Remote Sensing | Autumn Semester 2024

Spatial Analysis I

Zürcher Hochschule
für Angewandte Wissenschaften

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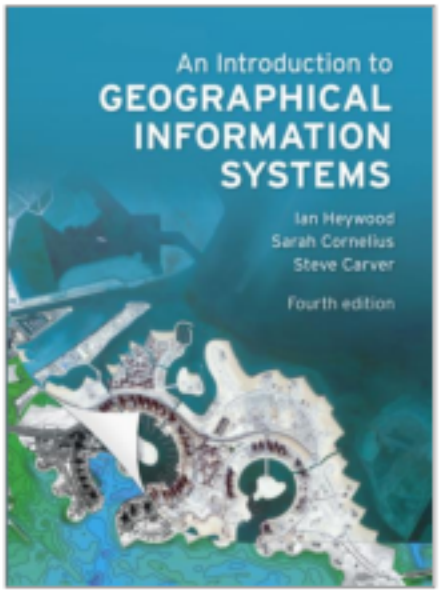
Learning Goals

- ✓ You can define the term "spatial analysis."
- ✓ You are familiar with data query approaches and can explain the difference between thematic and spatial queries.
- ✓ You know what SQL is and can formulate simple SQL statements.
- ✓ You understand the main operators of thematic queries.
- ✓ You can explain the difference between data querying and data manipulation in the context of spatial analysis and describe their characteristics.
- ✓ You can list the main categories of spatial analysis with geoprocessing (overlay, neighborhood, and connectivity analysis) and explain their features.
- ✓ You know the moste essential geoprocessing tools used in this week's exercises and understand how they function.

References

Books

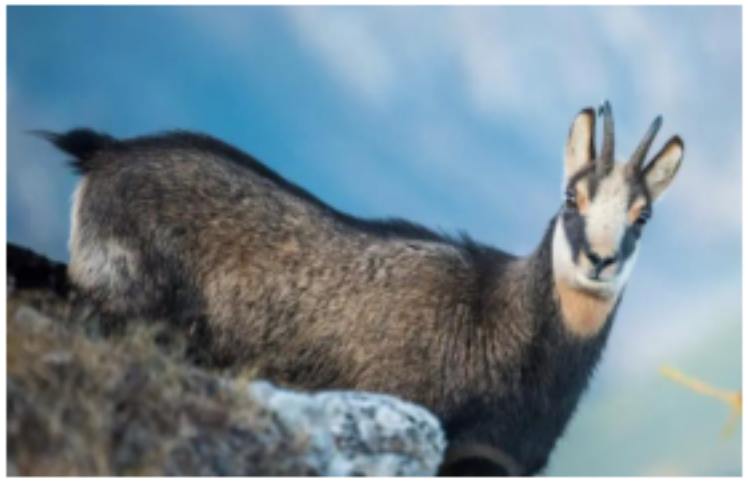
- An Introduction to Geographical Information Systems (Heywood et. al.)



Content

How can we answer these questions?

- Where are potential chamois habitats?
- Which buildings in the Gruyère district could be affected by a 100-year flood event?
- Where are suitable locations for new wind farms in Switzerland?



https://nationalpark.ch/en/flora-and-fauna/chamois/

https://www.wsl.ch/fileadmin/user_upload/News/2024/07_Unwetter/2005BrienzGlyssibach_QuelleSchweizerLuftwaffe.jpg

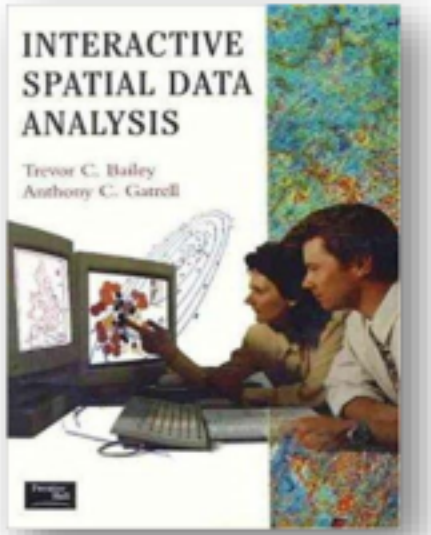
https://www.juvent.ch/de

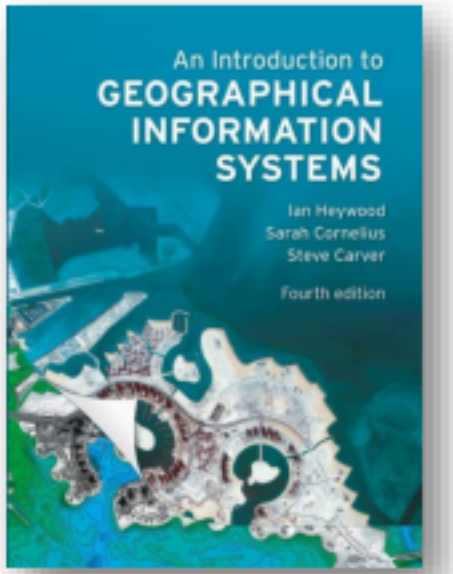
Spatial Analysis – An Attempt at a Definition

- *„(…) one might define spatial analysis as the **quantitative study of phenomena that are located in space**."*
  (Bailey et al. 1995)

- *„A general ability to **manipulate spatial data** into different forms and **extract additional meaning** as a result."*
  (Bailey 1994)

- *„The process of **examining the locations, attributes, and relationships** of features in spatial data through **overlay and other analytical techniques** in order to address a question or gain useful knowledge. Spatial analysis **extracts or creates new information from spatial data**."*
  (Heywood et al. 2011)





Spatial vs. Non-Spatial Analysis

According to the definition of the term "spatial analysis," the question arises as to what distinguishes "spatial analysis" from "non-spatial analysis."

- Assumption of *classical data analysis/statistics*:
  The values of a variable are independent of each other (random variable). As a result, the spatial distribution of variable values is independent of their position and spatial relationship (distance, neighborhood).
- In ***spatial analysis***, spatial characteristics such as ***distance***, ***neighborhood***, or ***direction*** are explicitly considered and included.

Content

Definition and Fundamentals of «Spatial Analysis»

Spatial Analysis in GIS Projects

Queries as Spatial Analysis

- Thematic Queries
- Spatial Queries

Geoprocessing as Spatial Analysis (Manipulation)

- Overlay Analysis
- Neighbourhood Analysis
- Connectivity Analysis

Excursus on Geoprocessing in GIS

Key-steps in a GIS Project

Workflow of a GIS Project

Issue
What should be done with GIS?

Data Modelling

Data Collecting and Preparation

Data Analysis

Presentation

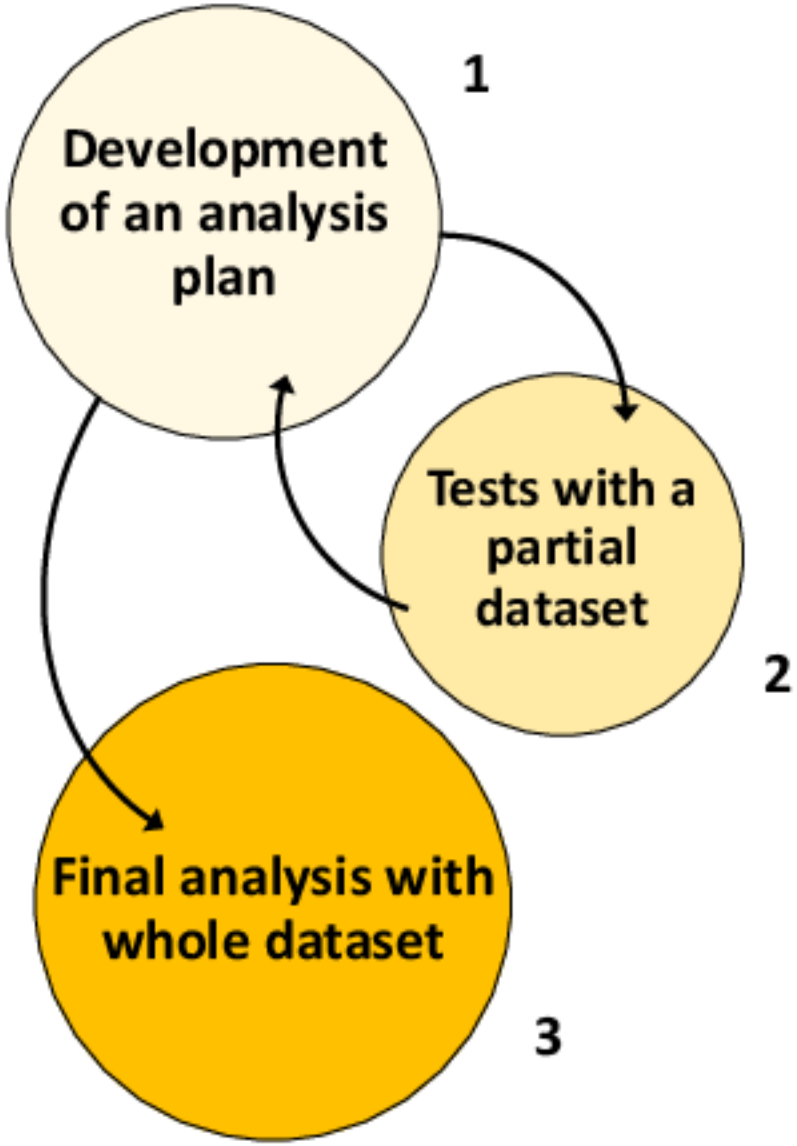
Documentation
Procedure and Result Description

Problem definition and breakdown

Creating data structure

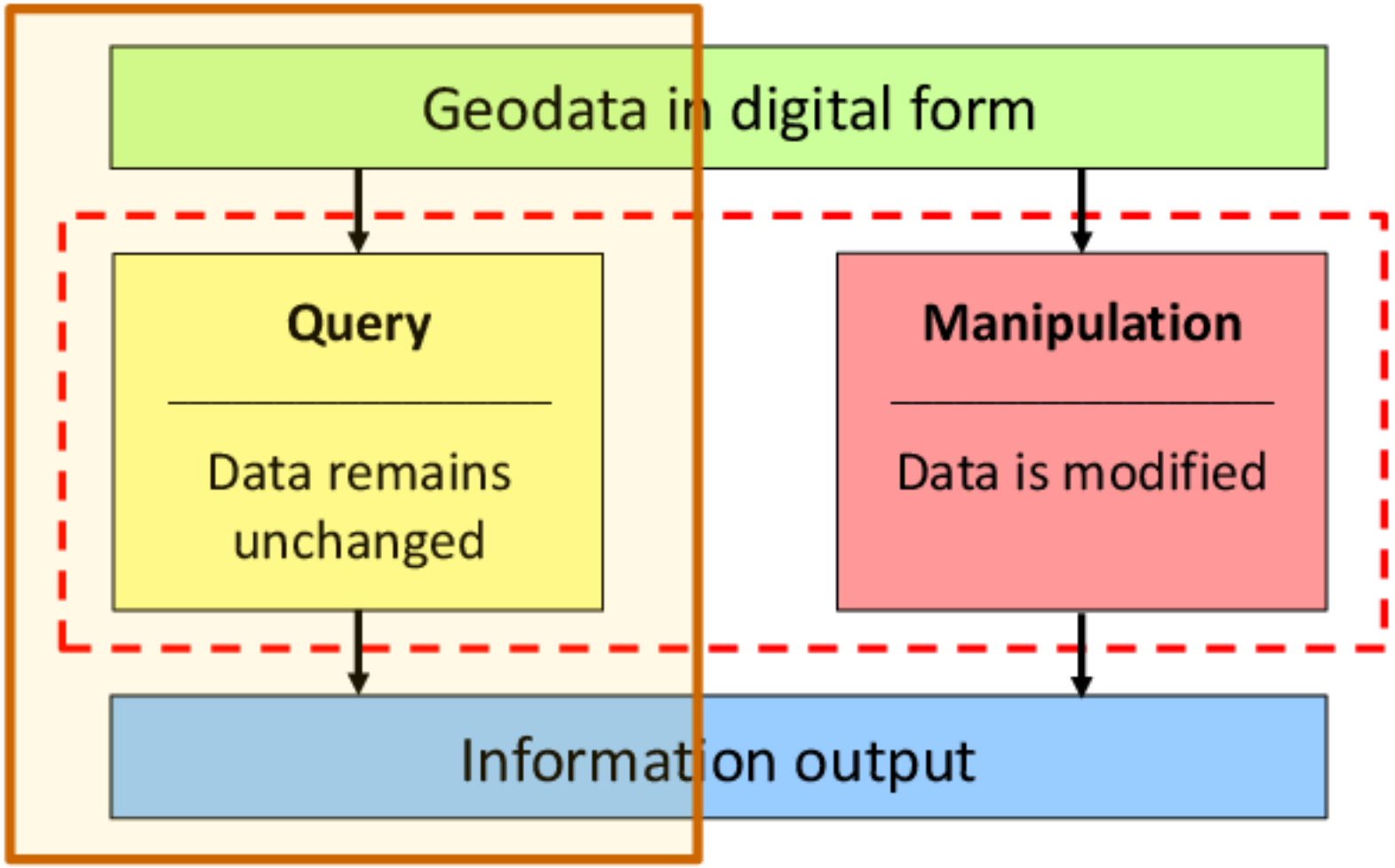
Data acquisition

Present, describe, and discuss results, draw conclusions



Queries vs. Manipulation in Spatial Analysis

In **queries**, subsets and information are extracted through **selection**. The data is **not altered**.



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Excursus on Geoprocessing in GIS

Spatial Analysis: Queries

- Queries process/examine data without making fundamental changes.
- They often start the spatial analysis but are useful in all stages.
  - **Measurements**
    Calculation of distances, perimeter, areas, etc.
  - **Reclassification**
    Transformation of value ranges
  - **Queries**
    Selection of subsets based on custom logical thematic and/or spatial criteria

Spatial Analysis: Queries

- Also referred to as "**selections**"
- 2 Types of selections:

Thematic Selection
(non-spatial queries)

Select by attribute
-> What…?

Spatial Selection
(spatial queries)

Select by location
-> Where…?

- Deliver subsets of the input dataset as output

Thematic Selections

- SQL (Structured Query Language) is used for thematic selections.
- Basic syntax includes:

SELECT *<attribute field>*	Column identification (which attribute field)
FROM *<table>*	Table identification (which attribute table)
WHERE *<clause>*	Definition of a specific clause
*	Alias for identifying all columns

- The simplest SQL statement **SELECT * FROM** data therefore returns all columns and rows from the table data.
- Important syntax elements of the **WHERE** clause are **operators** and **operands**:

Thematic Selections

Comparison operators

Operator	Meaning
=	Equal to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to
<>	Not equal to

In conditions that compare one expression with another, e.g.:

SELECT * FROM ***hotels*** WHERE ***category = 'luxury'***

SELECT * FROM ***streets*** WHERE ***length > 100***

-> Return TRUE or FALSE for each entity, where the selection set contains only the TRUE returns

Thematic Selections

Arithmetic operators

Operator	Meaning
+	Plus
-	Minus
/	Divide
*	Times

Are used to manipulate numeric operands, e.g.:

SELECT * FROM ***streets*** WHERE ***length * 5 > 100***

-> The output selection set differs from:

SELECT * FROM ***streets*** WHERE ***length > 100***

Thematic Selections

Logical (bolean) operators

Operator	Meaning
AND	TRUE if both Boolean expressions are true
OR	TRUE if either Boolean expressions is true
NOT	Negates a Boolean input
XOR	Precluding OR

Are used to expand conditions, e.g.:

SELECT * FROM ***streets*** WHERE ***length < 100*** **OR** ***length > 1000***

-> Does the following expression work?

~~SELECT * FROM ***hotels*** WHERE ***category = 'luxury'*** **AND** ***category = 'budget'***~~

NO, a hotel cannot be 'budget' and 'luxury' at the same time.

Thematic Selections

In all previous examples, selection is based on a single attribute ('uni-thematic').

SELECT * FROM *hotels* WHERE ***category*** = **'luxury'**

SELECT * FROM *streets* WHERE ***length*** > **100**

SELECT * FROM *streets* WHERE ***length*** ∗ **5** > **100**

SELECT * FROM *streets* WHERE ***length*** < **100 OR** ***length*** > **1000**

However, thematic selection is not limited to single-attribute queries.

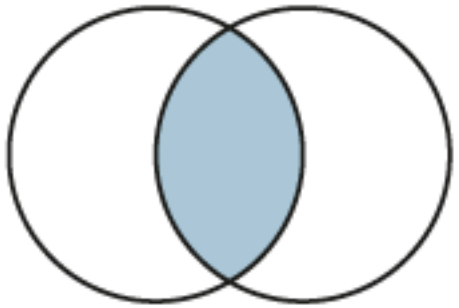
! Please note!

In an SQL statement, strings (text) are enclosed in single quotes (apostrophes) « '…. ' ».
Numbers, on the other hand, are not.

Thematic Selections

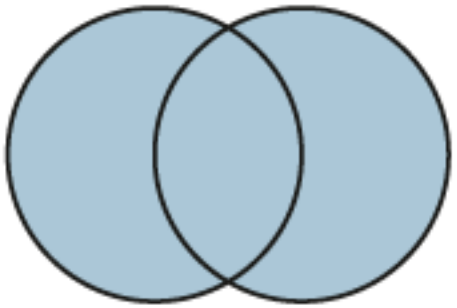
To query multiple attributes ('multi-thematic'), we use (again) logical operators, e.g.:

SELECT * FROM *hotels* WHERE *category* = 'luxury' **AND / OR / NOT / XOR** *beds* > 20



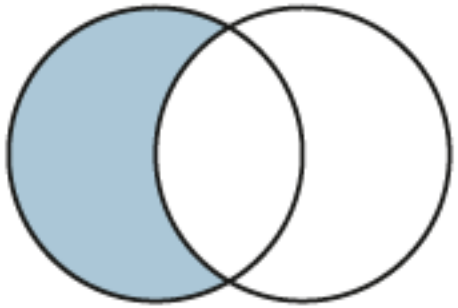
A AND B

e.g. Which hotels are in the 'luxury' category and have more than 20 bedrooms?



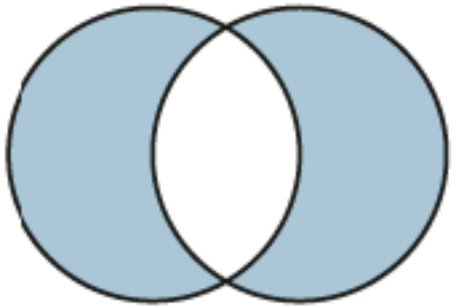
A OR B

e.g. Which hotels are in the 'luxury' category or have more than 20 bedrooms?



A NOT B

e.g. Which hotels are in the 'luxury' category but do not have more than 20 bedrooms?



A XOR B

e.g. Which hotels are either in the 'luxury' category or have more than 20 bedrooms but not both?

Image source: Heywood et al (2011)

Spatial Selections

Spatial selections are distinguished between **geometric queries** and **topological queries**:

- Geometric queries select objects based on spatial conditions, e.g.:

  «All houses that are within a distance of 500m from bus stops»

- Topological queries select objects based on spatial relationships, e.g.:

  «All houses that are completely outside of building zones»

Spatial Selections

Further examples of spatial selections based on **geometric selection criteria**:

- Which streets are wider than 10 meters?
- Which lakes are larger than 20 hectares?
- Which buildings are less than 100m from a highway?

Queries with **spatial conditions** either use functions for:

- Describing the **geometry** (i.e., properties of geometric primitives), e.g., the length of a line or the area/perimeter of a polygon,

or

- Measuring the **distance** or **direction** between two objects. For vector data, the distance between two objects is calculated according to the Pythagorean theorem and represents the shortest distance.

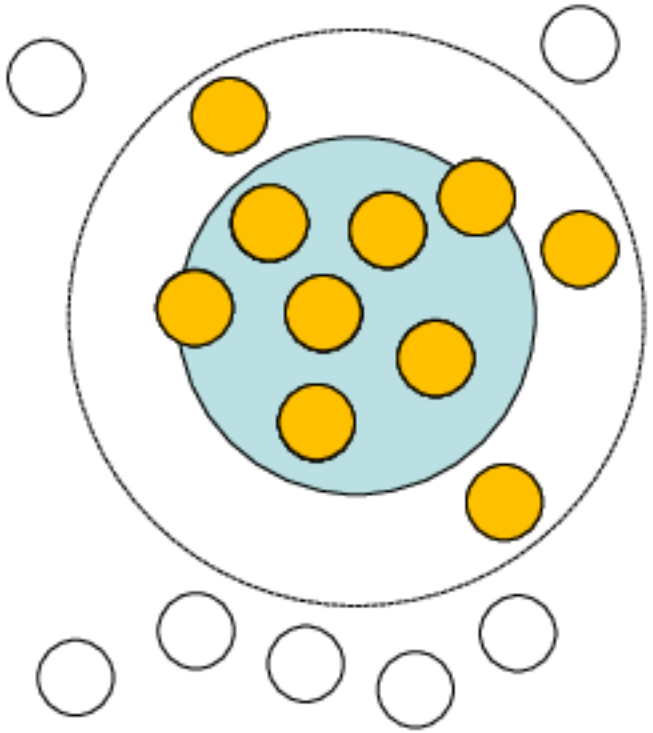
Spatial Selections

Further examples of spatial selections based on **topological conditions:**

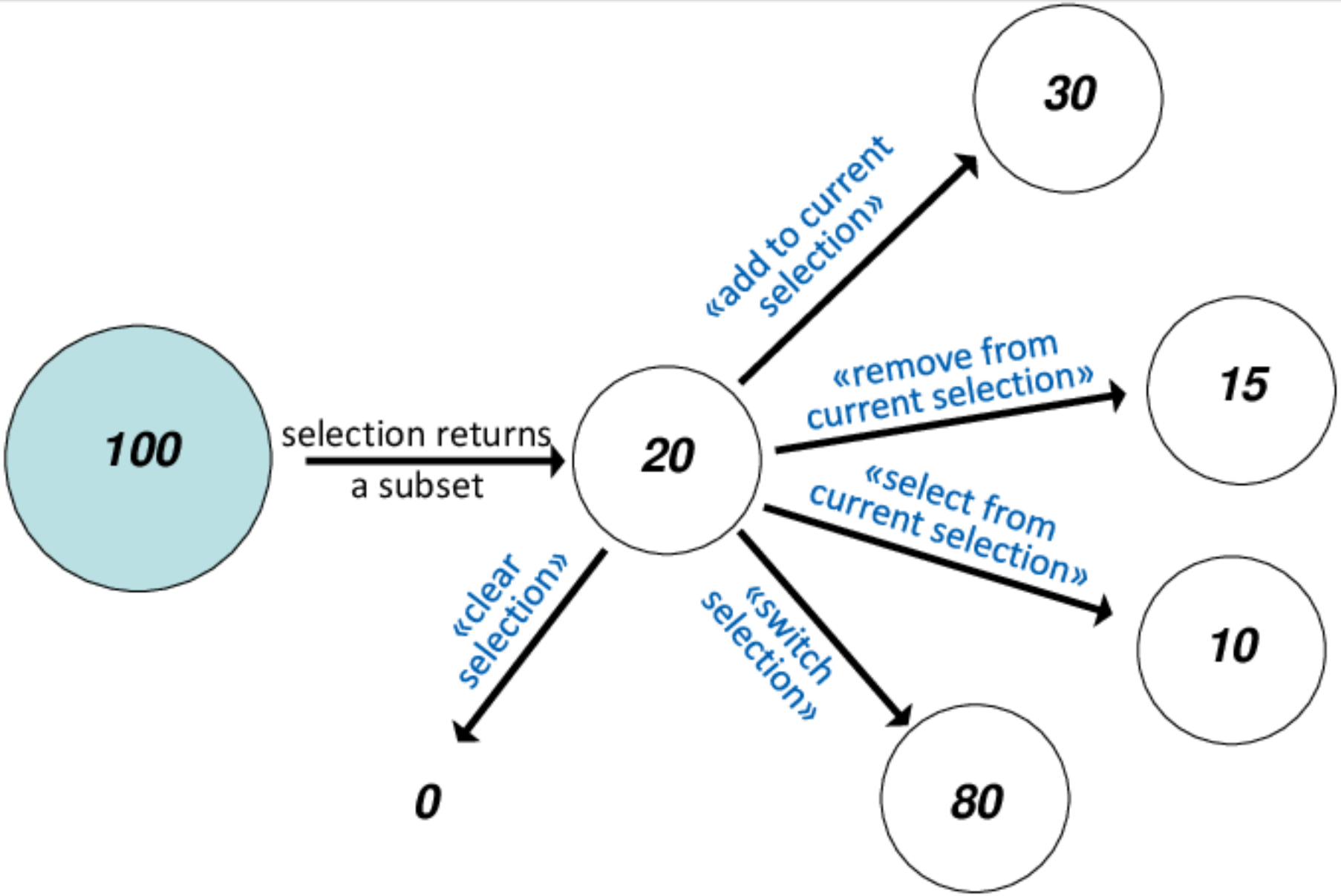
- Which streets are located within the city of Wädenswil?
- Which lake are completely within the canton of Zurich?
- Which buildings ( ) are located in hazard zones ( )?

Queries based on the **spatial relationship** by:

- «Containment»
- «Intersection»
- «Proximity»



Spatial Selections



Combination of thematic and spatial selections

- How many trees within the municipality of Wädenswil, with a height of more than 20m, are located outside of conservation areas?

- How many class 4 road segments with a length of more than 100m are located in the municipalities of Horgen and Wädenswil?

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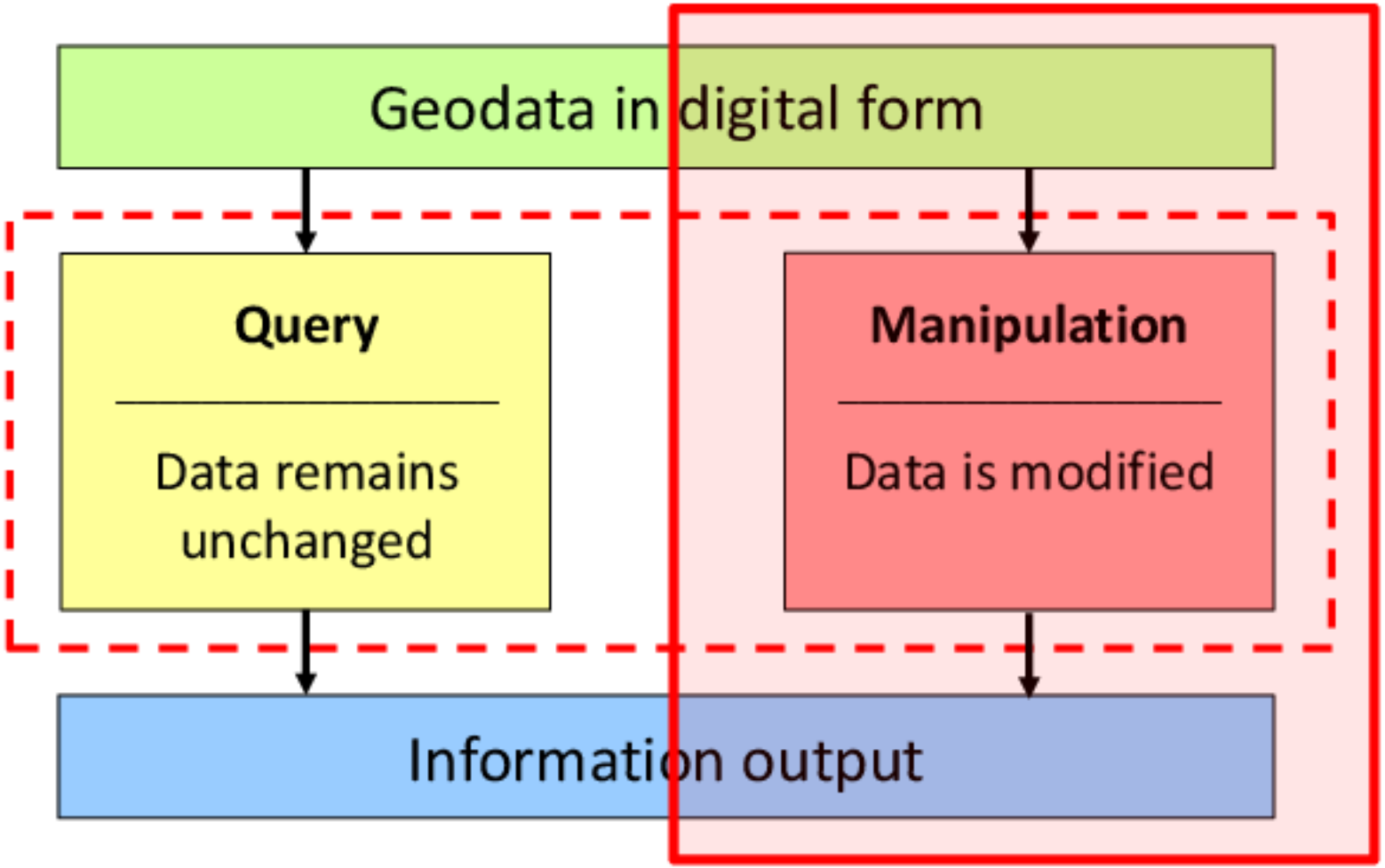
Excursus on Geoprocessing in GIS

Manipulation

Manipulations create new information from existing geodata by **altering the data.**

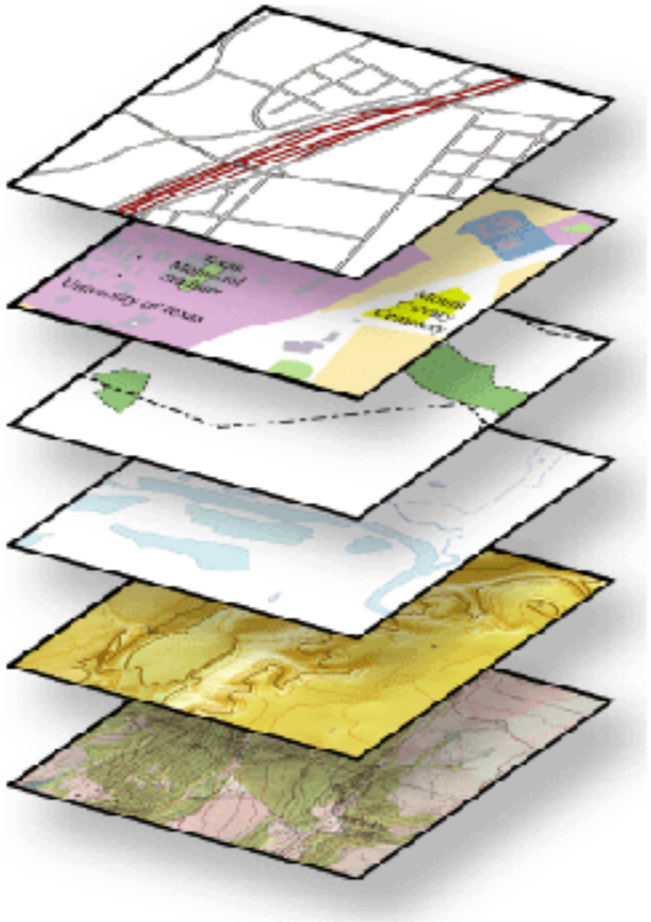


Overlay Analysis

Spatial analysis is the *„(…) process of examining the locations, attributes, and relationships of features in spatial data through **overlay** and other analytical techniques (…).”* (Heywood et al. 2011)

- The (probably) most well-known GIS analysis method
- **The principle of 'overlay analysis' is the combination of spatial information and features that occupy the same location**

  → new information is generated through the combination of data
- Data is altered and manipulated
- Overlay analysis can be performed using both raster and vector data



www.esri.com

Overlay Analysis

- today «*only*» vector-based Overlay-Analysis
- Overlay of **Points**, **Lines** and/or **Polygons**
- Elements (depending on tool):
  - Input - Layer
  - Overlay - Layer
  - Output - Layer
- are based on **Geometry** and **Topology**
- Attributes will be transferred (depending on tool)

Overlay Analysis

(i) Point-in-polygon

Application example: *Which climate stations are located in the forest?*

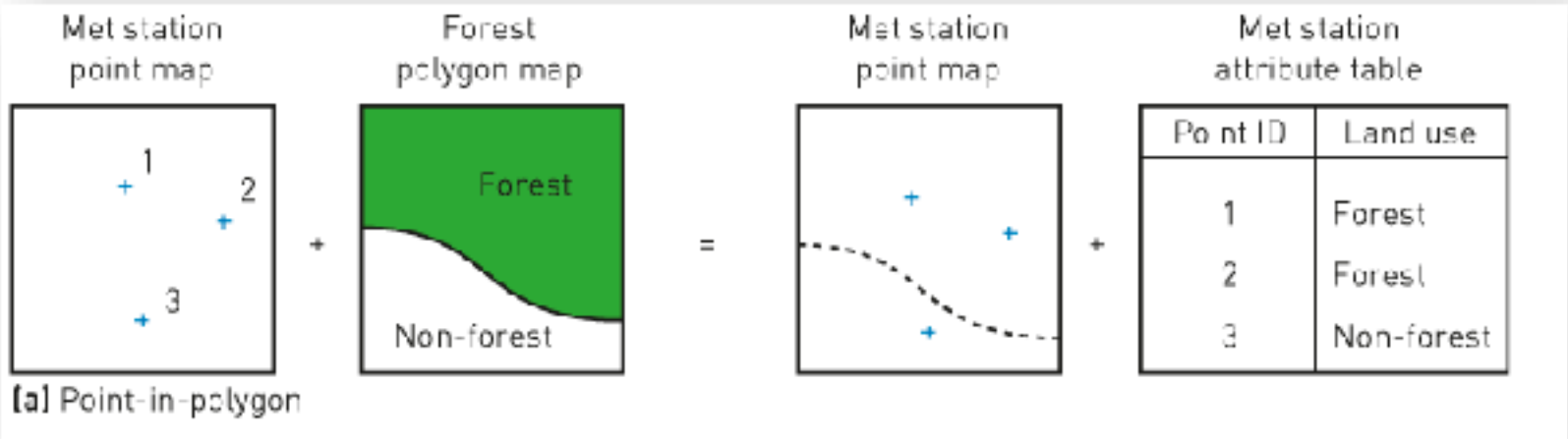
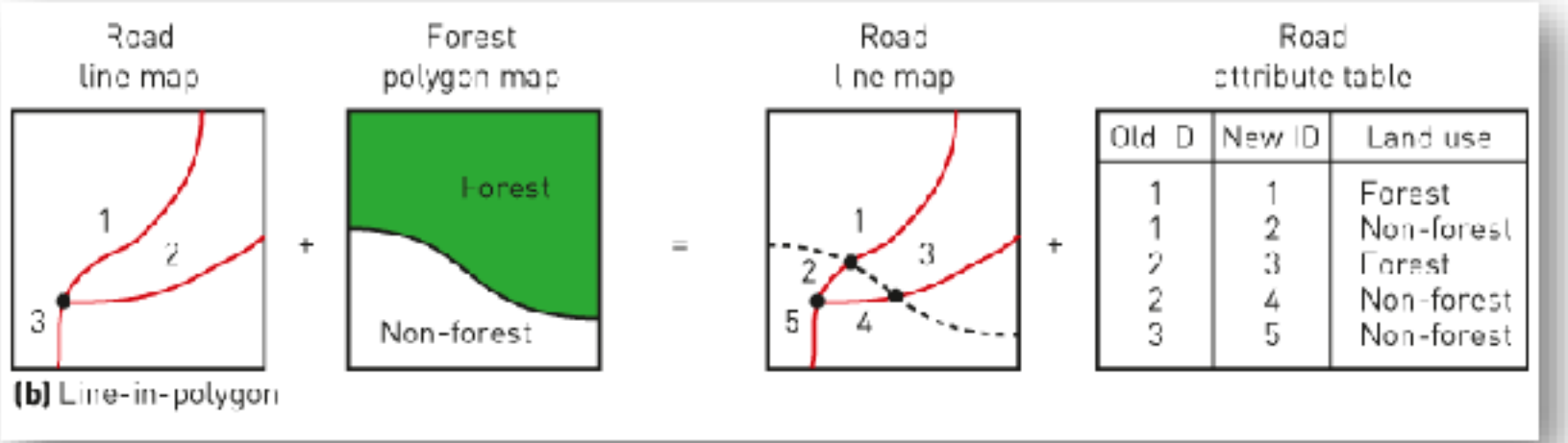


Image source: Heywood et al (2011)

Overlay Analysis

(ii) Line-in-polygon

Application Example: *Where do roads run in the forest?*



(b) Line-in-polygon

Image source: Heywood et al (2011)

Overlay Analysis

(iii) Polygon-on-polygon

Application examples:

Where is forest OR resort?

Where is forest and not resort? (NOT)

Which forest areas are within the resort? (AND)

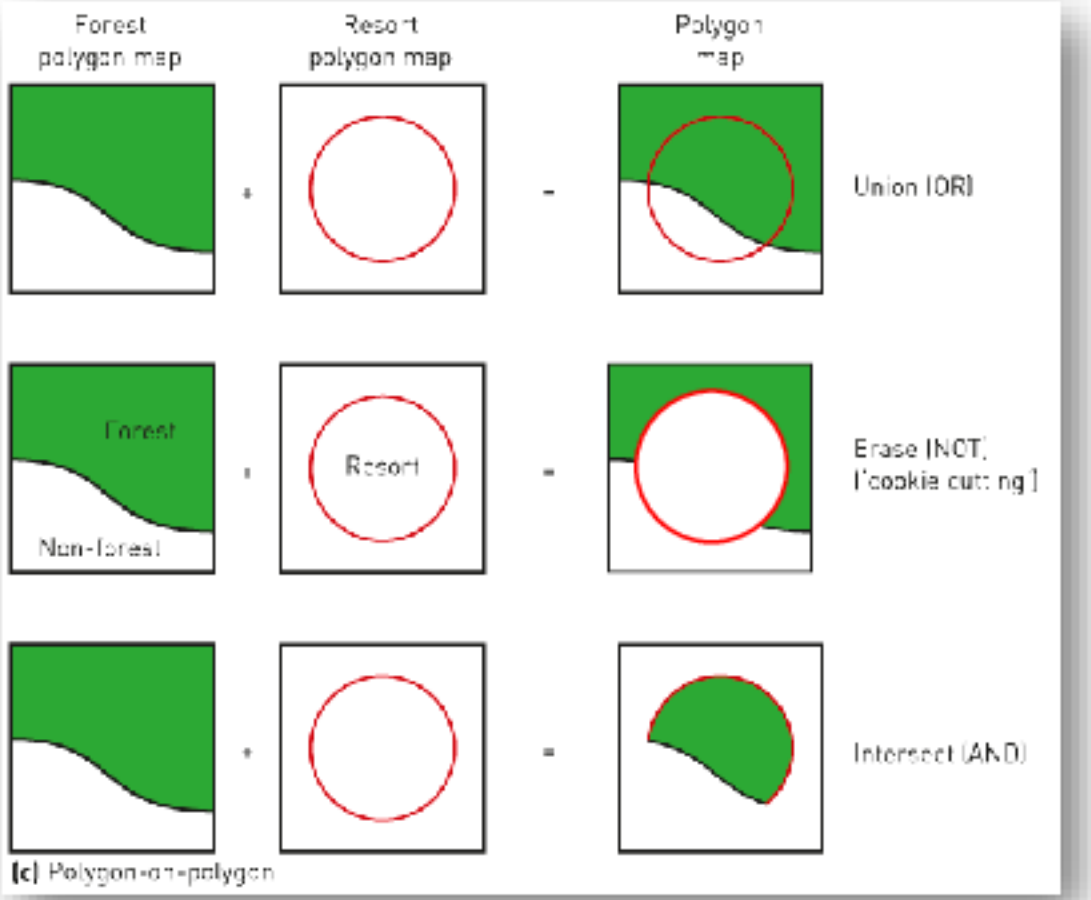


Image source: Heywood et al (2011)

Neighbourhood Analysis

- **Evaluate the characteristics in the vicinity of a location**

  (as opposed to 'overlay analyses,' which combine objects and features in the same location)

- Enable the analysis of **buffer zones** and **dispersion effects** to study the impacts of features/objects such as springs or volcanic eruptions.

Neighbourhood Analysis

- **Buffer zones (n)** around the geometric primitives **Points** (a), **Lines** (b) and **Polygons** (c)

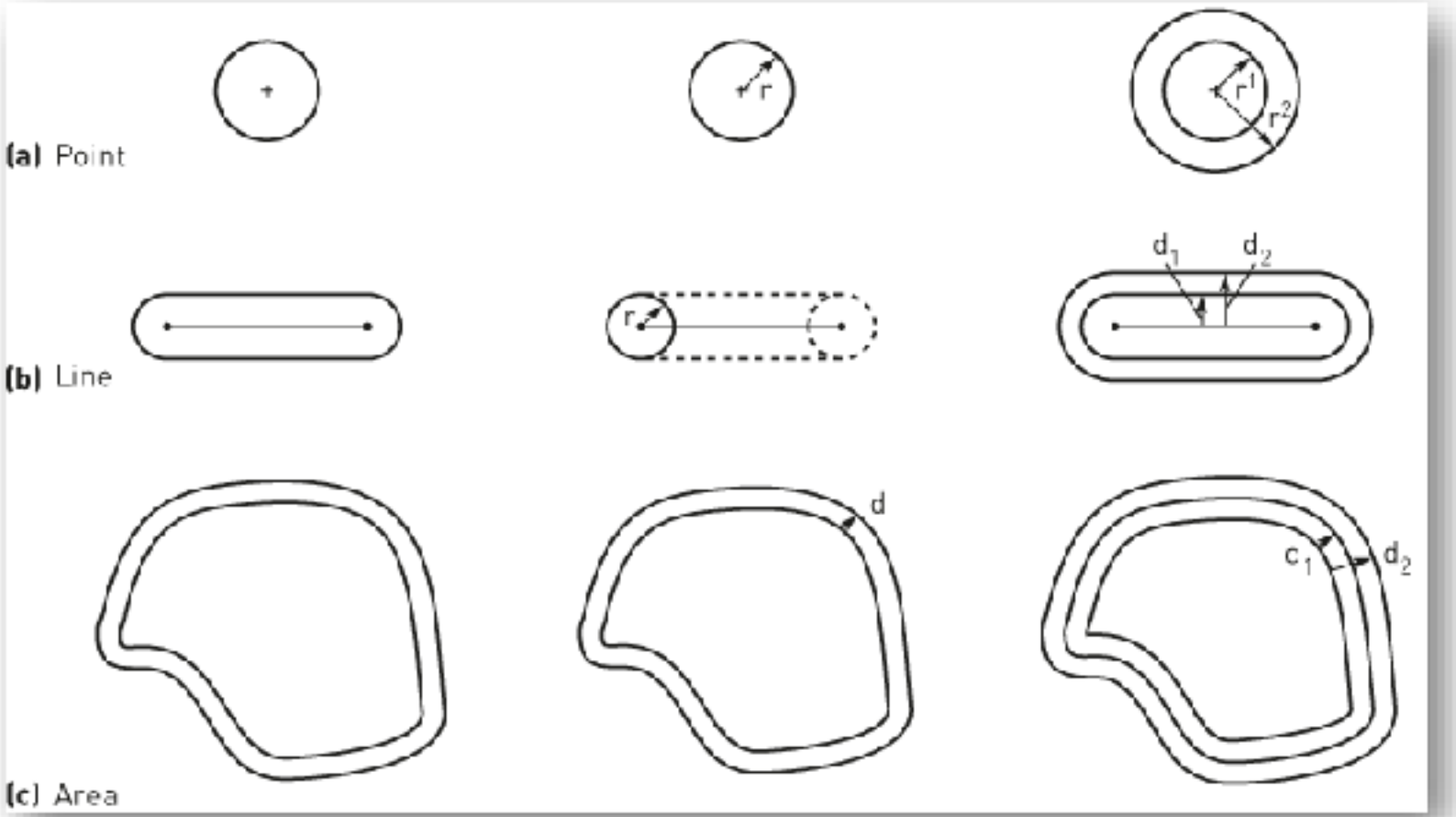


Image source: Heywood et.al (2011)

Neighbourhood Analysis

- **Variable buffer zones** (based on a specific attribute)

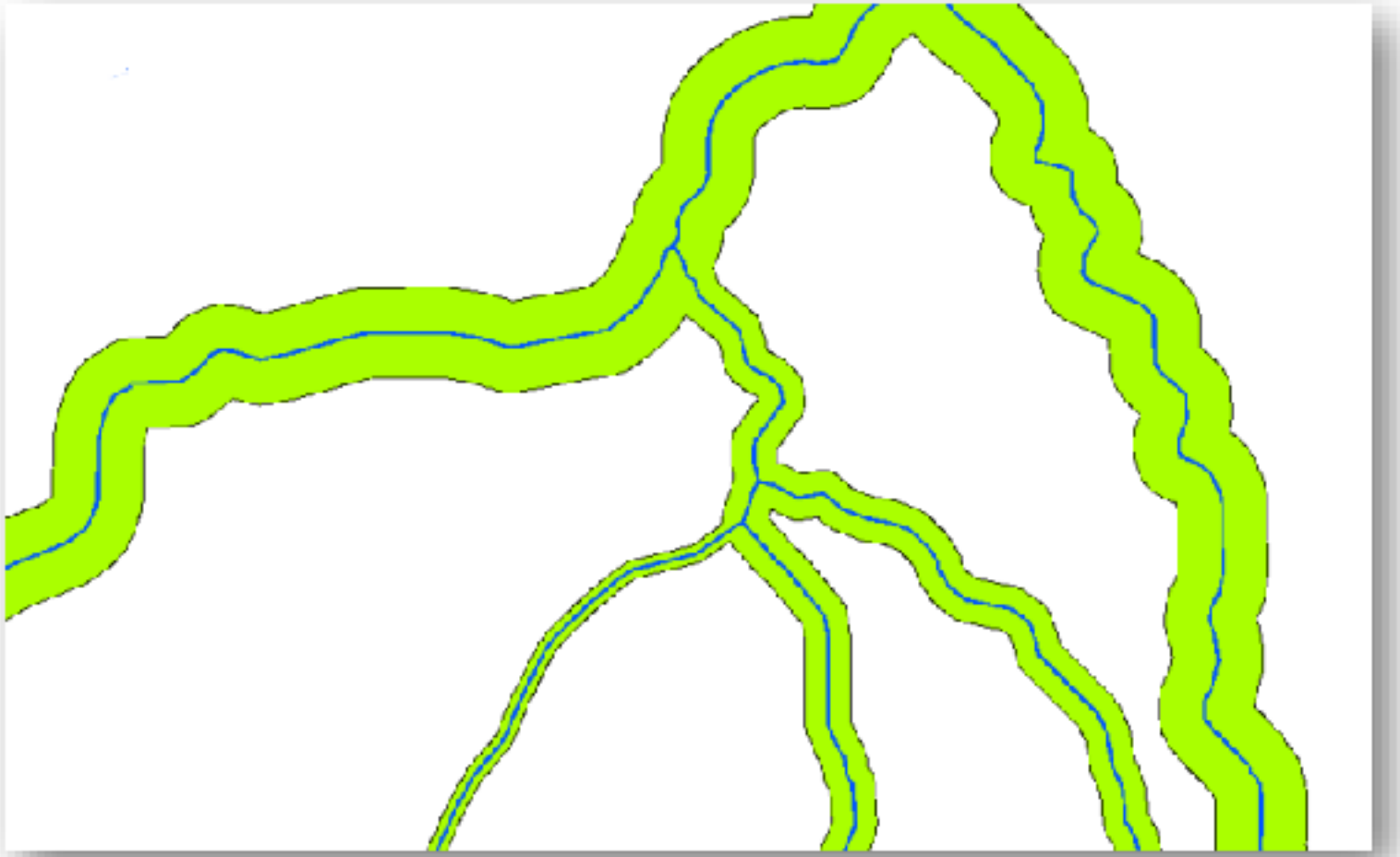


Image source: Heywood et.al (2011)

Connectivity Analysis

- **Evaluate connections and relationships between spatial objects**
- based on **graph theory** (networks with node-edge-node-topology)
- important analytical methods primarily involving linear phenomena
- Examples include road or communication networks, watercourse patterns, or location decisions

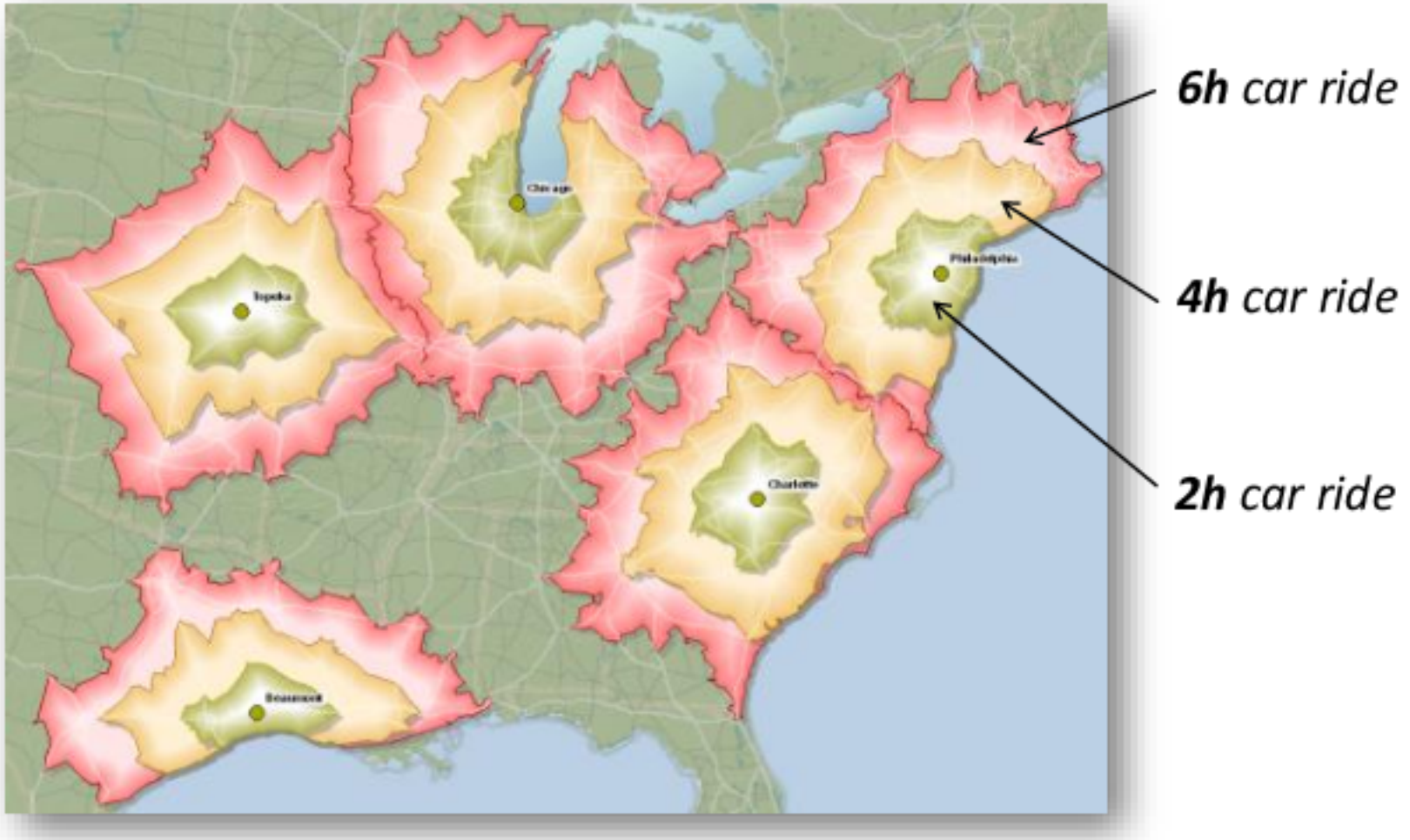
Connectivity Analysis

- The shortest path from ***«A»*** to ***«B»***….?

Image source: Heywood et.al (2011)

Connectivity Analysis

- Accessibility analysis



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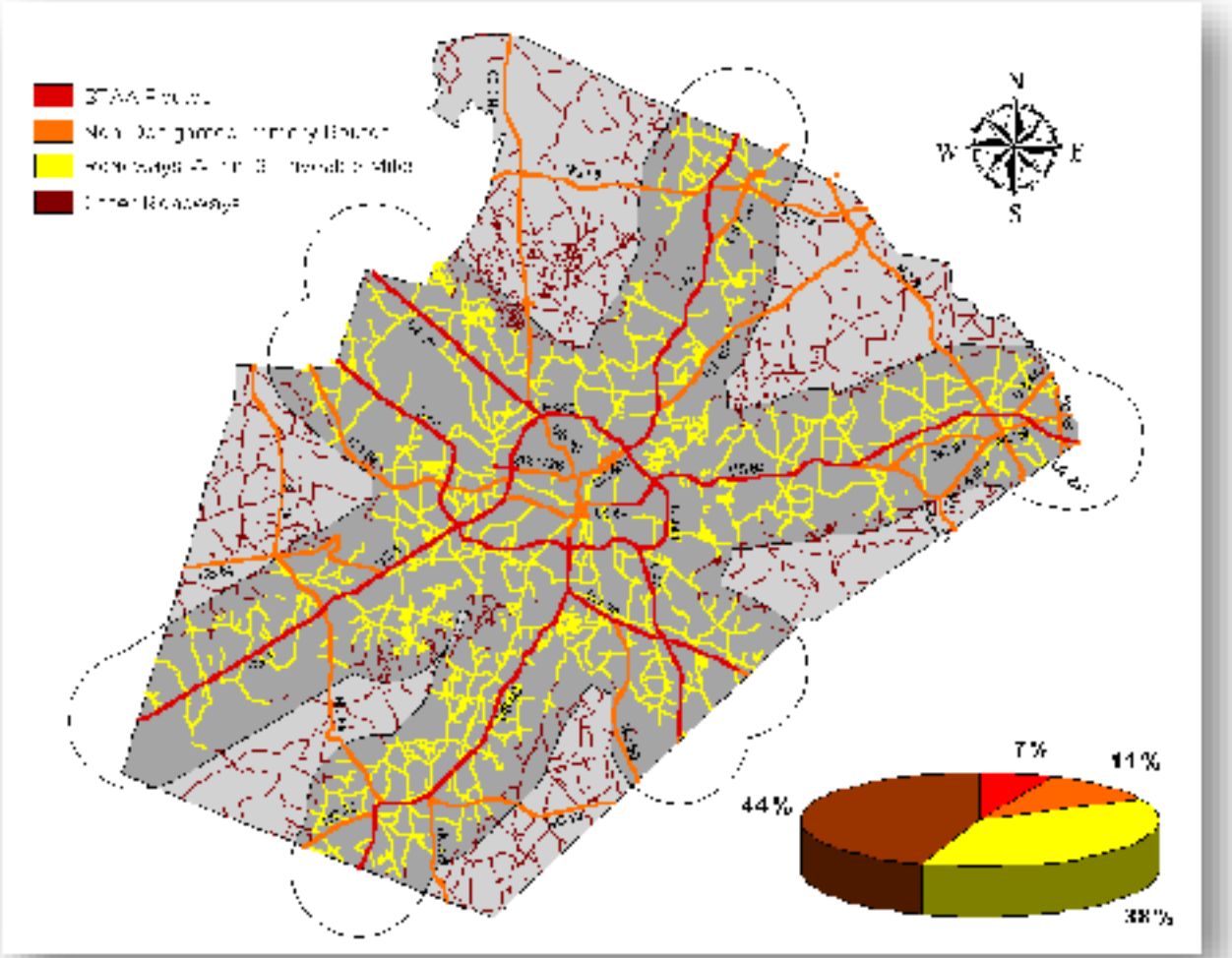
Connectivity Analysis

- Location and potential analysis



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Facts:

- 8 out of 10 GIS-based location decisions are successful
- 5 out of 10 NON-GIS-based location decisions are successful

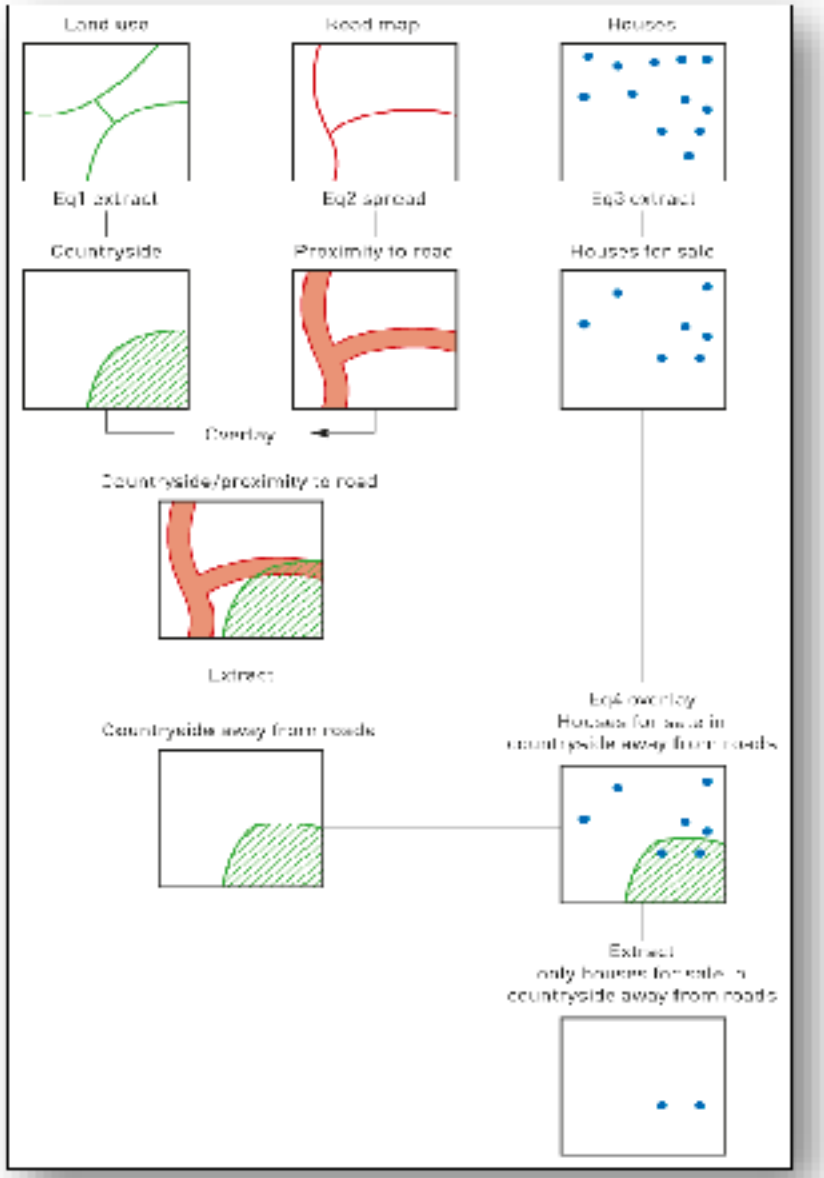
(www.wigeogis.com)

Simple Application Example

Apartment search?

Location criteria:

- rural environment
- minimum distance to heavily trafficked roads



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Excursus on Geoprocessing in GIS

Most Important Geoprocessing Tools

*"So you want to geoprocess like a **GIS guru**, do you?*

*Well, these **7 geoprocessing tools** always top the chart in the GIS guru's hit list.*

They're our bread and butter."

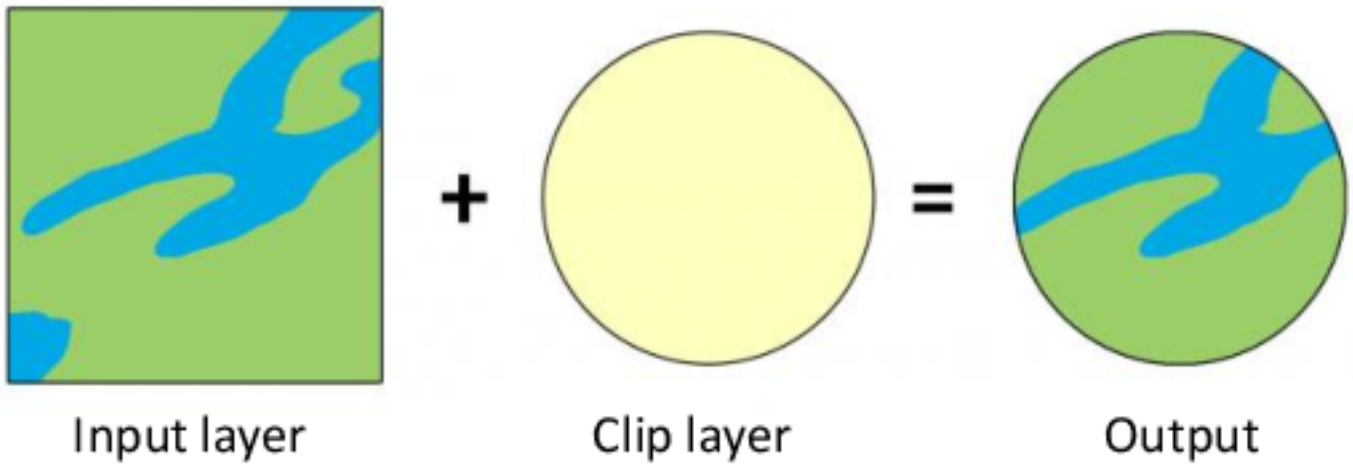
https://gisgeography.com/geoprocessing-tools/

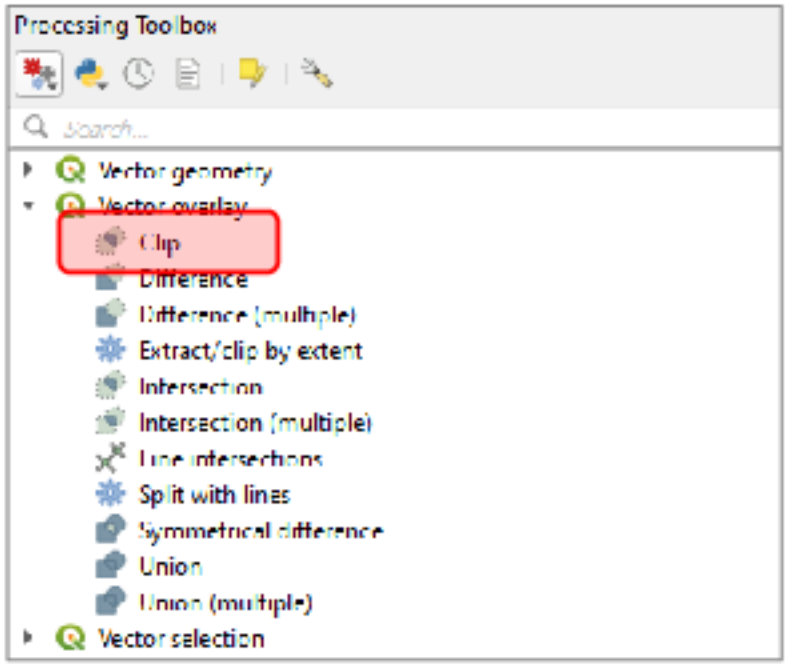
https://gisgeography.com

Geoprocessing Tools - Clip

The Clip tool cuts out an input layer to a defined feature boundary. Like a cookie-cutter, the output is a new clipped output.

- One layer (polygon) serves as a mask (clip layer). The input layer can be points, lines or polygons.
- The new layer (output) contains the parts of the input layer that overlap with the clip feature.
- The attributes of the clip feature are not passed on. Clip only retains the attributes from the input layer.

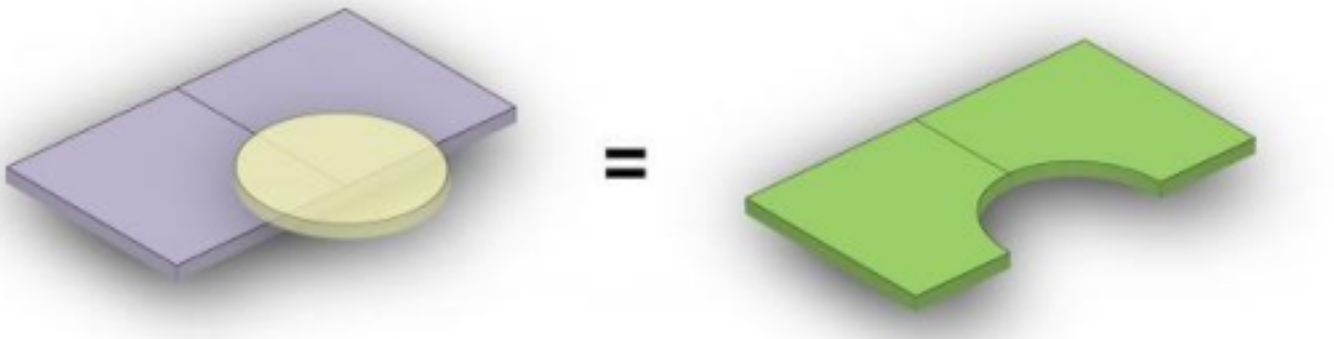




Geoprocessing Tools – Erase (Difference in QGIS)

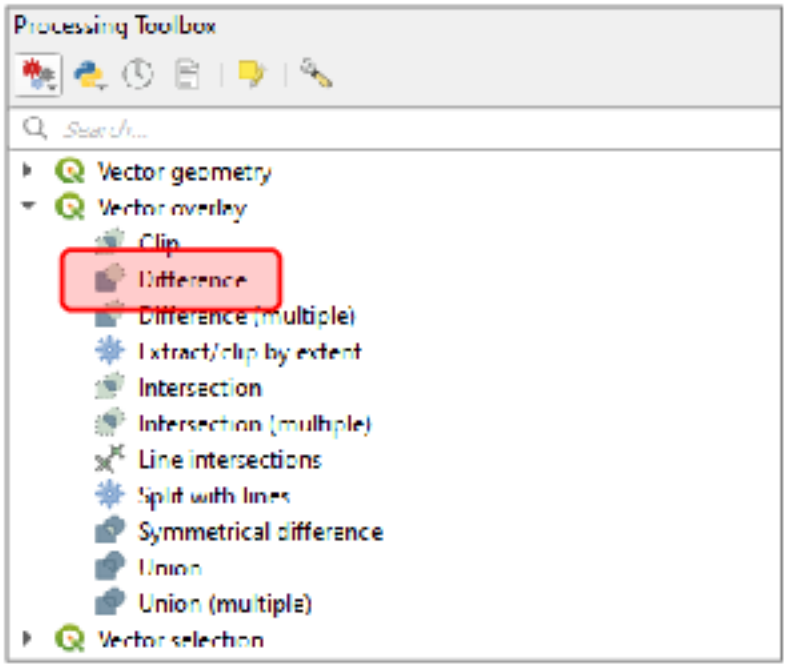
The Erase (Difference) tool creates an output layer by overlaying an input layer and an erase feature. Overlapping areas are removed from the input layer.

- Only attributes from the input layer are passed to the output.
- Input layers can be points, lines, or polygons.
- The erase feature must be a polygon.



Input & Erase layer

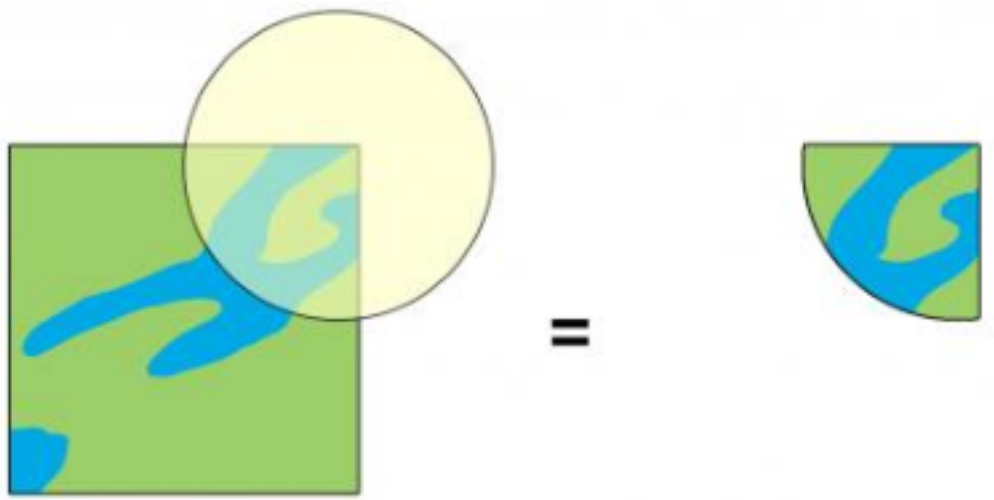
Output

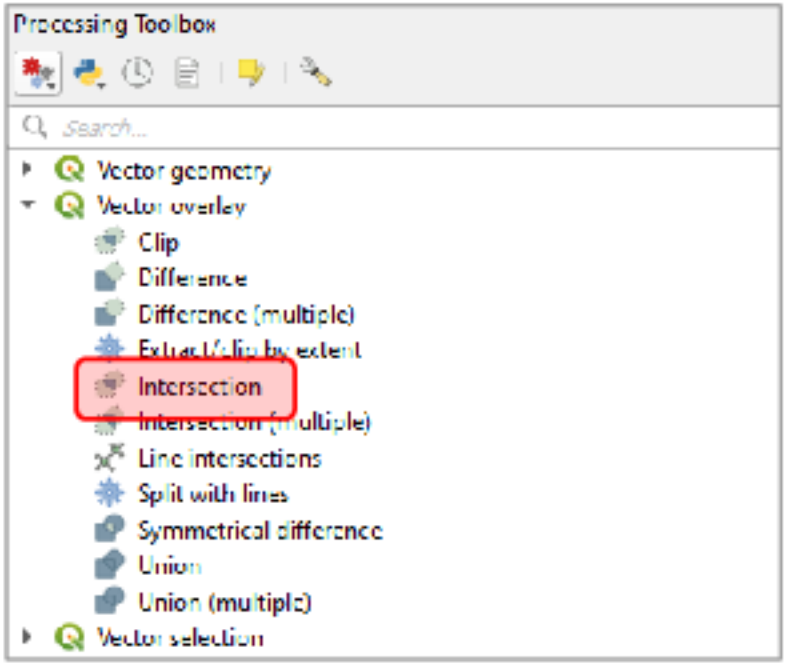


Geoprocessing Tools – Intersect

The Intersect tool creates a geometric intersection of multiple input layers.

- Where the polygon edges of the input layers intersect, new polygons are automatically created.
- The output layer contains only objects from the shared area.
- Attributes **from both input layers** are retained in the output layer.

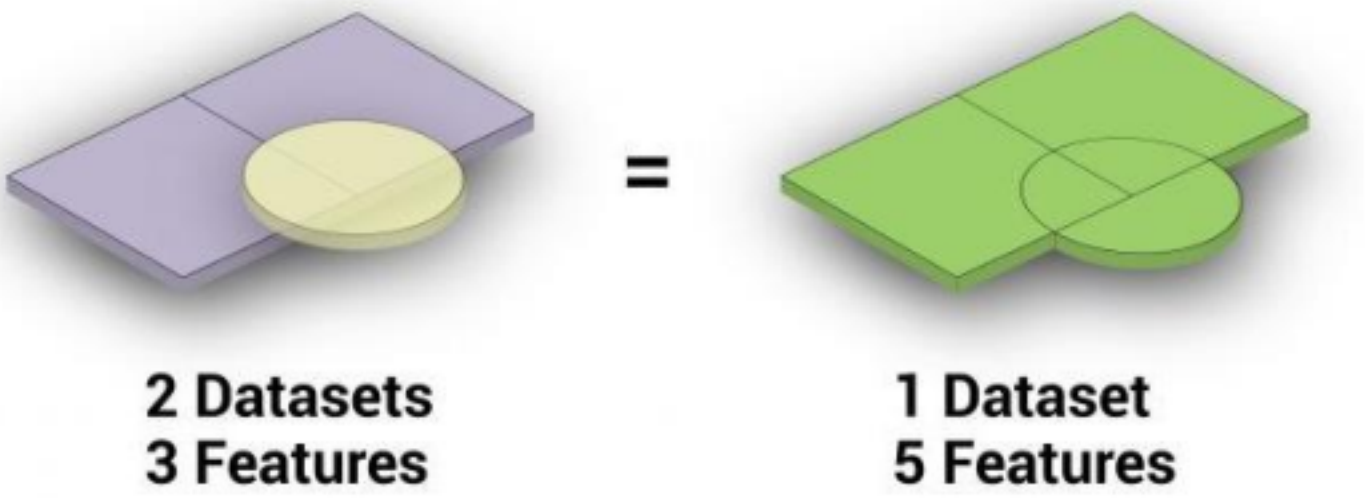


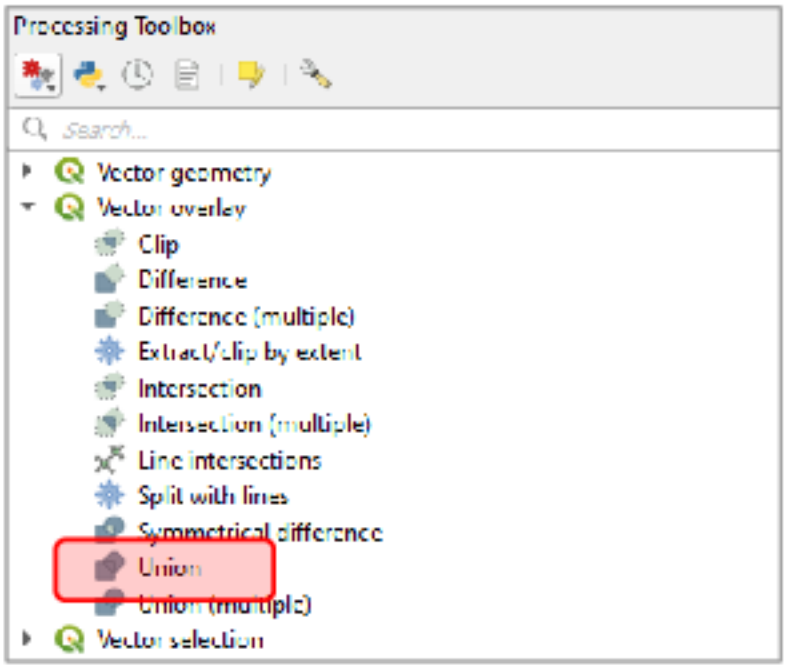


Geoprocessing Tools – Union

The Union tool creates a geometric overlay of multiple input layers.

- Where the polygon lines of the input layers intersect, new polygons are automatically created
- The output layer contains all objects from the input layers.
- Attributes **from both input layers** are retained in the output layer.
- Applicable only to polygons.

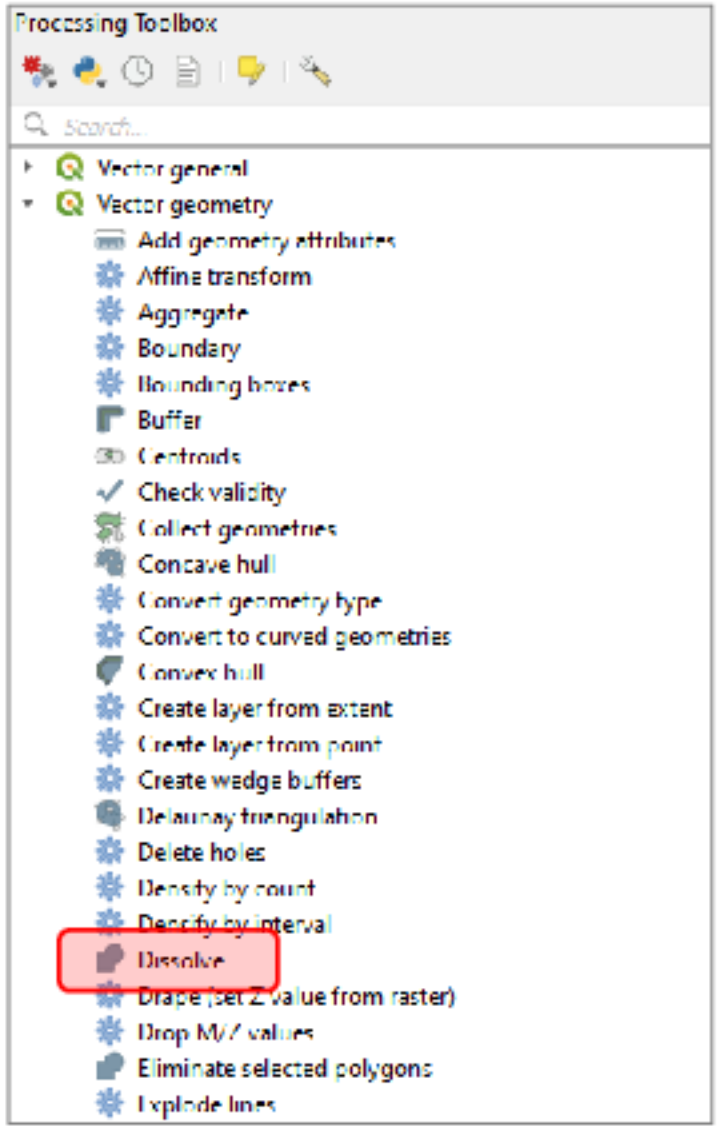




Geoprocessing Tools – Dissolve

The Dissolve tool aggregates features based on specified attributes.

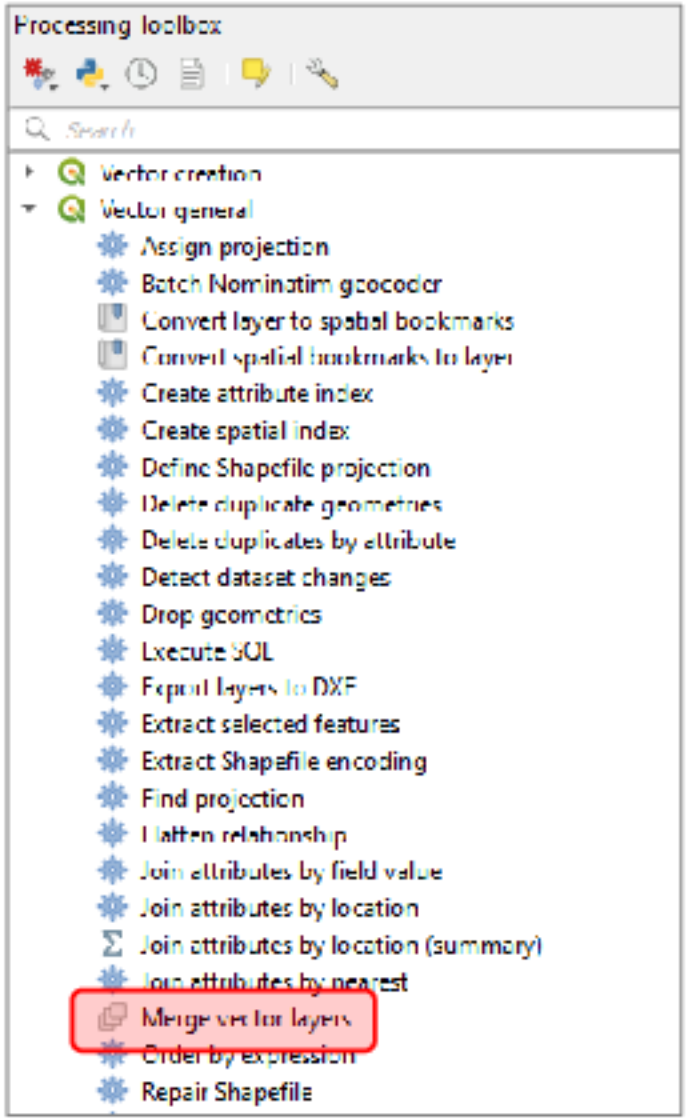
- Features with the same value combinations for the specified fields are aggregated into a single feature.
- The dissolve fields are written to the output layer.
- Multipart features can be created



Geoprocessing Tools – Merge

The Merge tool combines datasets that are the same data type (points, lines, or polygons). When you run the merge tool, the resulting data will be merged into one.

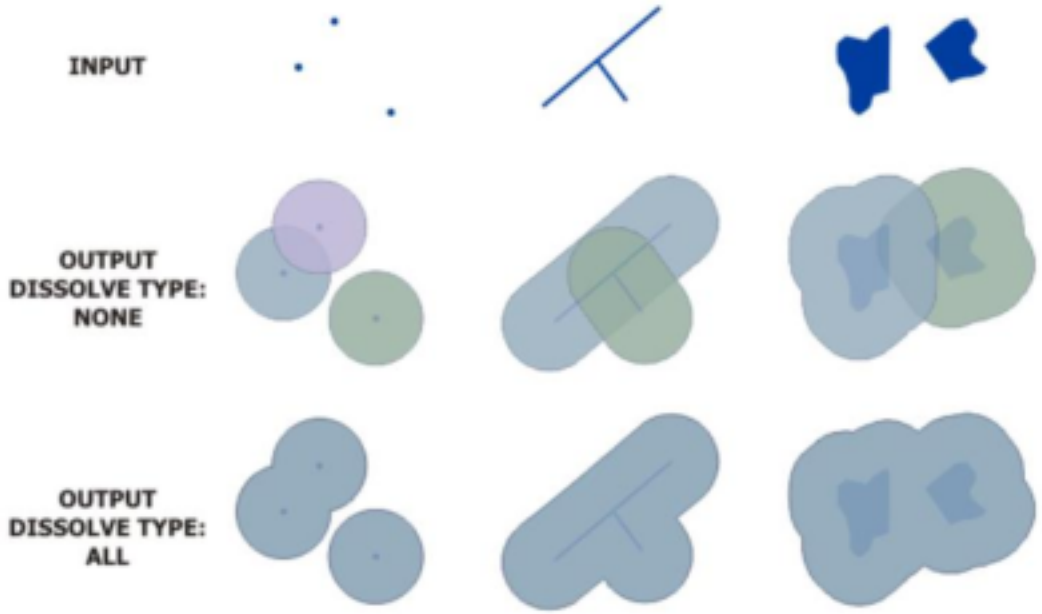
- For the field values of the output layer, the attributes of one of the input layers can be selected.
- If common fields exist for all input layers, the attribute values are retained

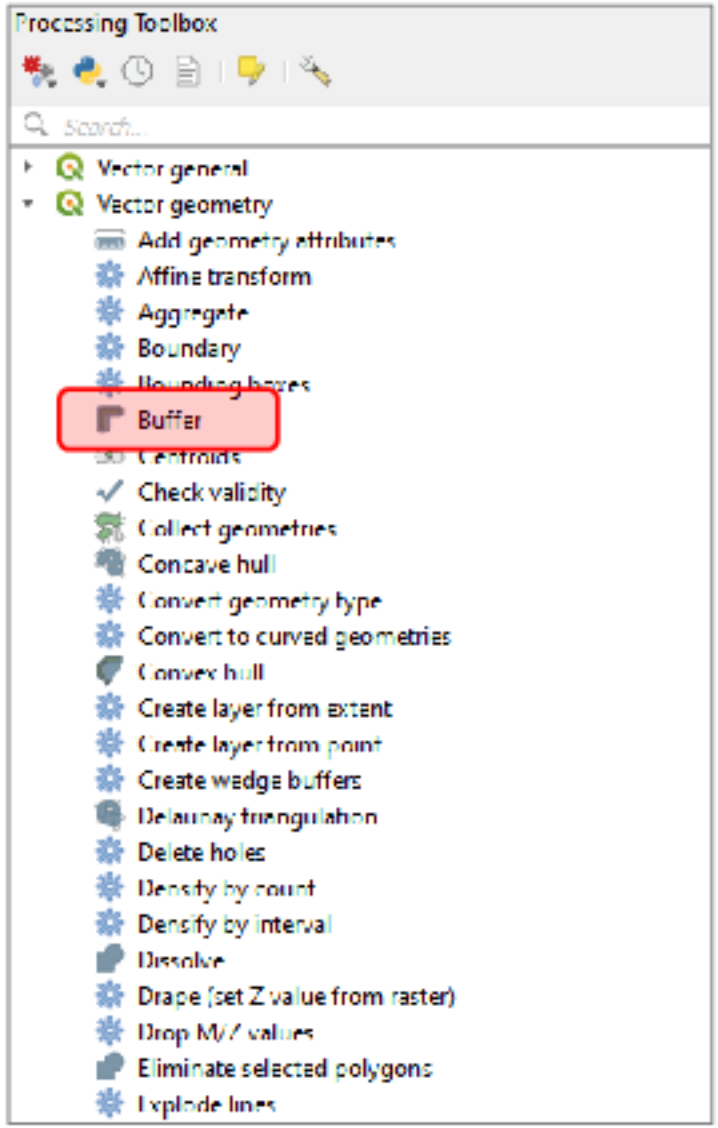


Geoprocessing Tools – Buffer

The Buffer tool creates buffer zones with defined distances.

- Input layers can be point, line, or polygon layers.
- Single as well as multiple buffers (multiple ring buffer) can be created.
- Negative or positive buffers can be calculated (for polygons).





Homework for tomorrow

Mandatory Reading:

- An Introduction to Geographical Information Systems (Heywood I. et.al.) – Chapter 6 (Data Analysis)
  - ➢ available on Moodle
- GISGeography – Learn These Essential Geoprocessing Tools (Website)
  - ➢ https://gisgeography.com/geoprocessing-tools/