Title

Units 090-091 - Natural Resources Data

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Unit 090 - Natural Resources Data

by Peter H. Schut, Canadian Soil Information System, Agriculture and Agri-Food Canada

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Advanced Organizer

Topics covered in this unit

- This unit provides a general overview of natural resources data, including:
  - types of data
  - typical applications
  - common problems and limitations
- Specific kinds of data are described in greater detail in the accompanying subsections.

Learning Outcomes

- After learning the material covered in this unit, students should be able to:
  - List the principal types of natural resource data
  - Identify the principal sources of natural resource data
  - Explain how natural resource data can be applied in a GIS context
  - Identify the issues of concern in the application of natural resource data

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Unit 090 - Natural Resources Data

1. Introduction

1.1. Purpose of natural resource databases

- natural resource-based data may be used
  - as an inventory tool
    - "what is here?"
    - "where can this resource be found?"
  - 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

1.2. Contents of natural resource databases

- there are several different kinds of information needed in an environmental database
  - the primary theme - geology, vegetation, hydrology, soils, etc
- however, to provide context, the environmental database may include several characteristics that are not generally perceived as "natural"
  - transportation network
  - political boundaries
  - management unit boundaries
- other data may be needed for modeling will not form a part of the GIS dataset, e.g. variables relating to:
  - erosion
  - groundwater flow
  - soil productivity

1.3. Sample Applications

  - Sample geographic queries and applications of natural resource-based GIS:

Type of query	**sample query**
Description	**What kind of** soils are found near the airport?
Location	**Show me where** I can find well drained sandy soils
Summary	**How much** is covered by poorly drained peatland?
Analysis	**Why might** fusarium head blight be restricted to this area?
Model validation	**Is** soil texture a reliable predictor of atrizine runoff?
Predictive modelling	**How will** global warming impact wheat production?

2. Characteristics of Natural Resources Data

2.1 General 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, some 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 for coarse rasters
- other resource databases have been vector based - soils, geology
  - vector based data is easy to gather manually
  - particularly useful where expert opinions define mapping units; where mapping is adequately or intuitively represented by groupings or associations

2.2. 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 these 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,
  - the raster may not be oriented the same way, or at a compatible scale.

2.3. Types of natural resource databases

- simple theme
  - e.g. elevation, or stream hydrography,
- multiple theme
  - e.g. soil type and properties (pH, texture, etc)
  - numerous properties are mapped on a single set of polygons
- complex theme
  - e.g. Ecoregions of North America

    multiple unrelated attributes (such as geology, climate, and topography) are used to define a set of conceptual polygons

2.4. Lineage

Databases can be populated by

- direct measurement (e.g. albedo)
- interpolated (e.g. precipitation)
- expert opinion (e.g. soil classification)
  - takes years to create
- interpreted (e.g. risk of erosion)

3. Sources of Data

3.1. Thematic

- thematic map series are compiled by various agencies:
  - soil maps (e.g. Soil Conservation Service)
  - land use (e.g. USGS land use series, Canada Land Inventory)
  - vegetation (forestry agencies, state governments)
  - surficial geology (Federal and State/Provincial geological surveys)
  - land ownership

3.2. Topographic

- topographic maps can supply:
  - elevations
  - roads and railroads
  - cultural features
  - streams and lakes
  - political and administrative boundaries
  - cadastral - "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

3.3. 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

4. Limitations

4.1. Completeness

- datasets are usually complete

coverage is quite often incomplete

4.2. Precision

- normally reported reasonably
- errors reflect instrument or expert capability

4.3. Attribute accuracy

- direct measurements are subject to:
    - instrument error
    - error due to spatial resolution
    - spatial referencing error
- interpolations subject to:
    - spatial sampling artifact errors,
    - errors due to interpolation algorithm,
    - errors due to spatial autocorrelation
- expert opinion subject to:
    - expert error,
    - expert bias,
    - impacts of expediency
- interpreted data subject to:
    - algorithm problems,
    - source data problems,
    - severe error propegation

4.4. Logical consistency

- frequently different datasets will provide conflicting data or can be used to produce conflicting interpretations
- datasets gathered at different times or by different authorities may not be compatible.

4.5. 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

5. Summary

- to be provided

6. Print References

Marble, D.F. et al., 1983. &QUOTGeographic 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. &QUOTThe 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.

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. &QUOTResearch 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.

7. 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?

Citation

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- author: Peter Schut

2. Details about the file

- unit title:
- unit key number: u090

3. Key words

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5. Prerequisite units

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7. Revision history

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Unit 091 - Soil Data for GIS

by Peter H. Schut, Canadian Soil Information System, Agriculture and Agri-Food Canada

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Advanced Organizer

Topics covered in this unit

- Overview of soil classification
- The mapping of soils
- Types and contents of soil surveys
- Structure of soil data in GIS databases

Learning Outcomes

- After learning the material covered in this unit, students should be able to:
  - describe the spatial nature of soil
  - explain how soil data is collected
  - list the characteristics of different scales of soil surveys
  - describe how soil data is stored in GIS databases
  - list some uses of soil data in GIS applications

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Unit 091 - Soil Data for GIS

1. Overview of soil and soil classification

1.1. Definition of Soil

- Soil results from the interaction of the surficial deposits (bedrock or sediments) with soil-forming processes, including between climate, living organisms, and relief
- Soil consists of breakdown products of surficial deposits, and accumulation of organic matter
- Material less than 15 cm deep is not considered to be soil (arbitrary definition)
- Materials at depths greater than one meter are not considered to be part of the soil although tree roots and soil dwelling organisms may extend below 1 meter (arbitrary definition)

1.2. Soil Classification systems

- Several classification systems exist; all based on observable / measurable parameters
    - Canadian System of Soil Classification
    - US 7^{th} approximation
    - Russian
    - FAO
- Soil classification systems are still undergoing development
- Classification systems are hierarchical in nature
    - Orders, which include
    - Great groups, which include
    - Subgroups, which include
    - Series.
- Since soil has a continuum of properties
    - classification systems have to have somewhat arbitrary boundaries to separate different soil types (e.g. >19%clay = one series, 20% = another)
    - extends right up to the level of Order, so two soils from different orders can actually be quite similar, separated by just a few relatively minor characteristics.
- The classification of a soil is often, but not always, a good predictor of its agricultural productivity

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2. Mapping soils and landscapes

2.1. Spatial Nature of Soil

- Soil is a continuum, spread thinly over bedrock in some places, thickly in others
- Soil properties can vary dramatically over the space of a few centimeters, often due to a discontinuity in the parent material (e.g. edge of sand deposited by an old delta)
- in other locations soil properties can undergo minor transitions over a distance of kilometers, where similar parent material, landscape, and climate combine to create a relatively homogeneous soil (e.g. level clay plain)
- Soil has an important 3 dimensional aspect, and characteristics vary with depth. Identifiable differences are used to divide the soil into layers or soil horizons
- Soils are typically intermingled, due to local drainage effects and the distribution of the

parent material
- mapping at a farm/field farm / field scale is only scale at which one soil can be mapped per polygon. Scales greater than 1:5,000 normally require assigning more than one soil per polygon

2.2. Soil Surveys

- Soil is normally surveyed by county
- Normally undertaken by a federal government agency
- Take a long time to perform (typically many months of fieldwork and lab analysis)
- Survey is an interpretation, so adjacent polygon coverages may not line up if they were produced by different soil surveyors.
- Concepts and analytical methods have changed over time, so adjacent surveys may not contain compatible information, and quite often older surveys will be missing key attributes
- Few countries have complete coverage at anything regional scale

2.3. Scale and soil survey

2.3.1. Generalized surveys

- scale: 1:1,000,000 and smaller
- Contents
  - Regional landforms
  - Local surface forms
  - Typical slopes
  - Parent material mode of deposition
  - example soils
- Used for national/provincial scale analysis
  - Estimates of productivity
  - climate change modeling
- Examples
  - Land potential database
  - Soil landscapes of Canada
  - STATSGO

2.3.2. Reconnaissance surveys

- scales 1:250,000 to 1:750,000
- Contents
  - Soil capability for agriculture
- Used for regional scale analysis
  - general land use planning
  - land inventory
- Examples
  - Canada Land Inventory (CLI)

US SURGO

2.3.3. Detailed soil surveys

- scales 1:20,000 to 1:125,000
- Contents
  - Soil type
  - texture
  - Drainage
  - stoniness
- Used for
  - Municipal Zoning
  - Environmental impact mitigation
  - Tax assessments
- Examples
  - US STATSGO

2.3.4. Farm/field surveys

- scales 1:1,000 to 1:10,000
- Contents vary widely
  - Soil type
  - Nutrients
  - texture
- Used for
  - precision agriculture
  - farm environmental plans

2.4. Soil associations (catenas)

- Soil characteristics vary in a somewhat predictable way as a function of landscape position.

- Well drained soils are found at the top of slopes
- Poorly drained soils tend to be found at the bottom of slopes or in depressions
- Drainage affects soil development (physical and chemical characteristics) and thus potential productivity

- Knowledge of topography and landscape effects can be combined with soil survey information to estimate locations of individual soils

2.5. Properties recorded in surveys

- The following soil properties are typically recorded in soil surveys

  - Parent material mode of deposition
  - Stoniness

- Rockiness
- Coarse fragment content
- Percent sand, silt, clay
- Organic carbon
- Bulk density
- pH
- base saturation
- calcareousness
- cation exchange capacity
- water retention
- drainage
- depth to water table
- rooting restriction
- electrical conductivity

- The following landscape properties are typically recorded in soil surveys
  - Slope
  - Local surface form
  - Regional land form

2.6. Coding of soil properties in GIS databases

- Normally stored as *vector coverages*
  - Polygon boundaries are often indistinct. This may be represented by an uncertainty (or fuzziness) factor
- Since soils are so complex, soil GIS databases normally rely on more than one data table (these may go by different names or be normalized somewhat differently)

- *Polygon Table*
  - Contains information applicable to each specific polygon
  - Rock outcroppings

- *Map Unit Table*
  - contains attributes which apply to a group of similar polygons

- *Soil Component Table*
  - Identifies one or more soil types found in a map unit or polygon
  - Identifies percentage occurrence of each component with polygon, or uses terms like dominant, co-dominant, subdominant
  - Contains one or more descriptors like slope, stoniness

- *Soil Name Table*
  - contains information applicable to that named soil
    - Parent material
    - Drainage characteristics
    - classification

- *Soil Pedon Table*
  - Contains information about the smallest mapped unit of soil
- *Soil Layer Table*
  - Contains information specific to soil horizons or layers

2.7. Mapping of soil and landscape attributes

- Commonly the dominant soil (or soil characteristic) is mapped
- Alternatively the percent distribution of a particular soil or characteristic is sometimes mapped
- For numeric data, spatially weighted averages can be employed

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3. Applications of soils data

- Land use planning
  - Agriculture
  - Forestry
- Agricultural production
  - Suitable cropping practices
- Pesticide registration
  - Similar soils need only be tested once
- Engineering
  - Foundation stability
- Site selection for radio towers
  - Electrical conductivity can affect radio wave transmission
- Weather modeling
  - Texture and organic content affects heat retention
- soil degradation risk assessment
  - wind erosion
  - water erosion
  - salinization

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4. Summary

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