involvement in projects that added data to the system

- referred to as MLMIS40 because the fundamental structure is a raster with 40 acre cells

- to improve spatial resolution, this is being gradually replaced with
    - vector files at a common scale of 1:24,000 (line- width resolution 12 m)

    - raster files with hectare grid cells

Example use of MLMIS data layers

- how might the database (and a GIS) be used to assist a county to locate a waste disposal incinerator?

REFERENCES

Marble, D.F. et al., 1983. "Geographic information systems and remote sensing," Manual of Remote Sensing. ASPRS/ACSM, Falls Church, VA, 1:923-58. Reviews the various dimensions of the relationship between the two fields.

Niemann, Jr., B.J., et al, 1988. "The CONSOIL project: Conservation of natural resources through the sharing of information layers," Proceedings GIS/LIS '88, San Antonio, TX, pp. 11-25. Reviews a multi-agency project in Wisconsin to design and evaluate an LIS for soil conservation.

Radde, G.L., 1987. "Under the Rainbow: GIS and Public Land Management Realities," Proceedings, IGIS '87, Arlington, VA, 3:461-472. A discussion of the MLMIS, describes some projects that have made use of the system and how policy makers attitudes towards GIS have changed.

Star, J.L., and J. Estes, 1990. Geographic Information Systems: An Introduction, Prentice-Hall, Englewood Cliffs, NJ. Chapter 5 reviews data sources.

Sullivan, J.G., and B.J. Niemann, Jr., 1987. "Research Implications of eleven natural resource GIS applications," Proceedings, IGIS '87, Arlington, VA, 3:329-341. A short review of several LIS for natural resource applications, discusses common themes, problems and techniques.

EXAM AND DISCUSSION QUESTIONS

1. Review the difficulties inherent in obtaining interpreted features and objects from remotely sensed images.

2. Assume that you have access to remotely sensed images of your city with a resolution of 80 m (roughly the pixel size of Landsat). What functions of city government or local business would be able to make use of this resolution?

3. Discuss the range of errors which may exist in a soils map.

4. Discuss each of the types of data mentioned in this class in terms of required frequency of update.

5. How does a soil map become outdated?

6. What layers might you want for siting a waste incinerator which are not in the MLMIS catalog?

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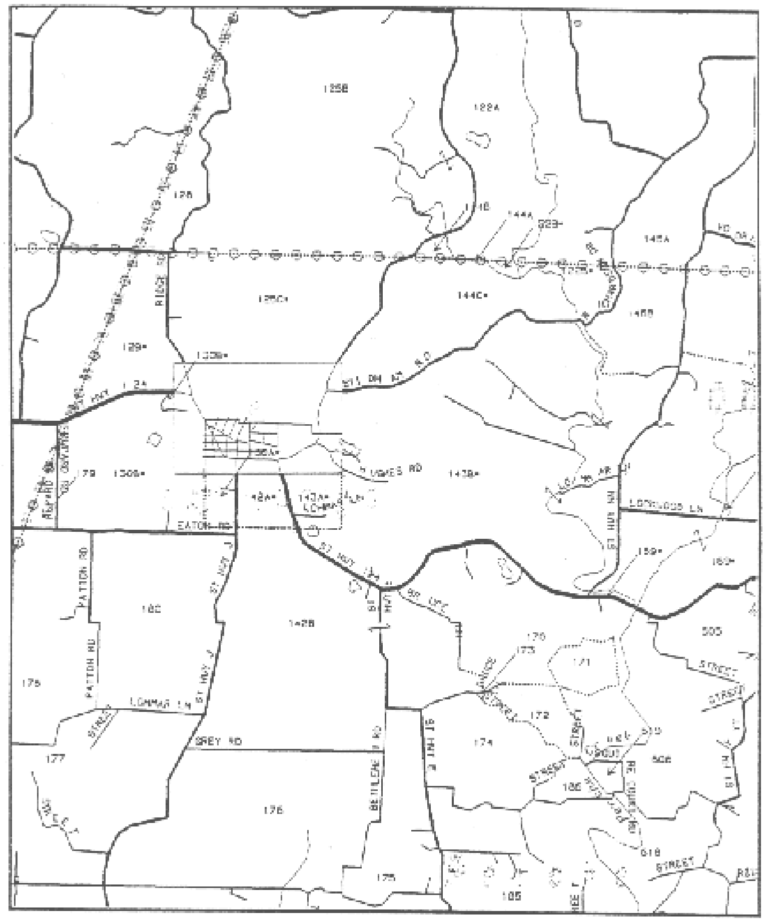
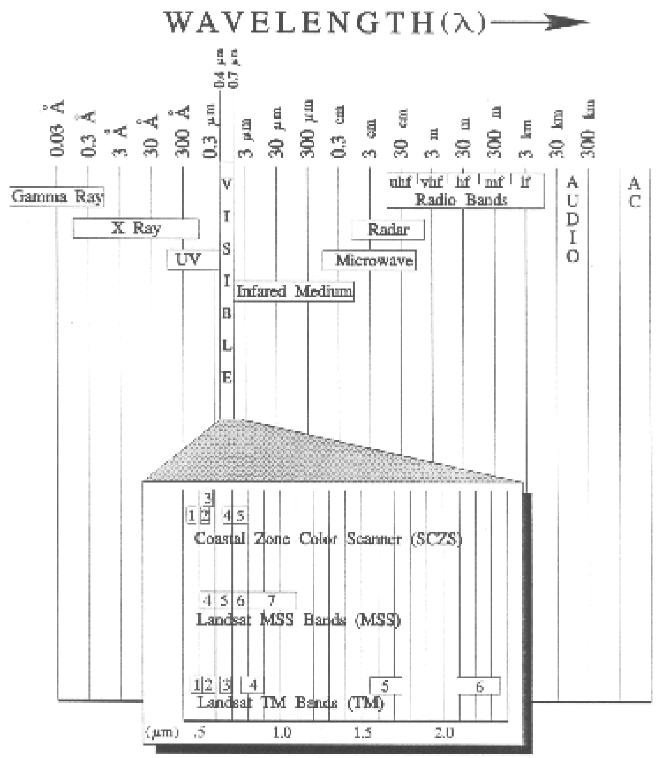
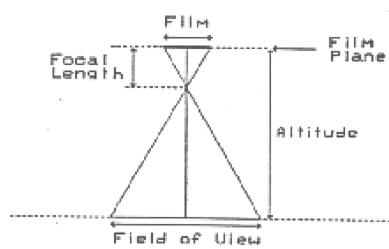
UNIT 9 IMAGES

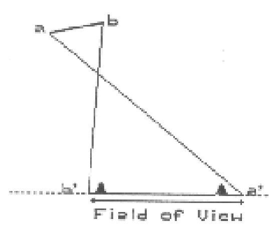
EXAMPLE OF A 1990 CENSUS MAP
GENERATED FROM TIGER

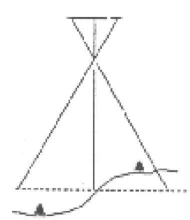




Electromagnetic Spectrum and Satellite Coverages







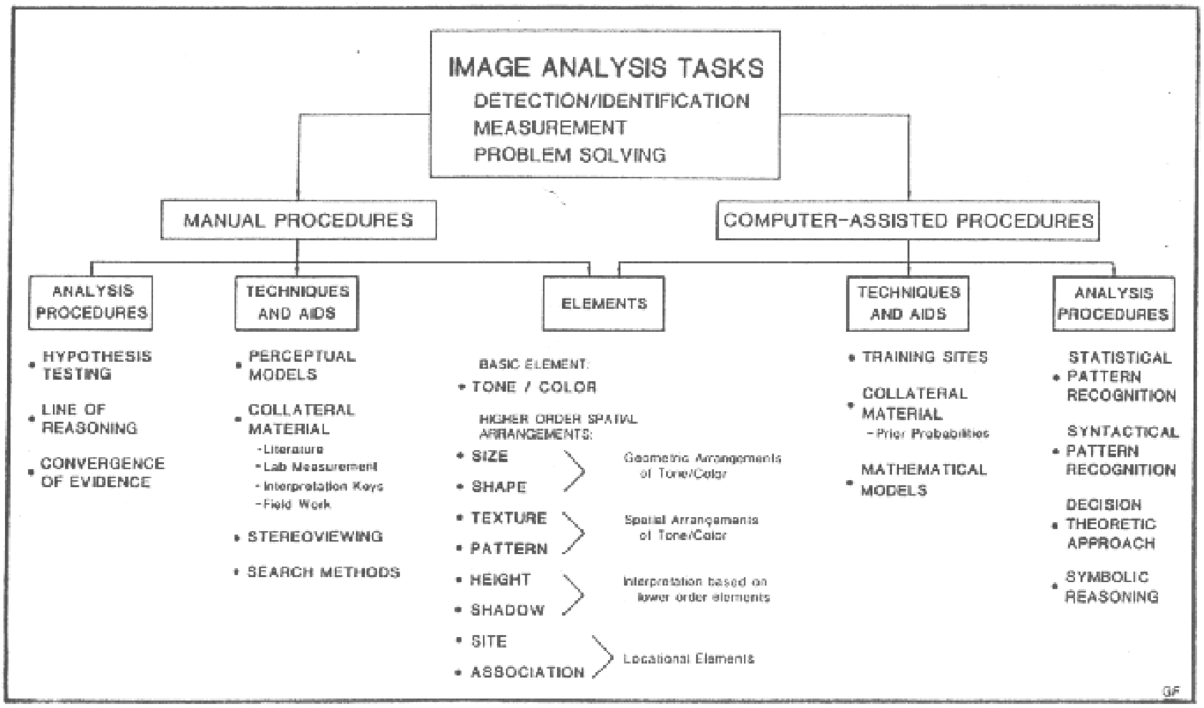


IMAGE ANALYSIS TASKS
DETECTION/IDENTIFICATION
MEASUREMENT
PROBLEM SOLVING
MANUAL PROCEDURES
COMPUTER-ASSISTED PROCEDURES
ANALYSIS PROCEDURES
• HYPOTHESIS TESTING
• LINE OF REASONING
• CONVERGENCE OF EVIDENCE
TECHNIQUES AND AIDS
• PERCEPTUAL MODELS
• COLLATERAL MATERIAL
-Literature
-Lab Measurement
-Interpretation Keys
-Field Work
• STEREOVIEWING
• SEARCH METHODS
ELEMENTS
BASIC ELEMENT:
• TONE / COLOR
HIGHER ORDER SPATIAL ARRANGEMENTS:
• SIZE
• SHAPE
Geometric Arrangements of Tone/Color
• TEXTURE
• PATTERN
Spatial Arrangements of Tone/Color
• HEIGHT
• SHADOW
Interpretation based on lower order elements
• SITE
• ASSOCIATION
Locational Elements
TECHNIQUES AND AIDS
• TRAINING SITES
• COLLATERAL MATERIAL
-Prior Probabilities
• MATHEMATICAL MODELS
ANALYSIS PROCEDURES
• STATISTICAL PATTERN RECOGNITION
• SYNTACTICAL PATTERN RECOGNITION
• DECISION THEORETIC APPROACH
• SYMBOLIC REASONING
GF