GEOG 204

LECTURE 9

Data Quality, Precision, and Accuracy

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Housekeeping

- Next week's week lecture will be a course review
- A good opportunity for questions

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Data Quality

- The power of GIS analysis is based on the assembly and manipulation of layers of data, but errors may rapidly propagate during analysis
- “Garbage in, garbage out”
  - Poor data quality leads to the poor decisions based on resulting from the analysis.
- …. High quality data are expensive

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Data Quality

- Geographic Information Systems
  - The context
    - Widely used for decision support applications
    - Reliance on data sourced from a myriad providers
      - Citizen Scientists, Open Data Portals, Government,
    - Low-quality data in decision making can have severe consequences
    - Inappropriate use of GIS functions can introduce errors
      - geometric and other transformations to the spatial data

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Data Collection

- Data Collection:
  - Traditionally, most spatial data were collected and held by individual, specialized organizations
    - national mapping agencies
    - energy supply companies,
    - local government departments
  - Increasingly, many users, agencies are collecting their own data.
    - Low cost of data capture equipment
    - Quality control is as much the responsibility of the producer as it is for the user

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Data Collection

- Data Collection:
  - If data are to be shared, considerations include
    - what data exists
    - where
    - format
    - quality requirements/specifications
    - metadata: the 'data about data'

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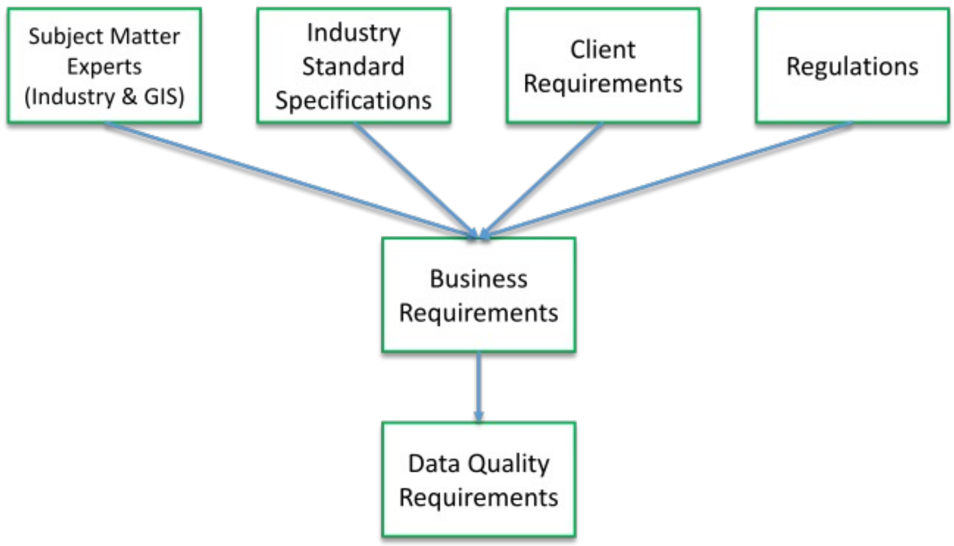
To collect data



Source: ESRI

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Sampling

- Provides knowledge about a whole population
    - i.e. make inference about a population from the sample data
- Larger sample sizes are more accurate representations of the whole
    - Large samples are costly: time, labour
        - Can be wasteful since we can statistically infer from appropriate samples
- A sampling strategy with the minimum bias is the most statistically valid

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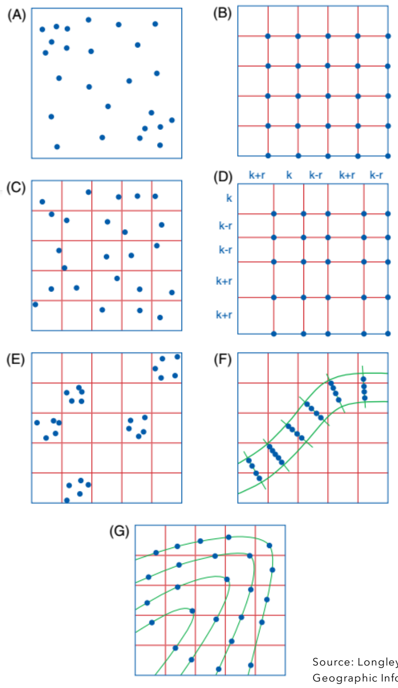

Sampling

Spatial sample designs: (A) simple random sampling, (B) systematic sampling, (C) stratified random sampling, (D) stratified sampling with random variation in grid spacing, (E) clustered sampling, (F) transect sampling, and (G) contour sampling.

Source: Longley, Paul A.; Goodchild, Michael F.; Maguire, David J.; Rhind, David W.. Geographic Information Science and Systems, 4th Edition. Wiley.

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Random Sampling

- Random sampling: each member of the population has an equal chance of being selected
  - Advantages:
    - Can be used with large sample populations
    - Avoids bias
  - Disadvantages:
    - Can disproportionately represent some parts of the population at the expense of others

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Systematic Sampling

- Systematic Sampling: Samples are chosen at regular intervals
  - Sample locations are evenly distributed for example every two metres along a transect line
    - systematic sampling implies a regularly spaced grid
      - Advantages:
        - It is more straight-forward than random sampling
        - Provides a good coverage of the study area
      - Disadvantages:
        - It is more biased: not all points have an equal chance of being selected
        - It may lead to over or under representation if there is periodicity in the data (e.g. sampling at the same interval as the location of erosion barriers along a beach. Or a city road grid)

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Stratified sampling

- Stratified sampling: used when the parent population is made up of sub-groups that of interest.
  - Divide the sampling design into strata(classes), and then select a sample from each stratum
  - The strata are defined so that individuals inside each class are similar based on the characteristic believed to influence the phenomena

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Stratified sampling

- Advantages:
  - If the proportions of the subgroups are known, the results are representative of the whole population
  - Correlations and comparisons can be made between subgroups
- Disadvantages:
  - The proportions of the subgroups must be known

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Air Photos for Stratified Sampling

- Looking for distinct, uniform areas
  - Crown size (age), harvest history
  - Hardwoods (gray) and softwoods (green)

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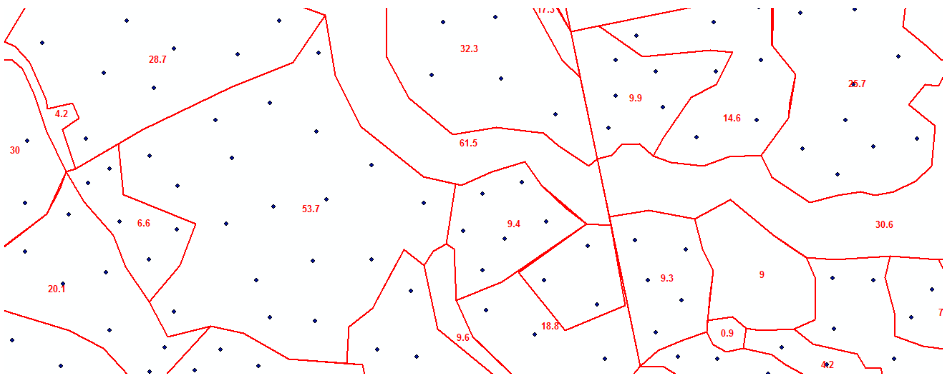
Stratified Sampling

- Generate sample points randomly
  - X points per area, e.g. 1 point every 3 hectares
  - Each point tied to polygon = unique stand



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Stratified Sampling: Population

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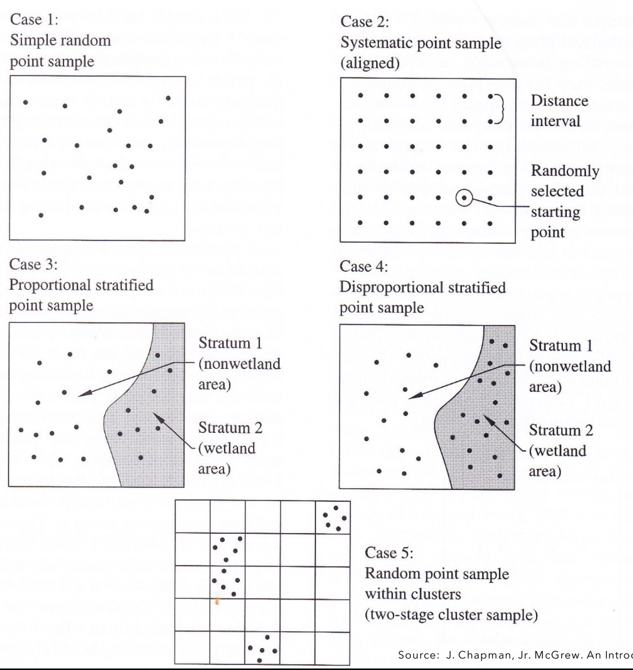

Point Sampling Methods

Source: J. Chapman, Jr. McGrew. An Introduction to Statistical Problem Solving in Geography

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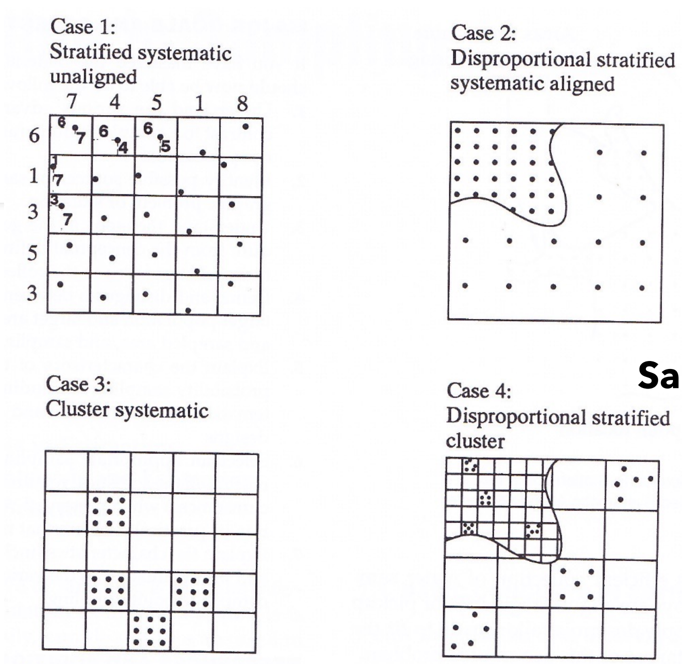

Hybrid Point Sampling Methods

Source: J. Chapman, Jr. McGrew. An Introduction to Statistical Problem Solving in Geography

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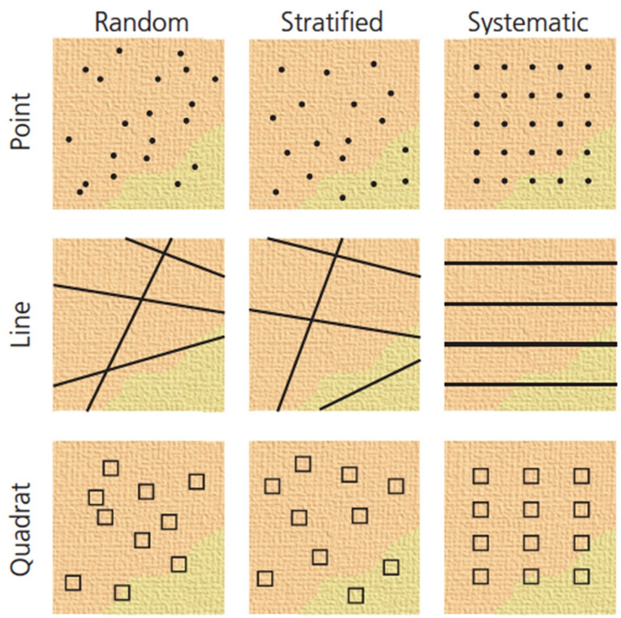

Source: https://www.geography-fieldwork.org/a-level/before-starting/methods/sampling/

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Errors in Data

- Sources of Errors:
  - **Human errors** include mistakes, such as reading an instrument incorrectly, and faulty judgments
    - e.g. ambiguous boundaries such as high water mark
    - e.g. Round off errors
  - **Environmental characteristics**, such as variations in temperature can result in measurement errors
  - **Instrument errors** Measurements are as precise as the instrument's capabilities.
    - The smallest measurement that can be made is the instrument's resolution.

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Elements of Data Quality

- Data quality elements:
  - Elements or components used to describe the quality of the data
  - They provide information on the suitability for data usage by describing
    - Why (purpose) data were collected
    - when (age) data were collected
    - How the data are created (method)
    - and how accurate the data are (limits)

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Elements of Data Quality

- Accuracy
  - Positional accuracy
    - closeness of locational information (usually coordinates) to the true position
    - Generally, paper maps are accurate to roughly one line width or 0.5 mm
      - On a 1:10,000 scale, 0.5mm is equivalent to?
      - NTS/NTDB 1:50,000 = ≤ 25 metres
      - BC TRIM: 1:20,000 = 10 metres
      - BC/Federal: 1:250,000 = 125 m
  - Thematic/attribute accuracy
    - the closeness of attribute values to their true value

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Elements of Data Quality

- Lineage
  - a record of the data sources and of the operations which created the database
    - how were they digitized, from what documents?
    - when were the data collected? By who?
  - is often a useful indicator of accuracy
- Logical consistency
  - refers to the consistency of the data model (particularly the topological consistency)
    - is the database consistent with its definitions?
    - is there exactly one label for each polygon?
    - are there nodes wherever arcs cross, or do arcs sometimes cross without forming nodes?

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Elements of Data Quality

- Completeness
  - degree to which the data exhausts all the possible items
    - are all possible objects included within the database?
  - affected by rules of selection, generalization and scale

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Elements of Data Quality

- Temporal quality
  - The quality of temporal attributes and temporal relationship of features.
- Data usability
  - Suitability to an application and its related functional requirement

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Data Quality - Key Issues

- Key Concepts
  - Accuracy, Precision and Uncertainty
- Accuracy:
  - closeness of the measurements, computations to the true values (or values accepted to be true)
    - spatial data are a generalization of the real world, the "true value" is thus an estimate of the real world
  - ~ absence of errors

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Data Quality - Key Issues

- Precision:
  - the number of decimal places or significant digits in a measurement
    - precision is not the same as accuracy - a large number of significant digits doesn't necessarily indicate that the measurement is accurate
  - a GIS works at high precision, mostly much higher than the accuracy of the data itself

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Data Quality - Key Issues

- Precision and Accuracy
  - Speak to data quality and the errors in the data.
    - Applies to geographic position, attribute/thematic information, conceptual accuracy (when modeling)
  - **Accuracy:** Closeness with which spatial data marches the values in the real world.
  - **Precision:** Exactness in the measurement or description of the data
    - Precise data may be inaccurate

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Data Quality - Key Issues

- Precision and Accuracy
  - If there are systematic variations in either the instruments used, or the phenomenon measured, this affects both accuracy and precision.

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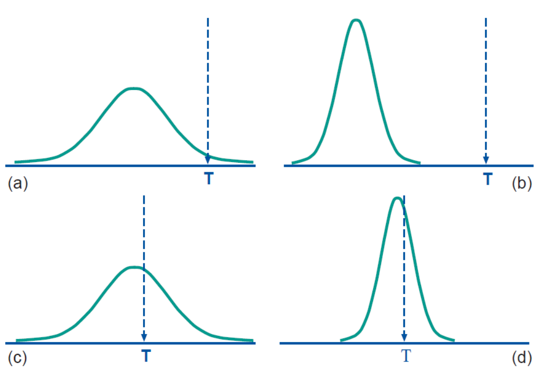
Data Quality - Key Issues

- Precision and Accuracy



Consider 40 students measuring the length of a line

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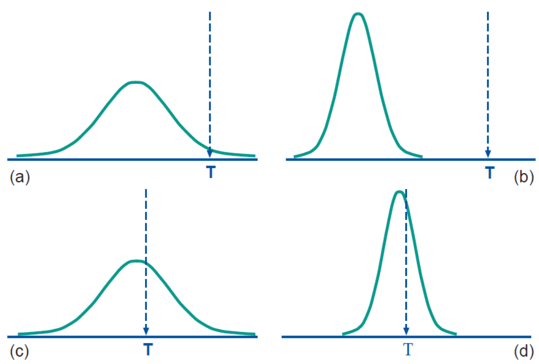
Data Quality - Key Issues

- Precision and Accuracy



Consider 40 students measuring the length of a line

Figure 5.2: A measurement probability function and the underlying true value T: (a) bad accuracy and precision, (b) bad accuracy/good precision, (c) good accuracy/bad precision, and (d) good accuracy and precision.

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Precision and Accuracy

- GIS software uses 'double-precision' – capable of storing 15 digits
  - E.g. decimal places (of meters – UTM) or 10 (latitude/longitude – WGS)
    - 560157.324687 or 52.4974294521

Lat	Lon
51.592443225	-122.242216653
51.590503265	-122.254802119
51.590917946	-122.252207907

- In most cases, this level of precision is <u>not</u> warranted by the data.
  - What is the justification for reporting millimeter precision on trail lengths?

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Data Quality - Key Issues

- *"All observations are inexact"*
- Spatial data are inaccurate to some degree therefore
  - accuracy assessment is important
  - tracking how errors are propagated through GIS operations is important
  - Take care not to assign greater accuracy to data than what it has
- Some data are intentionally imprecise
  - It is important to know the limitations

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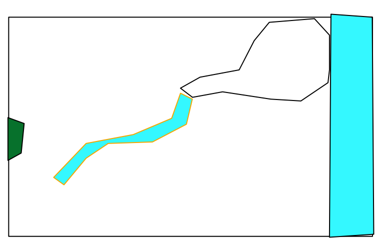
Data Quality - Key Issues

- Uncertainty: our imperfect and inexact knowledge of the world
  - Positional uncertainty
  - Attribute uncertainty
  - Definitional uncertainty
  - Measurement uncertainty



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Error and Uncertainty

- Uncertainty
  - A lack of sureness about something… the same as a lack of knowledge
    - lack of knowledge about level of error
      - Indicates the extent of unreliability
- Error
  - degree of doubt in a measurement
  - e.g. 5% error (calculated by difference between known & measured values)

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Error and Uncertainty

- UNCERTAINTY…
  - To you the scientist:
    - A statement of knowledge
    - Useful information on the limits
- UNCERTAINTY…
  - To the general public and decision makers:
    - Sign of weakness
    - Lack of trust and confidence
    - Confusing

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Data Quality

Some Considerations/Illustrations

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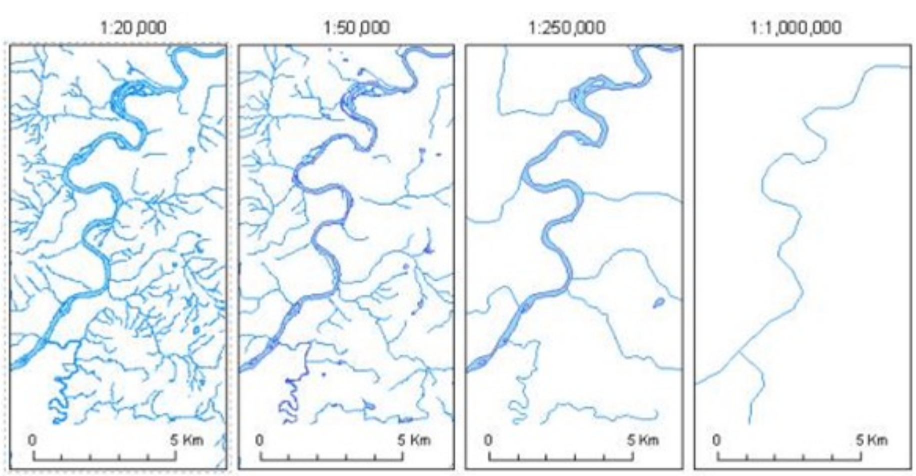
SCALE and PRECISION (not accuracy)

Data from a smaller scale has lower resolution (precision)
Details, number of features decrease with smaller scale
[both spatial location details and attributes]



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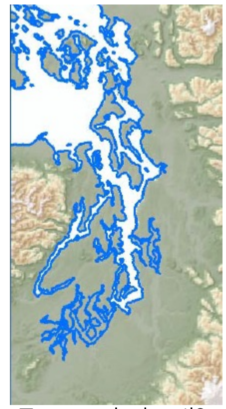
Data precision and display Scale

Scale – higher resolution shouldn't be used at smaller scales (too much data) and vice versa (too little).

Too little detail



Too much detail?

Image source: Esri

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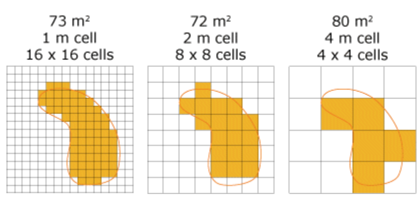
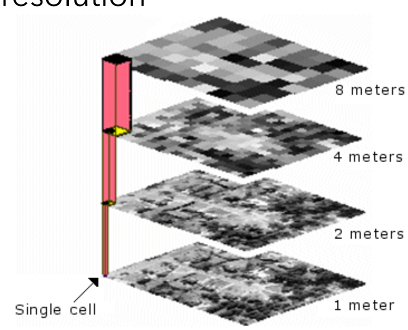
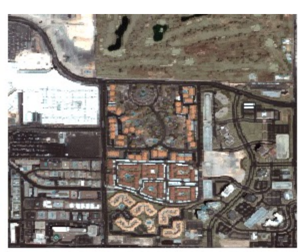
Raster precision = pixel size resolution

e.g. Landsat 30m, (Google) GeoEye 50cm





Scale 1:20,000
Cell size: 15 m



Scale 1:20,000
Cell size: 5m

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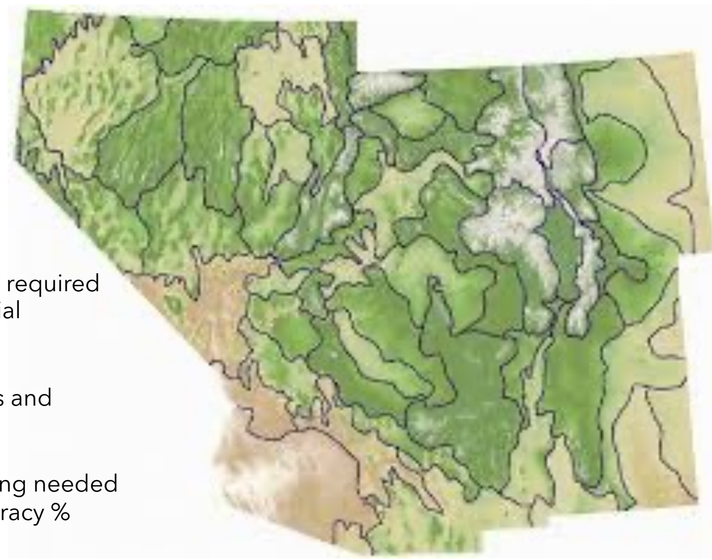
Uncertainty –in natural resources and gradual boundaries

Subjective: 10 people might digitize 10 different sets of lines – polygons and attributes



Consistency required e.g. provincial guidelines

And for soils and geology

Field checking needed to give accuracy %

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Data Quality in Natural Resources

- Some factors causing loss in data quality
  - Scale – spatial data and attributes
  - Density of observations and processing methods
  - Area cover – gaps due to accessibility
  - Age of data – precision and changes

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Summary

- Know the limitations of your data
  - When was it created
  - What level of precision was expected
  - What level of error was accepted
- Don't shoot the messenger if you're the boss
  - Input quality is a limiting factor
- Don't inadvertently lie to the client
- Be careful with simplified/smoothed data
- DISCLAIMERS? use them
- META DATA? Use them

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