GEO 478

SPATIAL INFORMATION SYSTEMS

Dr. Mohamed El Alfy

melalfy@ksu.edu.sa

Learning objectives

- Comprehensive view of GIS consisting of hardware, software, data, procedures and expert knowledge,
- Differences between GIS and related computer systems, such as graphics, CAD and DBMS,
- Overview of the range of function and tools in GIS, related to tasks in hydrology and water management

Topics

- Introduction
- The concept of GIS.
- Maps and spatial analysis
- Data entry, storage and retrieval
- Computer-based processing of geologic data
- Vector and raster data models and analysis
- Linking digital maps and attribute information
- Spatial interpolation
- Practical application through a real Life GIS project

Introduction

- Growing importance since mid 1980s, in scientific, technical and socio-economic disciplines and public sector
- Large number of different products for a large bandwidth of applications
- Term „Geographic Information System“ (GIS)
- Related to hydrological and water management problems

GIS – SOME DEFINITIONS

- GIS may include manual systems, however, it usually refers to a computerised database system for capture, storage, retrieval, analysis and display of spatial data (Huxhold, 1991).

- GIS is capable of assisting the storage, retrieval and manipulation of spatially referenced data such as street address or a census tract (Nedovic-Budic, 1999).

- GIS is most useful when used to perform data analysis (Lee and Wong, 2001, viii)

An Inelegant Definition for GIS

A system of integrated computer-based ***tools*** *for end-to-end* ***processing*** *(capture, storage, retrieval, analysis, display) of data using* ***location on the earth's surface*** *for interrelation in support of* ***operations management, decision making, and science.***

What is GIS

- It is a computerized technique used in collecting, processing, analyzing and visualizing data which are connected with geographic locations to get prolific results necessary for decision maker.

- GIS can carry out the traditional Database analyses process such query and statistical analyses.

- Therefore GIS has the ability to carry out the database analyses processes as well as the data visualization of geographic data such as different types of maps, air photo and satellite images.

What is GIS

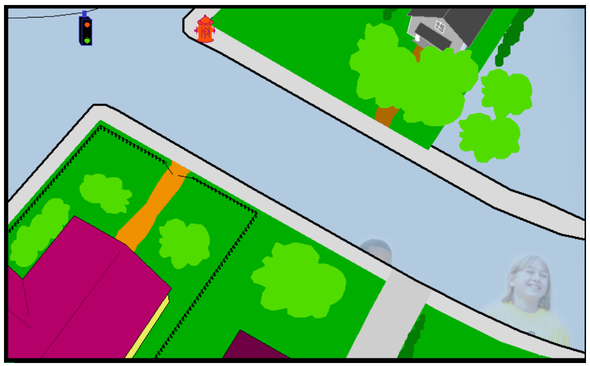
- GIS technique can be applied in wide different fields, such as Geology, hydrogeology, hydrology, agriculture, mapping, Geography, Environmental issues, Landuse, Survey, Urban planning and others.

GIS is very important due to its ability in:

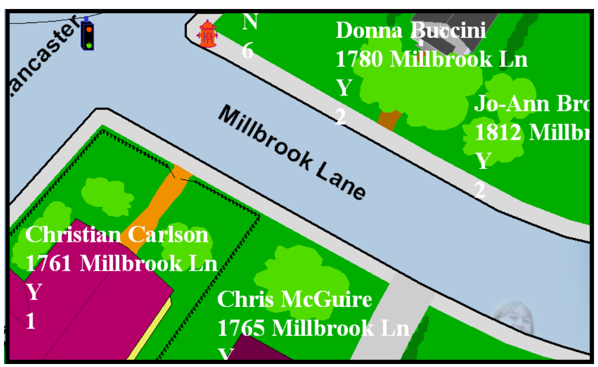
- Connecting tabular and spatial data
- Processing and analyses of different layers of information simultaneously.
- Supporting decision maker

What is GIS

- GIS takes the numbers and words from the rows and columns in databases and spreadsheets and puts them on a map.

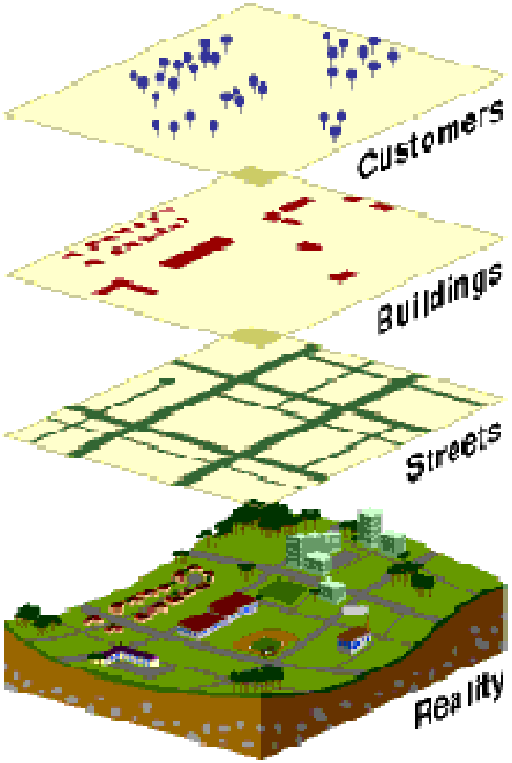


Chris Betz	1757 Millbrook Ln	28226	Y	2
Christian Carl	1761 Millbrook Ln	28226	Y	1
Chris McAfee	1765 Millbrook Ln	28226	Y	2
Dale Legere	1776 Millbrook Ln	28226	N	6
Donna Black	1780 Millbrook Ln	28226	Y	2
Doug Reinhart	1537 Sandberry Dr	28226	Y	1
Gary Walters	1541 Sandberry Dr	28226	Y	3
Holly Williamson	1200 Yamasee Dr	28210	Y	4
Jim Woods	980 Harrowfield Rd	28226	N	1
Jo-Ann Bushard	1812 Millbrook Ln	28226	N	2
Joe Redding	1090 Overhill Dr	28112	Y	4
Larry Yanich	1108 Kings Canyon Dr	28226	Y	3
Lee Rossman	1605 Bosham Ln	28226	Y	2
Marcia Augusta	1429 Quail Wood Dr	28226	Y	2
Mary Jo Fernandez	1432 Quail Wood Dr	28226	Y	1
Mike Donavan	1430 Quail Wood Dr	28226	Y	3
Mike Roads	1332 Cameron Forest Dr	28173	Y	3
Mike Serranno	1327 Red Hickory Ln	28173	Y	2



- It allows you to view, understand, question, interpret, and visualize data in ways simply not possible in the rows and columns of a spreadsheet.

•**GIS combines layers of information about a place to give you a better understanding of that place (Onion pile analogy)**



•**What layers of information you combine depends on your purpose.**

History

- GIS on all categories of computers from super computer to PC and even handhelds
- From cartography to integrative tool
- Integrated, multi-discipline approach
- Parallel development in land register (cadastre), topographic mapping, thematic maps, CAD (Computer Aided Design), geography, mathematical analysis of spatial variability, soil science, surveying, remote sensing, imaging, spatial planning

History

- Commercially available systems from appr. 1980 (ArcInfo 1981)
- GIS, RIS, LUIS, ...
- GIS for acquisition, storage, analysis, and presentation of spatial data.
- Spatial data are describing elements of reality with respect to
  - Position within a coordinate system
  - Spatial relationship (topology) like neighbourhood, proximity,
  - Properties (attributes) like groundwater table, land use, concentration of pollutants, etc.

History

GIS: OLD AND NEW

Traditional GIS

•MAP

•TYPEWRITER

•MANUAL DRAFING TOOLS

New GIS

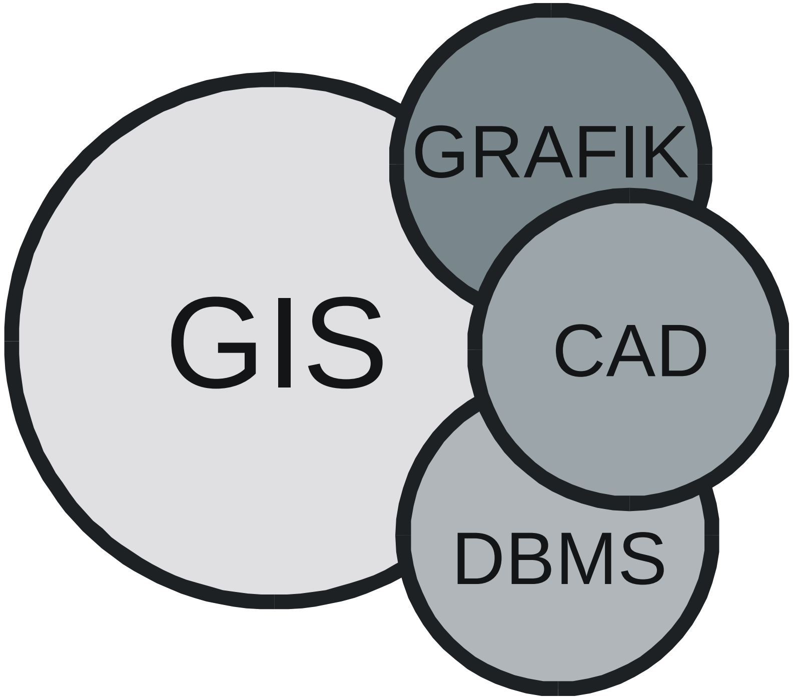
•COMPUTER

•PLOTTER

•CD-ROM

History

- Common elements of GIS and other software systems

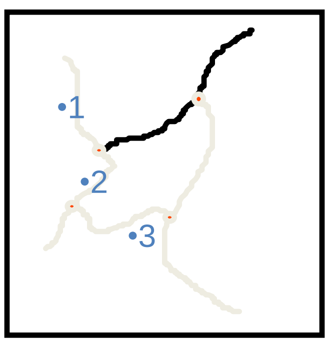


- GIS as a model of a part of the world

GIS: historical background

This technology has developed from:

- Digital cartography and CAD
- Data Base Management Systems

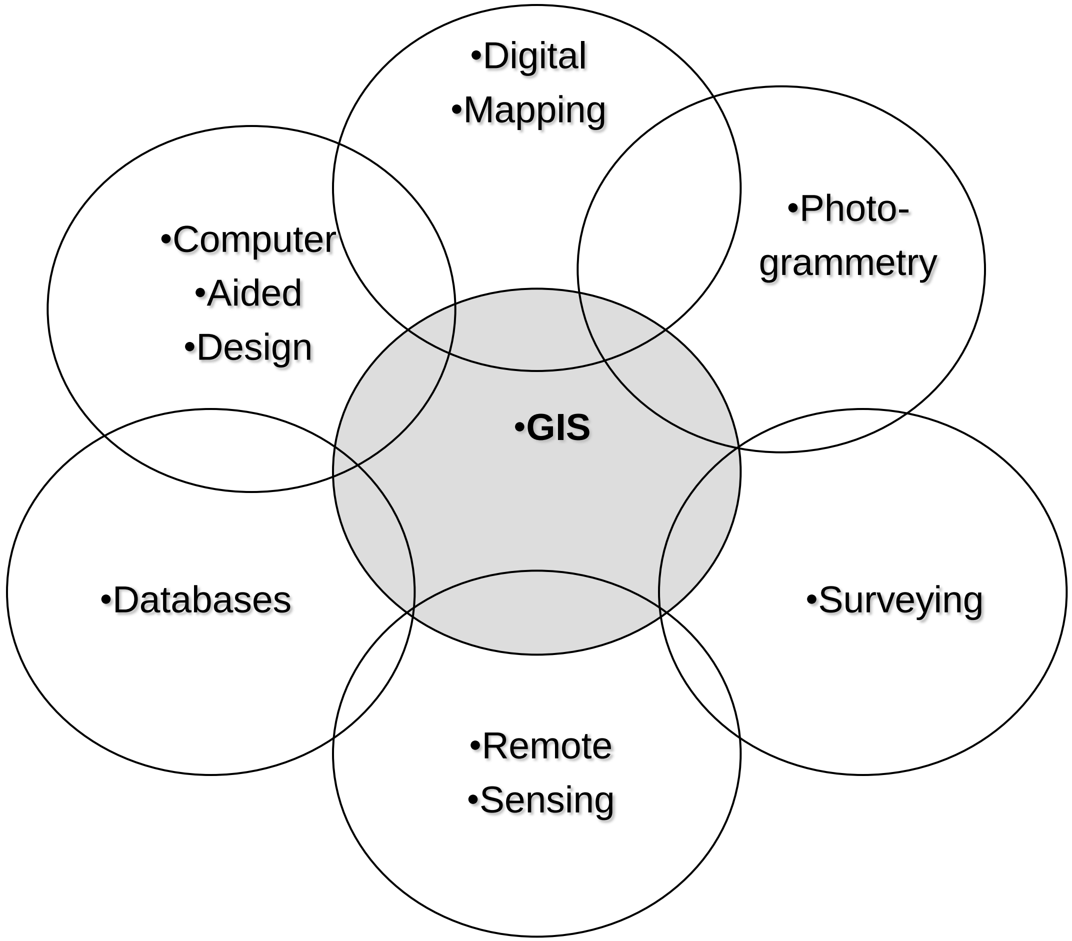


•CAD System

•ID	•X,Y
•1	
•2	
•3	

•ID	•ATTRIB
•1	
•2	
•3	

•Data Base Management System



•Cross-disciplinary nature of GIS

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Why GIS is very important?

- Decrease the time of production and increase work accuracy.
- Decrease the man power pro project.
- Decrease the project budget.

THE NEED FOR GIS

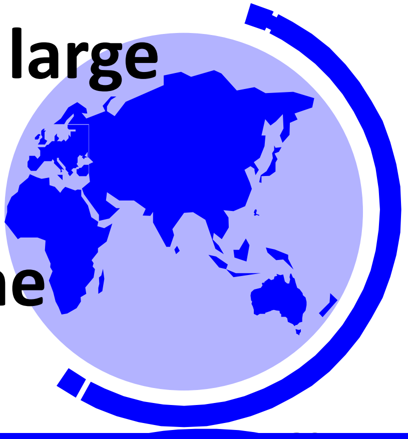
- the real world has a lot of spatial data
  - manipulation, analysis and modeling can be effective and efficiently carried out with a GIS
    - the neighborhood of the intended purchase of house
    - the route for fire-fighting vehicles to the fire area
    - location of historical sites to visit
    - the earth surface for purposes of army
- the earth surface is a limited resource
    - rational decisions on space utilization
    - fast and quality information in decision making

THE NEED FOR GIS

- complexity of management
  - due to the need to combine and process many sets of data, in addition to judge as many as possible, situation that might happen.
- intense competition
  - the need to use technology in making decisions and strategy in the world of intense competition.

Advantages of GIS

- It helps in planning of new project and expansion of the existing.
- It helps in handling enormous quantity of information in short time with high accuracy.
- It helps in taking the right decision in short time.
- It helps in distribution of information to a large number of users.
- Merging the spatial and tabular data in one database.



Advantages of GIS

- It helps in analyzing the spatial data with high accuracy.
- It helps in answering, querying, processing of tabular dat.
- It helps in visualizing spatial data.
- It helps in simulation of assumptions of proposals of new projects even before starting in realty.

GIS APPLICATION (I)

- environment
  - management of natural resources
    - land, forest, marine, etc.
  - monitoring/control of environmental pollution
  - environment impact study
- infrastructure
  - transport and irrigation management and maintenance
  - utility management and maintenance
    - electric, water, gas, telephone, etc.

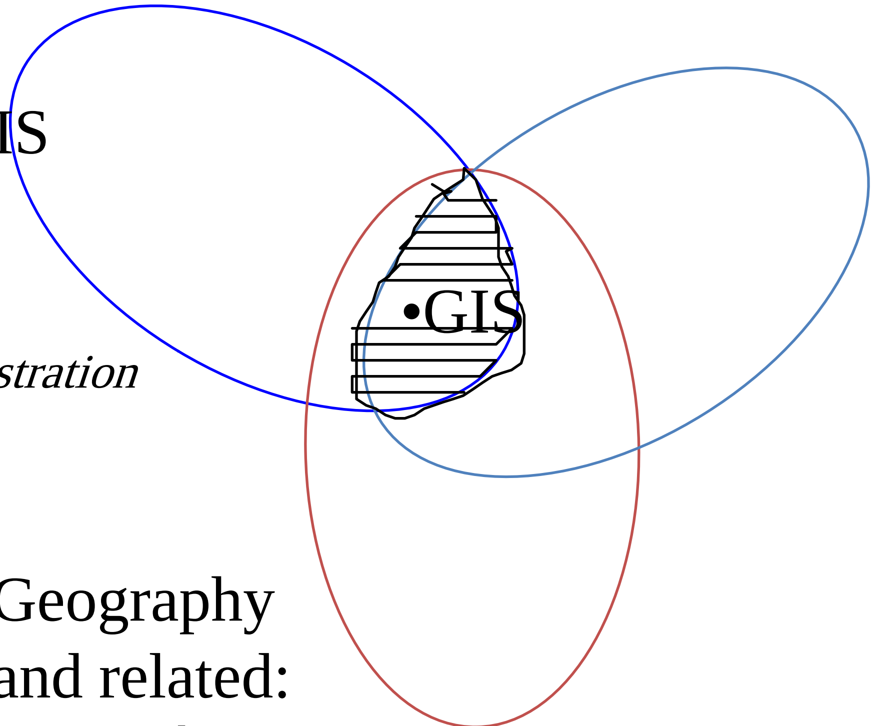
GIS APPLICATION (II)

- socio-economy
  - town and country planning
  - monitoring of population migration
  - disperse of resources/services
    - clinics, schools, etc
- military
  - land form visualisation
  - visibility analysis

- **GIS used in multiple disciplines:**
  - Agriculture
  - Archaeology
  - Architecture/Lanscape Arch.
  - Business
  - Computer Science
  - Environmental Science
  - Engineering
  - Journalism
  - Military Science
  - Natural Resource Management
  - Geography
  - Geology
  - Meteorology
  - Oceanography
  - Law Enforcement
  - Public Health
  - History
  - Sociology
  - Urban/Regional Planning

Knowledge Base for GIS

- Computer
- Science/MIS
- *graphics*
- *visualization*
- *database*
- *system administration*
- *security*



- Application Area:
- *public admin.*
- *planning*
- *geology*
- *mineral exploration*
- *forestry*
- *site selection*
- *marketing*
- *civil engineering*
- *criminal justice*
- *surveying*

- Geography
- and related:
- *cartography*
- *geodesy*
- *photogrammetry*
- *landforms*
- *spatial statistics.*

What do we need to use GIS?

- **1) Hardware**
  - Computers and peripherals needed to install the software on.
- **2) Software**
  - *GIS software provides the functions and*
  - *tools needed* to store, analyze, and display information about places

What do we need to use GIS?

- **3) Data**

  A GIS can use data from a wide range of data formats including images, CAD files, spreadsheets, relational databases, and many more sources

- **4) People**

  Those are the staff using the hardware and software, to display and analyze the data using the available tools.

- **5) Training and procedures**

  Good training will better help understand GIS tasks

1. Hardware

Input devices

Digitizer
Scanner
Digital camera
Data on EDP media
Remote sensing

Computer CPU

Mainframe
Unix workstation
PC

Output devices

Monitor
Inkjet printer
Laser printer
Offset printing
(Plotter)

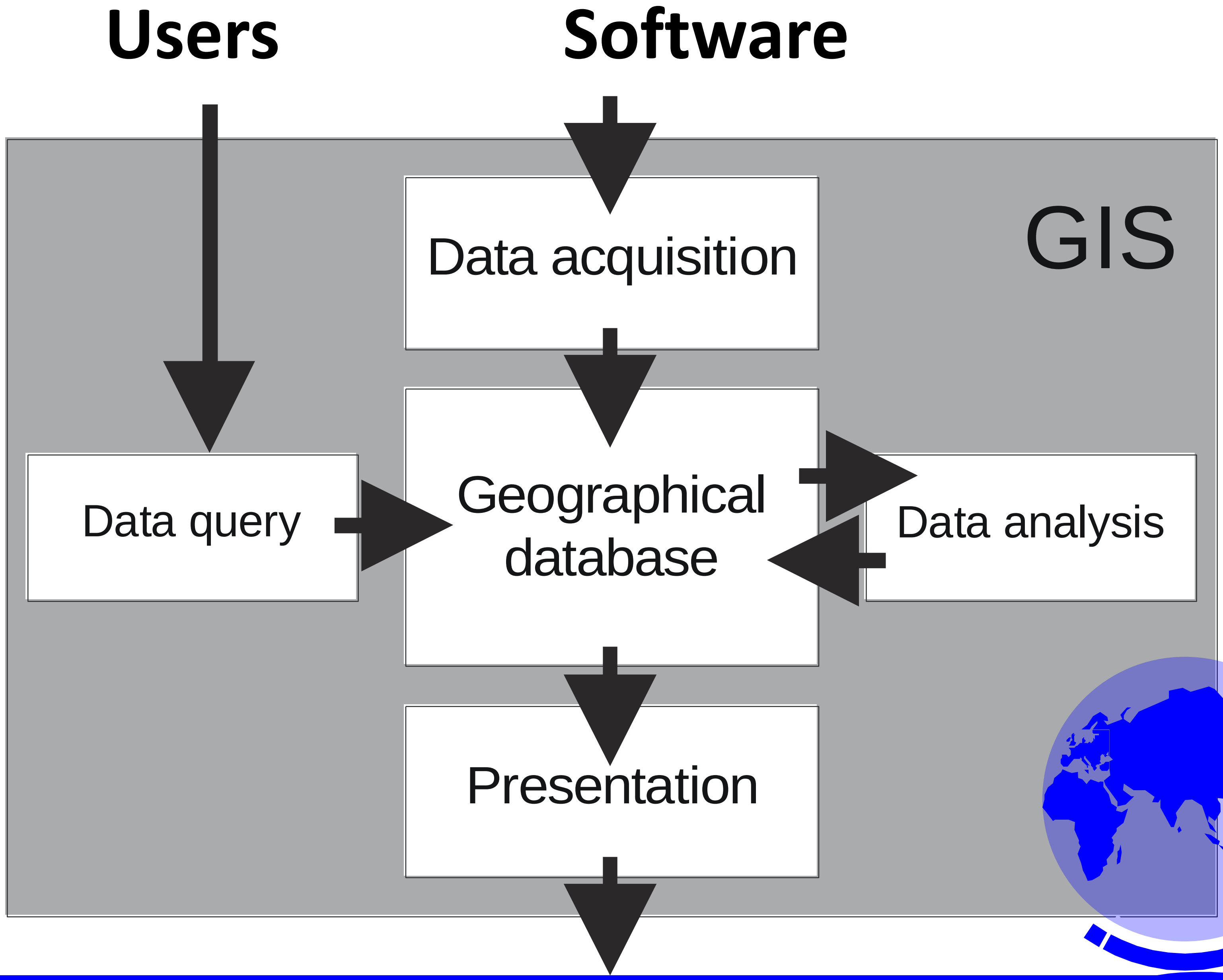
- Scanners
- Digitizers
- Printers
- Plotters

Hardware

- Main Frame, Unix workstation units and their installed GIS software are used in handling big projects.
- While for smaller projects, PC in network or in separate manner are used.
- Also GPS are used in gathering accurate coordinates

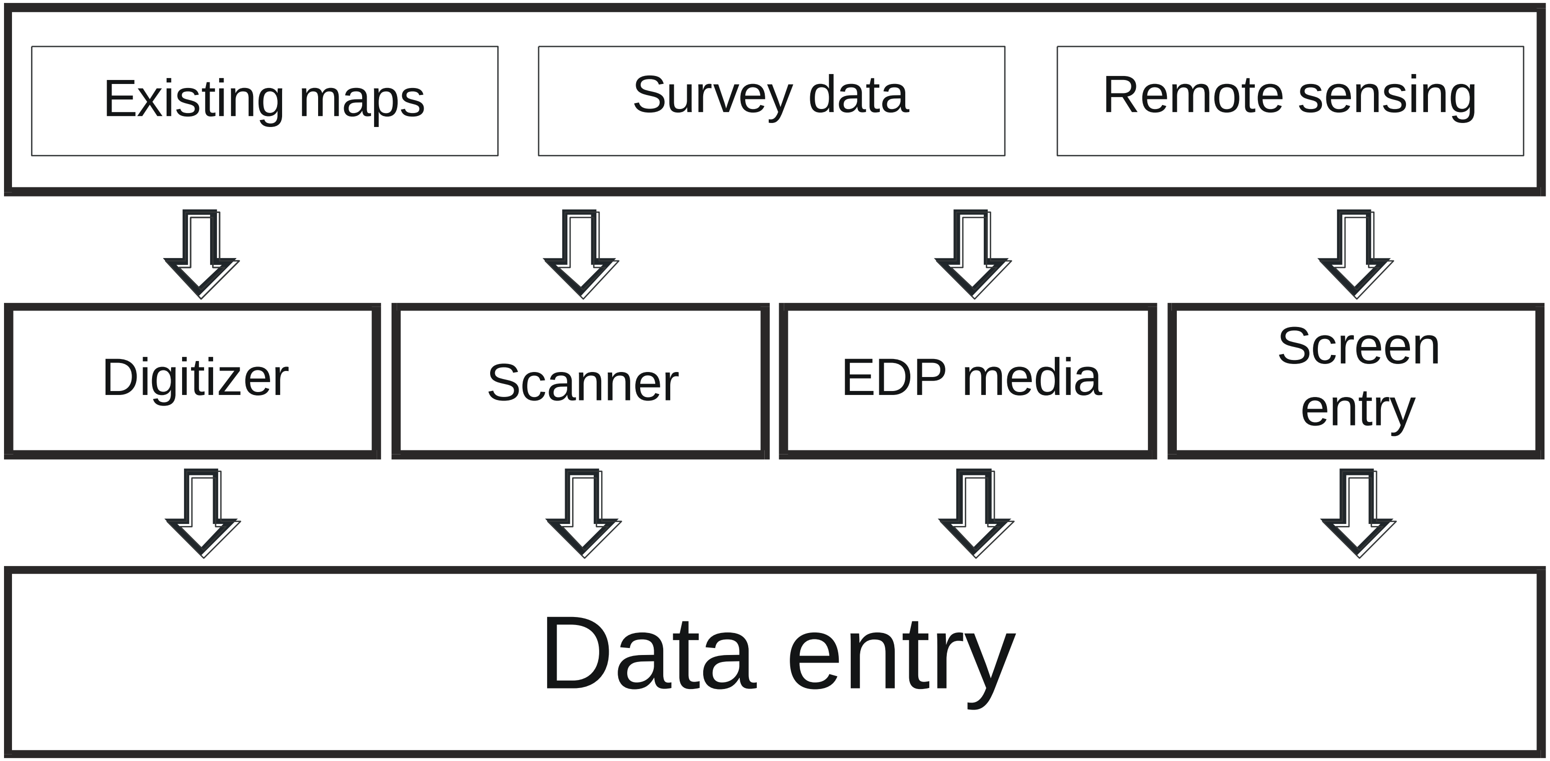
Software

- Software gives tools, procedures and ability to store, posses and visualize the spatial data.


Users
Software
GIS
Data acquisition
Data query
Geographical database
Data analysis
Presentation

Software

- data acquisition
  - Digitizer, import of raster data sets (scanner, satellites, video digitizer), import of external data sets.
  - Error correction, generation of topology, geo-referencing (Coordinate system)
  - Usually more than one source (e.g. groundwater study)
  - Increasing availability of digital data (surveying services, land register, digital hydrological atlas, remote sensing)
  - Exchange of data


Existing maps
Survey data
Remote sensing
Digitizer
Scanner
EDP media
Screen entry
Data entry

Software

- Data management: organisation, structuring and storage
  - Reliable storage,
  - Efficient access and unified interface for all software components to the data.
  - Organisation of information about a specific region usually organised by layers

Software

- Analysis: geographical database turns into an information system
  - Where is object A? The GIS reports the coordinates, e.g., of a monitoring site, or displays a map whith the object highlighted
  - Where is A in relation to B? The potential polluter (A) is within (outside of) the wellhead protection area (B)
  - How many objects of type A are within a distance D of B? How many monitoring wells (A) are available within the estimated extent (D) of a well‘s cone of depression? → buffer zones around object

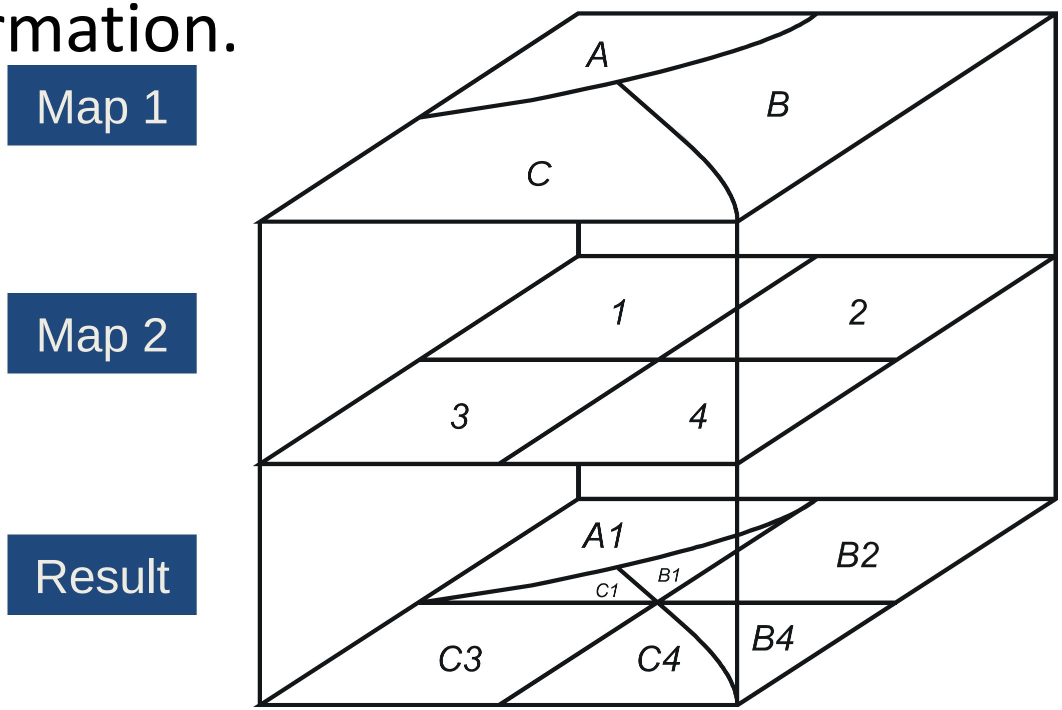
Software

- What is the value of function z at location x? E.g., the groundwater tables at some wells are given. For location x, the value of function z, here groundwater table, is to be interpolated.
- How large is B? Area, perimeter and length are often automatically managed by GIS. Used, e.g. to evaluate areal statistics for time-area diagrams.
- Which objects are adjacent to objects with a given combination of properties? Which land parcels are crossed by a planned irrigation canal?
- Combination of objects with a given combination of properties. Suitability of land for a desired use.

Software

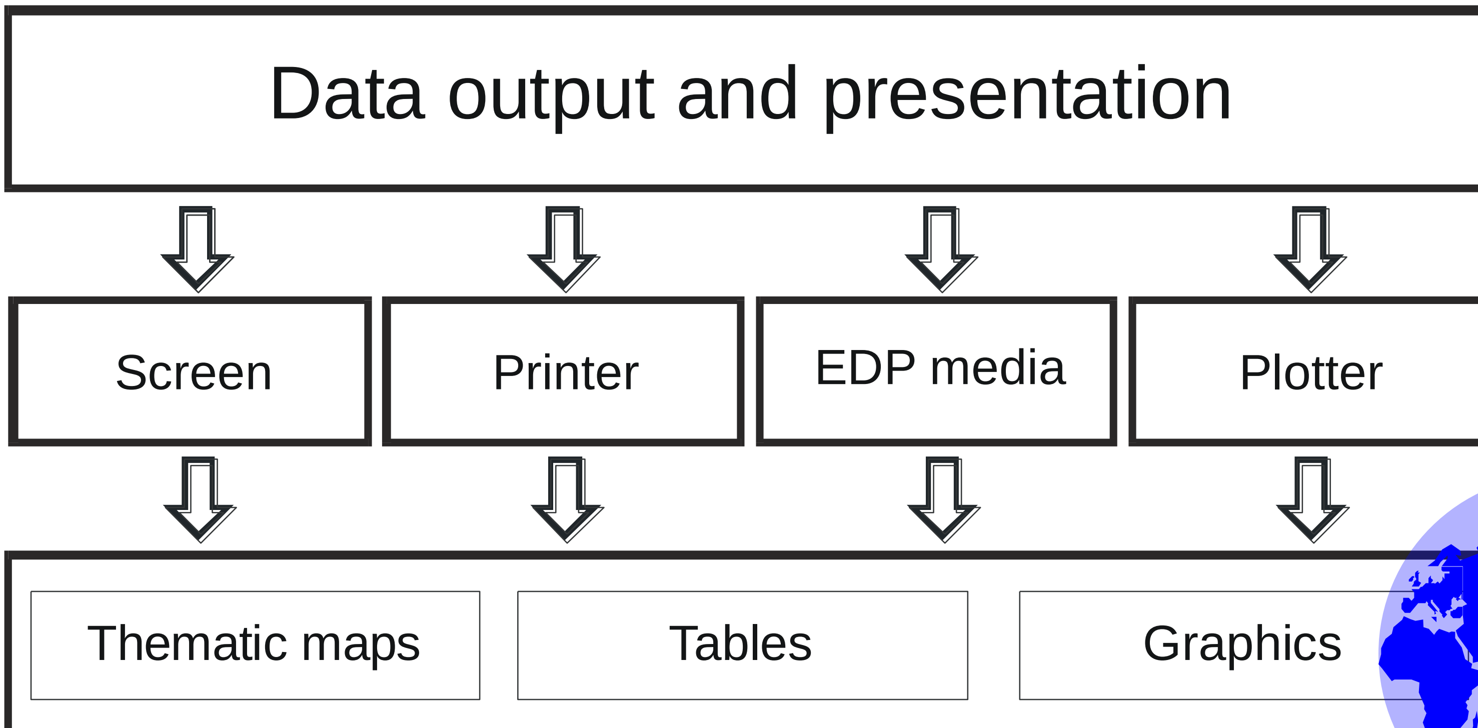
– What is the result of the overlay of 2 maps?

Logical combination (overlay) of information layers („thematic maps“), to derive new spatial information.



Software

- Presentation component



Tools (functions) in GIS

- Differences in the focus depending on specific software product
  - E.g. ArcInfo Workstation:
    - Data capture and automation
    - Error refinement and verification
    - Coordinate transformation
    - Topology generation and update
    - Generalization tools
    - Attribute automation and update
    - Database construction
    - Analysis and manipulation
    - Display and query
    - Using menus
    - Dynamic segmentation
    - GRID analysis
    - IMAGE analysis
    - Database integration
    - TIN

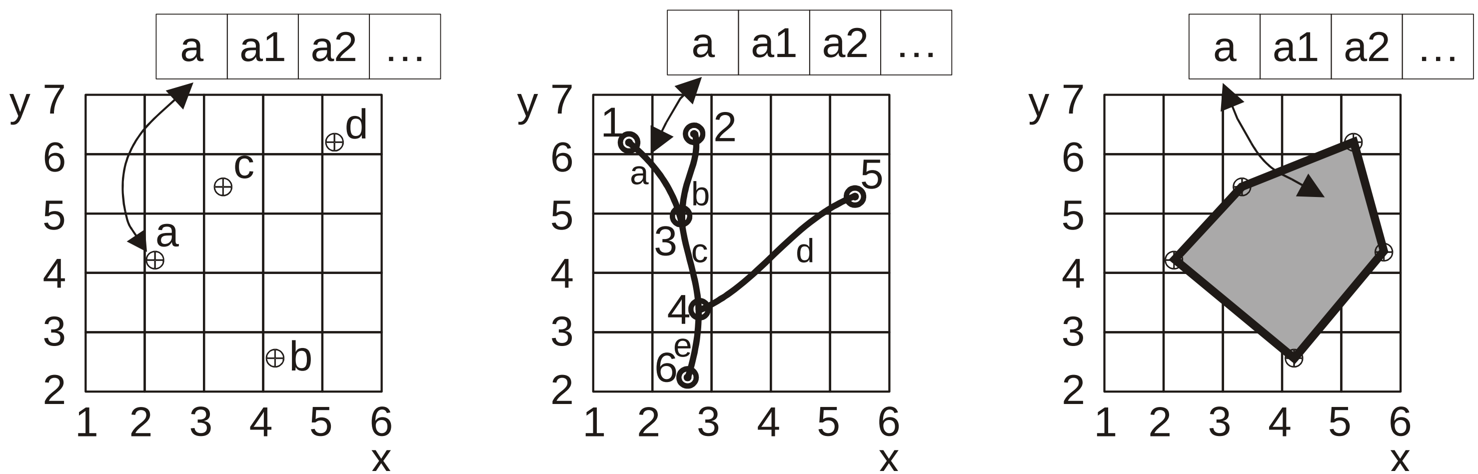
Summary

- GIS are computer based systems to acquire, manage, analyse and present spatial information.
- Development started in the 1960‘s, breakthrough in widely spread application in environmental information systems occured in the 1980‘s.
- A GIS should be seen not only as a software package, but rather as a comprehensive system, consisting of hardware, software, data and users.

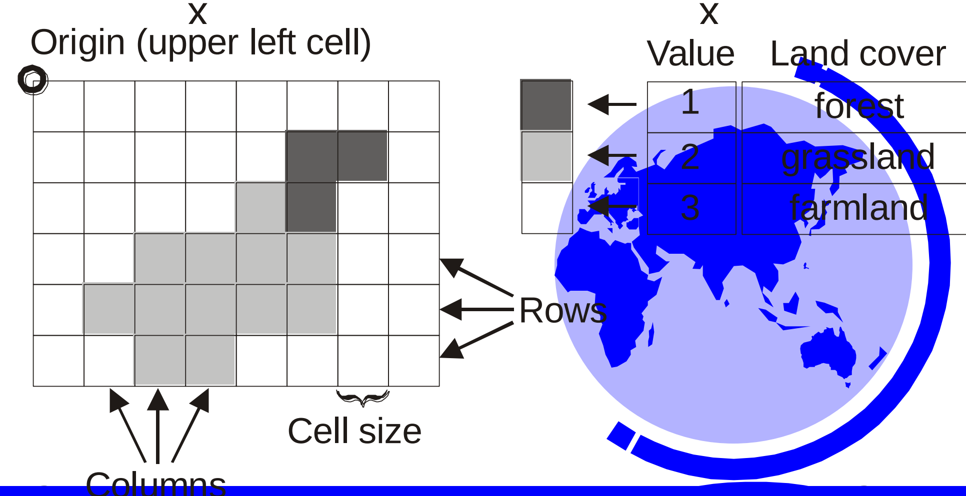
2 Data; Vector, Raster, and CAD

Geographical data models and geographical data primitives

- **geographical data primitives : points, lines, polygons (vector model)**



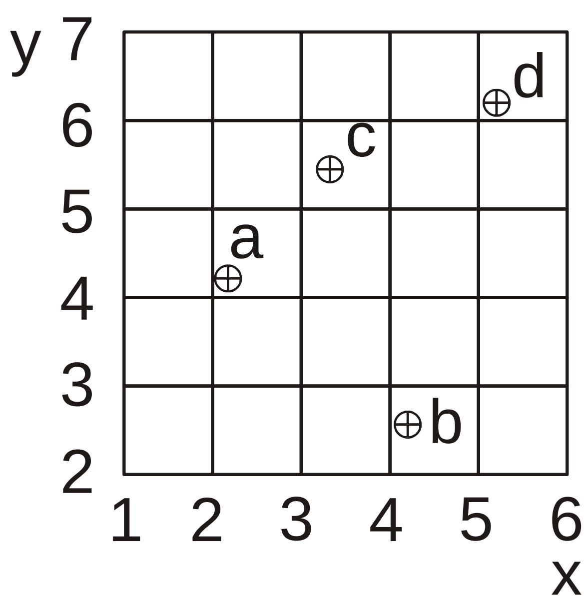
- **Pixels (raster model)**



- Vector models
  - simple points, lines and polygons
  - complex points, lines, polygons and objects
    - More complex definitions of points, lines and polygons can be used to capture the internal structure of an entity; functional or descriptive.
    - E.g.: ‘city’ contains streets, houses and parks, each having different functionality and may respond differntly to queries or operations.
    - Object-oriented systems support a hierarchical construction of objects from simple building blocks and a framework for description of properties as well as behaviour.

Points

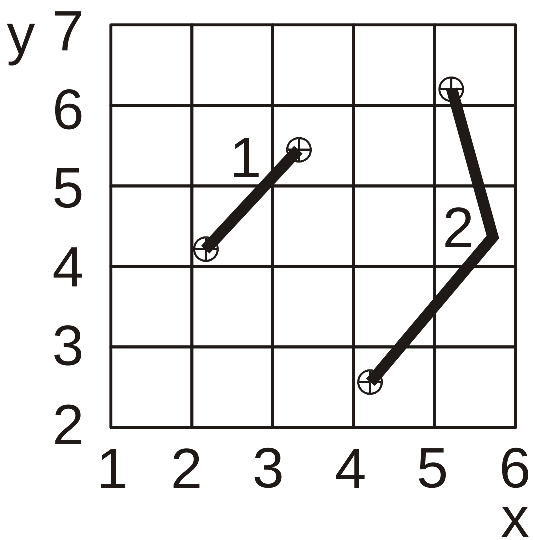
- **Position of points is defined by a single pair of coordinates (X, Y)**
- **Additional info: type of point, attributes**
- **Layer of point entities created from simple table**
  - **E.g. event theme in ArcView**



#	X	Y	A	B
1	2.2	4.1	a	r
2	4.2	2.6	b	s
3	3.4	5.4	c	t
4	5.2	6.1	d	u

Lines

- Sequence of (X, Y) coordinate pairs and connecting straight lines or curves



#1:

X	Y
2.2	4.1
3.4	5.4

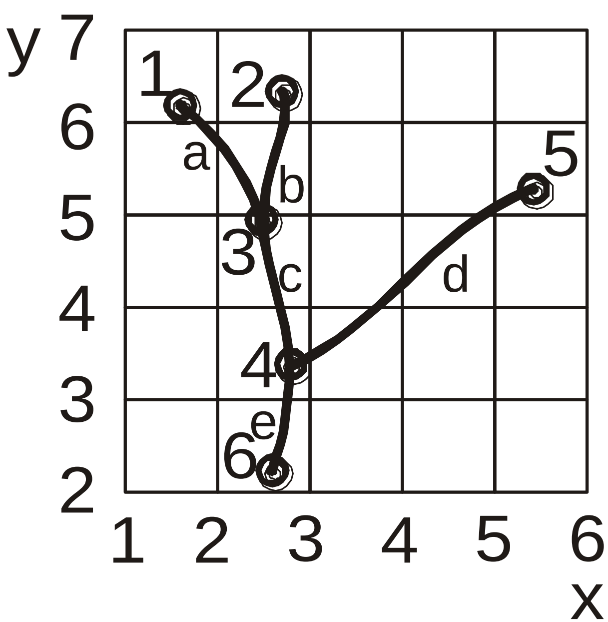
#2:

X	Y
4.2	2.6
5.7	4.3
5.2	6.1

#	A	B
1	a	r
2	b	s

Networks

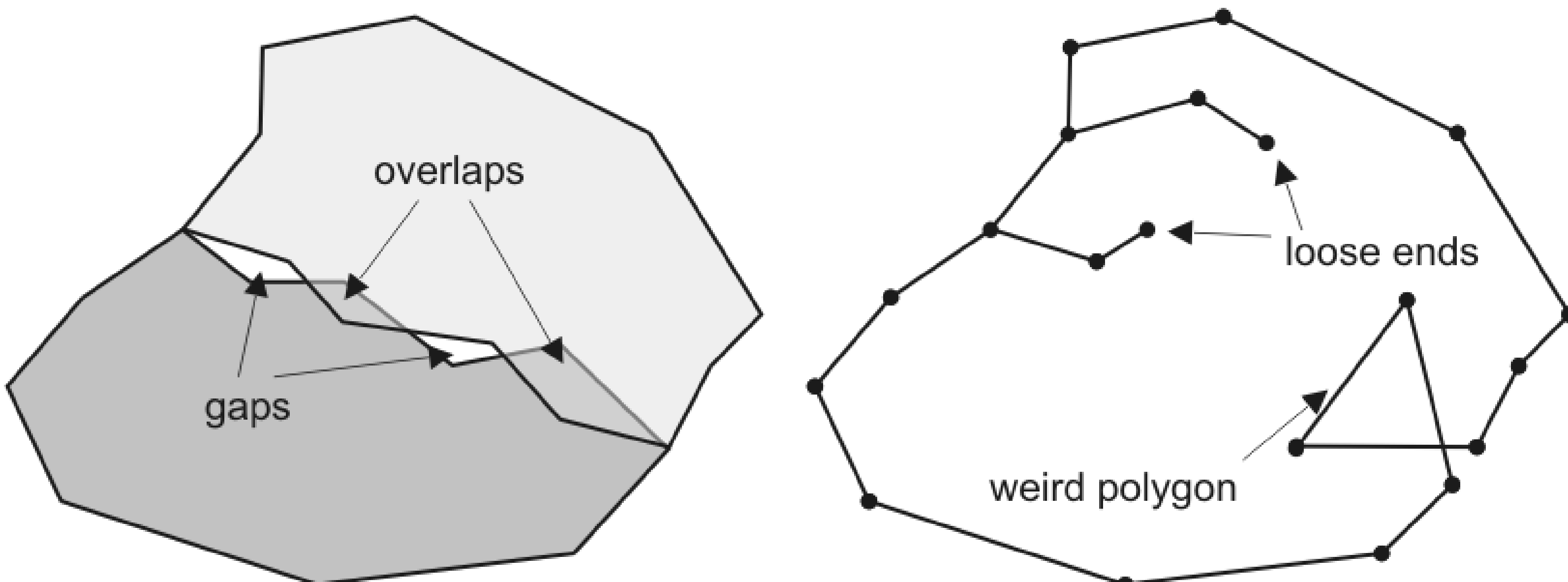
- **Information about connectivity with other line entities to represent street networks, utilities, rivers**
- **topological information in the data structures → connectivity tables**
- **Topological terms: „node“ and „arc“**
- ***arc-node topology***



Arc#	From#	To#
a	1	3
b	2	3
c	3	4
d	5	4
e	4	6

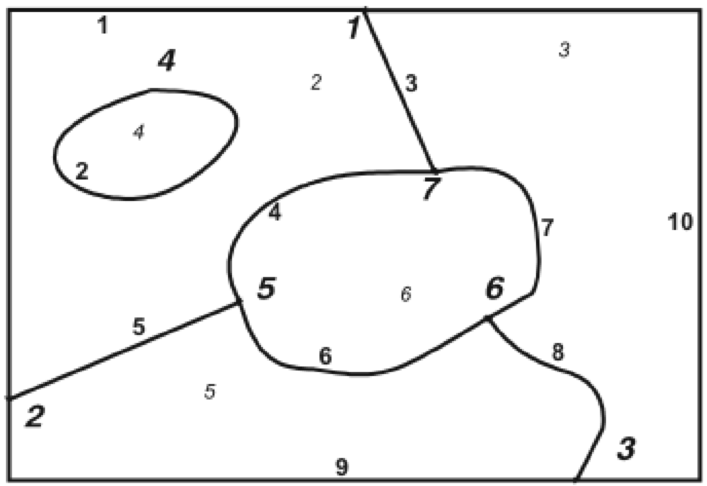
Polygons

- Shape, neighbours, hierarchy
- simple polygons: sequence of x,y coordinate pairs
  - Border lines between polygons are digitized and stored twice. Error: gaps, overlaps
  - No information on neighbourhood.
  - islands only graphically represented.



Polygons

- **Polygons by arc-node-topology**
  - **Underlying principle: free of redundancy**



Legend: 3 Line, 6 Polygon, 7 Node

Polygon	
Poly#	Line#
2	1,3,4,5,0,2
3	3,10,8,7
4	2
5	5,6,8,9
6	4,7,6

Coordinates	
Line#	(X,Y)
1	8,5 5,5 5,3
2	4,4 4,5 ...
3	8,5 9,4
4	9,4 8,3 ...
5	...
6	...
7	
8	
9	

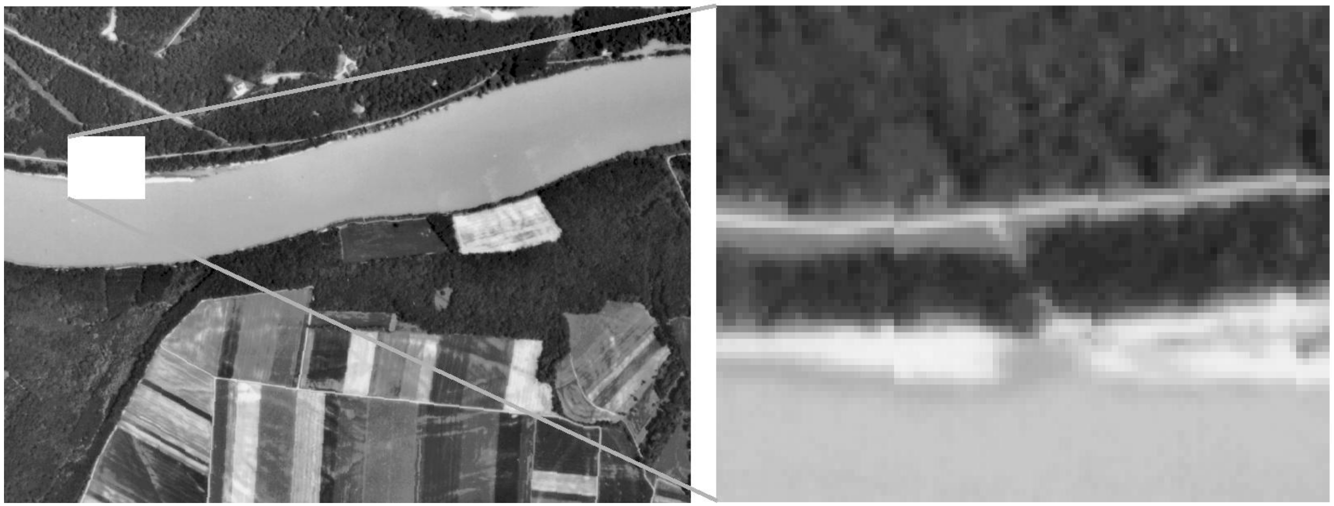
Line topology				
Line#	LP#	RP#	From#	To#
1	2	1	1	2
2	4	2	4	4
3	3	2	1	7
4	6	2	7	5
5	2	5	2	5
6	6	5	5	6
7	6	3	6	7
8	5	3	3	6
9	5	1	2	3

Raster models

- Mainly integer grids with lookup table of categories
- Loss of spatial resolution

Data organisation in raster data structures

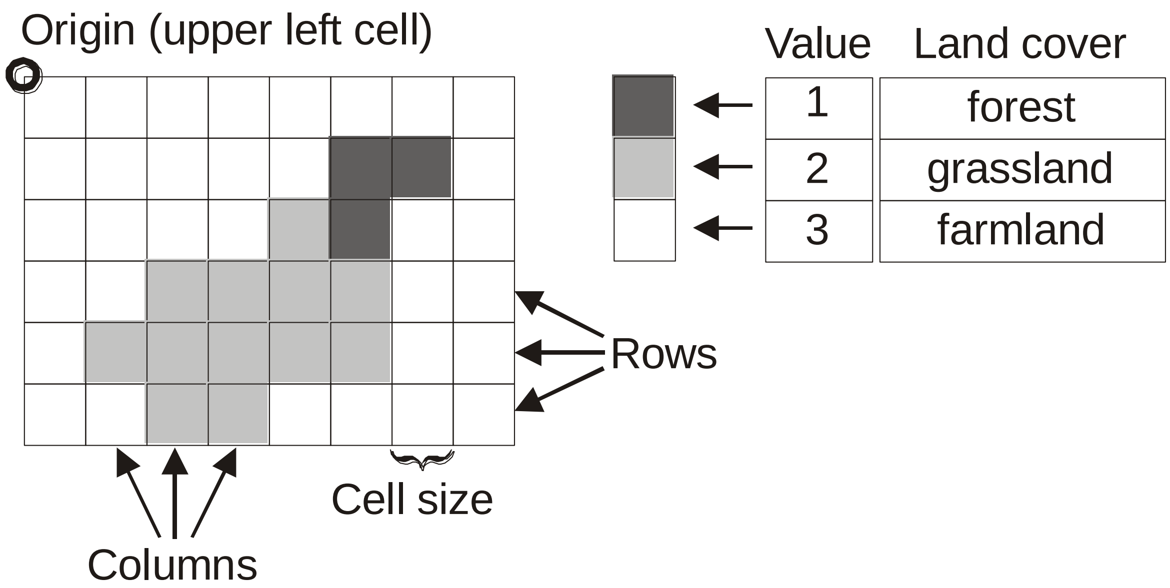
- Raster resembles photo



- 3 ways to interprete a pixel
  - classification: a range of values is allocated to certain objects (gray pixels are roads, blue pixels are water surfaces,...).
  - measure the value: intensity of a colour, concentration
  - relative height over reference height.

Raster data structure

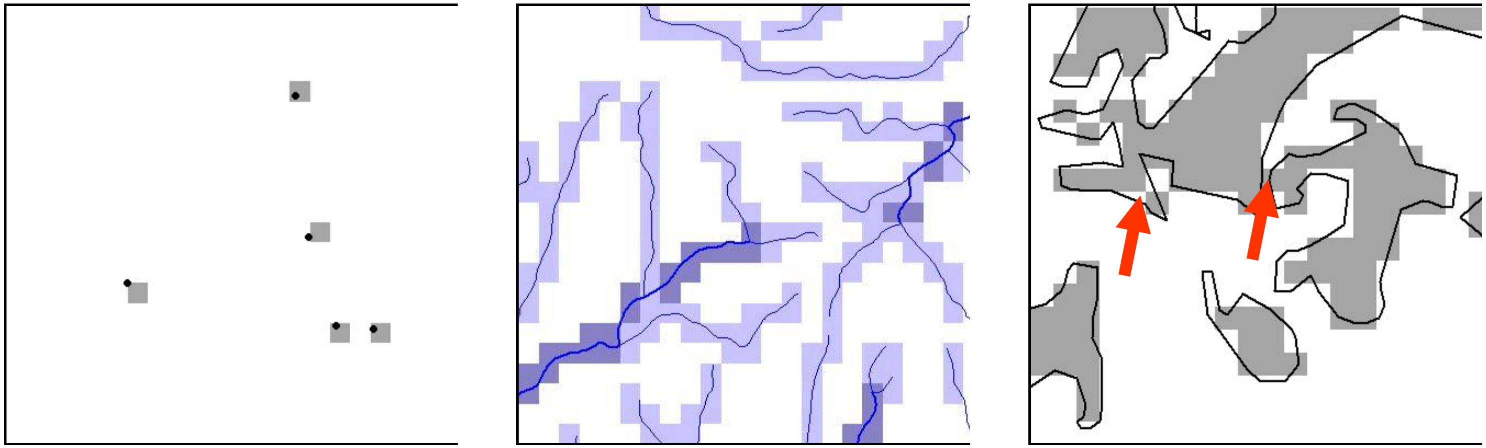
- **Position is represented by discrete cells**



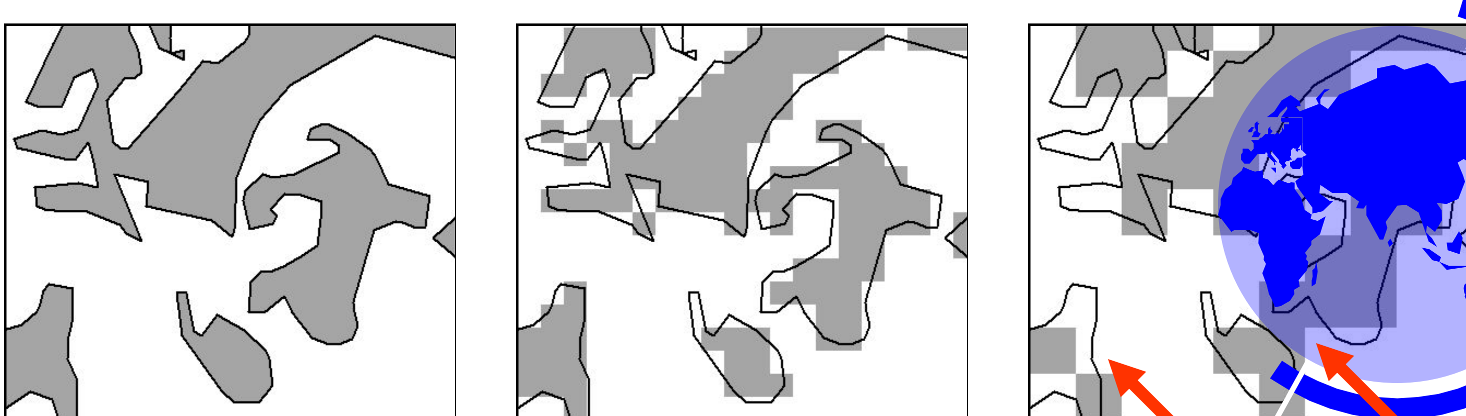
- **Types of raster maps**
  - **Nominal data like land use (forest, grassland, farmland, ...)**
  - **Continuous values, concentration, light intensity**
  - **relative measures like elevation.**

Raster data structure

- **Entities also in raster model**

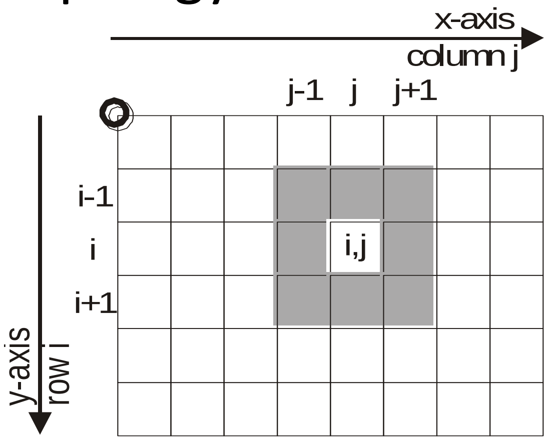


- **Cell size determines resolution: cell size max. 50% of smallest recognized object**

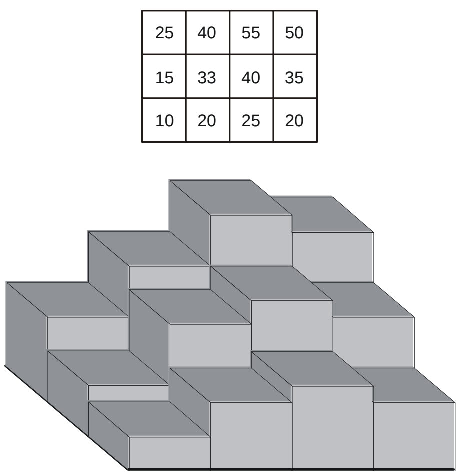


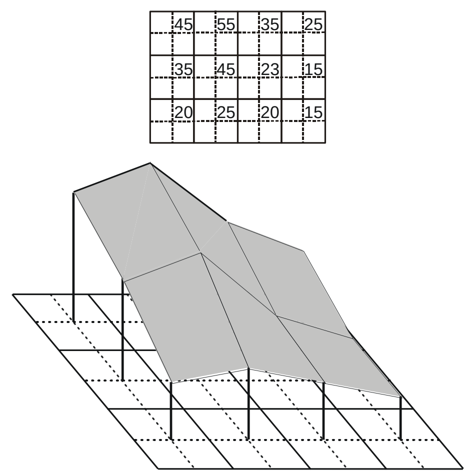
Raster data structure

- Topology described implicitly by raster



- Cell raster – point raster





- **Pictures can be used as map displays (e.g. satellite image, orthophoto) or also as attribute information (e.g. pictures of the measuring instruments linked to the measuring points on a measuring point map, photo of the houses in the information system of a real estate agent).**

Storage of images

- Similar to raster maps, with some specific properties
- Pixel (from picture element)
- Economical storage
  - 1, 8, 24 or 32 bit for coding of a colour value
  - Number of bits per pixel: colour depth
  - monochrome, grayscale, RGB, CMY, CMYK
  - Use of a lookup table

Image

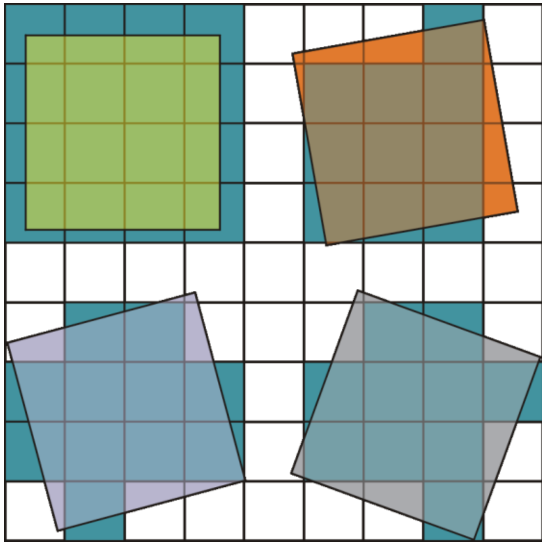
2	7	14	12	8
5	10	9	8	1
4	5	6	3	9
15	13	16	5	5
2	1	11	9	1

Display lookup table

pixel value	red	green	blue
1	0	0	0
2	10	35	5
3	15	20	21
4	123	210	33
.	.	.	.
.	.	.	.
16	255	255	255

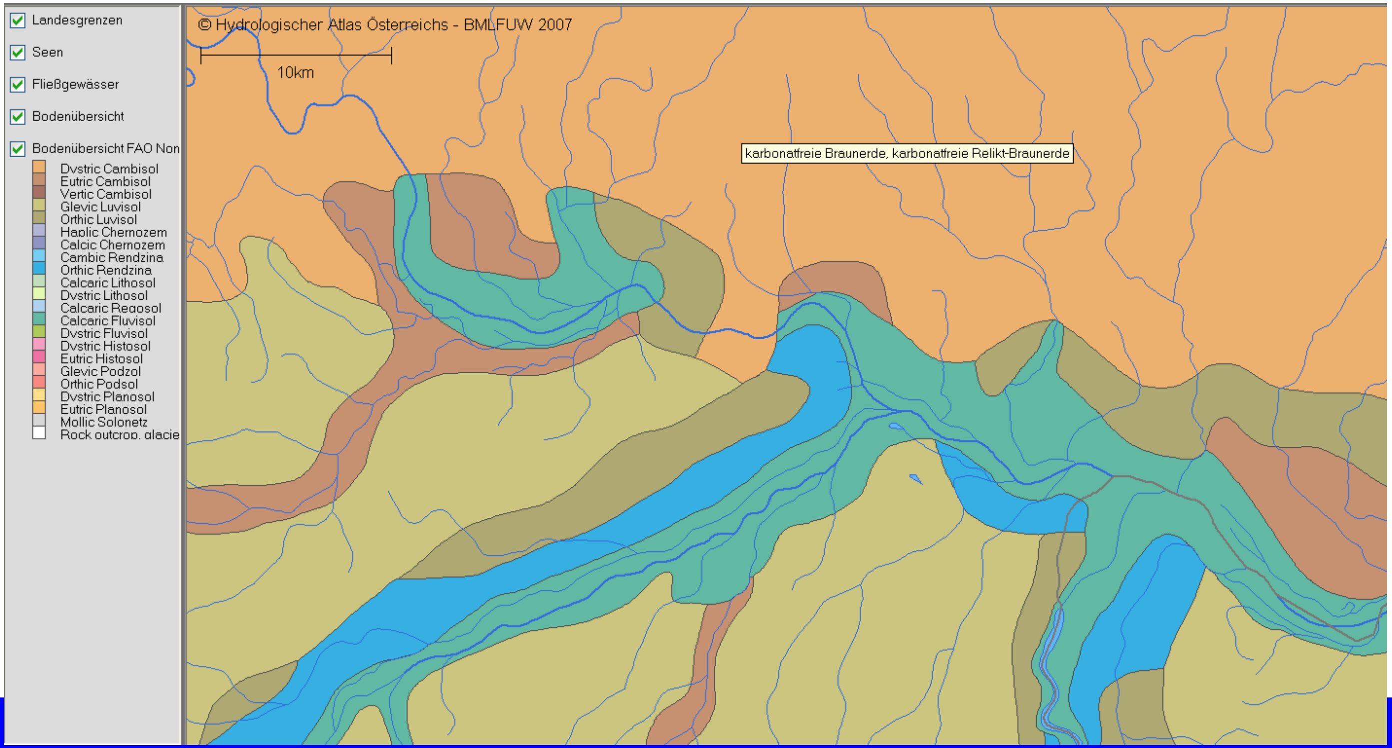
Georeferencing of images

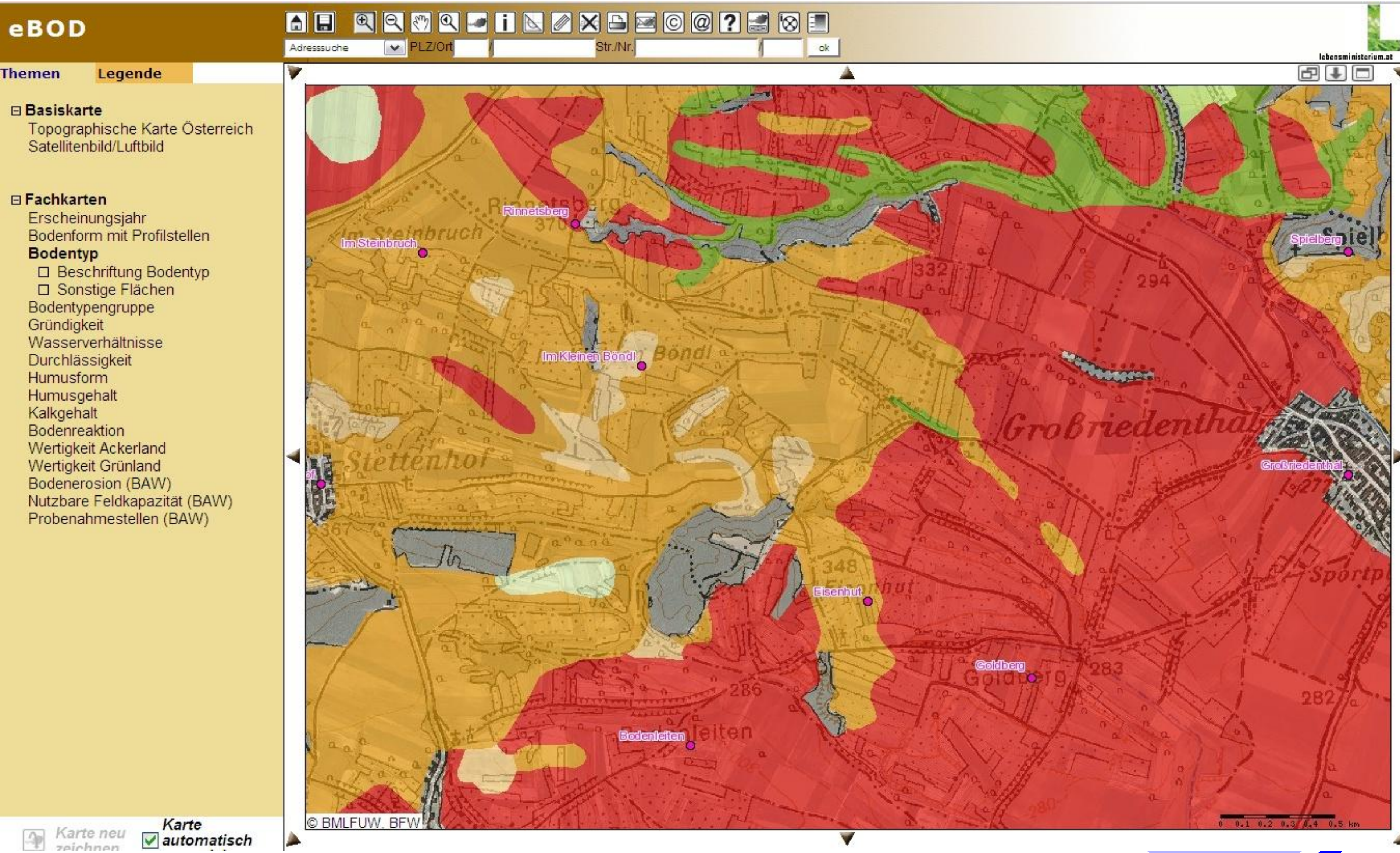
- Depending on the orientation of the coordinate system, objects equal in nature are represented differently in the raster model



- If distortions of image are small (flat terrain) → georeferencing by affine projection with >= 4 ground control points (polynomial transformation).
- Pixel are re-computed by interpolation or areal averaging, according to the type of variable → loss of information

- Raster model can also represent points, lines and polygons
- Loss of spatial resolution, because location is only expressed by multiples of pixel size
- Contour maps: Entities or fields?
- e.g: soil map

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Str./Nr.
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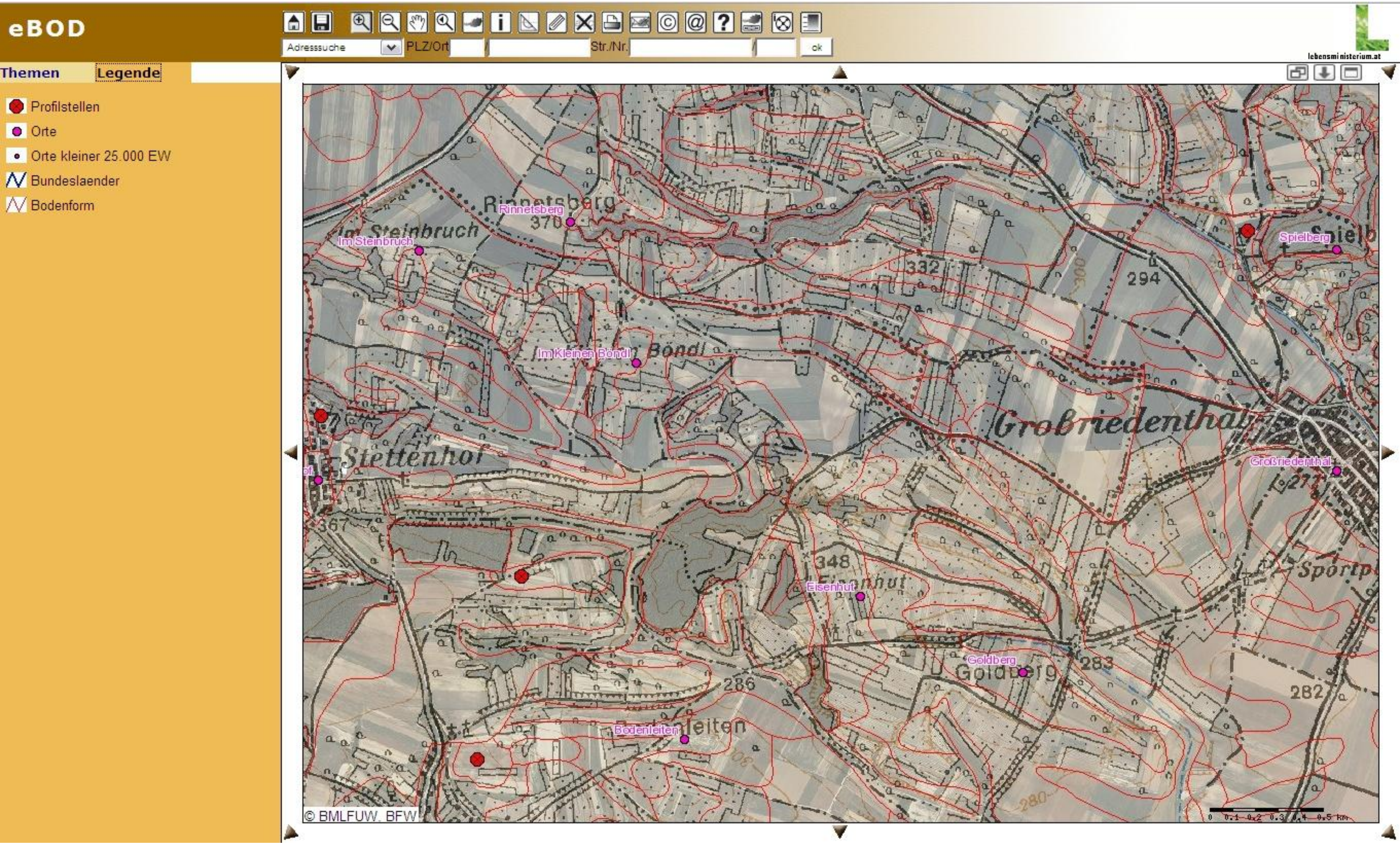
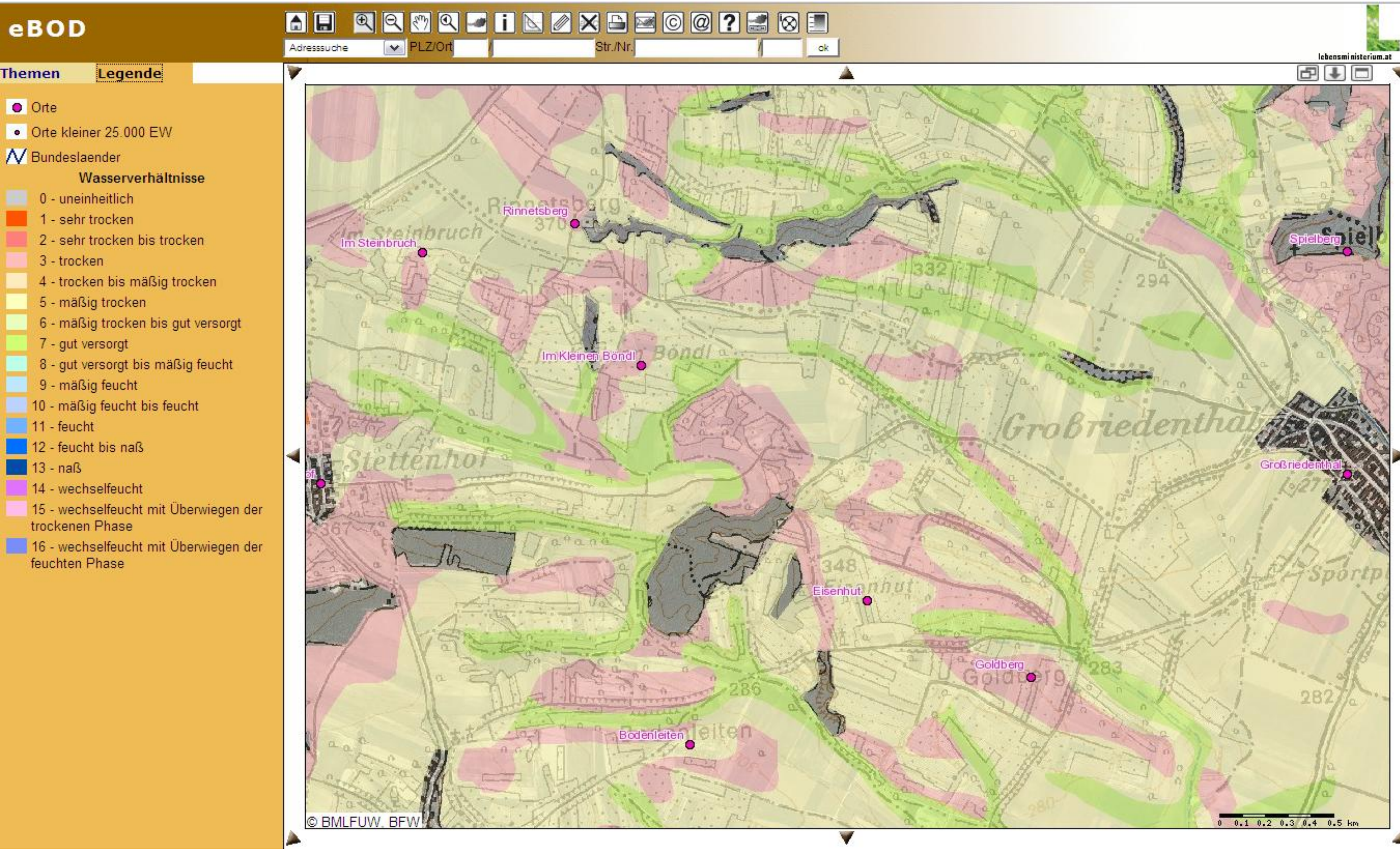
lebensministerium.at
Themen
Legende
Basiskarte
Topographische Karte Österreich
Satellitenbild/Luftbild
Fachkarten
Erscheinungsjahr
Bodenform mit Profilstellen
Bodentyp
Beschriftung Bodentyp
Sonstige Flächen
Bodentypengruppe
Gründigkeit
Wasserverhältnisse
Durchlässigkeit
Humusform
Humusgehalt
Kalkgehalt
Bodenreaktion
Wertigkeit Ackerland
Wertigkeit Grünland
Bodenerosion (BAW)
Nutzbare Feldkapazität (BAW)
Probenahmestellen (BAW)
Karte neu zeichnen
Karte automatisch
Rinnetsberg
Im Steinbruch
Spielberg
Im Kleinen Böndl
Großriedenthal
Stettenhof
Eisenhut
Goldberg
Bodenleiten
© BMLFUW, BFW
0 0.1 0.2 0.3 0.4 0.5 km


eBOD
Adresssuche
PLZ/Ort
Str./Nr.
ok
lebensministerium.at
Themen
Legende
Profilstellen
Orte
Orte kleiner 25.000 EW
Bundeslaender
Bodenform
Rinnetsberg
Im Steinbruch
Im Kleinen Böndl
Spielberg
Großriedenthal
Eisenhut
Goldberg
Bodenleiten
© BMLFUW, BFW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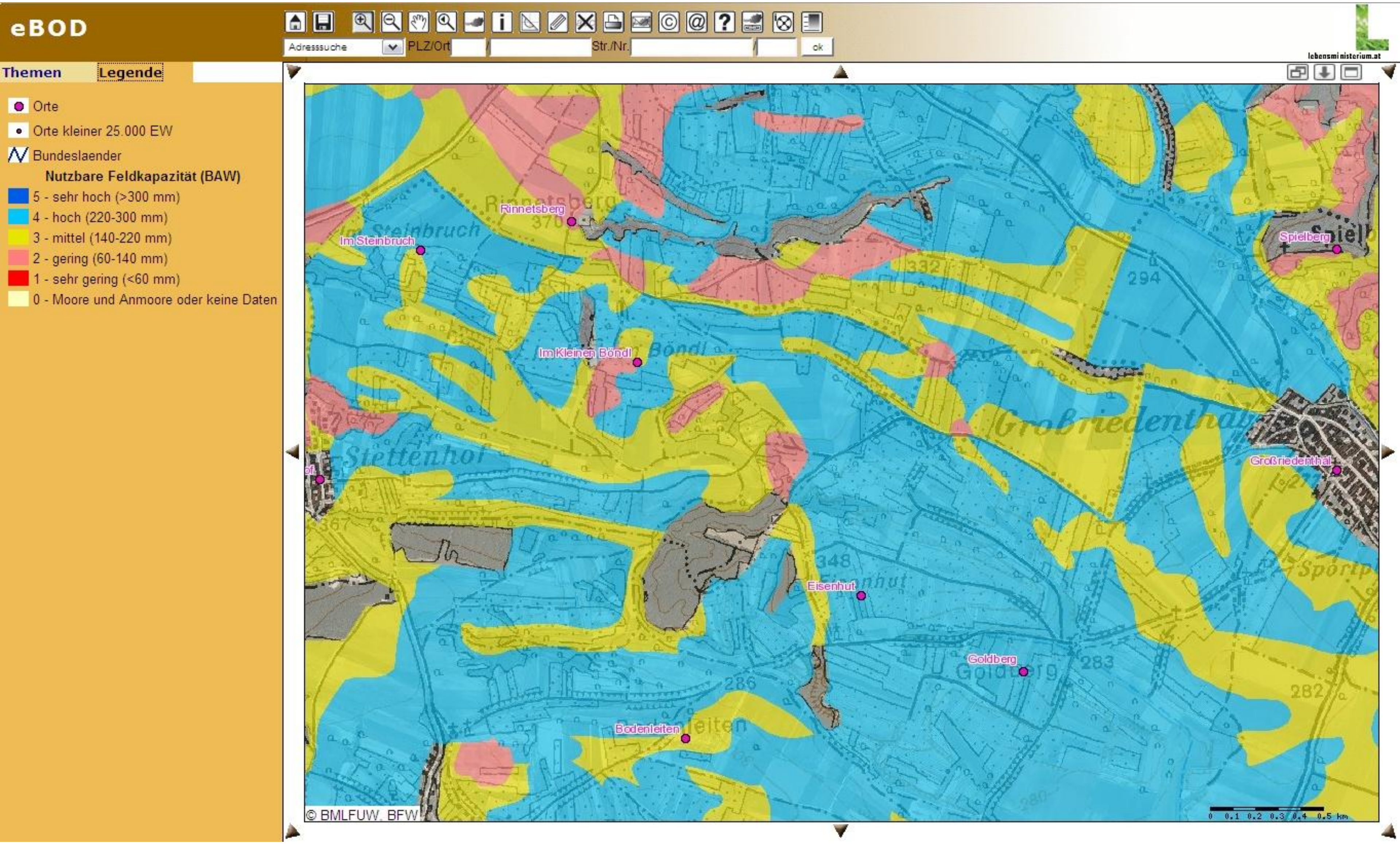
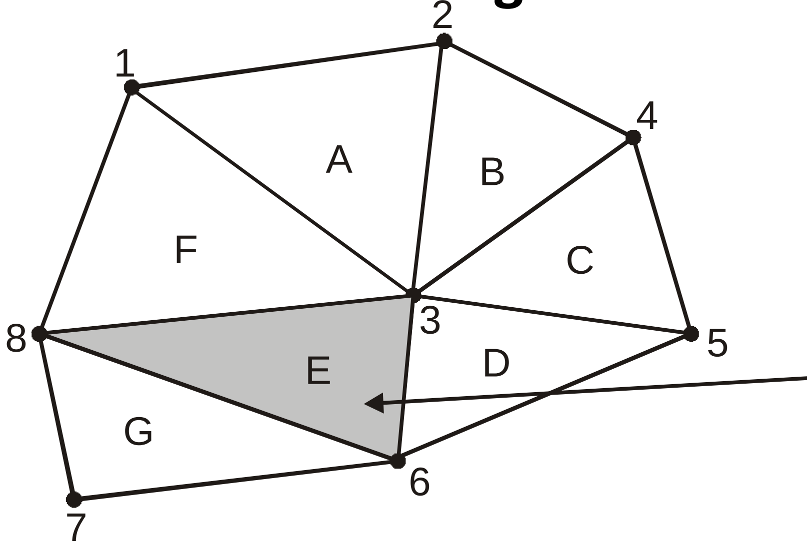
PLZ/Ort
Str./Nr.
ok
lebensministerium.at
Themen
Legende
Orte
Orte kleiner 25.000 EW
Bundeslaender
Wasserverhältnisse
0 - uneinheitlich
1 - sehr trocken
2 - sehr trocken bis trocken
3 - trocken
4 - trocken bis mäßig trocken
5 - mäßig trocken
6 - mäßig trocken bis gut versorgt
7 - gut versorgt
8 - gut versorgt bis mäßig feucht
9 - mäßig feucht
10 - mäßig feucht bis feucht
11 - feucht
12 - feucht bis naß
13 - naß
14 - wechselfeucht
15 - wechselfeucht mit Überwiegen der trockenen Phase
16 - wechselfeucht mit Überwiegen der feuchten Phase
Rinnetsberg
Im Steinbruch
Spielberg
Im Kleinen Bondl
Großriedenthal
Eisenhut
Goldberg
Bodenleiten
© BMLFUW, BFW
0 0.1 0.2 0.3 0.4 0.5 km


eBOD
Adresssuche
PLZ/Ort
Str./Nr.
ok
lebensministerium.at
Themen
Legende
Orte
Orte kleiner 25.000 EW
Bundeslaender
Nutzbare Feldkapazität (BAW)
5 - sehr hoch (>300 mm)
4 - hoch (220-300 mm)
3 - mittel (140-220 mm)
2 - gering (60-140 mm)
1 - sehr gering (<60 mm)
0 - Moore und Anmoore oder keine Daten
Rinnetsberg
Im Steinbruch
Spielberg
Im Kleinen Böndl
Großriedenthal
Eisenhut
Goldberg
Bodenleiten
© BMLFUW, BFW

Triangulation of continuous fields

- **Node list and triangle list**



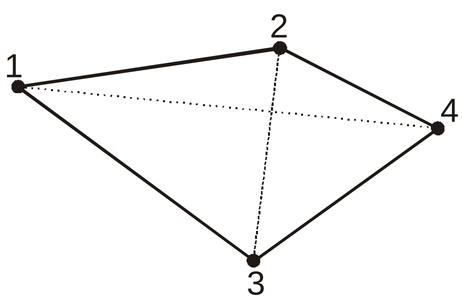
TIN list of triangles

Triangle	Node list	Neighbours
A	1,2,3	-,B,F
B	2,4,3	-,C,A
C	4,5,3	-,D,B
D	5,6,3	-,E,C
E	3,6,8	D,G,F
F	1,3,8	A,E,-
G	6,7,8	-,-,E

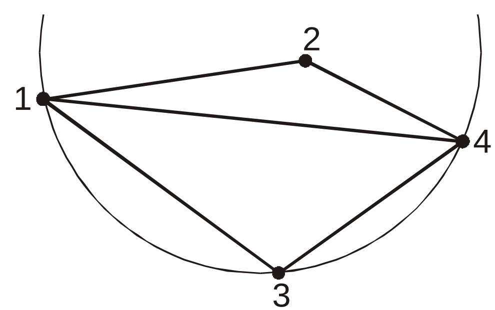
- no neighbour

- **Optimal TIN by Delaunay criteria**

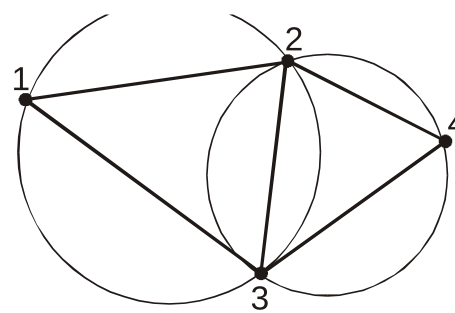
2 possible triangulations for 4 given points



This triangulation **fails** the Delaunay criteria, because the circle around triangle 1, 4, 3 contains node 2.



This triangulation **satisfies** the Delaunay criiteria because a circle around each triangle contains no other node



3 The Concepts of GIS

GIS Concepts

- *GIS Concept #1:*

- Features have attributes associated with them.

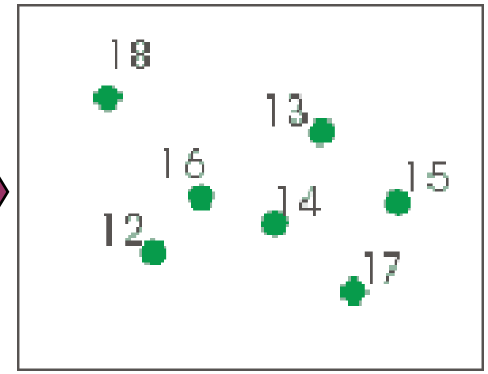
- These attributes describes the properties and characteristics of these features.

- Each Feature on the map has one record in the database associated with it.

GIS Concepts

- Example:

ID	Type	Age	Height
12	Cedar	110	67
13	Pine	135	80
14	Cedar	120	72
15	Cedar	120	70
16	Spruce	80	65
17	Spruce	75	60
18	Pine	125	73



- Using GIS we can map the location of wells, and identify which attributes belong to which well.

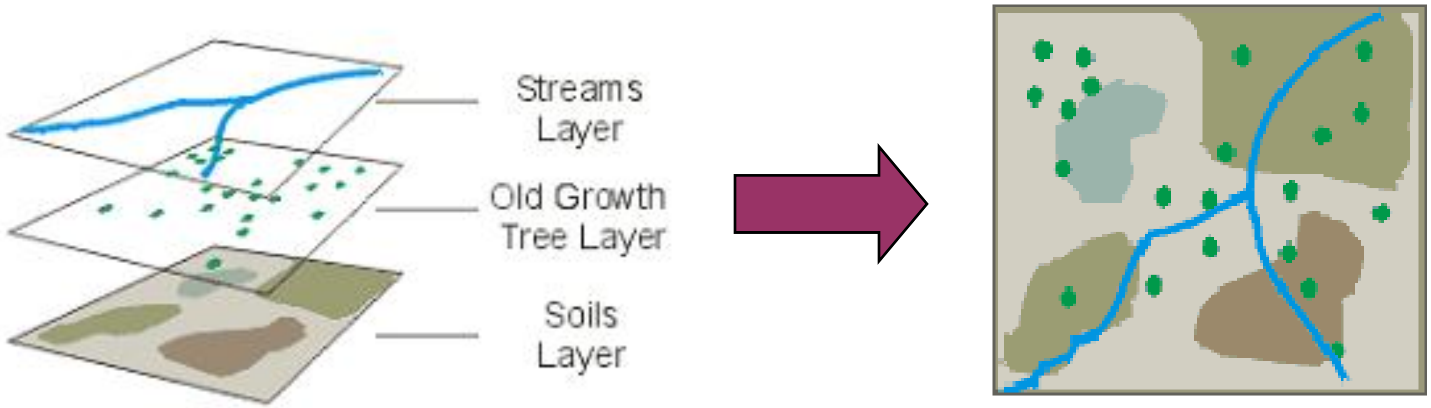
- We can know what information relates to which well

GIS Concepts

- *GIS Concept #2:*
- Information is separated into layers.
- Each layer carries information about features of the same type (streets, rivers)
- Layers represent data in a variety of ways (Raster, Vector or Tin layers)

GIS Concepts

- Example:



- Any information can be represented as a layer.
- We can have a layer with rivers and a layer with soil types and a third for trees locations.

- With individual layers we can conduct analysis between layers and only display layers of interest

Coordinate Systems and Map Projections

Introduction

- Coordinate system:

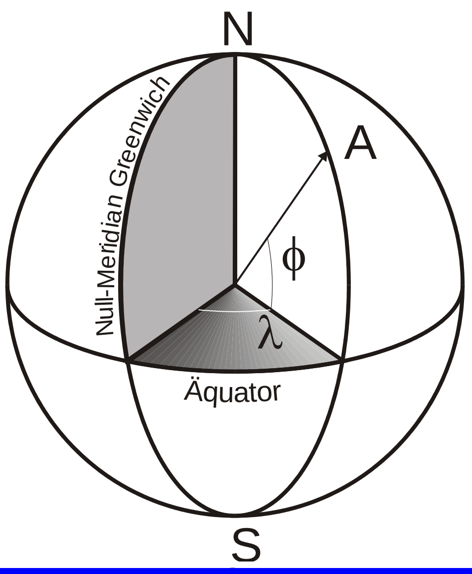
reference system for geographic location → Georeferencing

- Map projection:

Mapping of 3D earth surface to plane

Georeferencing

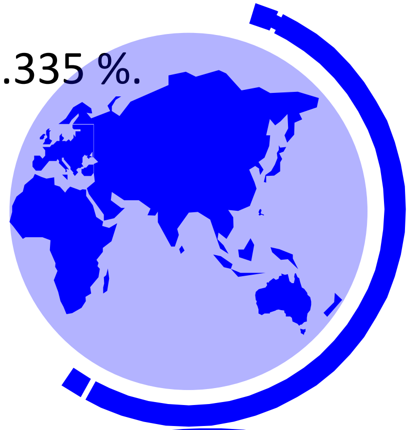
- Longitude λ and latitude ϕ
  - Angle from equator: latitude ϕ
  - Angle east of Greenwich: longitude λ
- Coordinate systems are based on agreements
- Coordinates relative to a „model“ of the earth
- Heights must refer to the irregular field of gravitation



The shape of the earth

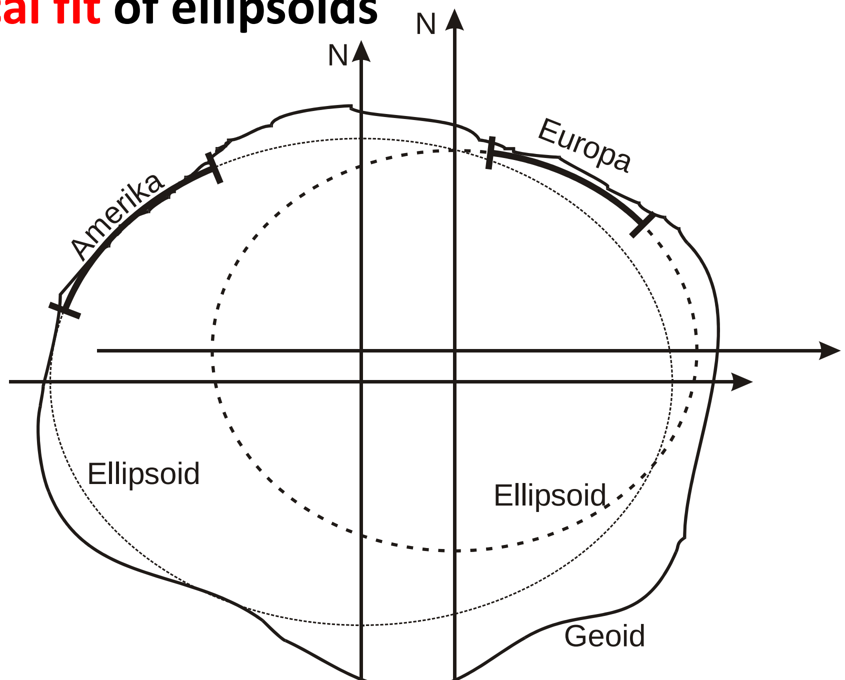
- Model plane: survey by theodolites, whose vertical axes are defined by a bubble level → trigonometry in a plane
- From the sphere to an ellipsoid of rotation (spheroid)
  - Polar flattening. Meridians are ellipses → ellipsoid of rotation (spheroid).
- The flattening of the smoothed Earth's surface in the World Geodetic System (WGS-84) is 1:298.257223563 (which corresponds to a radius difference of 21.385 km (13 mi) of the Earth radius (6378.137 – 6356.752 km) and would not be realized visually from space, since the difference represents only 0.335 %.

$$f = \frac{(a-b)}{a} \approx 1/298$$



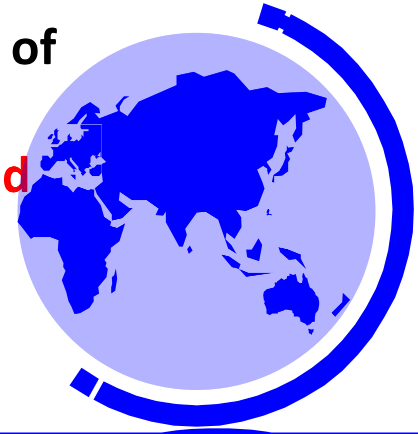
The shape of the earth

- **The geoid: the „true“ shape of the earth**
  - **Due to irregular distribution of masses within earth the geoid is irregular**
  - **Geoid is only approximated ellipsoid of rotation**
  - **Local fit of ellipsoids**



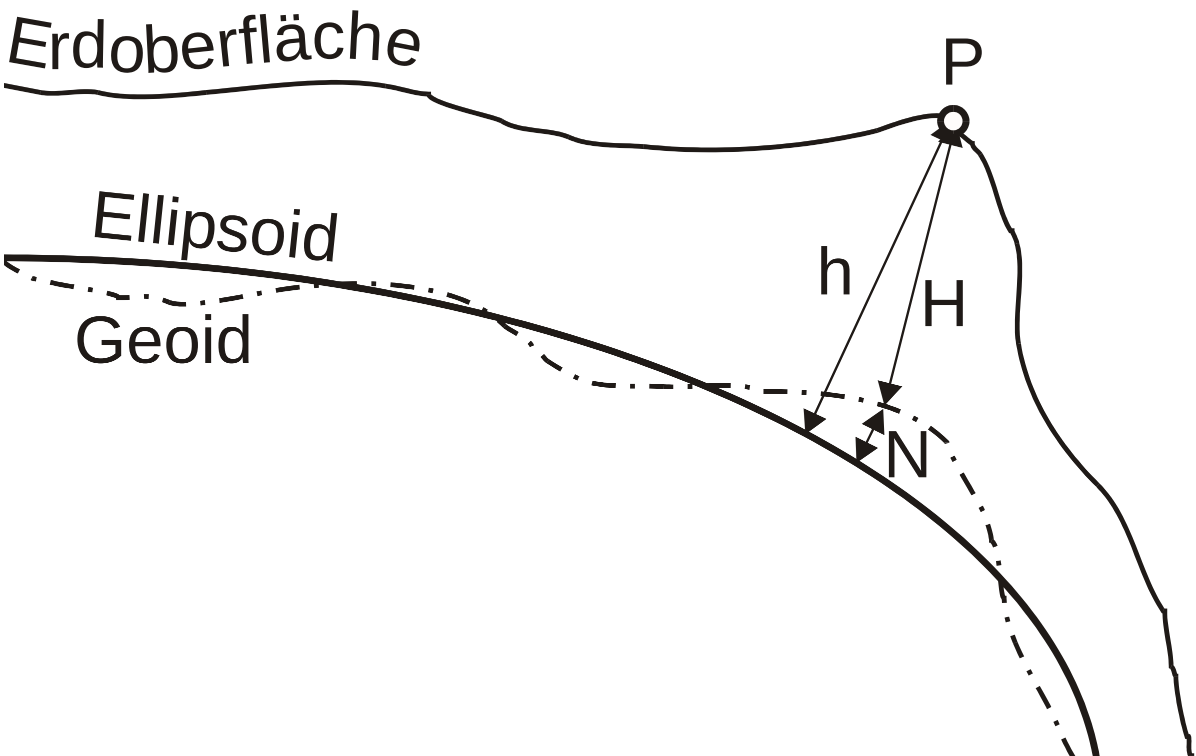
The shape of the earth

- plain, sphere, ellipsoid, geoid?
  - Local surveys → plane trigonometry
  - Navigation → earth model „sphere“ .
  - National surveys → ellipsoid of rotation
  - Geodetic high precision reference surveys or investigation of changes of the earth‘s body → consider undulation of geoid



Heights

- Very important for many and other hydrological applications
- Height above ellipsoid h, height above geoid H, geoid undulation N
- Heights required relativ to level (level instrument!)

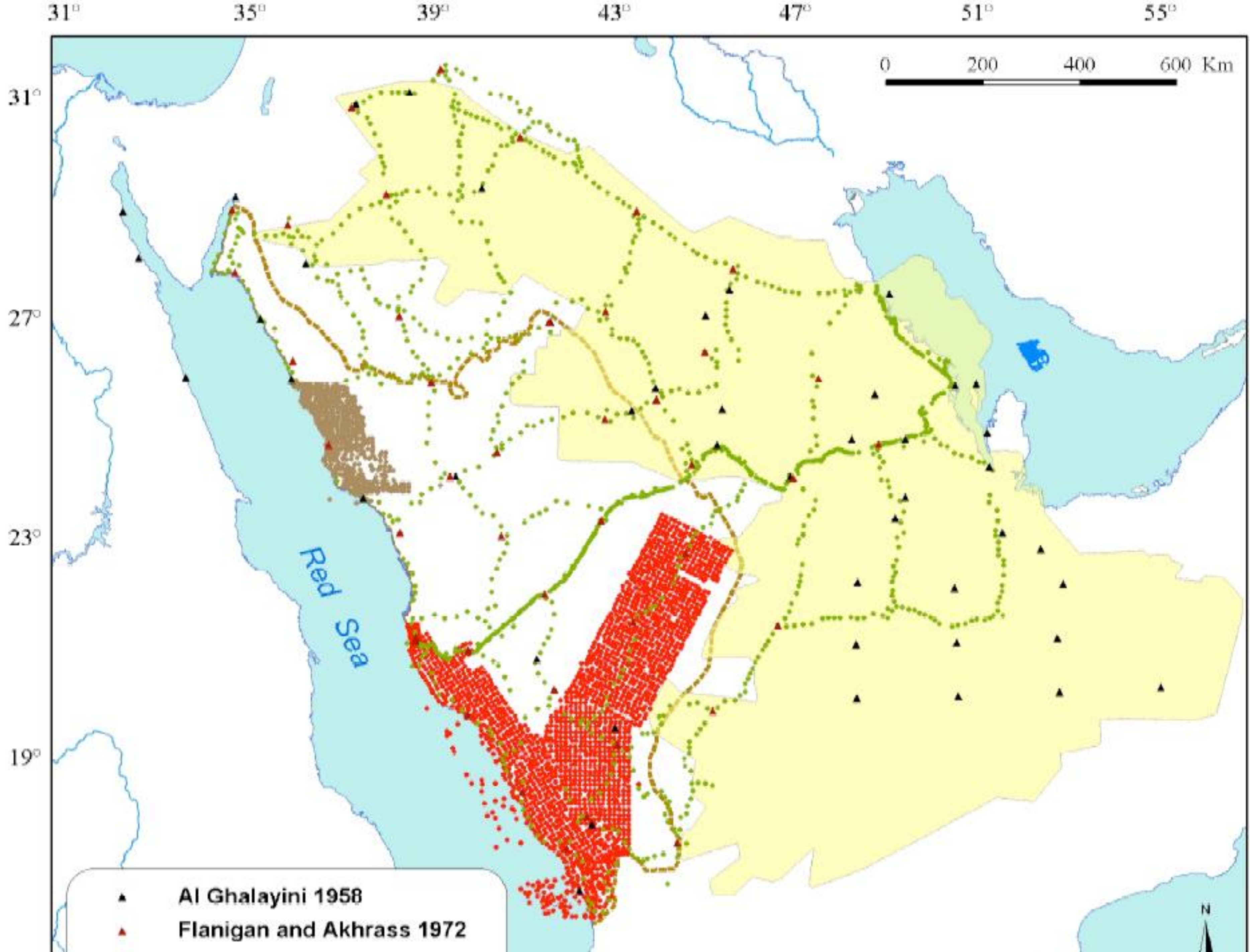


Geodetic reference systems

- **Geodetic reference system: set of all theoretical conventions to define a coordinate system for geodetic purposes.**
- **Reference surface (ellipsoid + rules for handling gedodetic measurements).**
- **Datum: set of parameters defining a coordinate system, and a set of control points whose geometric relationships are known, either through measurement or calculation: origin, direction of axis, reference point for elevations**

Geodetic reference systems

- Reference network: geodetic implementation of reference system. Computation of coordinates and heights of given points by means of geodetic surveys
- Usually „grown“ over long time → not free of contradiction. Unique conversion between coordinate system, e.g. GPS, to e.g., Ain Al Abd, 1970 not possible. Fit by reference points into reference network.
- Austrian 3D geodetic reference field: 57.000 triangulation points and 263.000 additional points, average distance 400 to 1.500 m


31°
35°
39°
43°
47°
51°
55°
31°
27°
23°
19°
0
200
400
600 Km
Red Sea
Al Ghalayini 1958
Flanigan and Akhrass 1972
N

Map projections

- Properties of map projections
- Projection types (class)
- aspect
- Naming of projections
- Choice of appropriate projection
- Examples of important projections

Properties of map projections

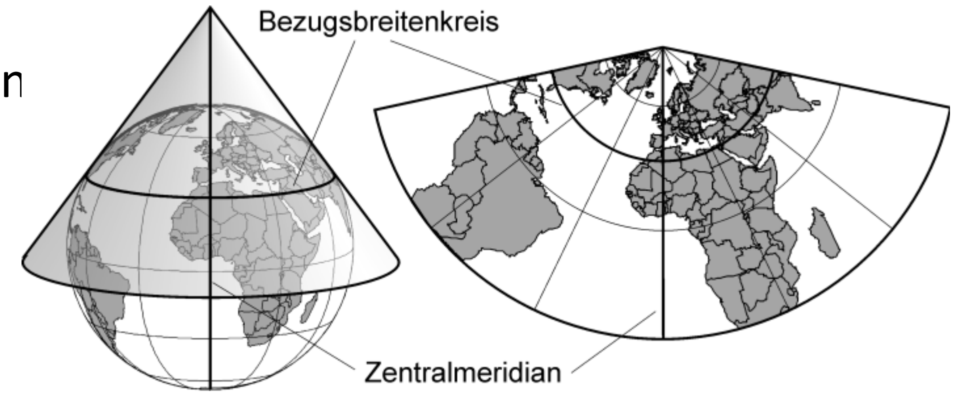
- Conformal projections
  - Preserve local shape → graticule lines on globe are perpendicular
- Equal-area projections
  - Preserve area of features → angle and/or scale may be distorted
- Equidistant projections
  - Preserve distances between certain points; scale is not maintained correctly on an entire map
- True-direction projections
  - True-direction or azimutal projections map great-circles through the center point as straight lines

Type of projection

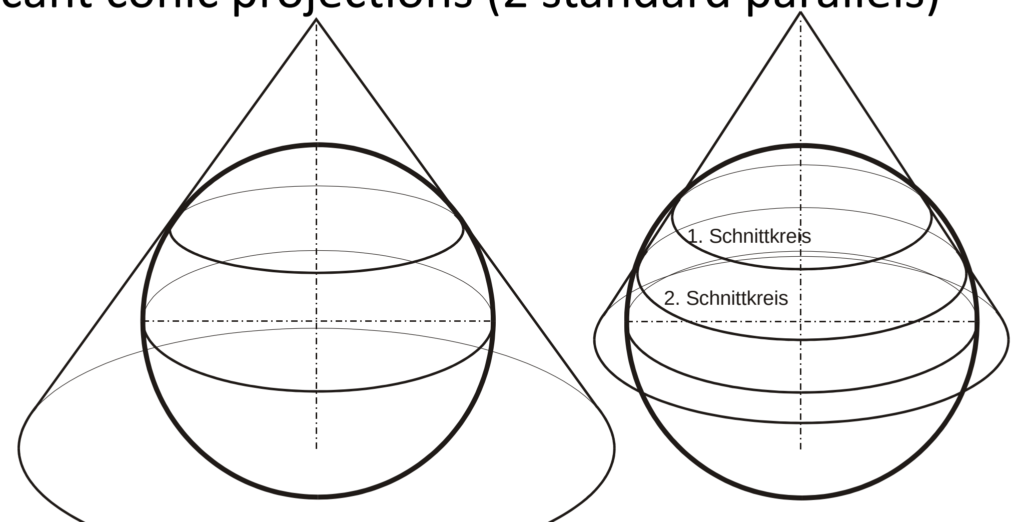
- Projection onto geometric surfaces (plane, cone, cylinder), which can be flattened by unrolling
- Not just pure „optical“ projection, but rather mathematical expressions which preserve the desired properties.

Type of projection: conic projections

- Tan

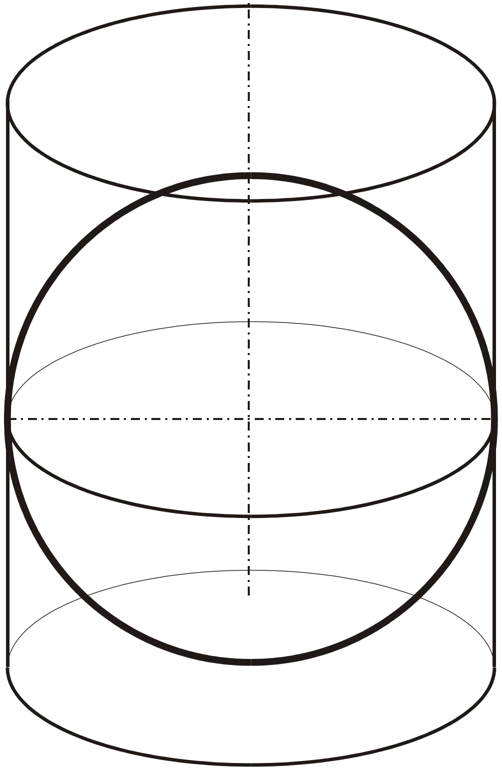


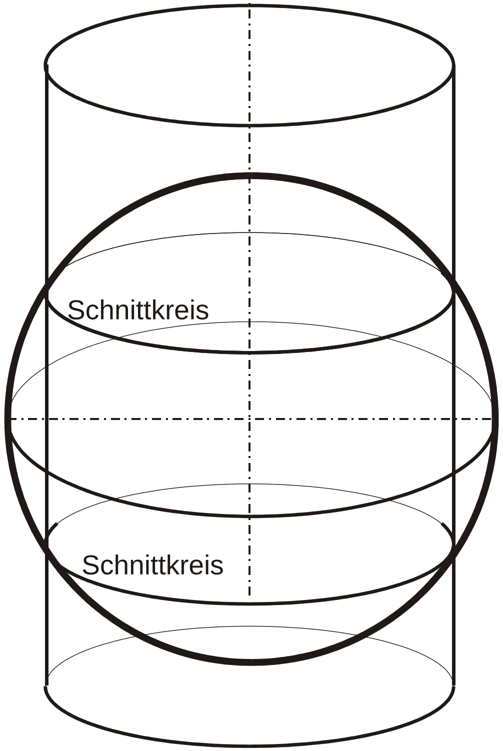
- Secant conic projections (2 standard parallels)



Type of projection: cylindrical projections

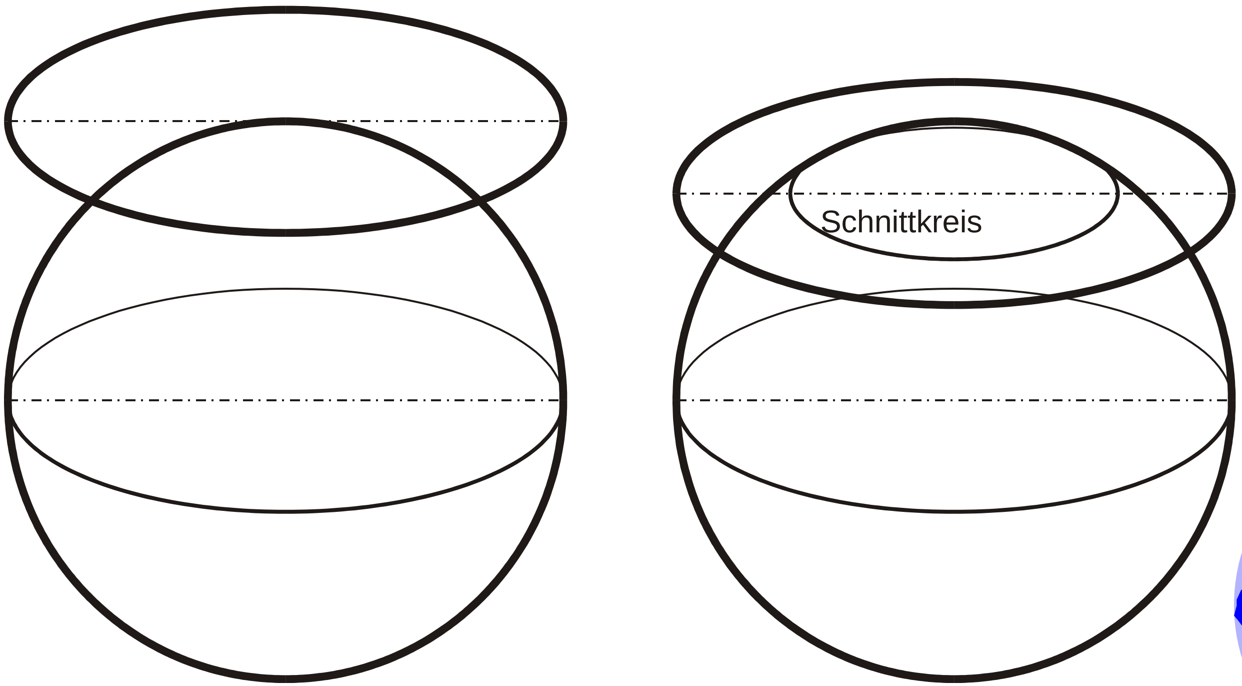
- Tangent or secant
- Mercator projection, touches at equator
- Transverse Mercator projection touches at meridian

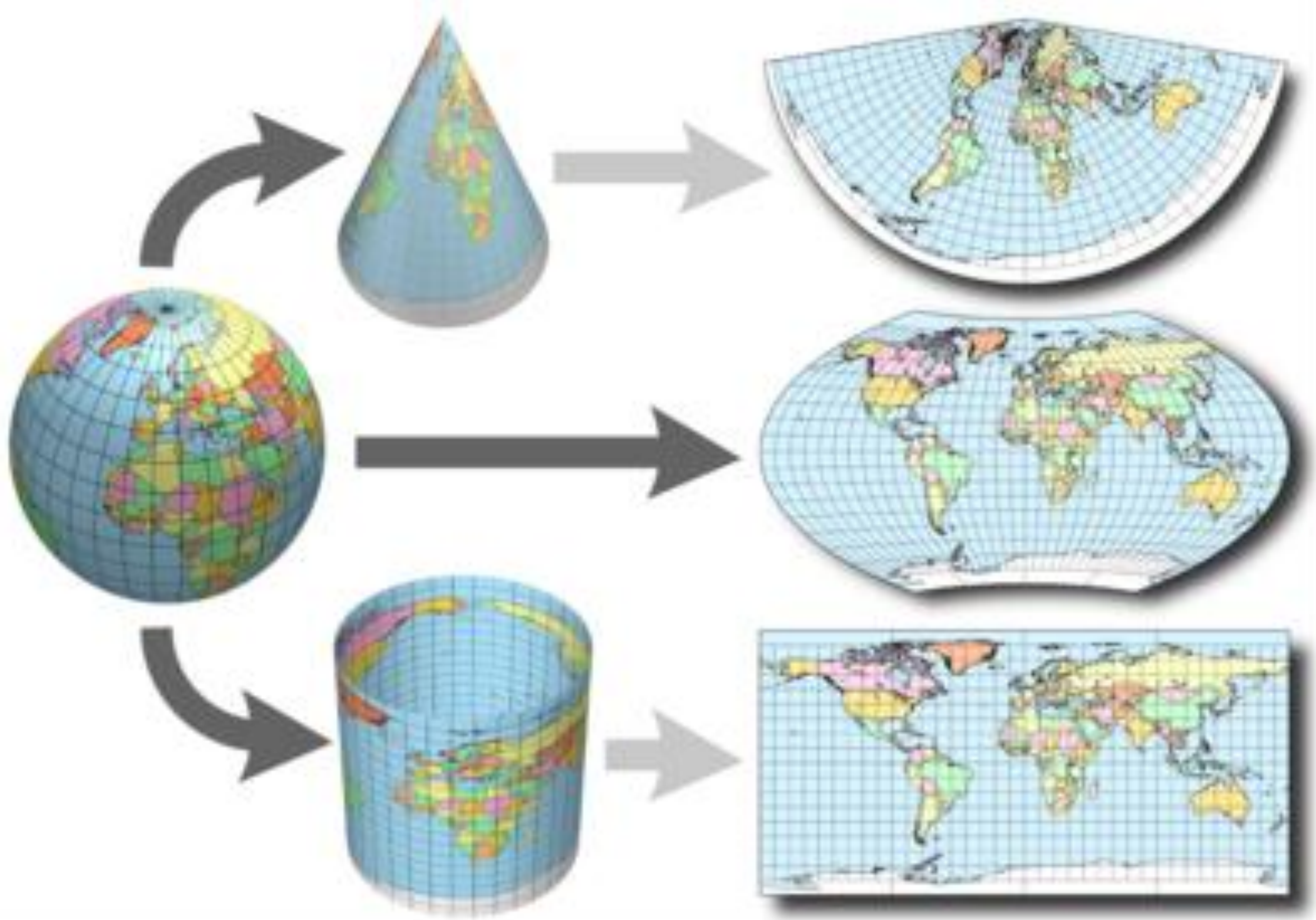


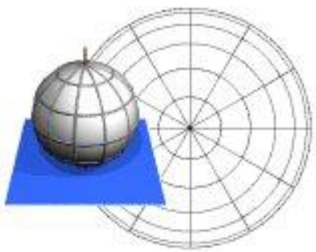


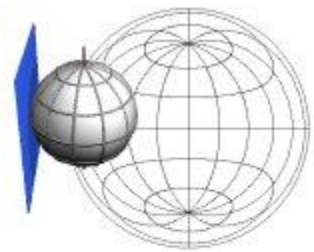
Type of projection: planar (azimuthal) projections

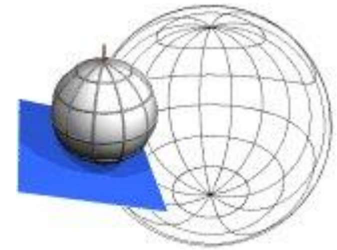
- Tangent or secant
- polar, equatorial or oblique

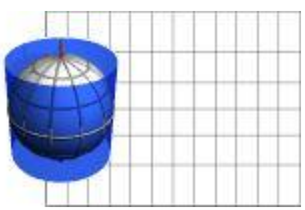


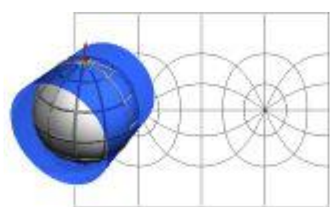


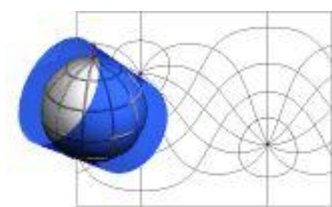












Naming of projections

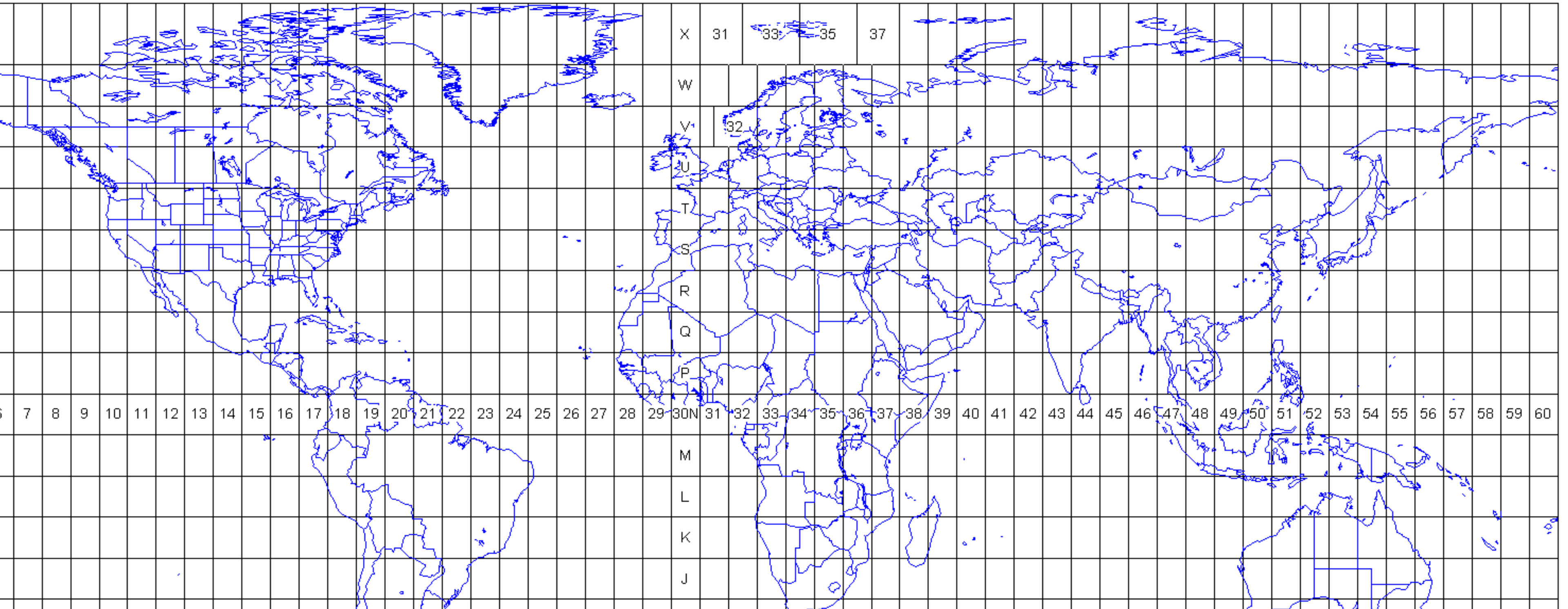
- Identified by giving:
  - class,
  - aspect,
  - property.
- Specific properties:
  - name of originator,
  - nature of any modifications.
- Topographic overview map 1:500.000: normal secant conformal conic projection (Ain Al Abd, 1970) with standard parallels 19° and 28° N latitude

Selecting a suitable map projection

- Considerations
  - How can results be best presented on a map?
  - For analysis in GIS, all maps must have a common reference
  - To be able to quantify areas, lengths, etc. the respective accuracy must be determined
- Rules of thumb
  - Errors and distortions increase from the origin of the projection towards its edges
  - In tropical areas → cylindrical projections
  - In temperate latitudes → conic projections
  - Polar regions → planar (azimuthal) projections
- Topographic maps: conformal projections

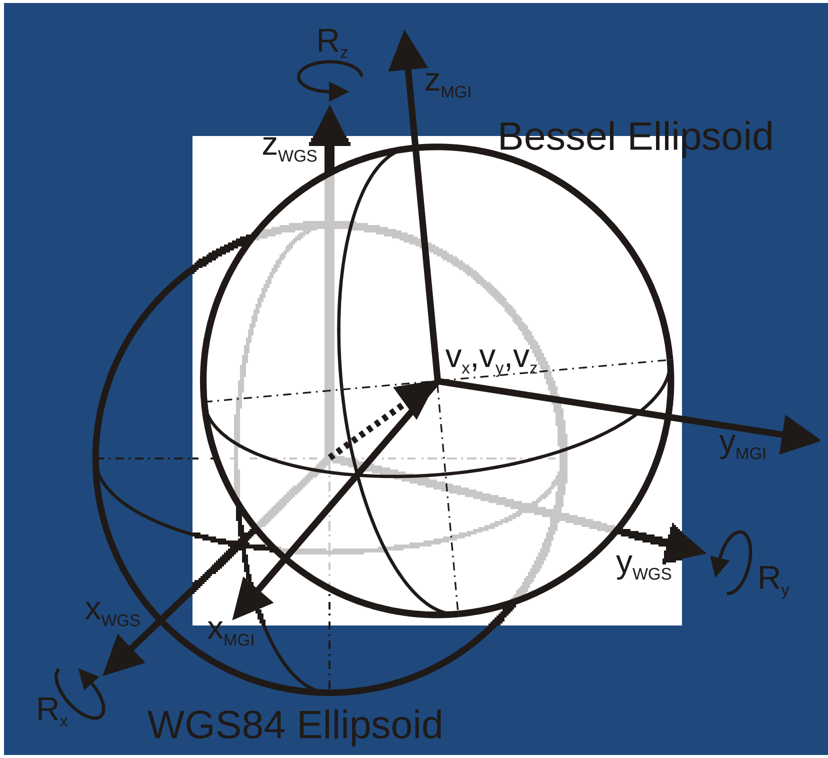
Examples of important map projections

- UTM (Universal Transverse Mercator) System
  - Ain El Abd, 1970 version of transverse Mercator projection.
  - For cartography between 18° N and 31° S.
  - 5 UTM zones :



Examples of important map projections

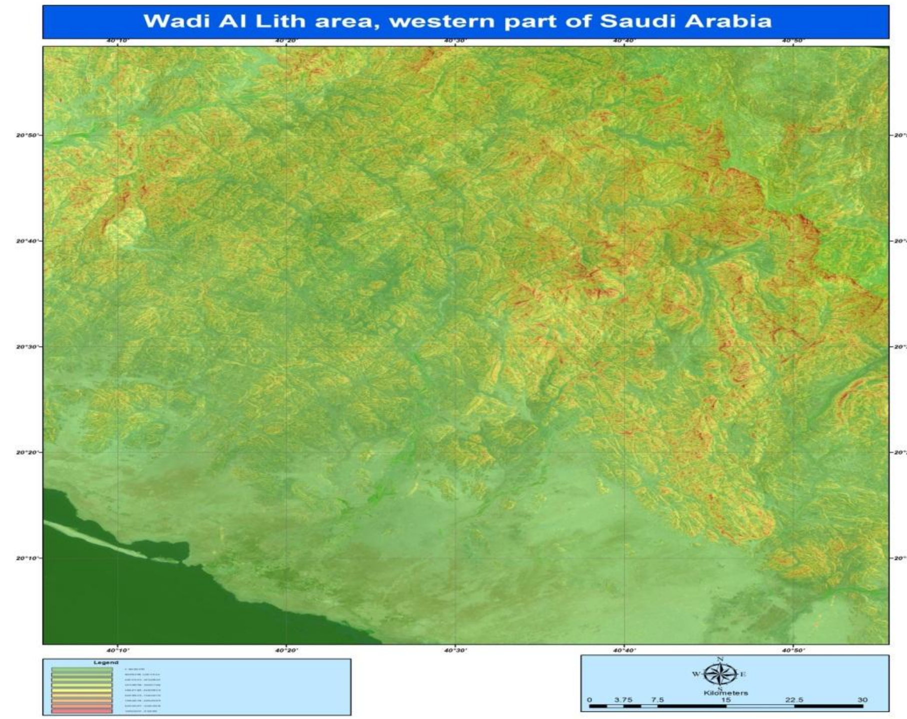
- WGS84
  - Measurements by GPS (Global Positioning System)
  - Approximate conversion of GPS coordinates into national system using local parameters; fit into national system by reference points



$$v_x = -577{,}326 \text{ m} \pm 0{,}92 \text{ m}$$
$$v_y = -90{,}129 \text{ m} \pm 0{,}80 \text{ m}$$
$$v_z = -463{,}919 \text{ m} \pm 0{,}94 \text{ m}$$
$$d_m = -2{,}4232 \text{ ppm} \pm 0{,}09 \text{ ppm}$$
$$R_x = 15{,}8537 \text{ cc} \pm 0{,}08 \text{ cc}$$
$$R_y = 4{,}5500 \text{ cc} \pm 0{,}12 \text{ cc}$$
$$R_z = 16{,}3489 \text{ cc} \pm 0{,}06 \text{ cc}$$
$$\mathbf{X}_{MGI} = \mathbf{v} + (1 + d_m)\, \mathbf{R}\, \mathbf{X}_{WGS}$$

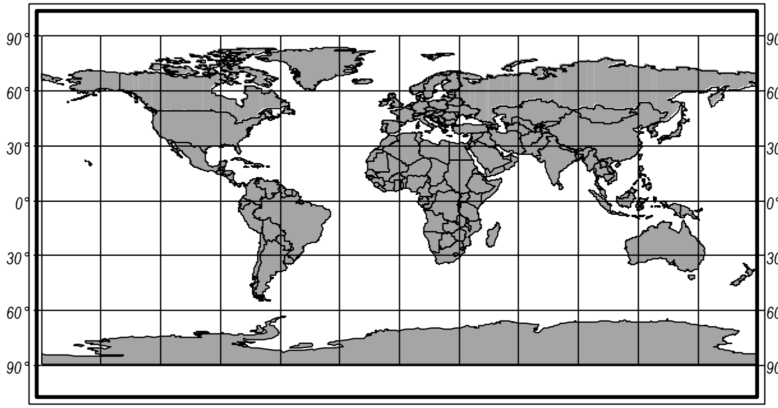
Examples of important map projections

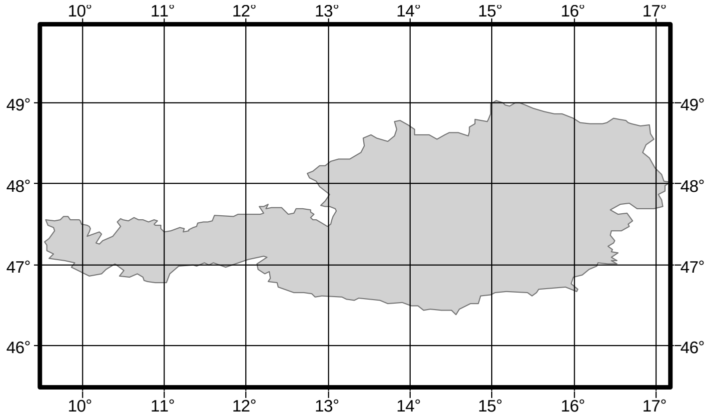
- Ain Al Abd projection
  - Used frequently for overview maps
  - Austria 1:500.000: standard parallels 46° and 49° N, central meridian 13° 20’. origin 47° 30’ N und 13° 20’ E, „false“ coordinates (400.000, 400.000)



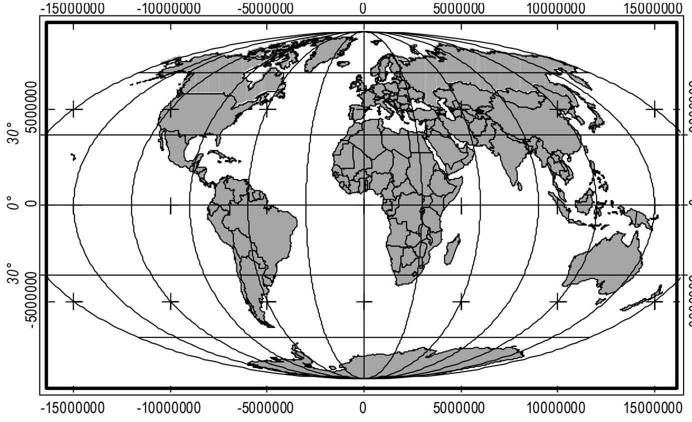
Projections of the world

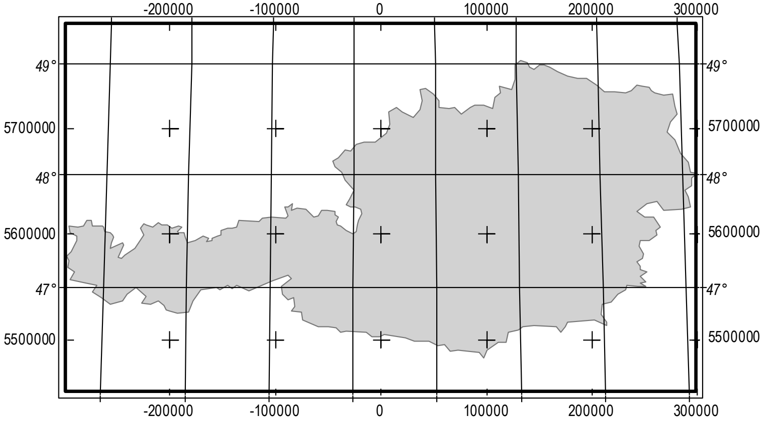
- Geogr. coordinates





- Mollweide (equal area)





Summary

- Coordinates for georeference, map projections for presentation
- According to requirements and size of study area, earth‘s shape is modelled as a plane, sphere, ellipsoid of rotation or geoid
- National coordinate systems are based on reference networks
- Position related to ellipsoid
- Gravitation field to be considered for heights
- Distortions due to projection: a projection cannot maintain conformity, equal area, equidistance AND true direction at the same time
- important: UTM, Gauß-Krüger, Lambert conformal conic projectio

Analysis of Spatial Data

Learning objectives

- In this section you will learn:
  - how thematic overlays work,
  - overview of the diversity of spatial analysis tools and
  - overview of methods to query and select by attributes and spatial criteria to serve as a basis for GIS based decision support.

Outline

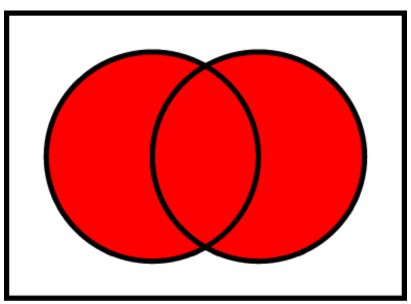
- Introduction
- Geometric overlay
- Analysis in attribute space
- Integrated analysis of spatial and thematic data
- Raster-GIS functions
- Example: Delineation of hydrologically similar areas
- Summary

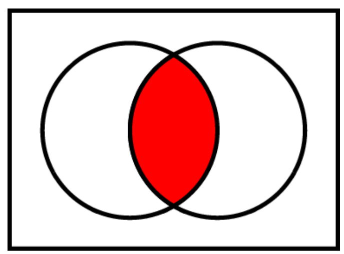
Introduction

- Most important functionality of GIS
- GIS data basis as a model of reality
- „single layer“ analyses
- „multiple layers“ analyses
- Useful distinction from a technical viewpoint:
  - Functions for analysis in attribute space
  - Functions for analysis by spatial (topological) criteria

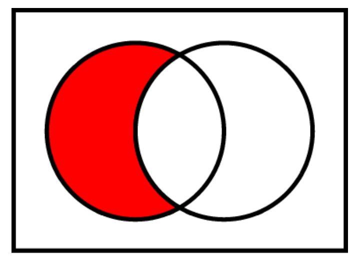
Geometric overlay

- Statements about a location combining information from 2 or more thematic maps → „overlay“ of 2 or more maps
- requires common spatial reference
- In raster-GIS automatically met
- Geometric overlay (intersection) in vector-GIS required→ overlay operators

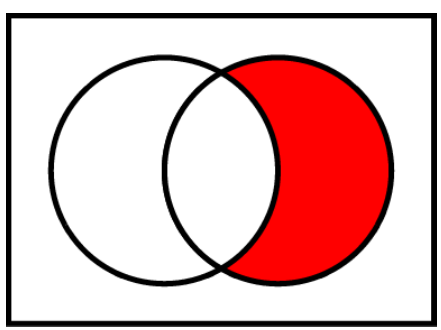


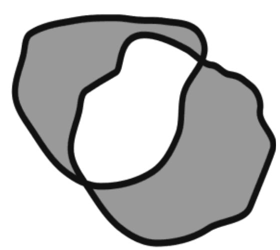


A AND B

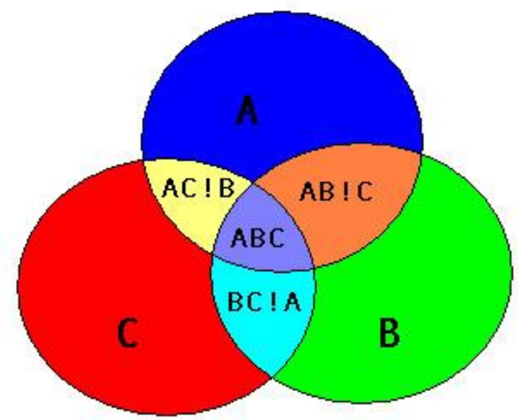


A MINUS B



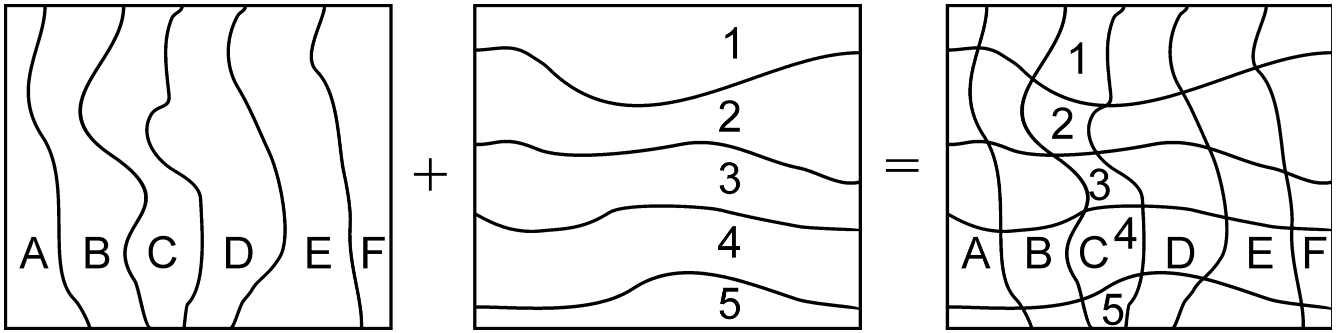


A XOR B



Geometric overlay

- **Topological fragmentation**



Id1	x	y	z
A			
B			
C			
D			
E			
F			

Id2	r	s
1		
2		
3		
4		
5		

Id12	x	y	z	r	s
A1					
A2					
..					
B1					
B2					
..					
F5					

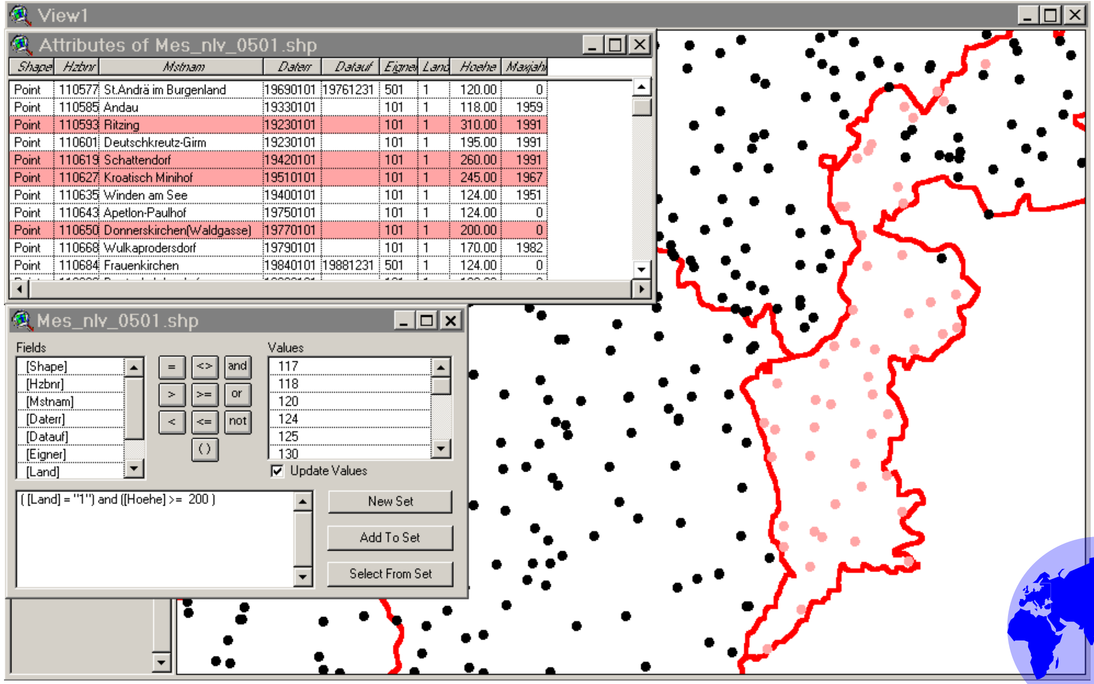
Analysis in attribute space

- Query,
- Generalisation,
- Calculation.

Query

- Selection of attribute data, without changes in database
- SQL (Structured Query Language)

- ARCGIS 9.3

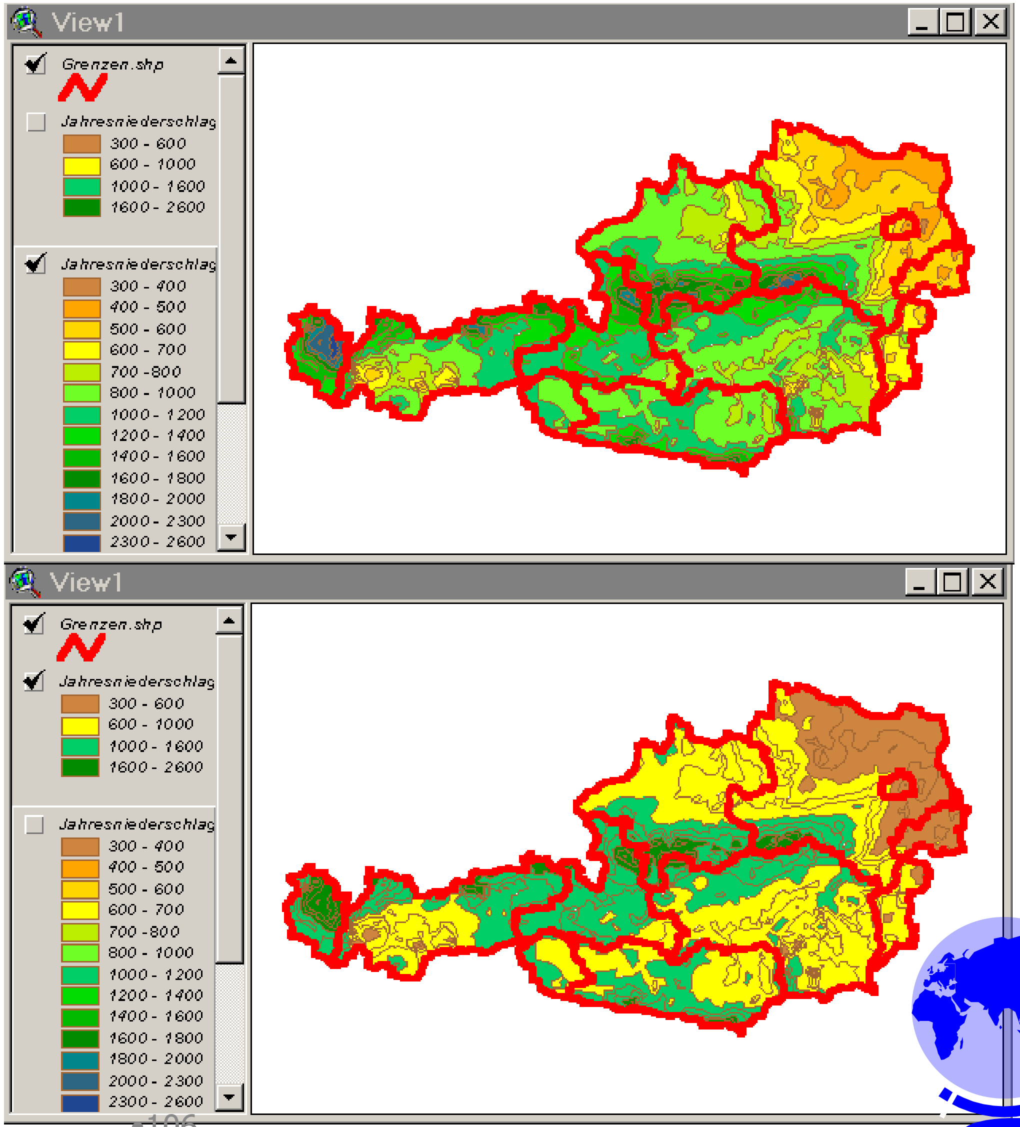


Generalisation

- Classification of data by user defined rules, without change of existing attributes
  - Clearer view of inherent patterns
- Examples:
  - Weekly and monthly precipitation depths,
  - Soil classification by hydrological criteria,
  - Classification of slopes for stability analysis,
  - Hydrological Response Units (HRU)

Generalisation

Generalisation by classifying an attribute



Calculations

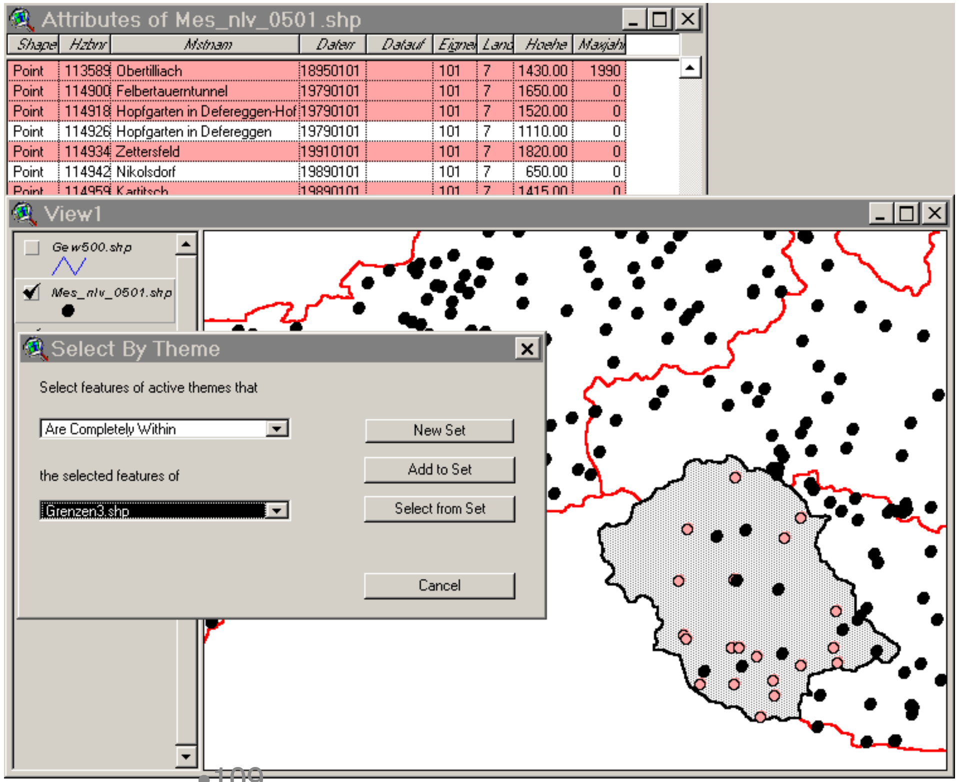
- Operations:
  - arithmetic,
  - mathematical (functions) and
  - logical (binary)
- E.g.: Amount of groundwater = Thickness x porosity
- SQL DBMS like Oracle or MS Access such attributes are commonly stored in a „view“ or „query“

Integrated analysis of spatial and thematic data

- The focus of GIS
- Power of analytical functions and software architecture varies
  - Wide range from specialised modules for catchment analysis (e.g., WMS) to libraries of elementary general purpose spatial operators

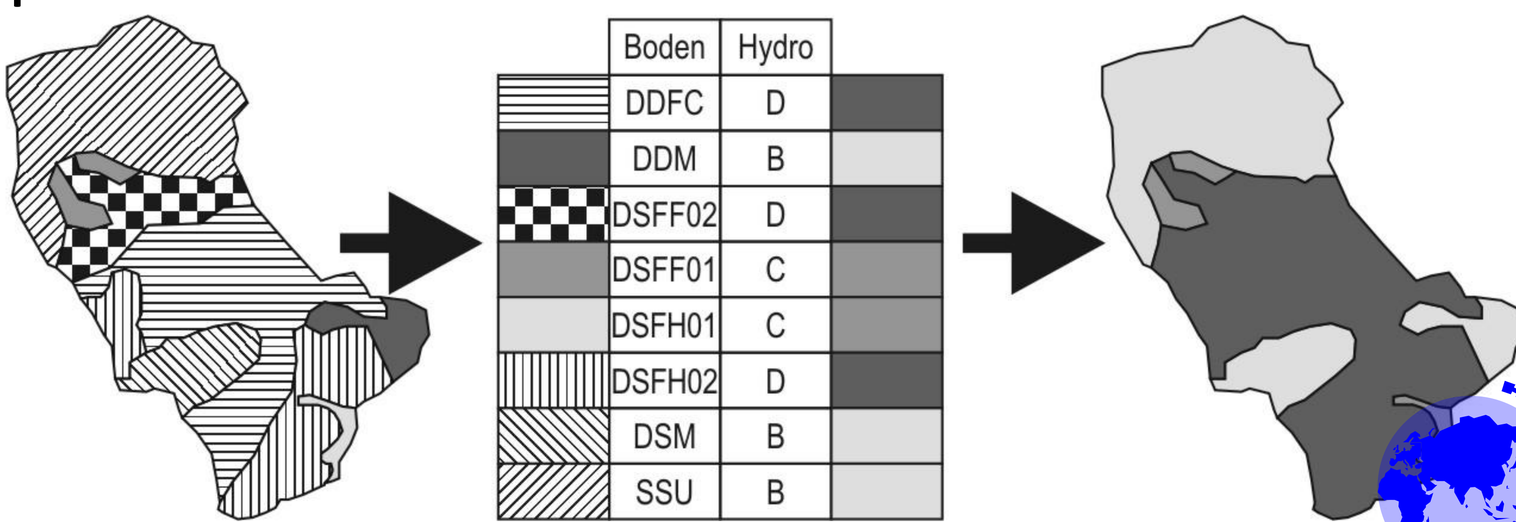
Selection, classification and measuring

- **Combined spatial and attribute based selection**
- **`E.g.: Select features of active themes that Are completely within the selected features of Gizan.shp`**



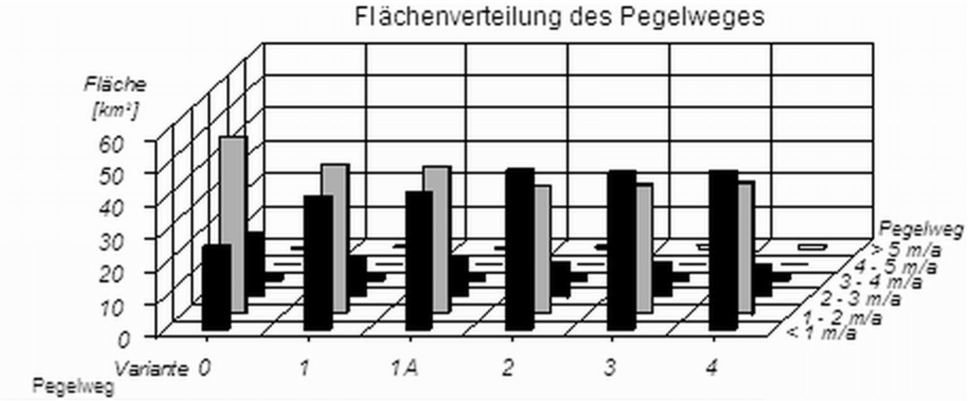
Classification

- (Re-)assignment of thematic attributes
- Examples:
  - Elevation zones from DEM
  - Re-classification of a soil map by hydrological criteria
  - Scale-dependent reduction of number of attribute values, e.g. in a map of land cover



Measure

- Assess numbers, distances, lengths, areas, volumes
  - Many of these are automatically maintained in GIS (area and perimeter of polygons, length of lines),
  - Sometimes elaborate procedures (e.g. travel time as a function of road conditions, vehicle and current traffic)



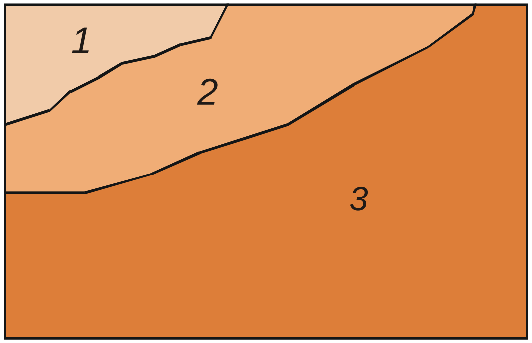
Pegelweg						
> 5 m/a	0	0,25	0	0,5	0,88	0,63
4 - 5 m/a	0	0	0	0	0	0
3 - 4 m/a	1,5	1,38	1,38	1,38	1,38	1,38
2 - 3 m/a	19,5	12,63	12	10,63	10,38	10
1 - 2 m/a	53,75	45,25	44,75	38,88	39,25	39,75
< 1 m/a	25,25	40,5	41,88	48,63	48,13	48,25

Overlays (Intersection)

- M:N relationship between entities of 2 maps with different geometrical basis
- 1:N relationship between a polygon and ist attributes by geometric-topological intersection
- After intersection analysis is done in a single layer
- Operations:
  - arithmetic (addition, multiplication, ...) and
  - logical (AND, OR, XOR) operations as well as
  - Application of conditions (rules)

Overlays (Intersection)

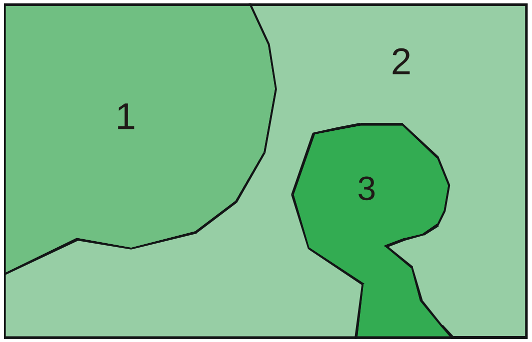
- Example of arithmetic overlay



Durchwurzelungstiefe [cm]

Root depth

WTID	WTIEFE
1	50
2	75
3	89



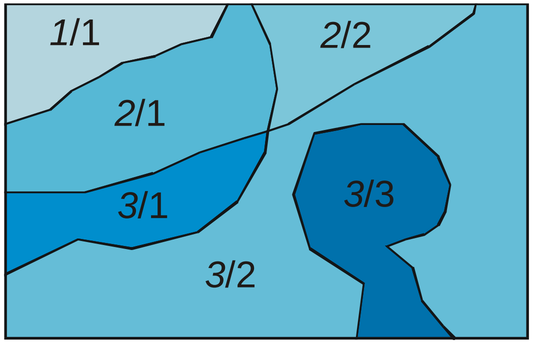
Bodenfeuchte [%]

Soil moisture

BFID	BFEUCHTE
1	23
3	34
2	18

Intersect

Water available for plants



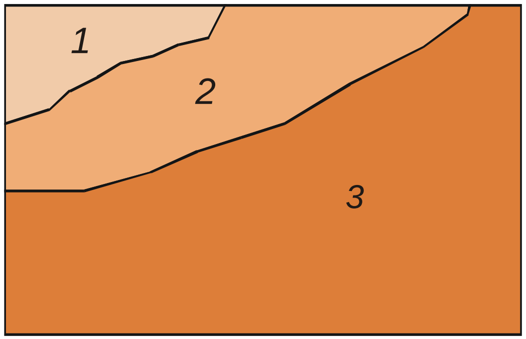
Pflanzenverfügbares Wasser [mm]

PWASSER = WTIEFE * BFEUCHTE / 10

WTID	WTIEFE	BFID	BFEUCHTE	PWASSER
1	50	1	23	115
2	75	1	23	173
2	75	2	18	135
3	89	1	23	205
3	89	3	34	303
3	89	2	18	160

Overlays (Intersection)

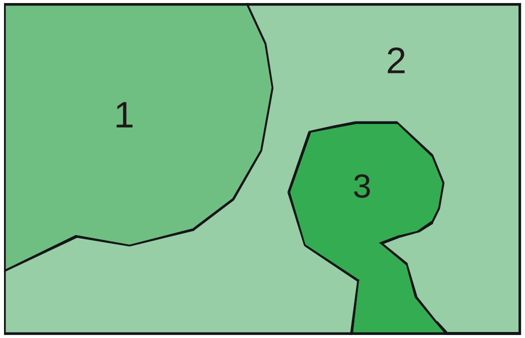
- Example of a logical overlay



Durchwurzelungstiefe [cm]

WTID	WTIEFE
1	50
2	75
3	89

Root depth



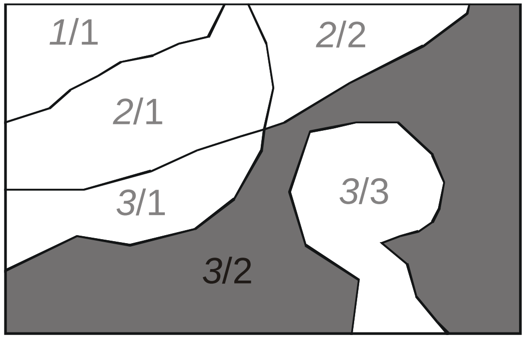
Bodenfeuchte [%]

BFID	BFEUCHTE
1	23
3	34
2	18

Soil moisture

Intersect

Root depth > 80 AND Moisture < 20



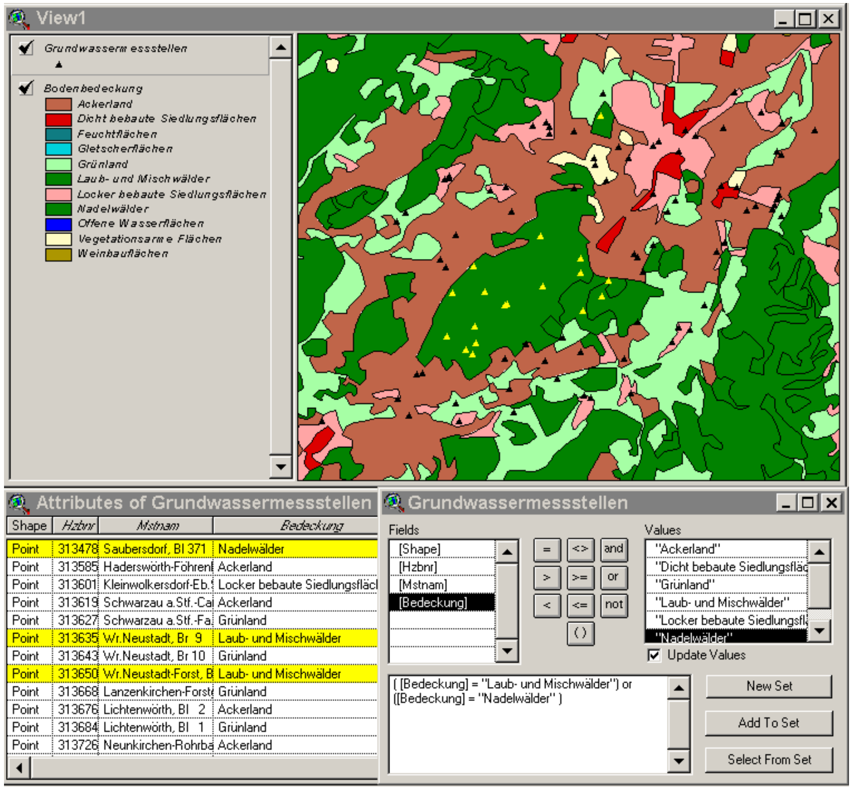
Tiefe Durchwurzelung, geringe Feuchte

WTIEFE > 80 **AND** BFEUCHTE < 20

WTID	WTIEFE	BFID	BFEUCHTE
1	50	1	23
2	75	1	23
2	75	**2**	**18**
3	**89**	1	23
3	**89**	3	34
3	**89**	**2**	**18**

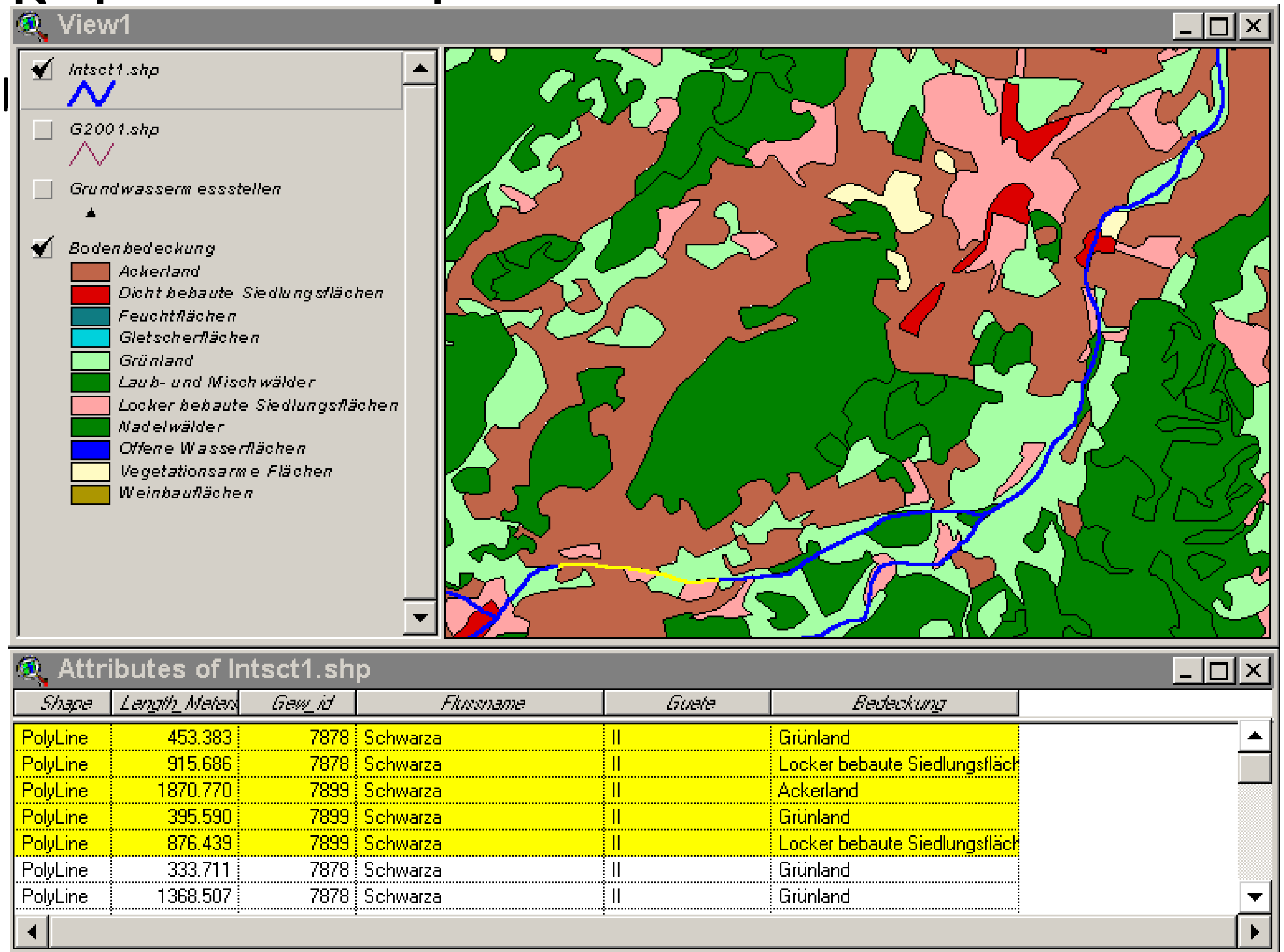
Overlays (Intersection)

- **Point in Polygon overlay by Spatial Join in ARCGIS: groundwater sites receive an attribute „Land cover“ (Bedeckung) by spatial join with the map „Land cover“ (Bodenbedeckung).**



Overlays (Intersection)

- Line in
  land cover l



Surface operations

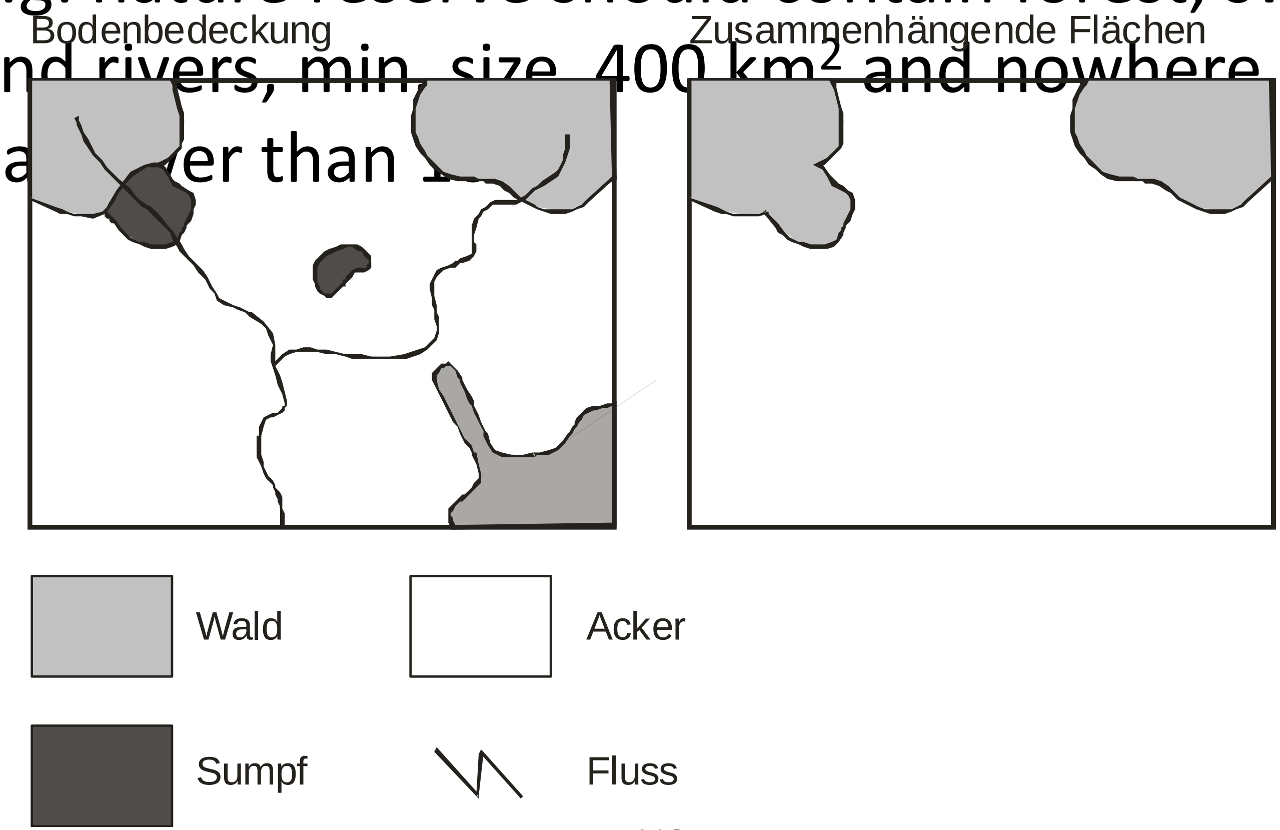
- neighbourhood of a point is included in the evaluation for this point
- Generally a „smooth“ surface is assumed
  - Topographic functions (slope, aspect, relief),
  - illumination (e.g. hillshading),
  - Pseudo-3D displays (Perspective) and
  - Interpolation.

Connectivity

- Entities with common properties AND spatial connection
  - Contiguity
  - Proximity: based on measures of distance, including time, cost, etc. E.g. buffer zones, Thiessen polygons, flow times).
  - Spread: e.g. floods, pollutants.
  - Seek: optimal paths, according to decision rules,
  - Network functions: utilities, drainage network.

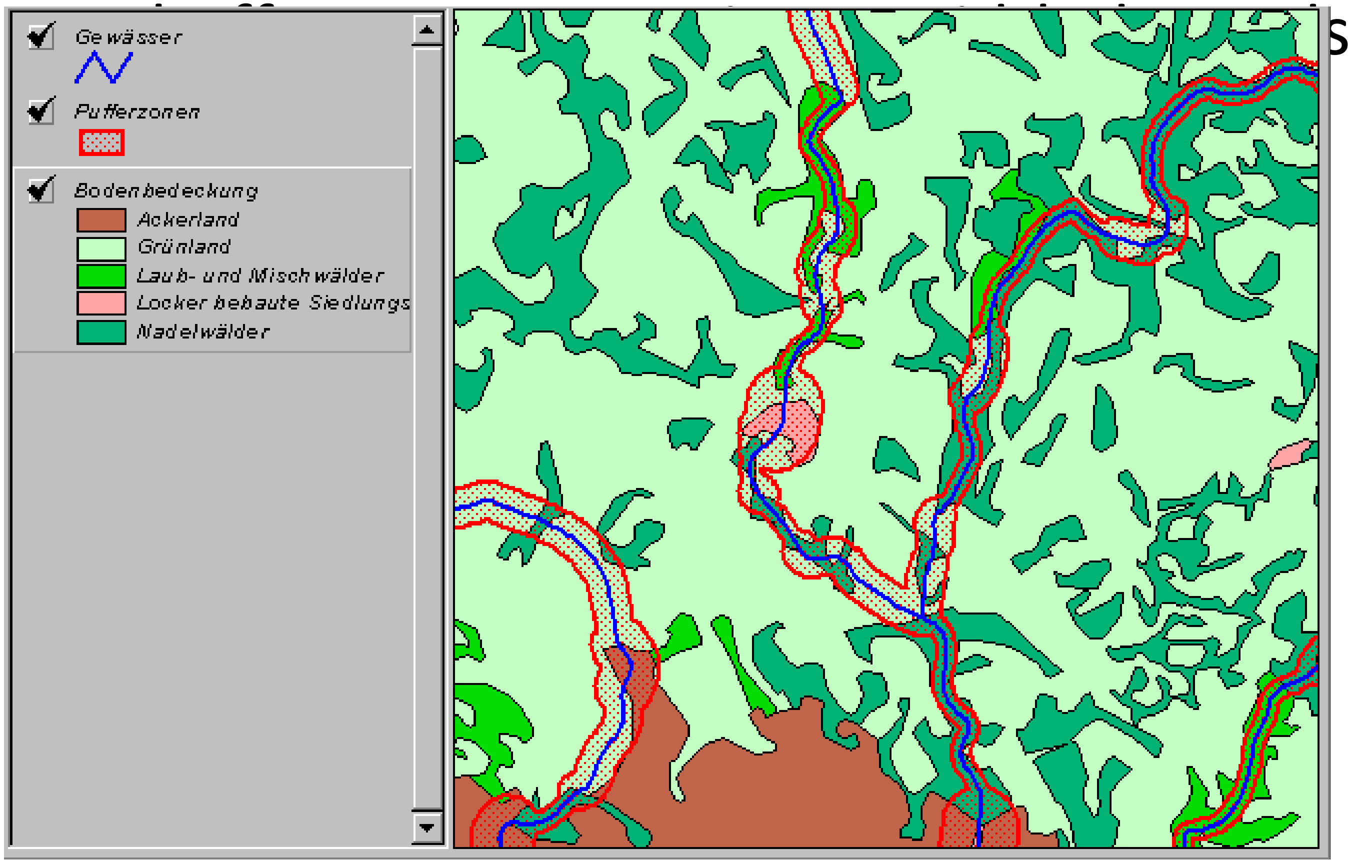
Connectivity

- contiguity:
  - E.g: nature reserve should contain forest, swamp and rivers, min. size 400 km^2 and nowhere na[illegible]er than 1[illegible]



Connectivity

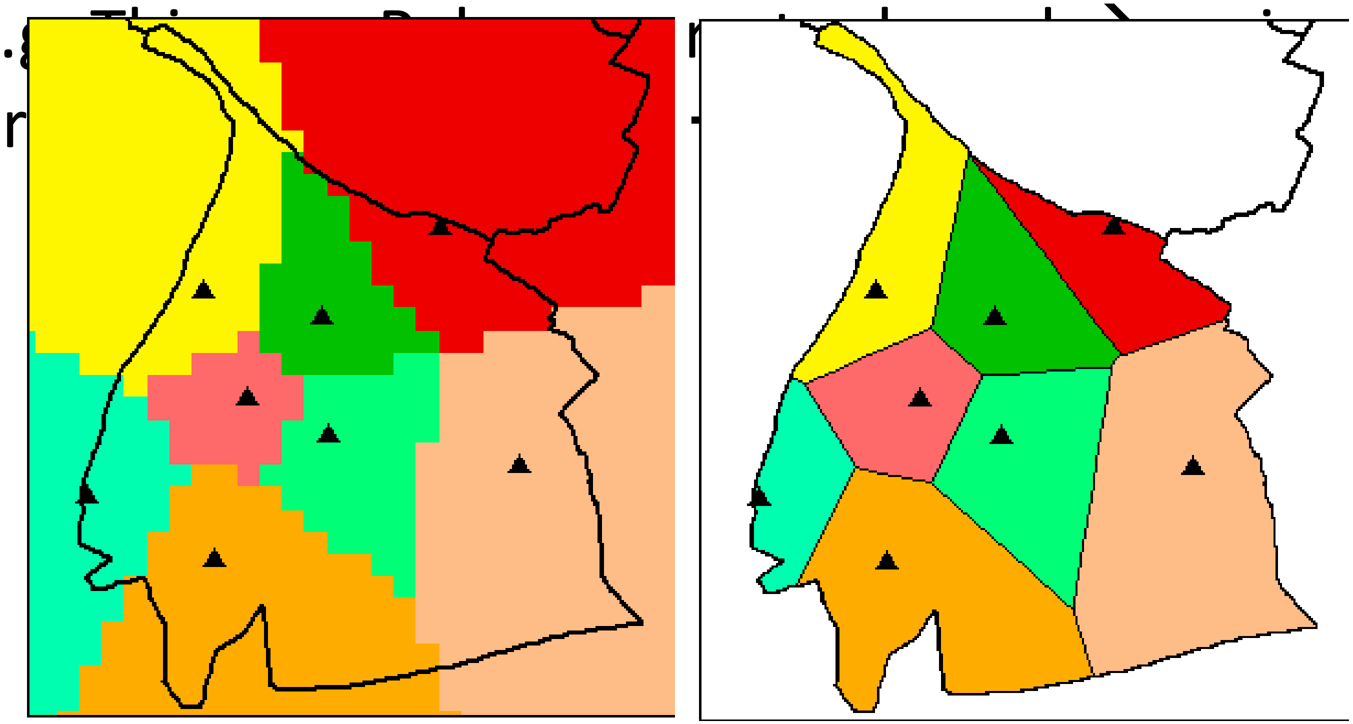
- proximity:
  - – s on



Connectivity

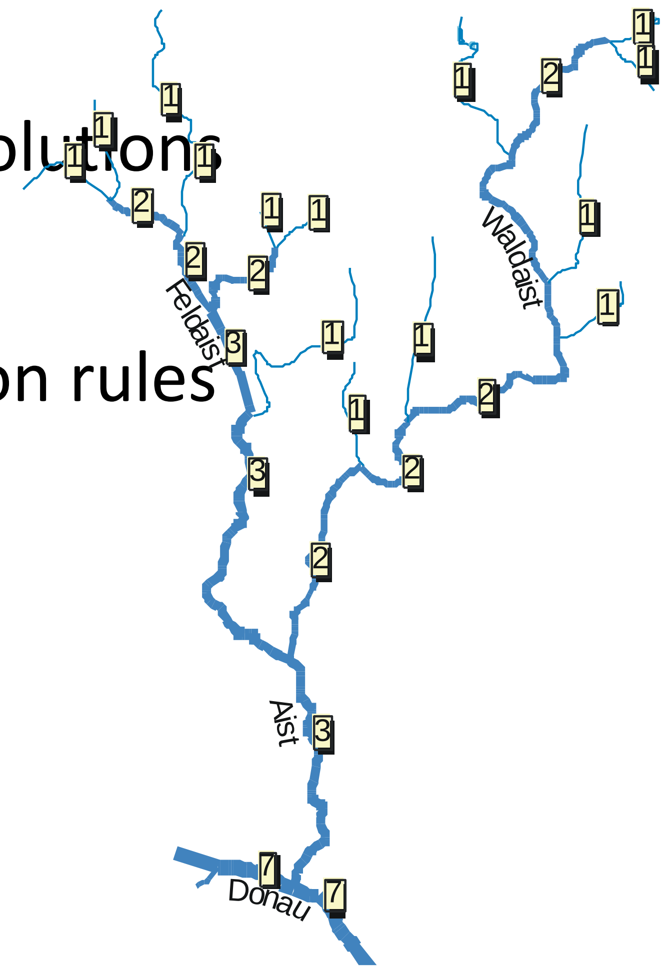
- proximity:
  - E.g.

    pr



Connectivity

- Spread (flood, noise, pollutants in groundwater)
  - in GIS usually only simplified solutions
- Seek
  - Find optimal path using decision rules
- Network functions (roads, sewers, utilities, rivers)
  - Movement of resources
  - Strahler order



Raster-GIS functions

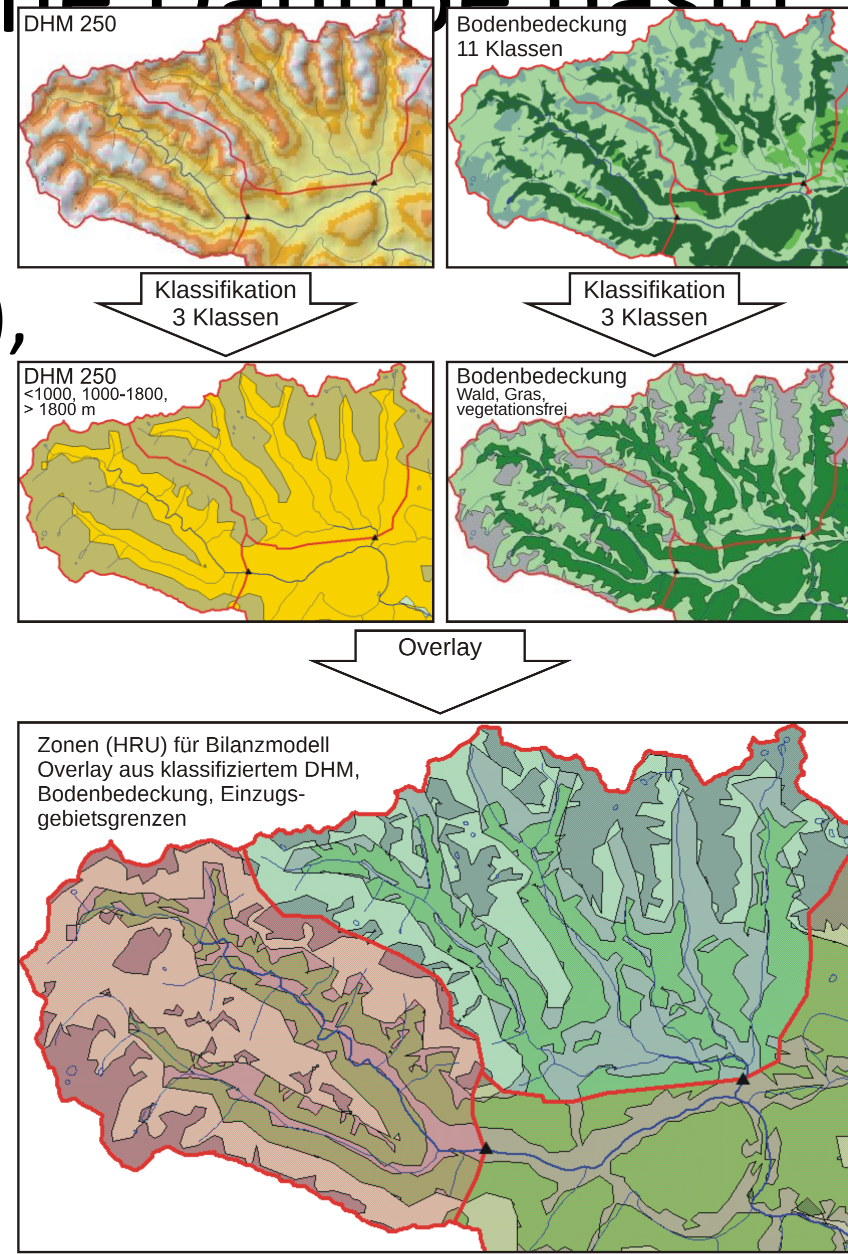
- Local functions
  - Only one cell, neighbouring cells do not influence result
- Focal functions
  - Result for a cell is based on neighbourhood cells (linear filter, mean, median, standard deviation)
- Zonal functions
  - Evaluated for a zone, i.e. for all cells with a common value
- Global functions

Example: Delineation of hydrological response units

- Semi-distributed conceptual models with HRU concept (e.g. PRMS)
- Important steps:
  - Selection of input data: 5 layers, DEM (slope, aspect), land use, soil, geology
  - classification input data into small number of categories (3-6).
  - Overlay of input layers.
  - Reduction of the resulting number of unique attribute combinations (HRU) by analysis and classification in DBMS

Water balance of the Danube basin

- HRU using DEM (250 m resolution), maps of land cover and hydrological sub-basins



Summary

- Analysis of spatial data is the most important function of GIS
- Single-layer analysis is done within 1 layer
- Multi-layer analysis
  - Transform into single-layer problem by geometric-topological intersection → 1:M relationship between object and attributes.
- Analyses in attribute space include query, generalisation and calculations based on the attributes only
- Integrated analysis of spatial and attribut data

Analysis of Spatial Data

Learning objectives

- In this section you will learn:
  - how thematic overlays work,
  - overview of the diversity of spatial analysis tools
  - overview of methods to query and select by attributes and spatial criteria to serve as a basis for GIS based decision support.

Outline

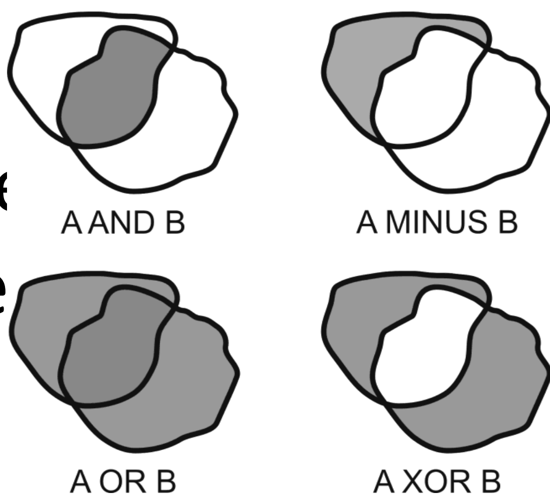
- Introduction
- Geometric overlay
- Analysis in attribute space
- Integrated analysis of spatial and thematic data
- Raster-GIS functions
- Example: Delineation of hydrologically similar areas
- Summary

Introduction

- Most important functionality of GIS
- GIS data basis as a model of reality
- „single layer“ analyses
- „multiple layers“ analyses
- Useful distinction from a technical viewpoint:
  - Functions for analysis in attribute space
  - Functions for analysis by spatial (topological) criteria

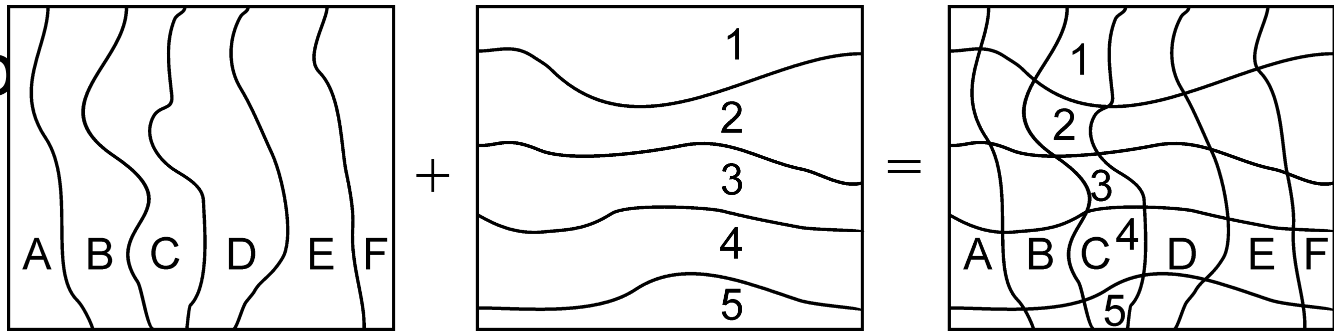
Geometric overlay

- Statements about a location combining information from 2 or more thematic maps → „overlay“ of 2 or more maps
- requires common spatial reference
- In matically met
- Ge y (intersection) in vector-GIS re y operators



Geometric overlay

- To



Id1	x	y	z
A			
B			
C			
D			
E			
F			

Id2	r	s
1		
2		
3		
4		
5		

Id12	x	y	z	r	s
A1					
A2					
..					
B1					
B2					
..					
F5					

Analysis in attribute space

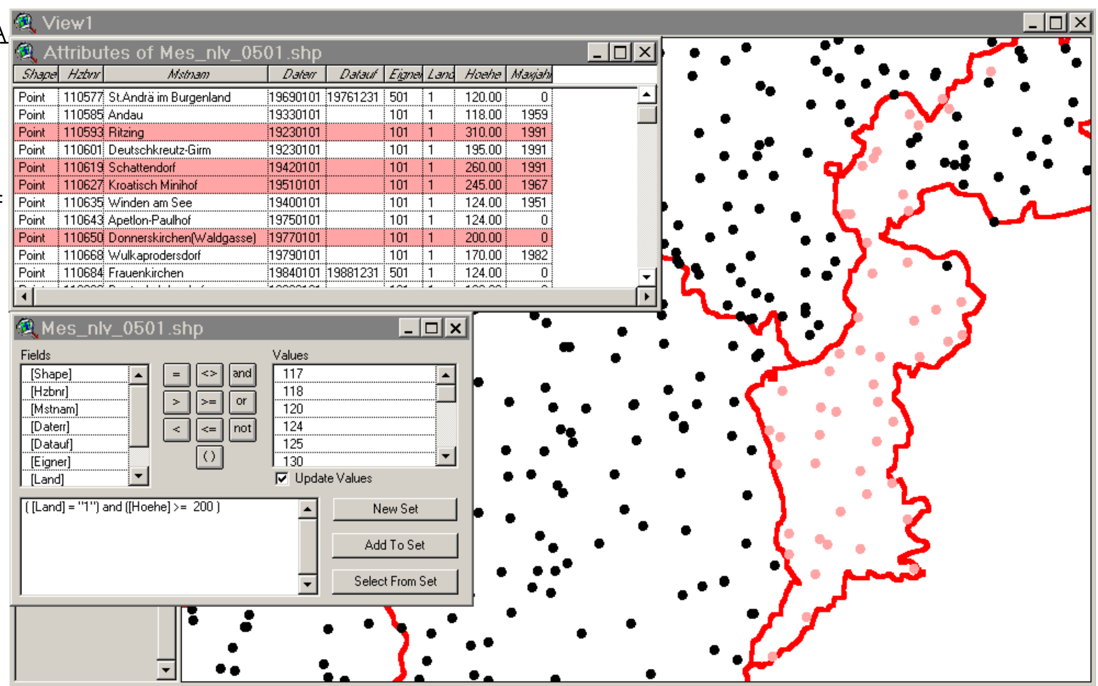
- query,
- generalisation,
- calculation.

Query

- Selection of attribute data, without changes in database
- SQL (Structured Query Language)

```
 SELECT KENNUNG, STA
MESSPUNKT
FROM HEADER_HYDRO
WHERE MESSVARIABLE =
´LICHTLOT´;
```

- ArcView 3.x:



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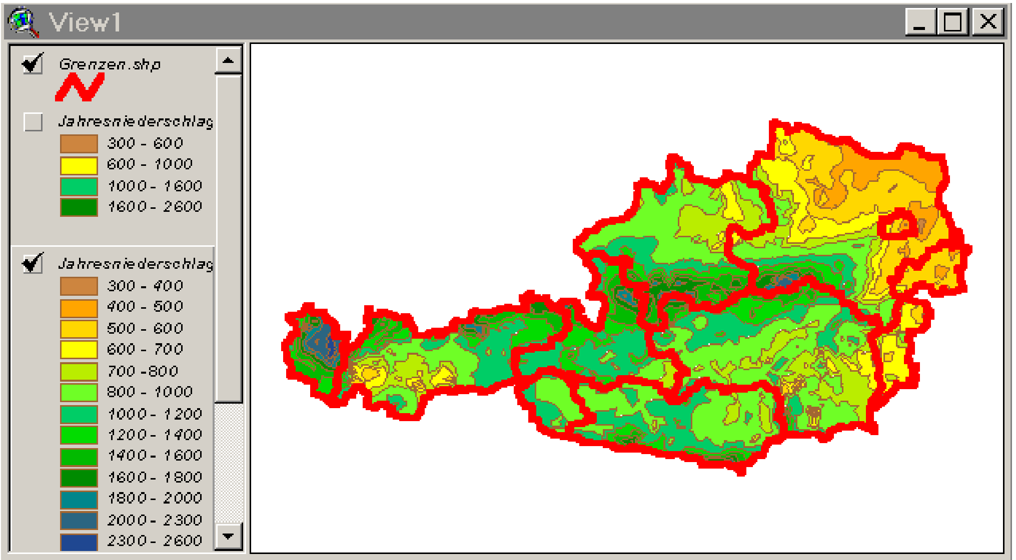
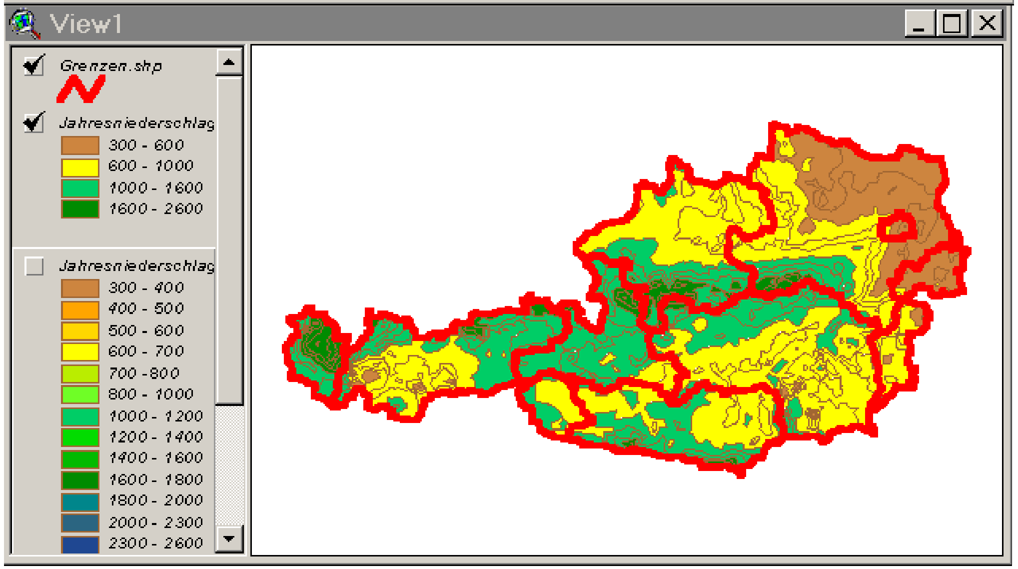
- Generalisation by





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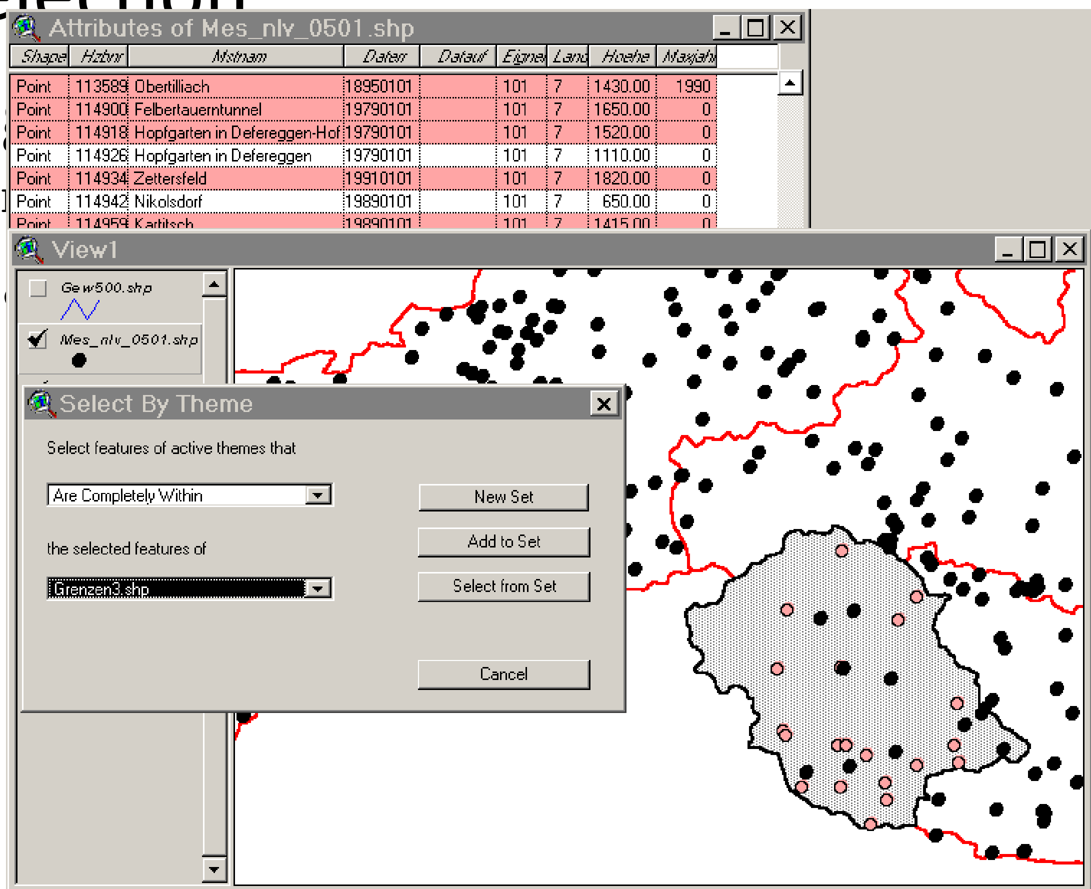
- E.g ... es that Are co... res of Gr...



Classification

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  - Re-classification of a soil map by hydrological cri
  - Sc
    va