Digital soil mapping as a tool for soil protection

I. DSM: introduction and methodology

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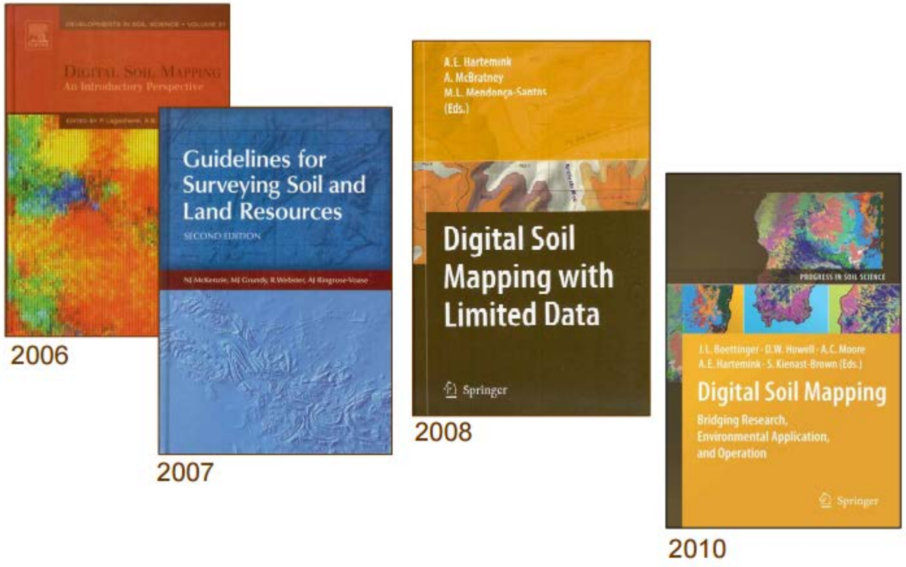
Structure of presentation

- Soil degradation and protection
- Spatial soil information
- Conventional soil mapping
- Why we need DSM?
- Methods of DSM
- Input data
- Validation
- Software and applications
- Case studies



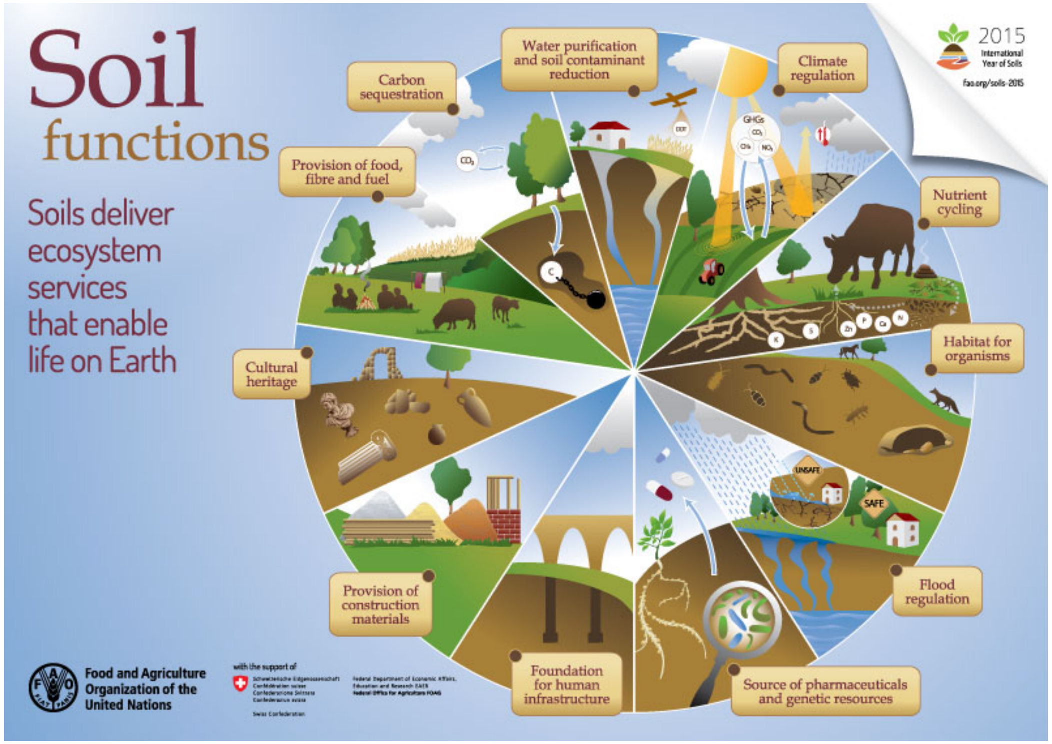
Soil as a non-renewable resource

- Soil an important non-renewable natural resource

- Soil produces about 90% of world human calorie intake !

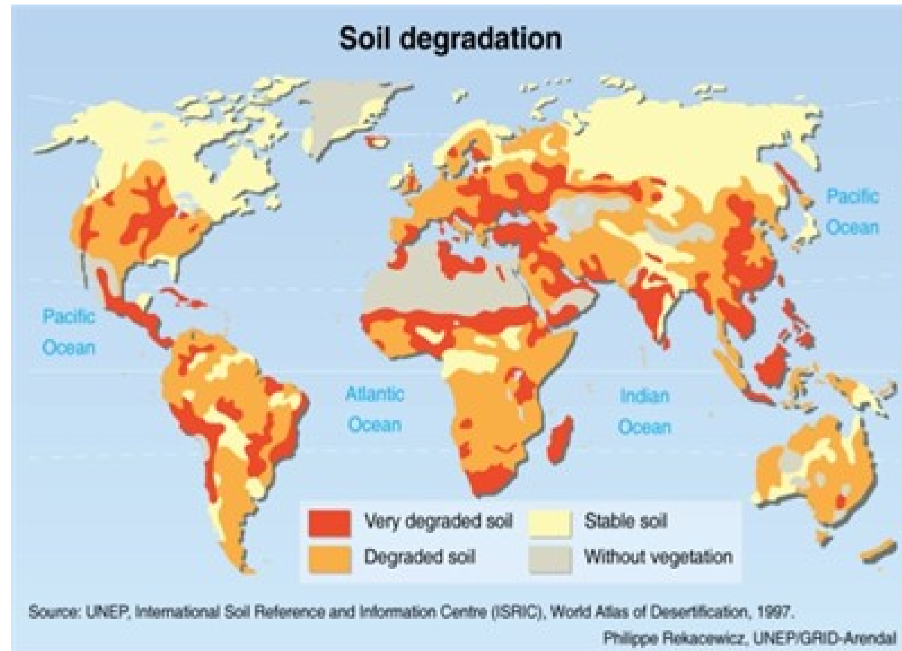
Soil functions

- Food and other biomass production
- Environmental Interaction: storage, filtering, and transformation
- Biological habitat and gene pool
- Source of raw materials
- Physical and cultural heritage
- Platform for man-made structures: buildings, highways



Soil degradation

- a process that leads to decline in the fertility or future productive capacity of soil as a result of human activity



Human induced activities leading to soil degradation:

- Poor agriculture practices
- Extension of cultivation
- Overgrazing
- Deforestation
- Landtake
- Industrial and mining activities
- Overpumping of groundwater

Factors of soil degradation

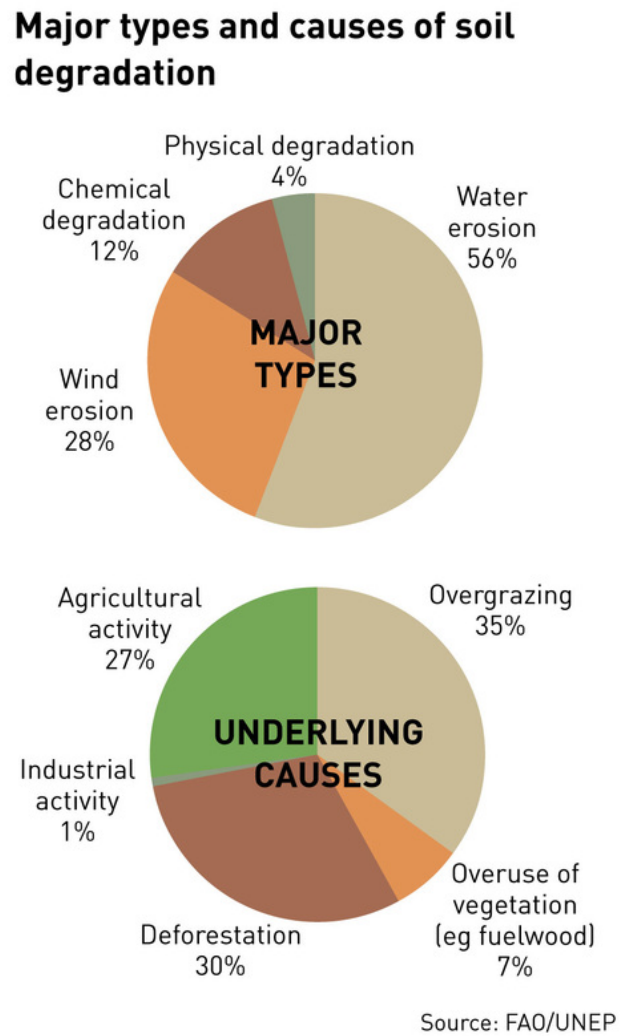
- 1. **Physical factors**, e.g. loss of fertile top soil due to water or wind erosion

- 2. **Chemical factors** e.g. depletion of nutrients or the toxicity due to acidity or alkalinity (salinization) or water logging

- 3. **Biological factors** which affect the micro-flora and reduce the microbial activity of the soil. These factors reduce the yield.

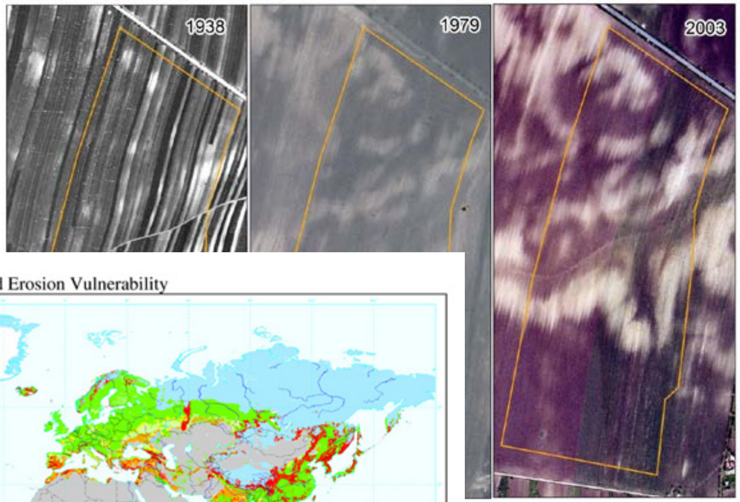
The main reasons for unproductiveness or degradation of soils are as follows:

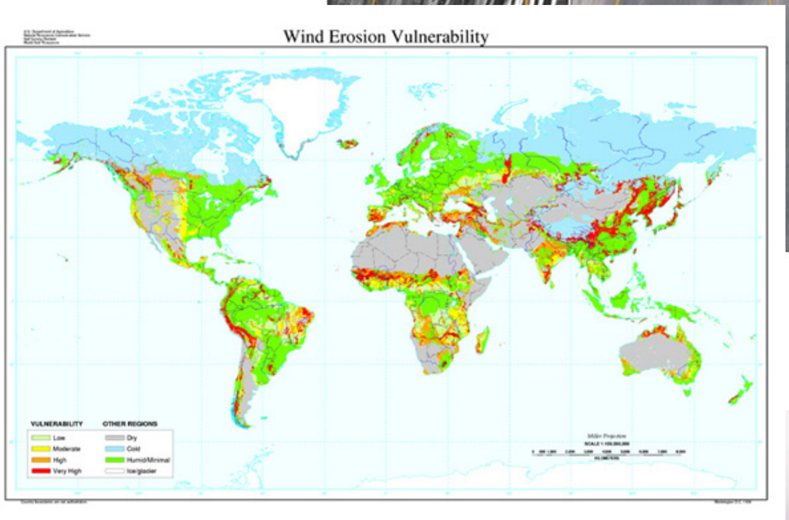
- Erosion
- Compaction
- Salinity
- Contamination
- Nutrient disorder
- Soil sealing
- Water-logging
- Biological degradation
- Other causes....

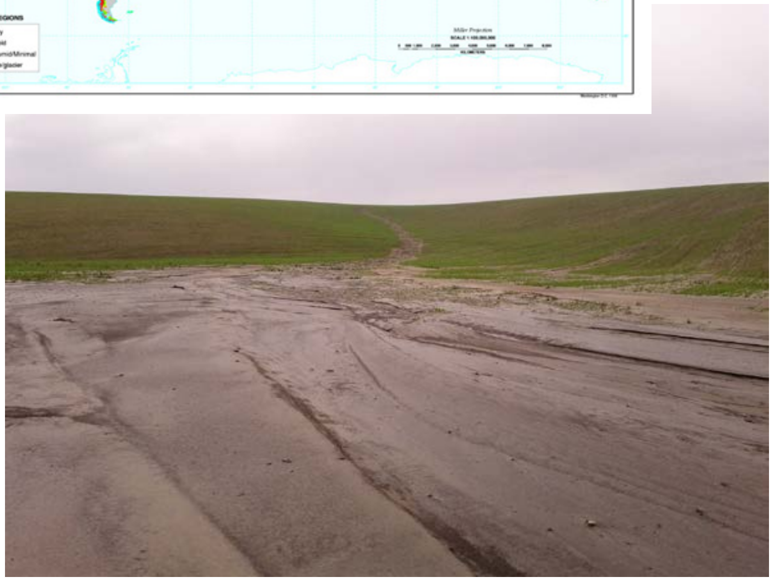


Erosion

- Loss of soil material and nutritions
- Damages to surrounding environments and infrastructure
- Depends on:
  - **Rainfall**
  - **Soil type**
  - **Slope gradient**
  - **Soil use**





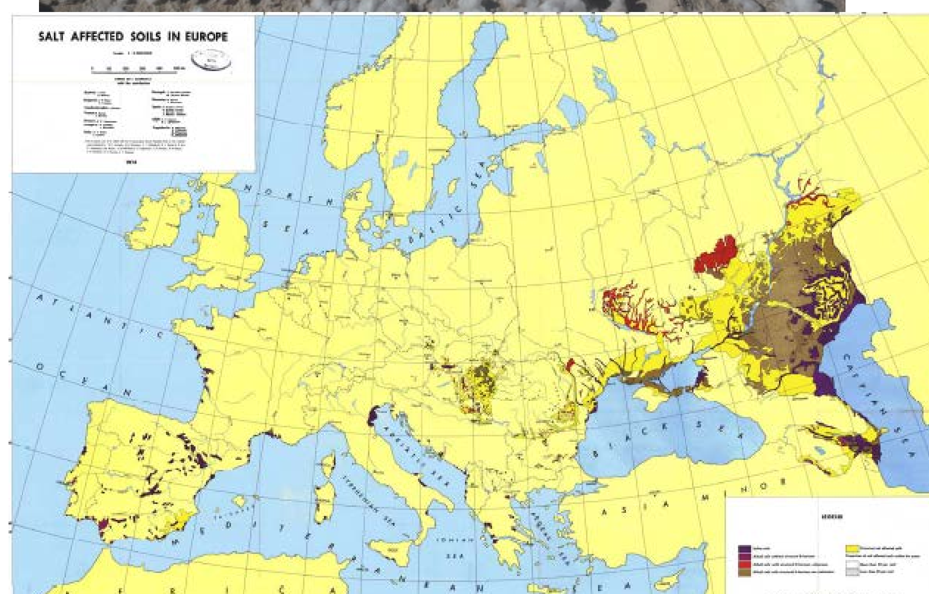


Compaction

- Degradation of physical properies (increase of bulk density)
- Decreased infiltration (erosion, flooding, droughts,…)
- Direct effect of plant grow (limited development of roots)
- Depends on:
  - Soil type
  - management

Salinity

- Increased content of soluble salts
- Depends on:
  - Soil type
  - Climate
  - Geology
  - Terrain settings
  - Management
  - Irrigation practices



Contamination

- Increased content of hazardeous elements or chemicals that can enter into the food chain
- Depends on:
  - Soil type
  - Agriculture practicies
  - Human activities (industry, mining,…)

Soil sealing

- Lost of the agriculture land due to land take
- Depends on:
  - Land planning
  - Population grow
  - Economical development

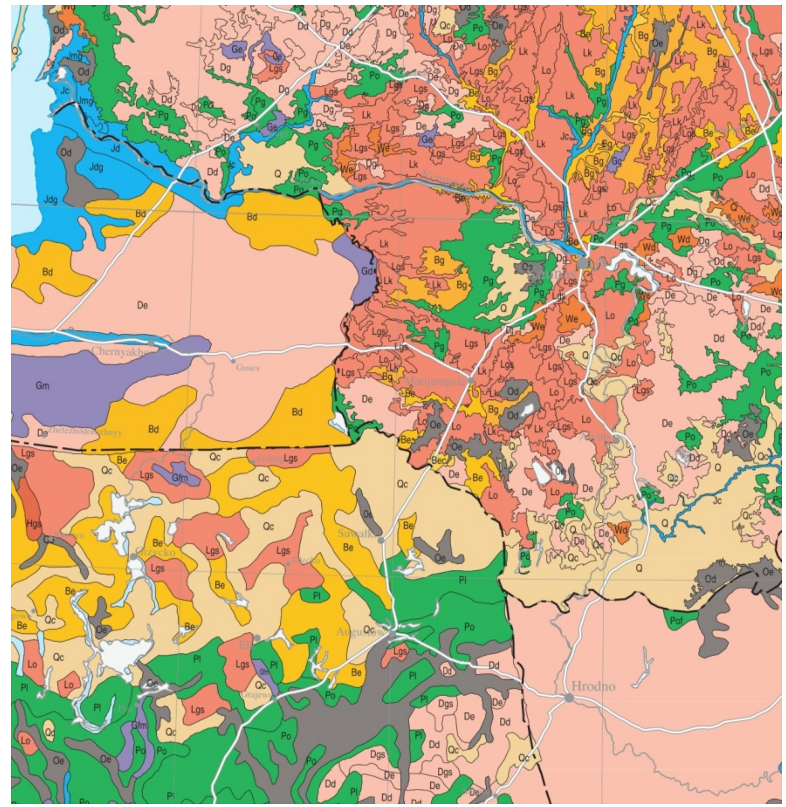
Soil protection

- **What** we protect?
- **Where** we need to protect?
- How we protect?

NEED OF SPATIAL SOIL INFORMATION

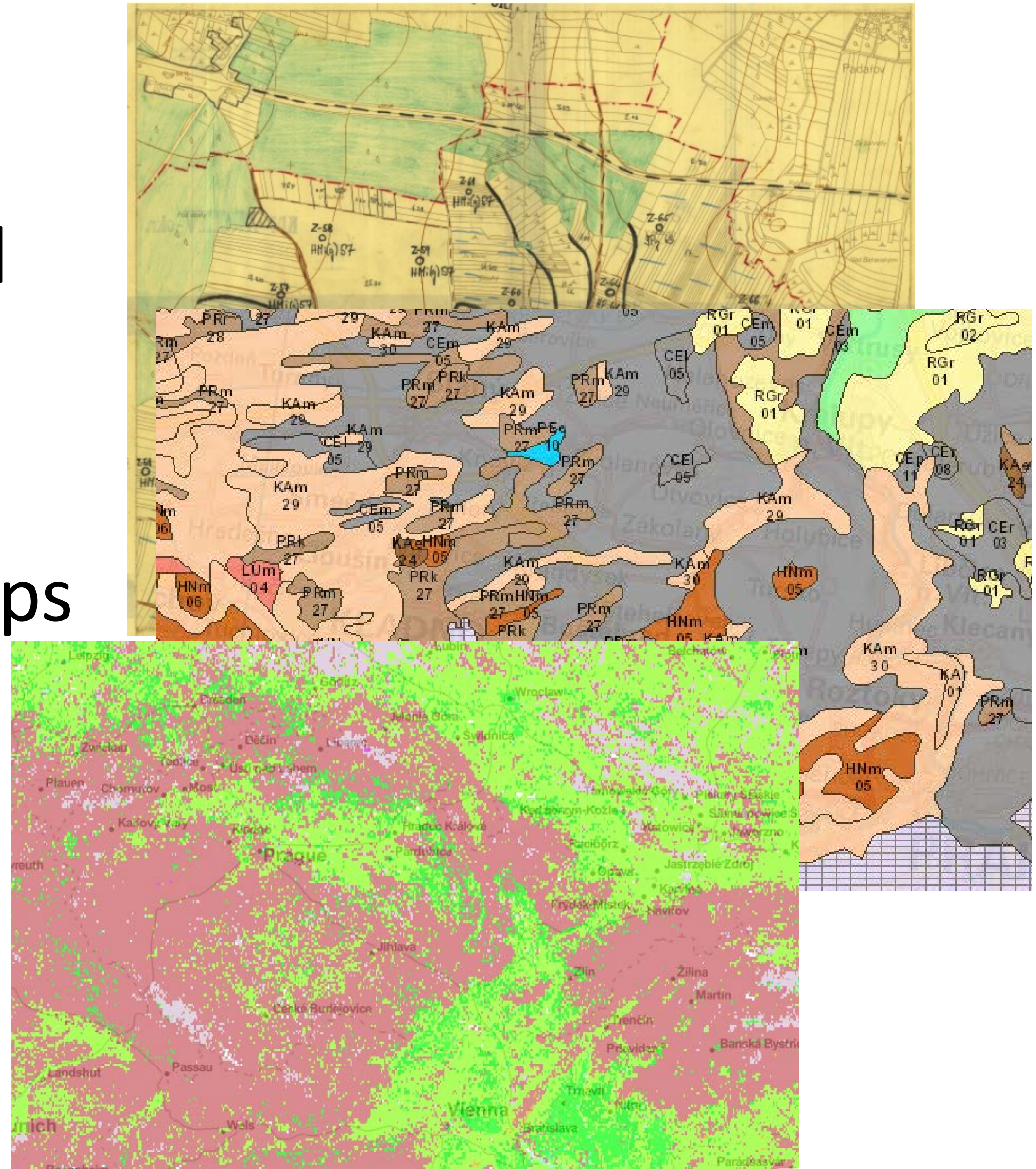
Requirements for soil spatial data

- Spatial and attribute accuracy a precision
- Soil variability description
- Digital format
- Data harmonization
- Knowledge of data accuracy



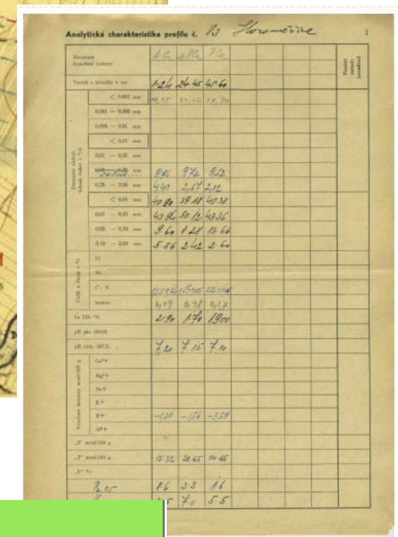
Spatial information on soils

- Traditional (conventional) soil maps
- Digitalized soil maps (geodatabases)
- Digital soil maps



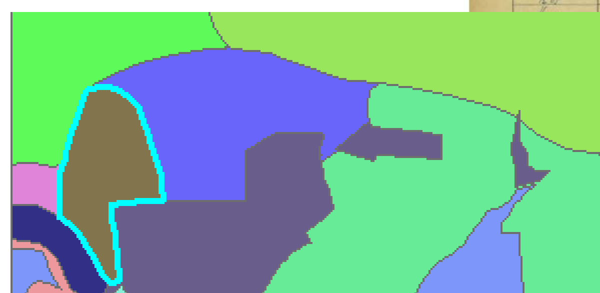
Map x geo(graphical) database

- MAP - analogue paper maps
  - Accompanied by report and typical soil profiles description



- GEODATABASE
  - vectorised maps with connected database (tabular data) connected to the polygons

    raster map (ussually obtained by rasteraing vector maps or by modelling



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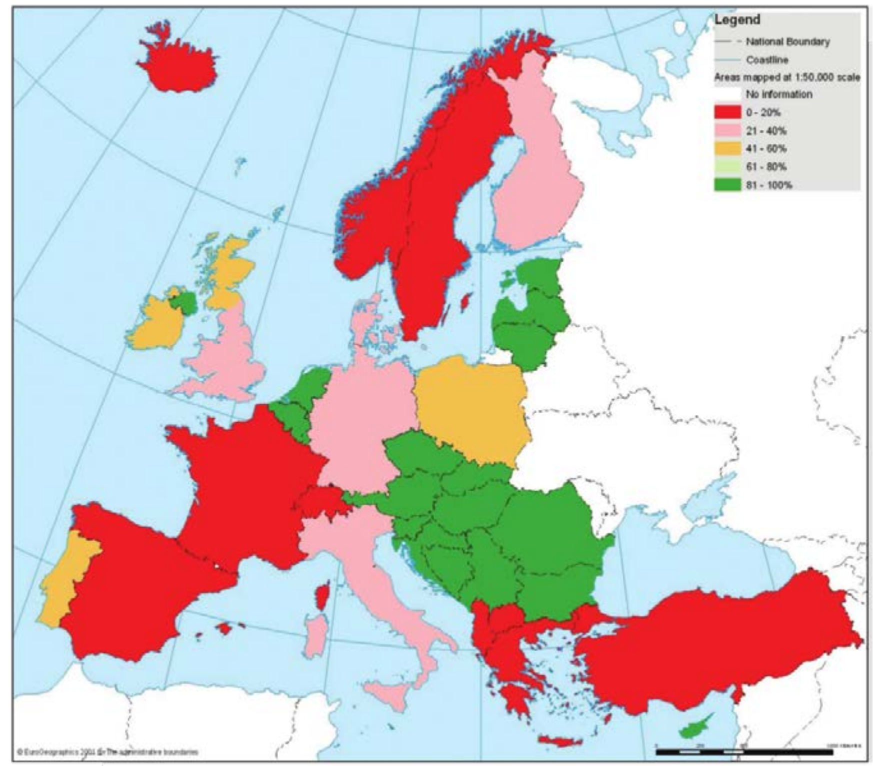
19	Polygon	20	141680	1.41.68	1416
20	Polygon	21	141780	1.41.78	1417
21	Polygon	22	160000	1.60.00	1600
22	Polygon	23	162000	1.62.00	1620
23	Polygon	24	210000	2.10.00	2100
24	Polygon	25	226040	2.26.04	2260
25	Polygon	26	226040	2.26.04	2260

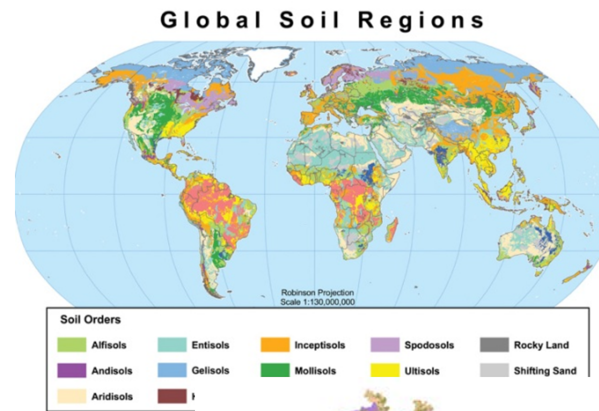
Existing soil maps and databases

- based on traditional soil survey/mapping
  - legacy data
- limited availability
  - big regional differences
- missing harmonisation
- data format
  - Analog (paper maps) or digitized
- age of data

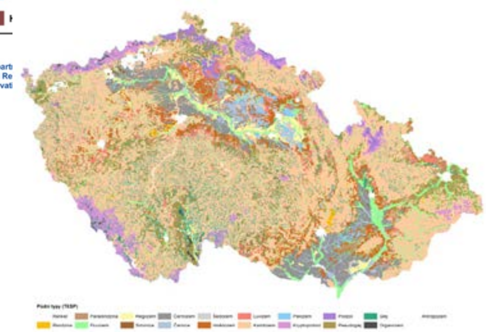


Level of mapping

- Global level
  - FAO, ISRIC (World information center)

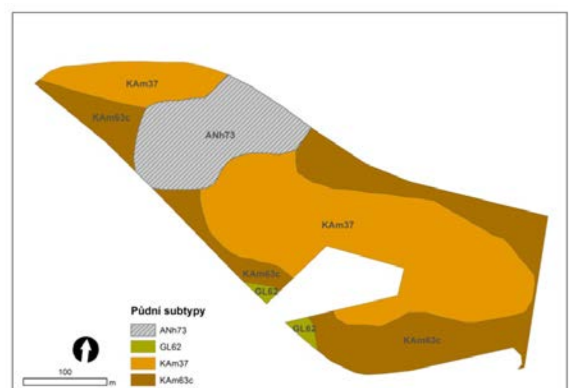


- Regional
  - EU- Joint research centre, …



- National
  - national soil services, …

- Local



Purpose of mapping

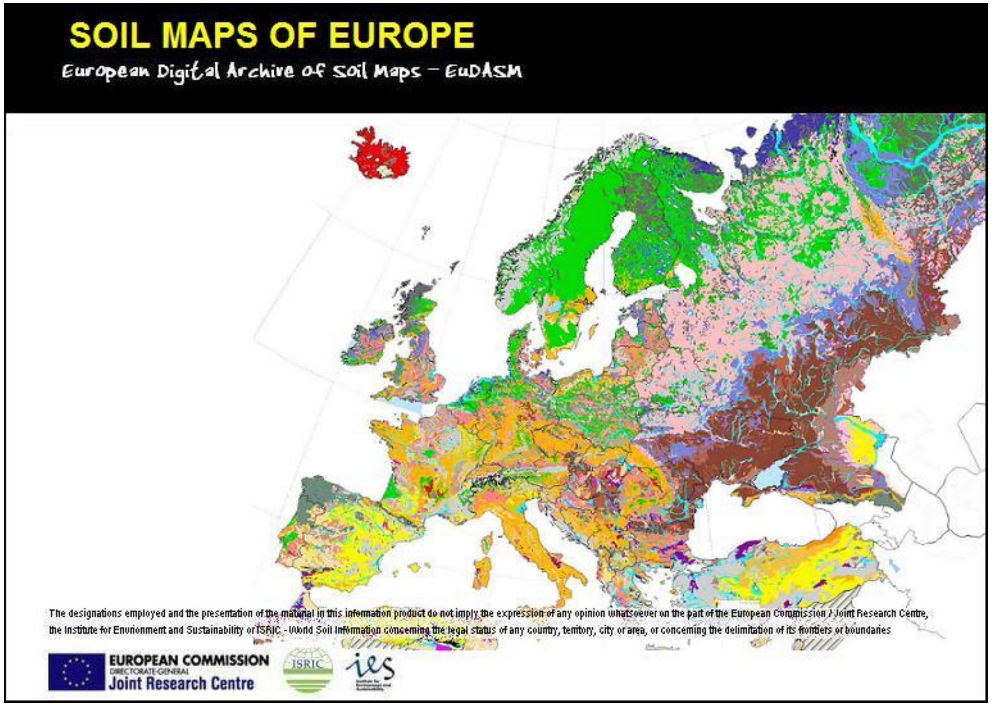
- Global level
  - soil typological units maps
  - General information about land cover
  - **Environmental modeling**
  - Origin: collation of existing information

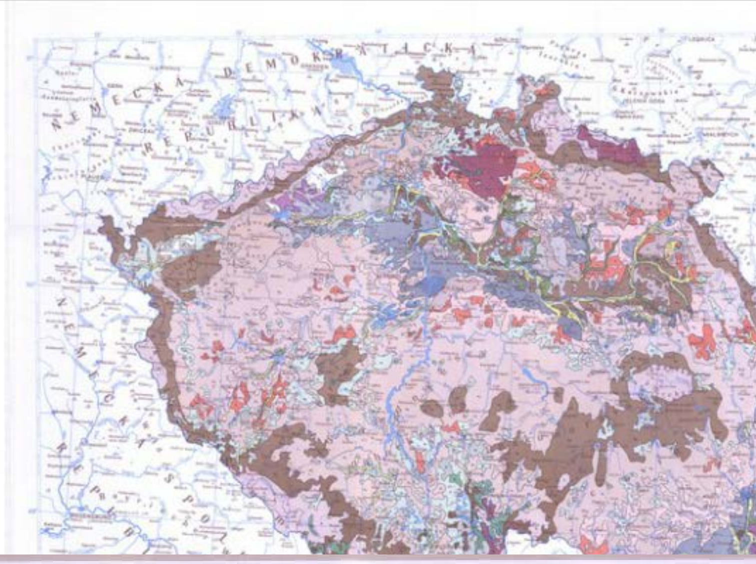
- Regional level
  - Soil typological unit
  - Thematic (property) maps
  - **Environmental and agriculture modeling**
  - Origin: collation of existing information

- National and local level
  - Soil typological units, property maps, interpretation maps, **land quality maps**
  - Agriculture, **hydrology**, **erosion**, taxation, level of subsidies
  - Origin: soil survey

European digital archive of soil maps

- Archive of scanned soil (mainly soil) maps
- Cooperation project of JRC and ISRIC
- Available at: http://eusoils.jrc.ec.europa.eu/esdb_archive/eudasm/indexes/access.htm






ПОЧВЕННАЯ КАРТА КАЗАХСКОЙ ССР
SOIL MAP OF THE KAZAKH SSR
1:2 500 000


ПОЧВЕННАЯ КАРТА СРЕДНЕАЗИАТСКИХ РЕСПУБЛИК
Масштаб 1:2 500 000

Pros /Cons

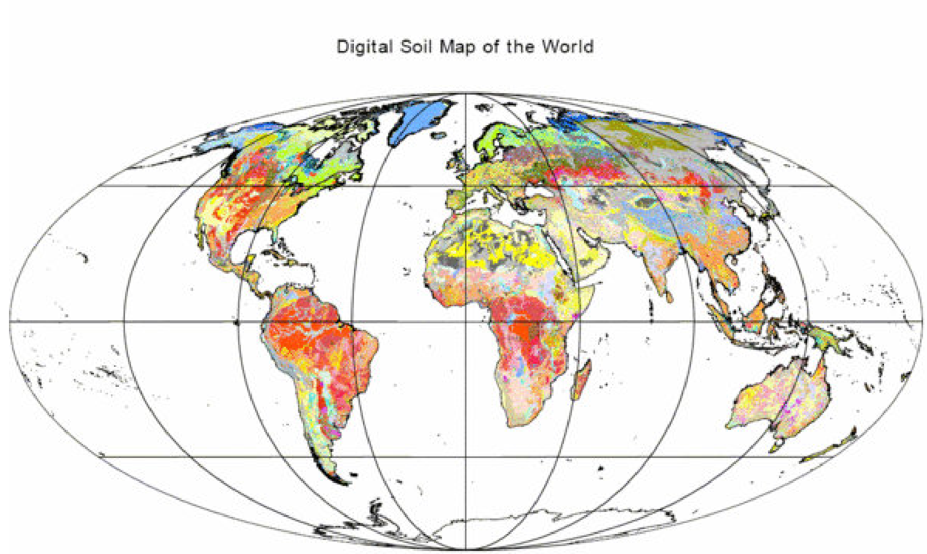
+ Preservation of legacy data

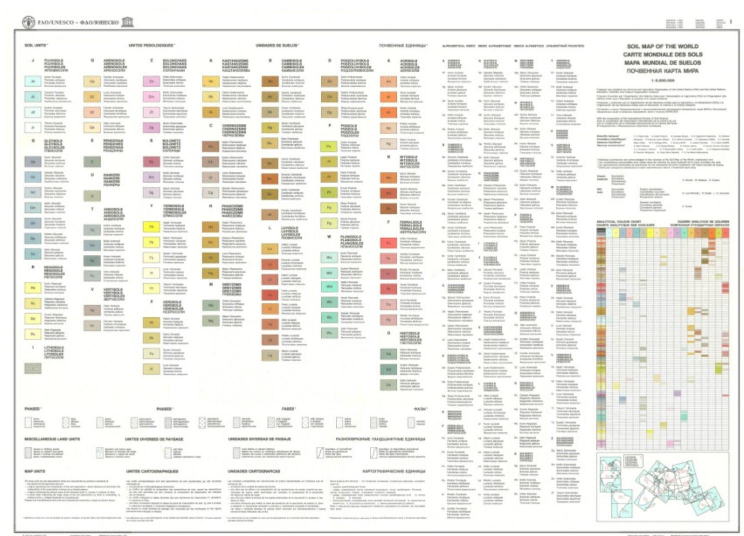
- Partial digitalization
  - only scanned,
  - not georeferenced maps
  - no attribut data
  - no.....

FAO world map 1:5M

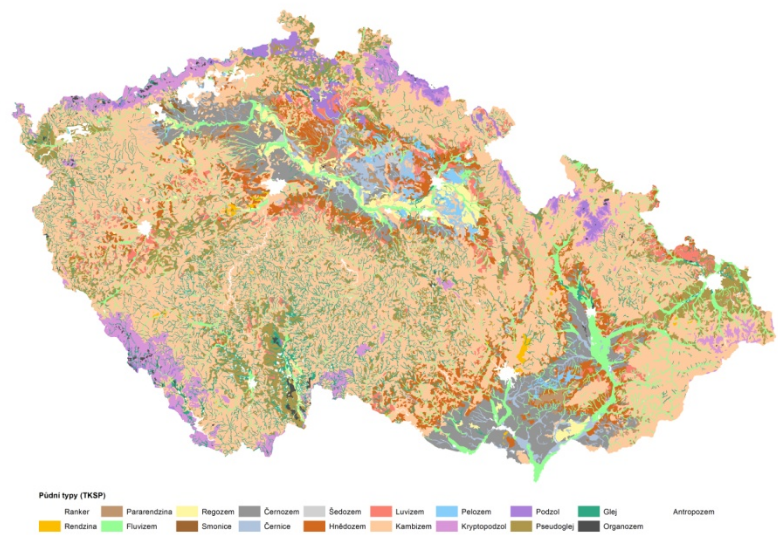
- Scale 1:5M
- Iniciated in 1961
- Leged serves as internationally recognised soil classification
- Vector and raster maps
- Soil units maps + some property maps (pedotransfer functions)
- Available at:

  http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/faounesco-soil-map-of-the-world/en/






Pl 5-1ab
Lo 73-2ab
Lo 78-1/2a
Bd 67-2b
Bd 72-2b
Bd 67-2b
Bd 72-2b
Ch 21-2ab
Be 120-2bc
Bd 71-1/2 b
Lg 43-2ab
Lo 92-2b
Lo 15-2ab
Hc 2-2a
PRAHA


Půdní typy (TKSP)
Ranker
Pararendzina
Regozem
Černozem
Šedozem
Luvizem
Pelozem
Podzol
Glej
Antropozem
Rendzina
Fluvizem
Smonice
Černice
Hnědozem
Kambizem
Kryptopodzol
Pseudoglej
Organozem

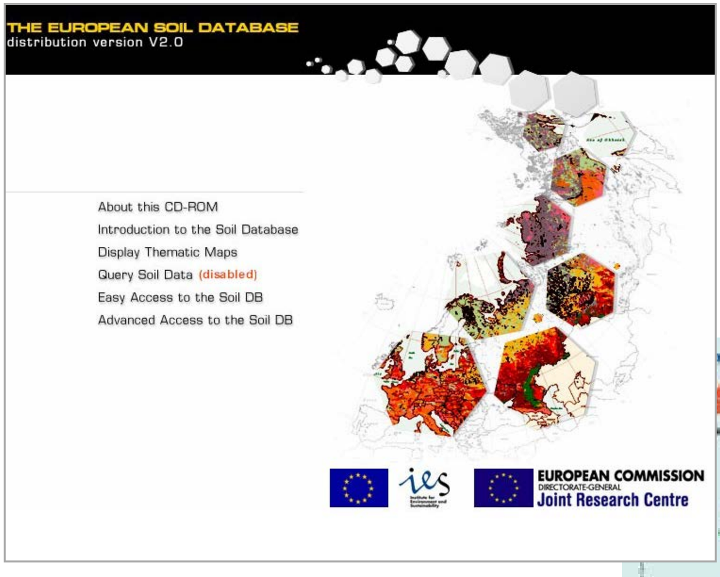
Pros /Cons

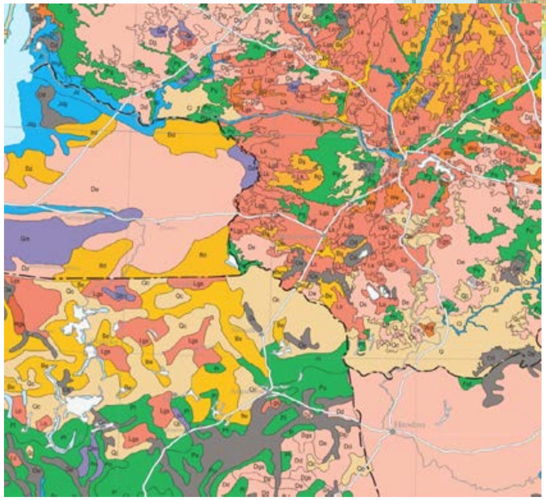
+ Global product
+ Harmonized
+ Digitized

- Resolution
- Complex mapping units
- Missing numerical data
- Typical profiles

European Soil Database 1:1M

- Scale 1:1,000,000
- built on ESDB v1.0 (1999)
- European Soil Information System (EUSIS)
- soil types is based on the terminology of the F.A.O. legend
- database contains a list of Soil Typological Units (STU)
- variables (attributes) - texture, the water regime, the stoniness, etc.





European Soil Database

The European Soil Database has 4 components:

- the Soil Geographical Database of Eurasia at scale 1:1,000,000 (SGDBE)
- the Pedotransfer Rules Database (PTRDB)
- the Soil Profile Analytical Database of Europa (SPADBE)
- the Database of Hydraulic Properties of European Soils (HYPRES)

Pros /Cons

+ regional product
+ Digitized
+ Numerical data
+ Pedotrasfer fuctions

- Resolution
- Complex mapping units
- Partial harmonisation
- Typical profiles

WISE – Harmonised soil profile database

- compilation from a wide range of soil profile data
- 10,250 soil profiles
- 47,800 horizons
- Non regular geographic distribution of the data
- ISRIC
- Report: http://www.isric.org/sites/default/files/ISRIC_Report_2008_02.pdf

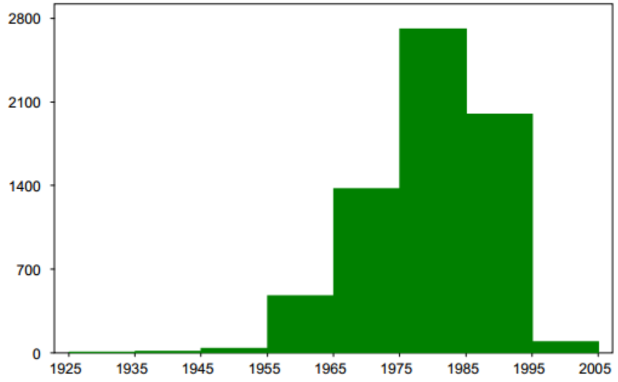


Figure 4. Frequency by sampling year of WISE3 holdings
(6685 cases plotted, 3568 cases no data)

Pros /Cons

+ Global product
+ Harmonized
+ Digital

- Irregular spatial representation
- Age of data

National soil mapping programs

- Different level of data existence and availability
- Data are based on soil survey
- Local national soil services
- Purpose:
  - agriculture production
  - Hydlology and environmental modelling
  - Land quality and taxation

Pros /Cons

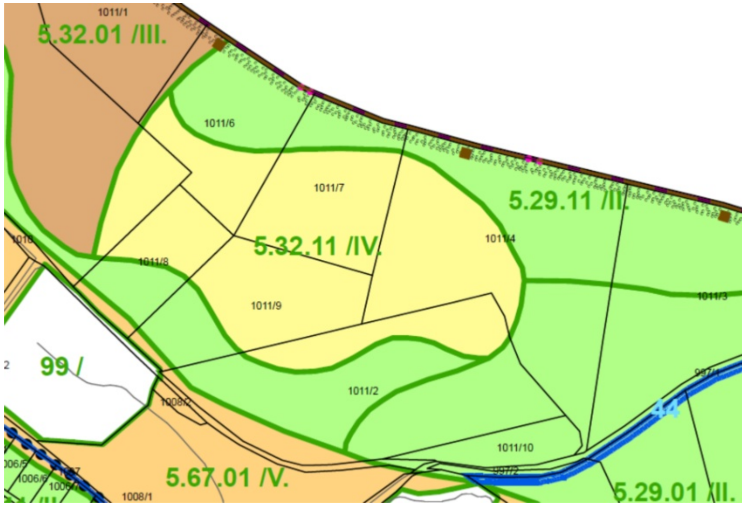
+ High resolution
+ Real data

- Age of data
- No harmonization
- Different format of data

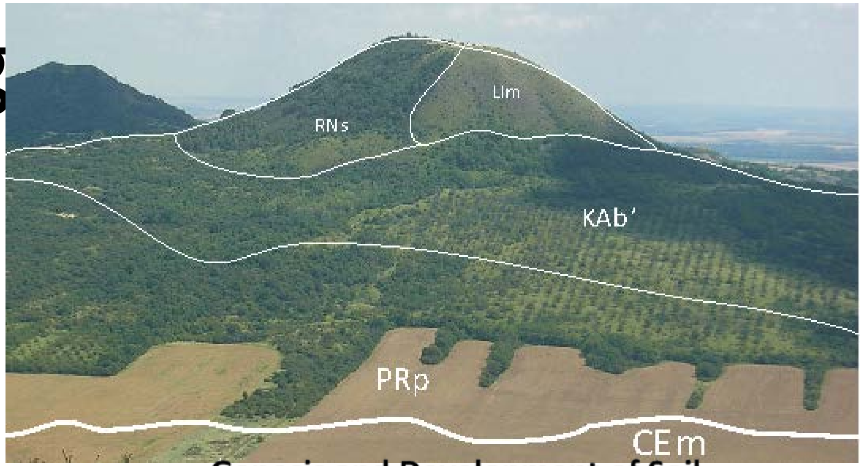
Tradition soil mapping

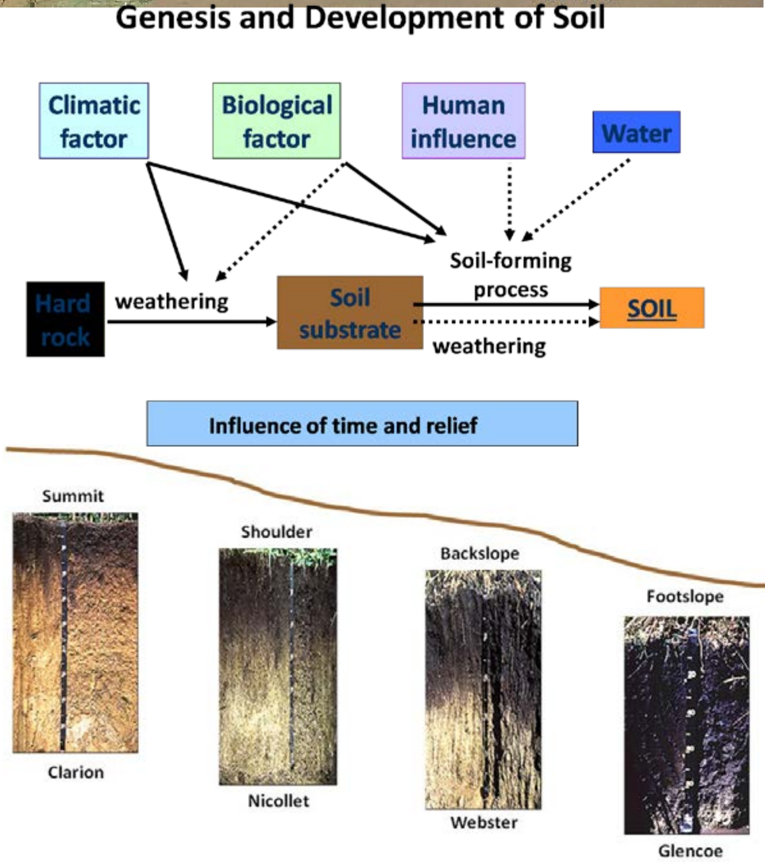
- Expert knowledge = mental and verbal models of soil surveyors are used to delineate the maps

- S = (cl, o, r, p, t, …) (Jenny, 1941)
  - Soils are determined by the influence of soil-forming factors on parent materials with time.
    - Parent material
    - Climate
    - Organisms
    - Relief
    - Time
    - …
- No quantitative definition of the relationship



Tradition soil mapping



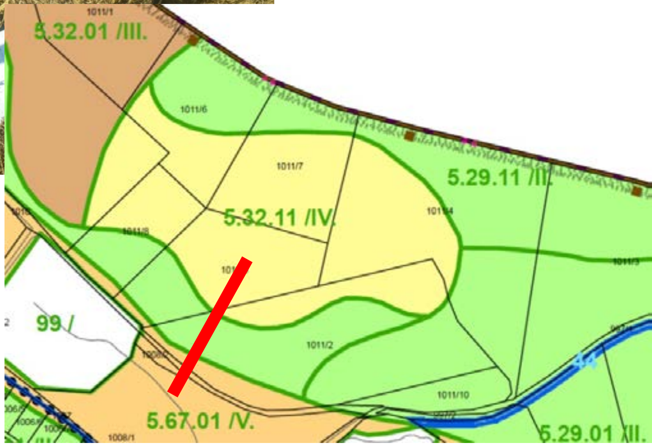


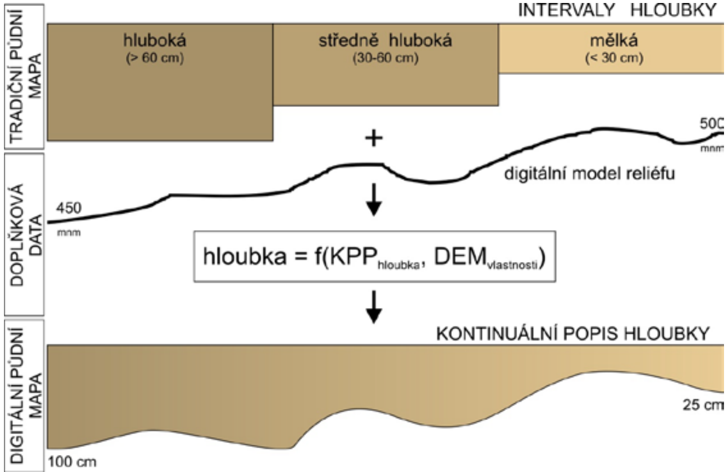
- The soil-landscape model is derived as a mental model of soil surveyors

Tradition soil mapping

- Based on soil survey
  - Expert knowledge approach
  - Unknown accuracy

- Polygon based maps
  - Homogenous areas
  - Mapping units
  - Discrete delineation

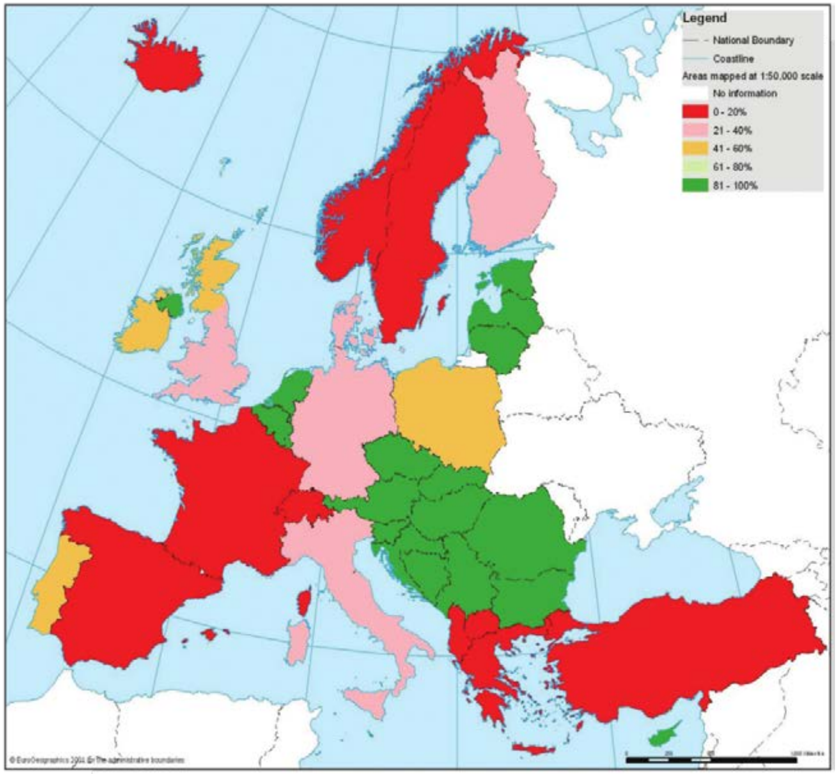




Digital soil mapping (DSM)

Why do we need DSM?

- Missing soil spatial data
- Cost of traditional soil survey
- Data update and harmonization
- Continuous spatial data representation

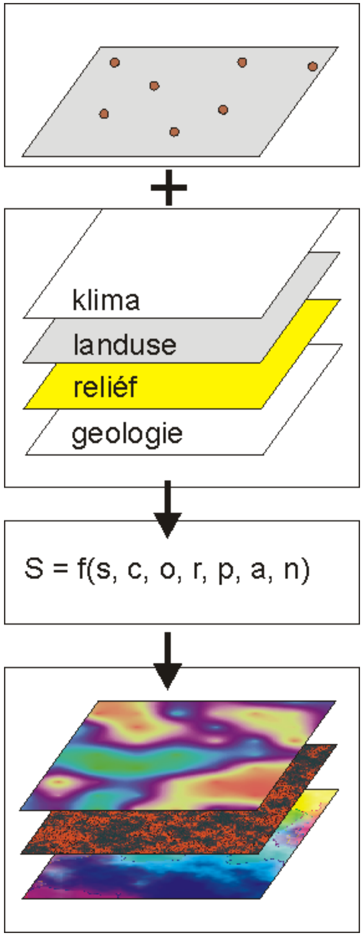


DSM - concept and definitions

- Synonyms:
  - Predictive mapping
  - Pedometrics

- Computer assisted production of soils and soil properties.

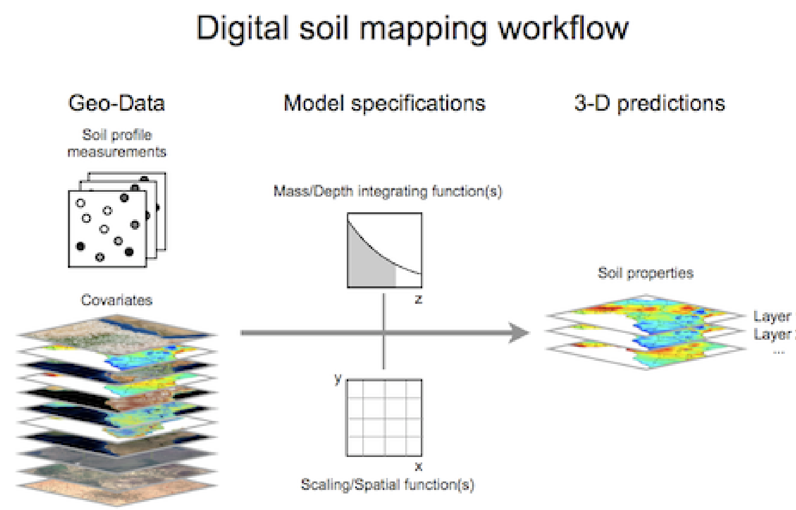
- Mail difference between traditional soil papping and digital soil maping:
  - „expert knowledge“ x quantitative soil modelling



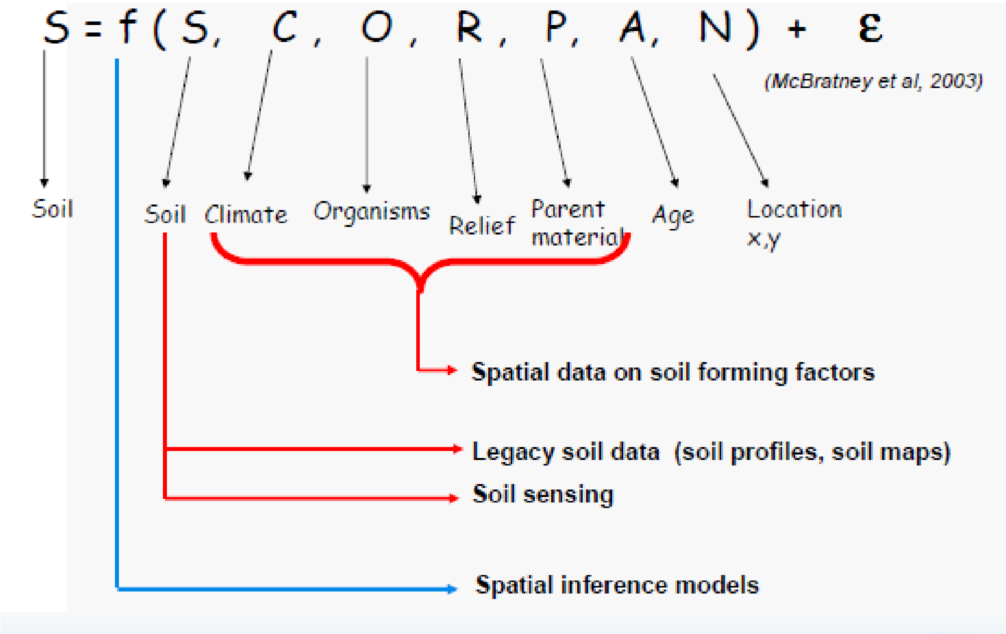
Digital soil mapping

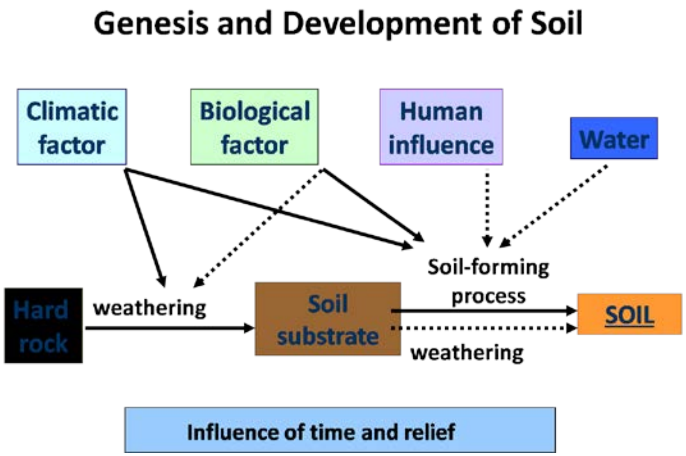
- Quantitative definition between soil and soil farming factors + spatial influence of soils

- **S = f(s, c, o, r, p, a, n, …)**
  - Soil variability is understood as:
    - Soil attributes measured at a specific point
    - Climate
    - Organisms
    - Relief
    - Parent material
    - Age (time)
    - Space



Digital soil mapping





Main steps in DSM:

- Step 1: Aim of soil mapping
  - Aim and resolution
  - Soil units/properties
- Step 2: Data
  - Soil data
  - Auxiliary data
- Step 3: Data collection
  - Soil data
  - Auxiliary data
- Step 4: Model definition
  - Model application
  - Output data (format, ….)
- Step 5: Validation
  - Methods, approaches

L SOIL MAPPING WG Technical report

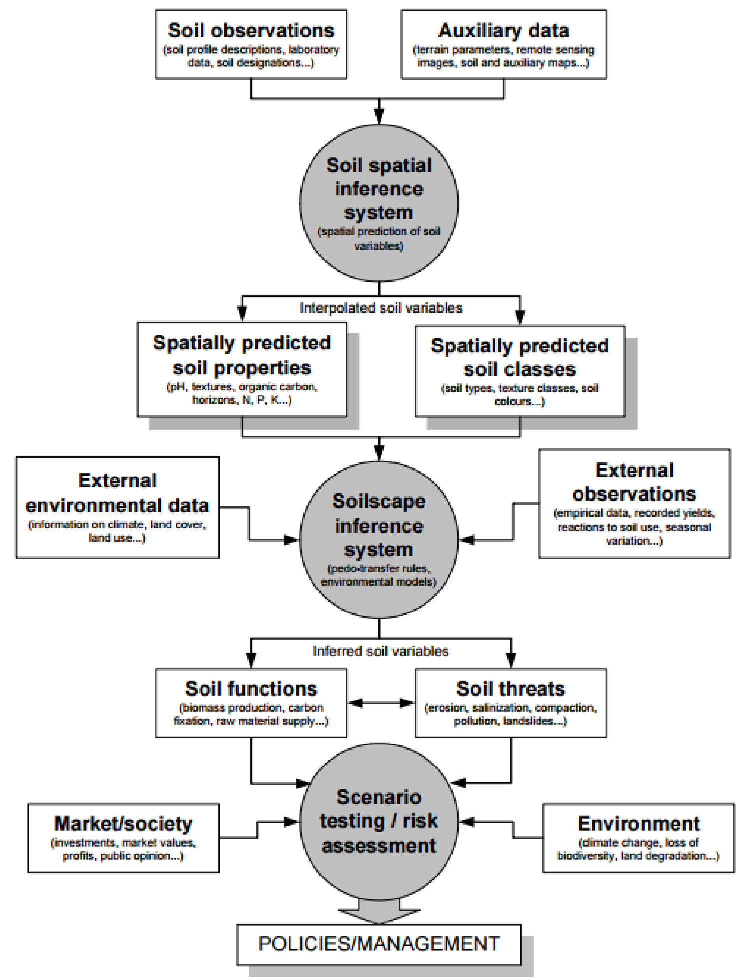


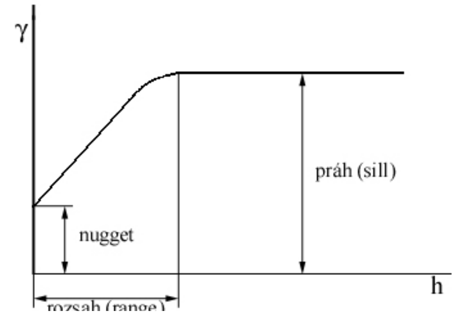
Fig. 1.1. Digital Soil Mapping steps for decision-making and policies management

History of DSM approaches

- Models based on:
  - Spatial statistics (geostatistics)
  - Combined methods
  - SCORPAN

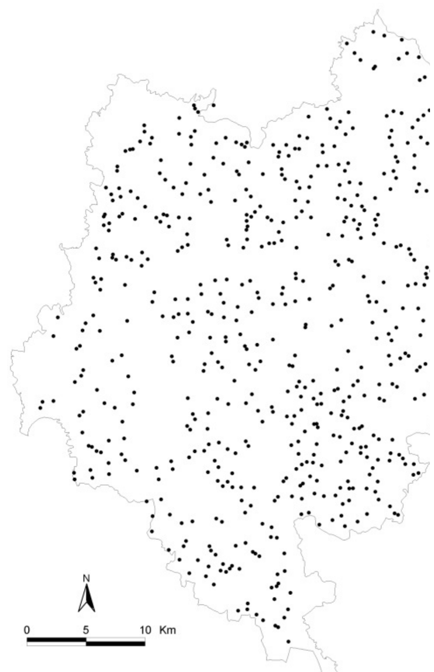
Geostatistics

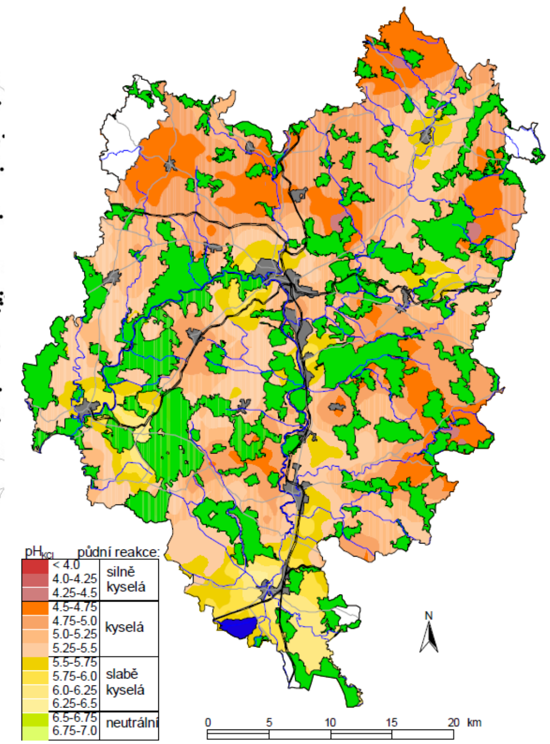
- Description of spatial variability of soil properties



Geostatistics is used to:

- map and identify the spatial patterns of given attributes across a landscape.
- improve the efficiency of sampling networks.
- identify locations in need of remediation (disjunctive kriging→Probability map)



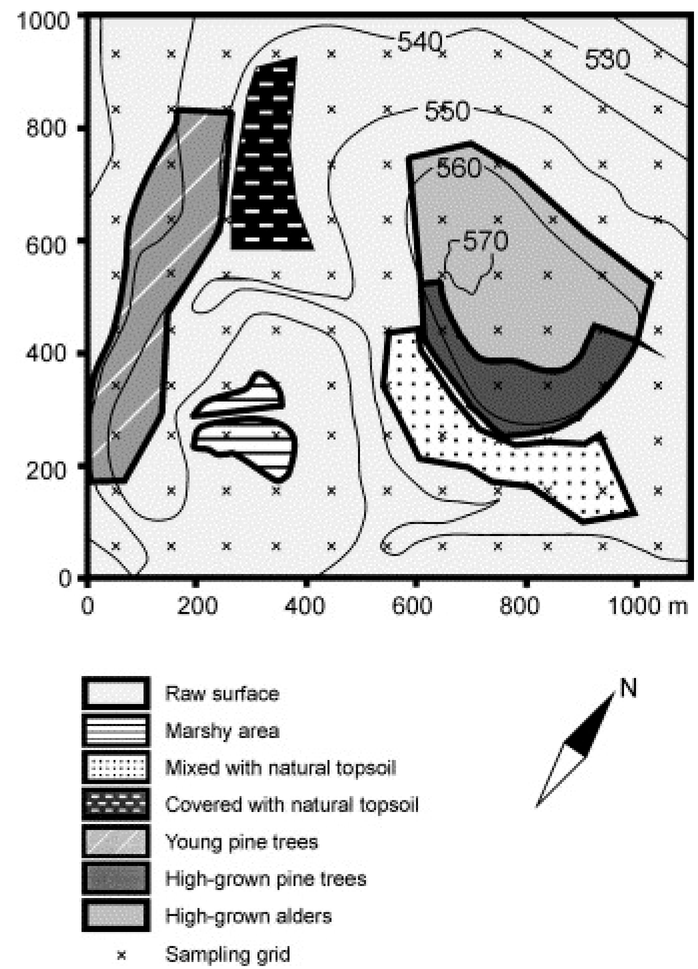


Penížek (2002)

- It is not possible to sample every location.

- Therefore, unknown values must be estimated from data taken at specific locations that can be sampled.

- The size, shape, orientation, and spatial arrangement of the sample locations are termed the support and influence the capability to predict the unknown samples.



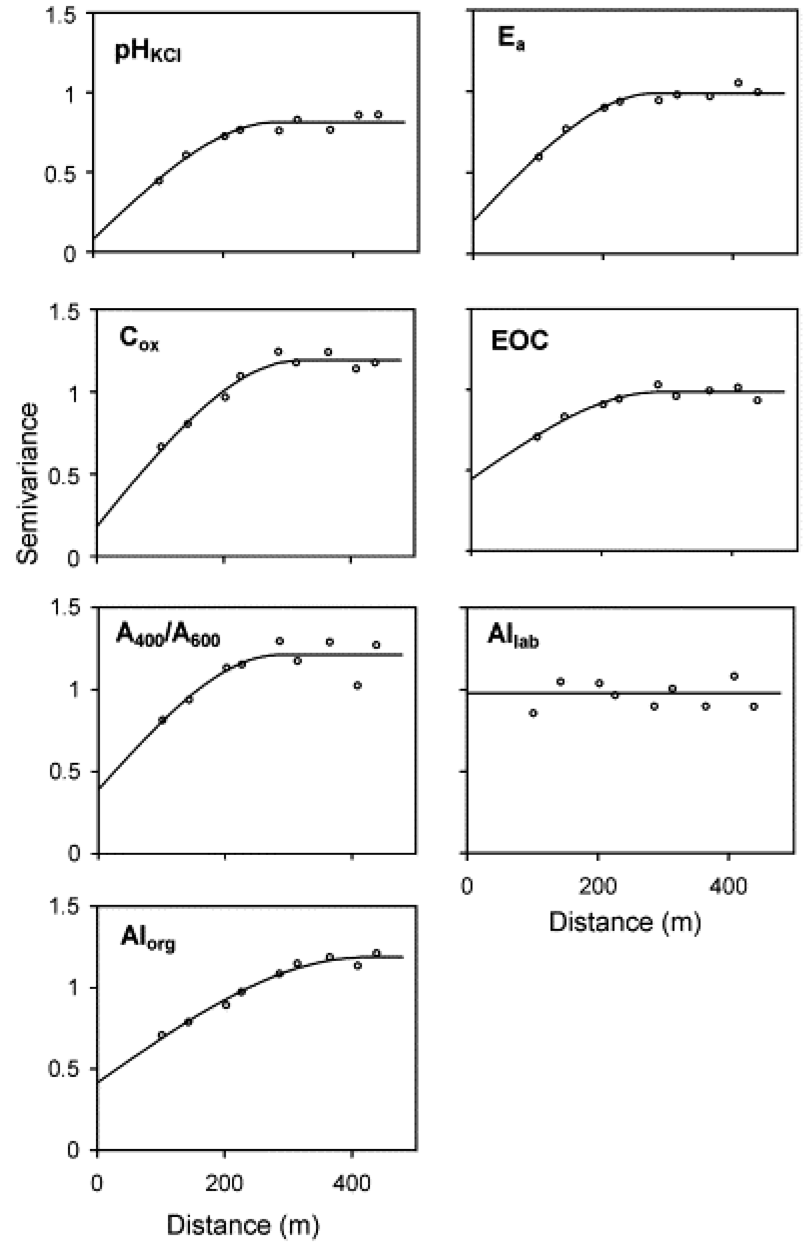
Semivariance

- Z_i is the measurement of a regionalized variable taken at location i ,
- Z_{i+h} is another measurement taken h intervals away *d*
- N_h is number of separating distance = number of points –Lag (if the points are located in a single profile)

$$\boxed{\gamma(h) = \frac{1}{2N_h}\sum_{i=1}^{N_h}(z_i - z_{i+h})^2}$$

Semivariance

- semivariance :The magnitude of the semivariance between points depends on the distance between the points. A smaller distance yields a smaller semivariance and a larger distance results in a larger semivariance.



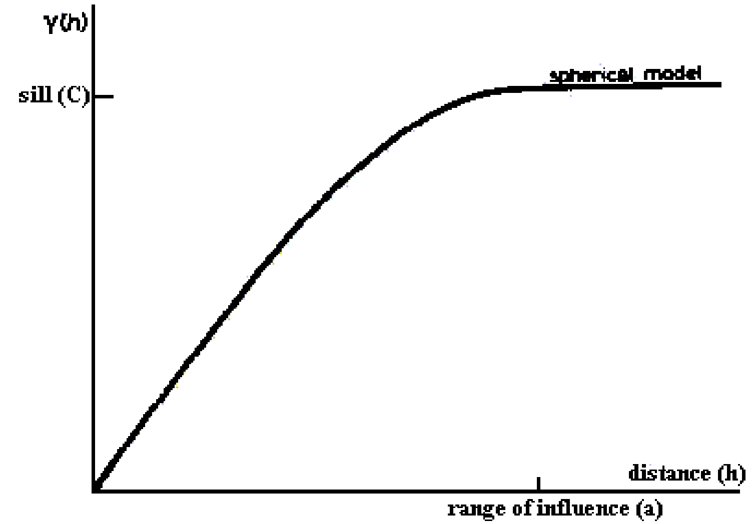
Variogram

- The semivariance at a distance d = 0 should be zero, because there are no differences between points that are compared to themselves.

- However, as points are compared to increasingly distant points, the semivariance increases.

- The range is the greatest distance over which the value at a point on the surface is related to the value at another point.

- The range defines the maximum neighborhood over which control points should be selected to estimate a grid node.

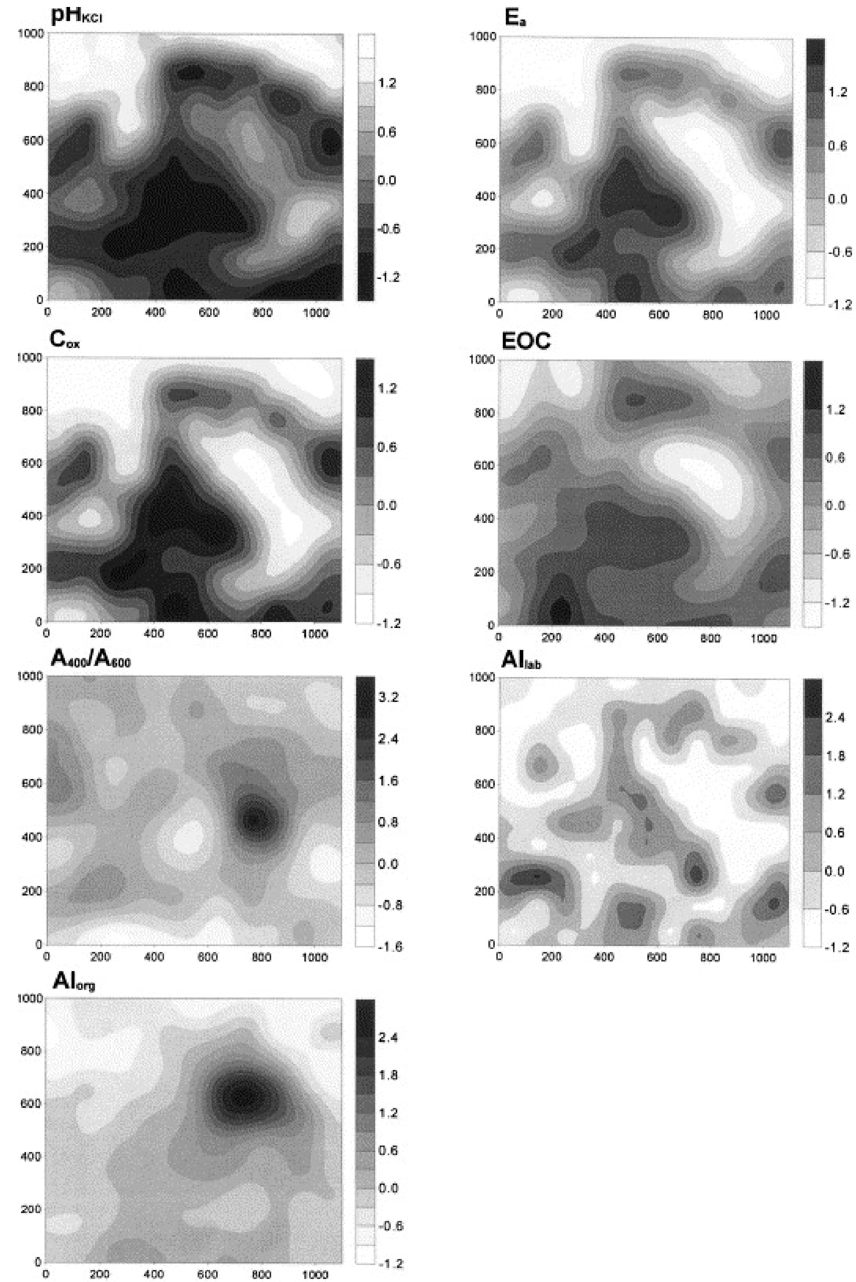


Kriging Interpolation

- The procedures involved in kriging incorporate measures of error and uncertainty when determining estimations.

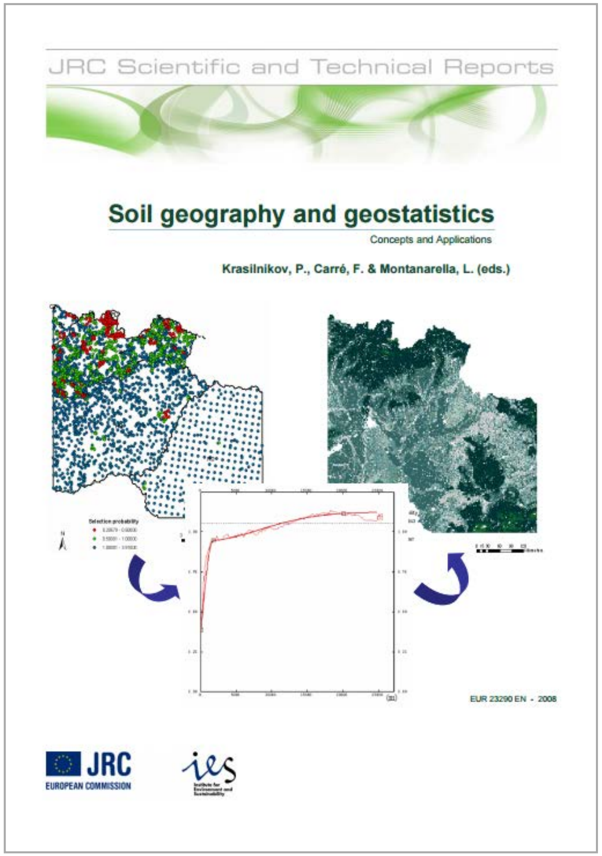
- Based on the semivariogram used, **optimal weights** are assigned to known values in order to calculate unknown ones.

- Since the variogram changes with distance, the weights depend on the known sample distribution.



Variogram Modeling Suggestions

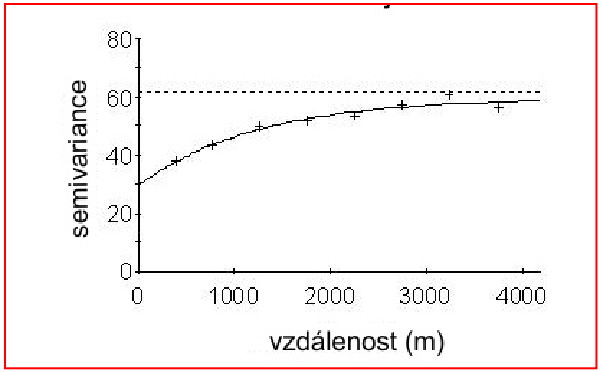
- Check for enough number of pairs at each lag distance (from 30 to 50).
- **Removal of outliers**
- Truncate at half the maximum lag distance to ensure enough pairs
- Use a larger lag tolerance to get more pairs and a smoother variogram
- Use transforms of the data for skewed distributions (e.g. logarithmic transforms).



Combined methods

- other variable are used to make better predictions of main variable of interest

- Different methods:
  - Co-kriging
  - Regression kriging
  - Factorial kriging



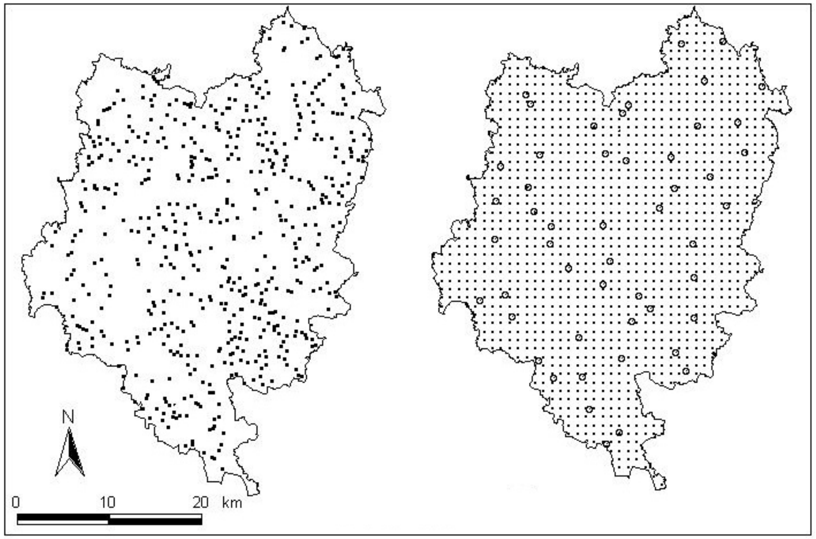
Soil depth=88,8 +1,20*ASPECT +0,0573*ALTITUDE – 2,491*SLOPE

	Nr.	Mean (cm)	S.d.	Min. (cm)	Max. (cm)	Range (cm)	t	P	
DEPTH	50	112	592,2	50	150	100			
BK	50	110	160,7	86	136	50	0,527	0,601	
VK	50	108	236,0	67	140	73	1,073	0,289	
REK	50	79	155,1	52	106	54	7,684	< 0,001	*
RE	50	109	9,7	103	116	13	0,793	0,431	

Penížek a Borůvka (2004)

Combined methods

- interpolation technique that allows one to better estimate map values by kriging if the distribution of a secondary variate sampled more intensely than the primary variate is known



- Secondary variable:
  - Another soil properties
  - Auxiliary data (DEM,…)

SCORPAN model

- ***S = f(s, c, o, r, p, a, n)***

  s – soil/soil properties,

  c – climate,

  o – organisms (edafon, plants, men,…),

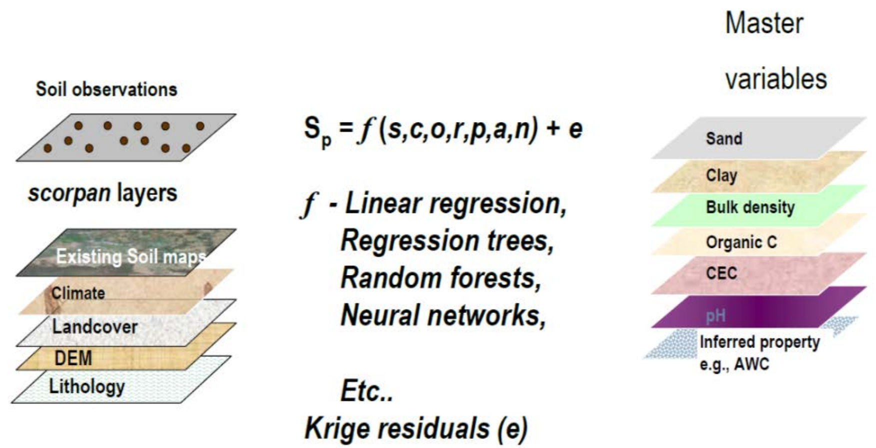
  r – relief,

  p – parent material,

  a – time (age) and

  n – spatial distribtion

  (McBratney et al., 2003).

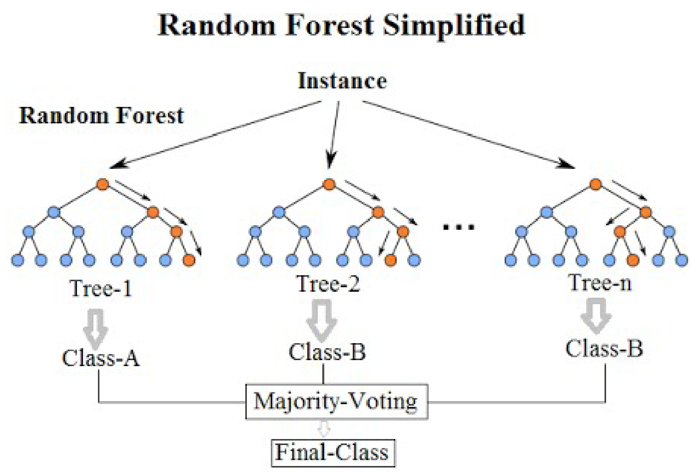


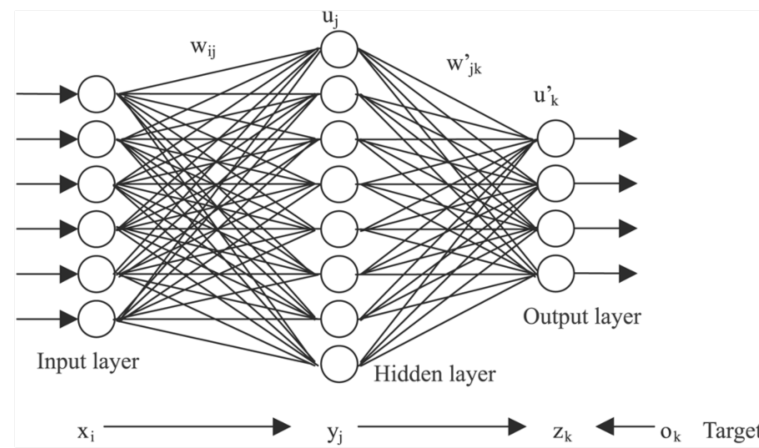
SCORPAN model

- Usually point soil data with full cover of auxiliary data
- Quantitative definition of relationship between soils and auxiliary data
- Many possible models and methods

Scorpan models

- Statistical methods
  - Regression
  - Factorial analysis
  - ....
- Machine learning methods
  - Classification trees
  - Boosted trees
  - Random forest
  - Neural networks
  - Support vector machines





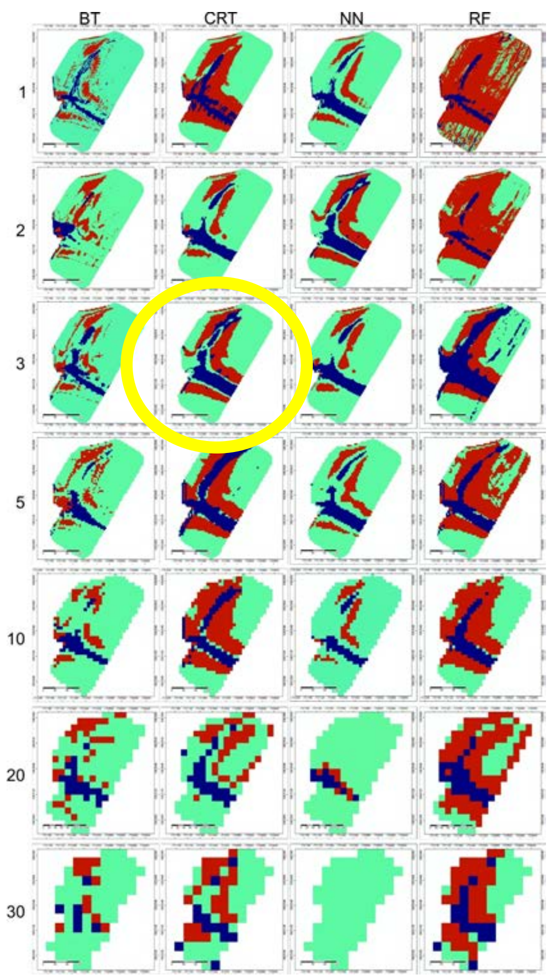
Machine learning methods

- a broad set of models used to discover patterns in data and to make predictions
- most often applied to large databases
- spatial predictions of soil classes

Scorpan models

- Often testing of several methods
  - Enabled by computations capacities
  - Hard to find universal best method

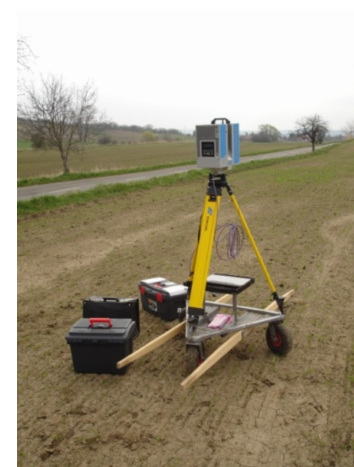
- Comparison by validation
  - Training + validation data set



Soil data $S = f(\boldsymbol{s}, c, o, r, p, a, n)$

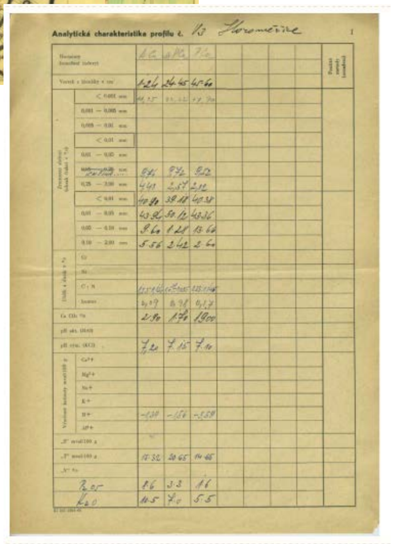
- Legacy soil data
  - Point data (soil profiles,…)
  - High resolution soil maps

- New data collection
  - Direct (soil survey – point data)
  - Sensing (remote sensing, spectroscopy,…)



Soil data: legacy data

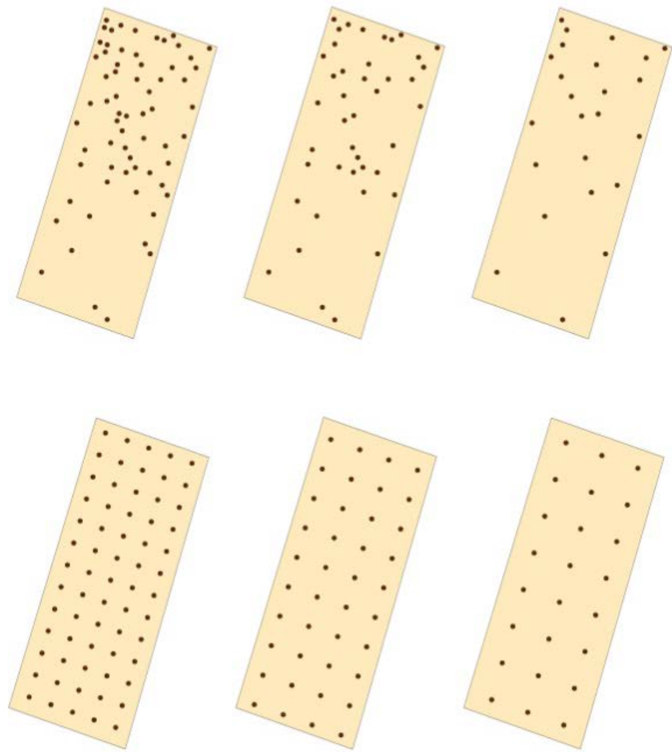
- From conventional soil survey
- Should be taken in consideration:
  - **Age of data**
  - **Sampling scheme**
  - Analytical methods



Soil data: soil data collection

- New soil survey
  - number and location of sampling points is driven by demand of best description of the soil and covariates variability
  - Point data

- Undirect soil data collection
  - Sensing (remote sensing, spectroscopy,…)



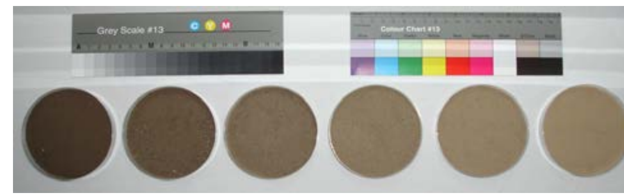
Sampling strategies

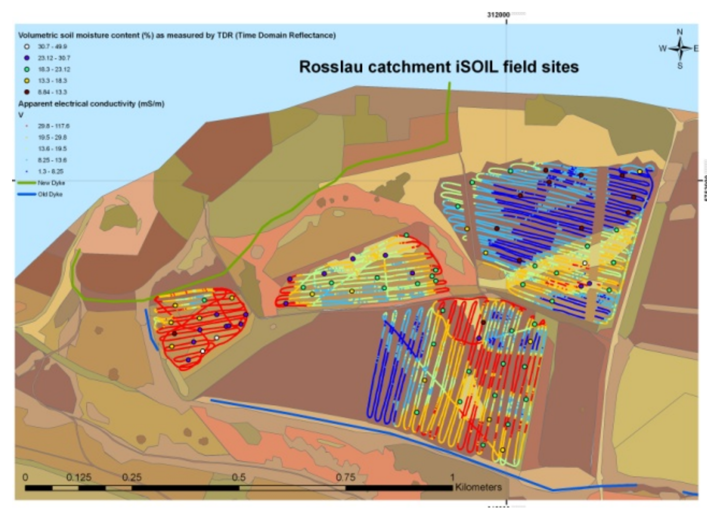
- Aim: cover max.range of the soil properties and covariates (auxiliary data)

- Many possible methods:
  - Regular
  - Random
  - Hyperlatincube
  - toposequence

Soil data collection

- Remote sensing
  - bare soil surface
  - Vegetated surface
    - Radar – thermal properties
    - indirect indication (soil moisture regime)
- Ground spectral measurements
- Geophysical methods
  - more that a surface information





Auxiliary data $S = f(s, \boldsymbol{c}, \boldsymbol{o}, \boldsymbol{r}, \boldsymbol{p}, \boldsymbol{a}, \boldsymbol{n})$

- Any available spatial data representing soil forming factors:

  c – Climate (precipitation, temperatures,…)

  o – Organisms (vegetation, landuse,…

  r – relief/terrain – digital elevation models

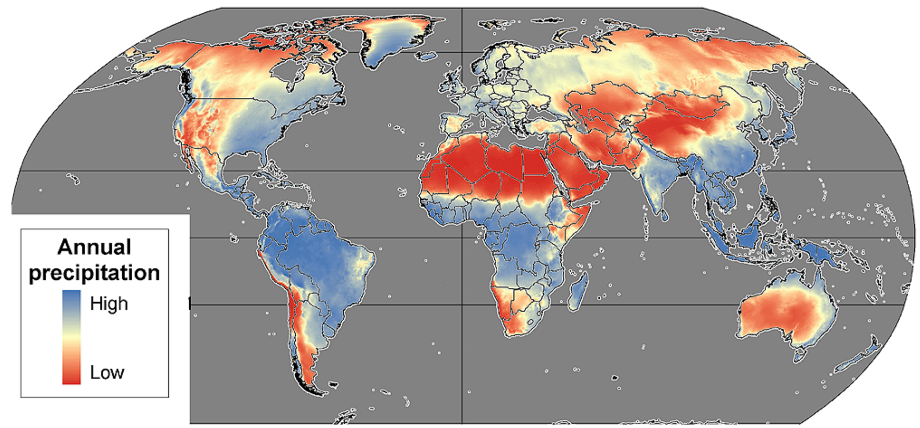
  p – parent material (geological maps,…

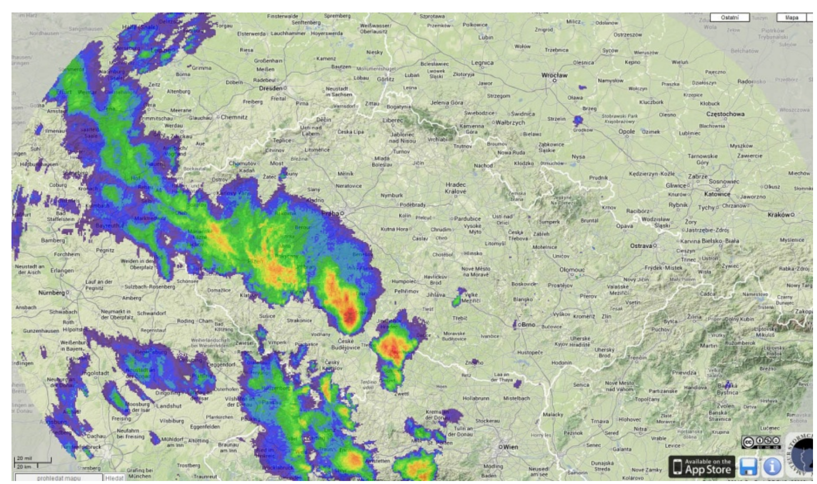
  a – time

  n – spatial relationship

Auxiliary data - climate

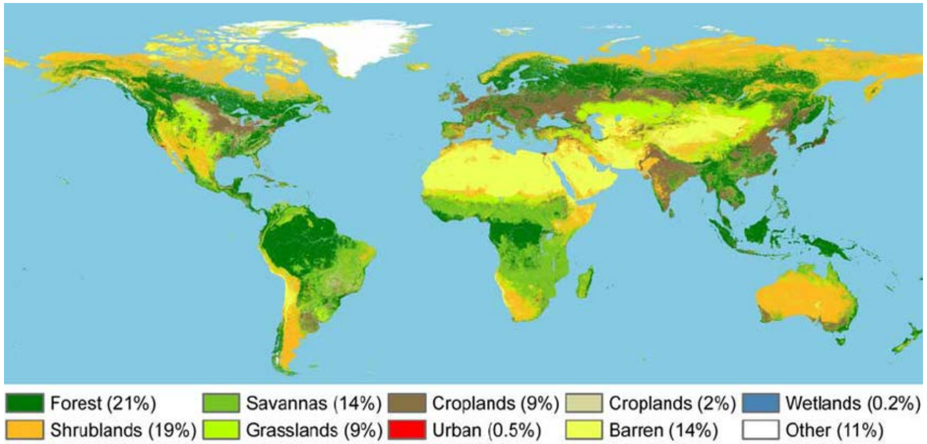
- Climate derivatives:
  - Temperatures
  - Precipitation
  - Evapotranspiration
  - Aridity index
- Mean values, temporal changes, single events
- Source:
  - Meteorological stations + interpolation
  - Satellite, radar data





Auxiliary data - organisms

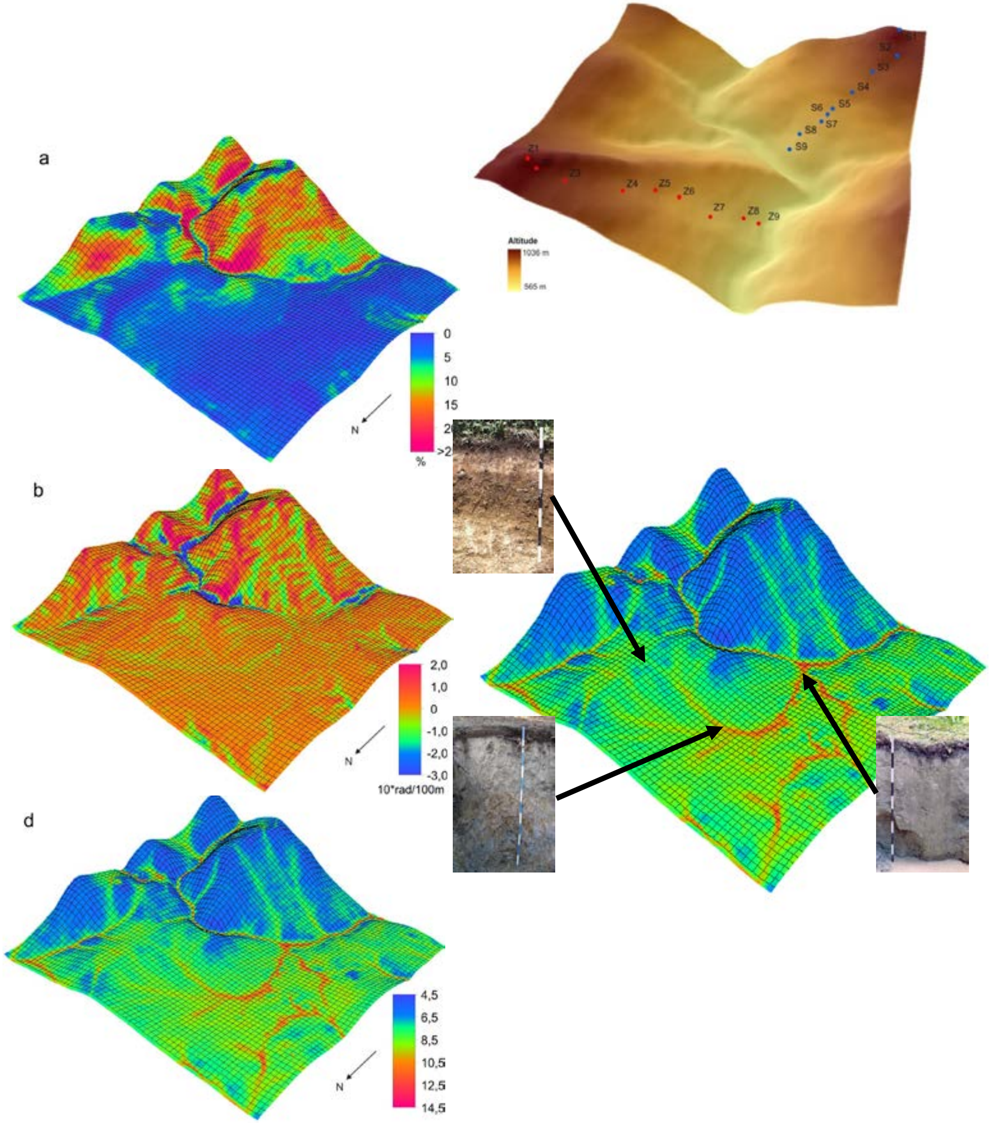
- Mainly vegetation or landuse
  - Categorical data (interpreted data)
  - Satellite measurements
    - MODIS mosaics……
- Development of vegetation in time (NDVI index,…)



Auxiliary data - relief/terrain

- Digital terrain models
  - Primary derivatives
  - Secondary derivatives
  - Advanced indexes

- Most used auxiliary data
  - Easy accessible variable
  - Important variable in soil formation at local scale
  - Modeling in soil degradation processes (erosion)



Terrain characteristics

<u>Primary:</u>

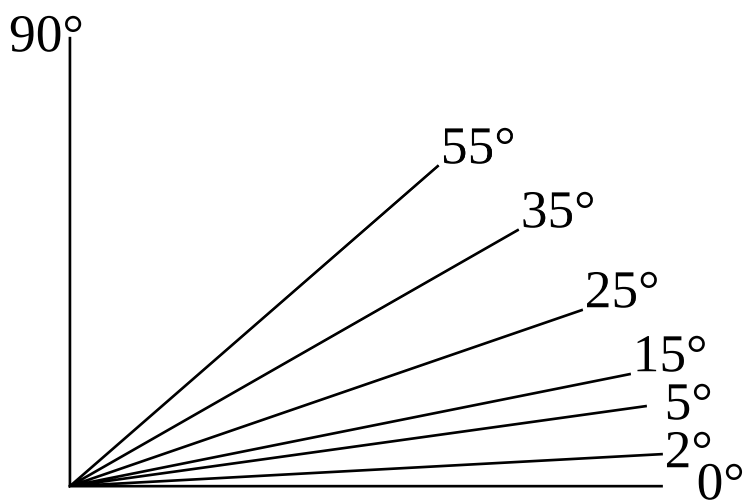
- aspect
- steepness
- shape
- specific catchment area
- maximum flow path lenght

<u>Secondary:</u>

-Topographic (wetness) index
- index of stream power
- Solar (energy) indexes

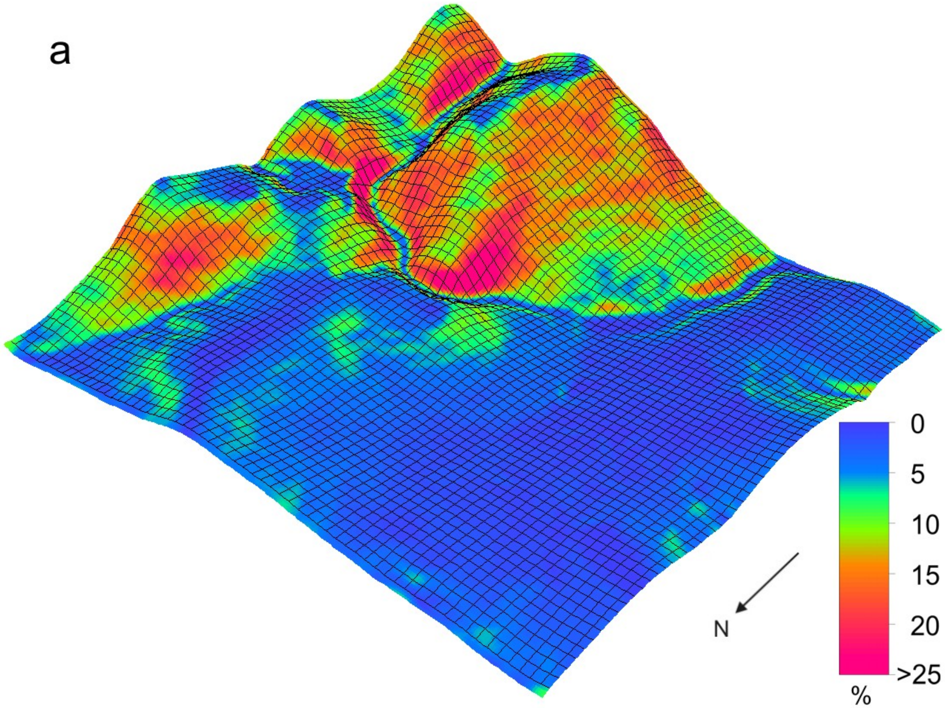
Primary characteristics - SLOPE

- Change of the elevation in the direction of steepest pathweg
- Influences water and solid material movement
- Drives erosion potential

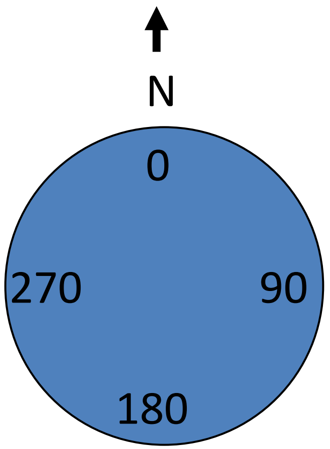


Steepness (SLOPE)

- Units are in grades (º), percent (%), radians (rad)
- **!** 45º = 100%
- radians = grades / 57.29578



ASPECT



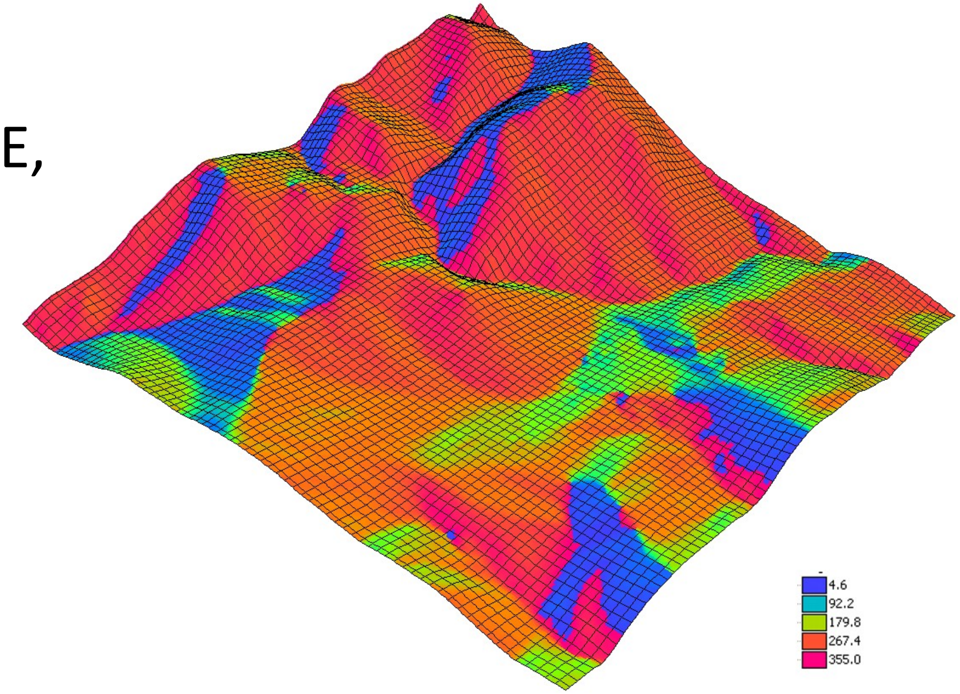
- Orientations of the slopes to N, S, W, E

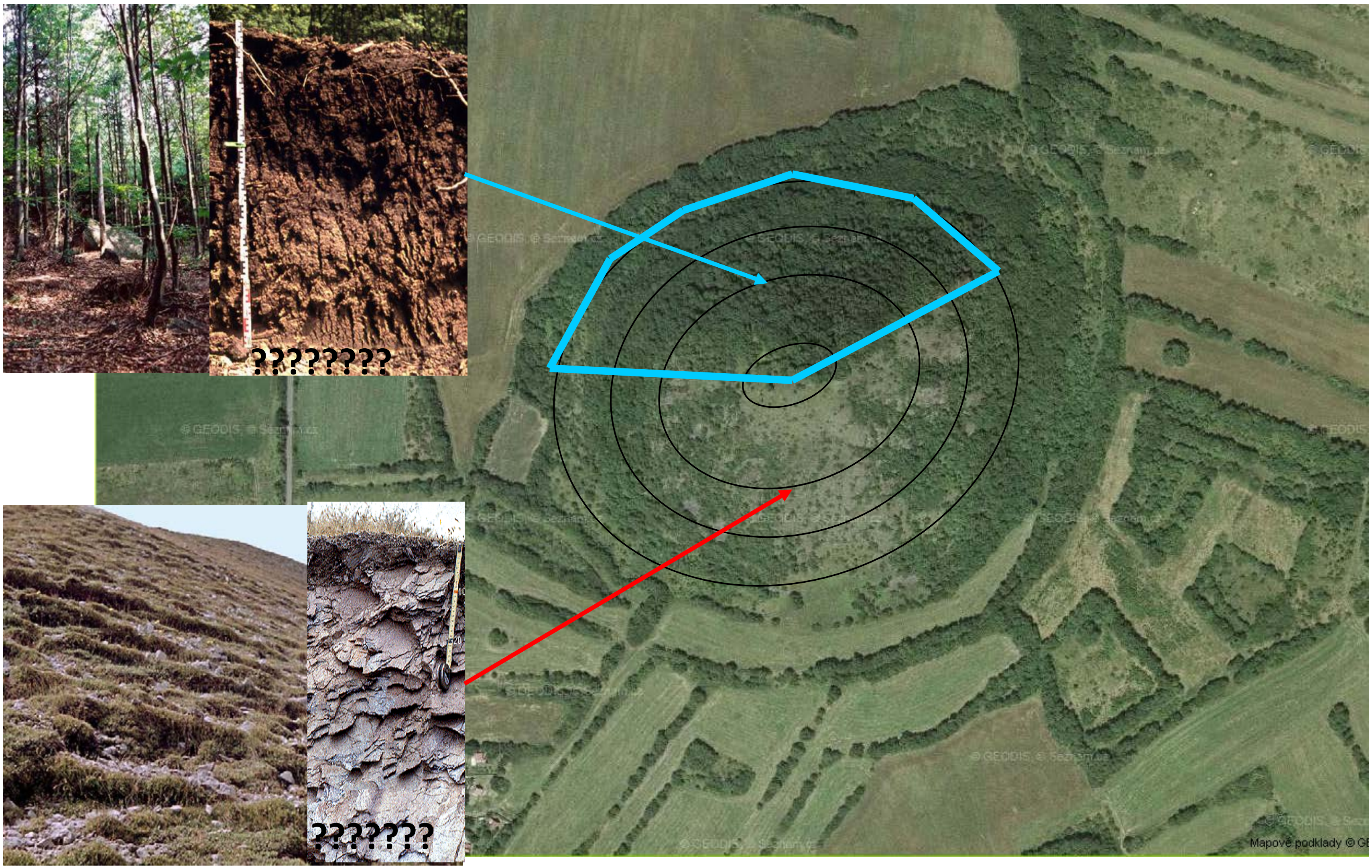
usually measured in direction of steepest pathweg from norths clockwise

- Slopes are: N, S, E, W, NW, SW, NE, NW

! Nord slope – slope facing to north!!!

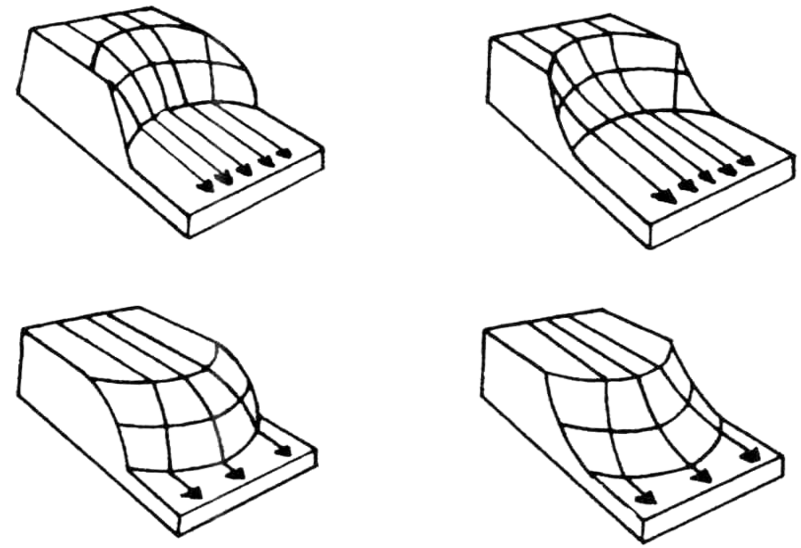
- Transformation by trigonometry (sin,cos eg. 0=1, 180=-1, 90,270=0,…)





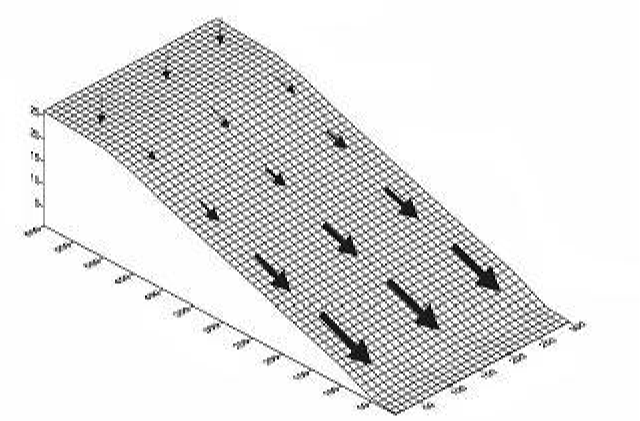
SLOPE SHAPE (slope curvature)

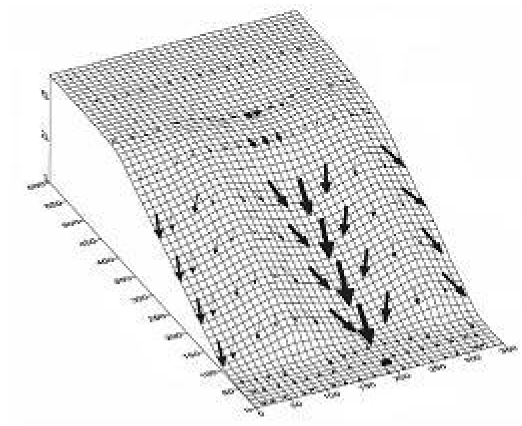
- Change of the slope steepness in horizontal or vertical direction
- Calculation is based on second derivation (first derivation is slope)

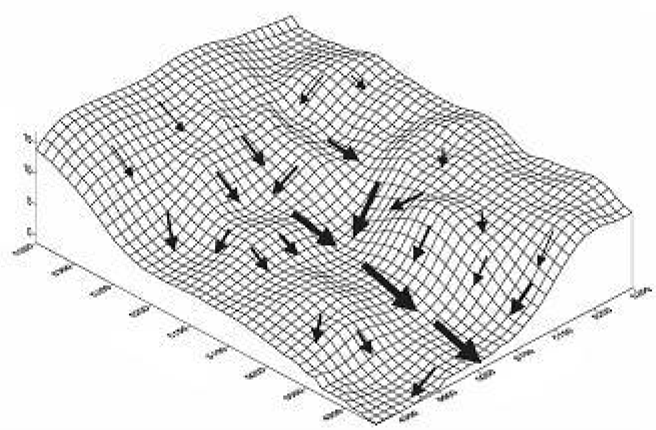


- horizontal
- vertical
- total (overall)

Slope shape (slope curvature)



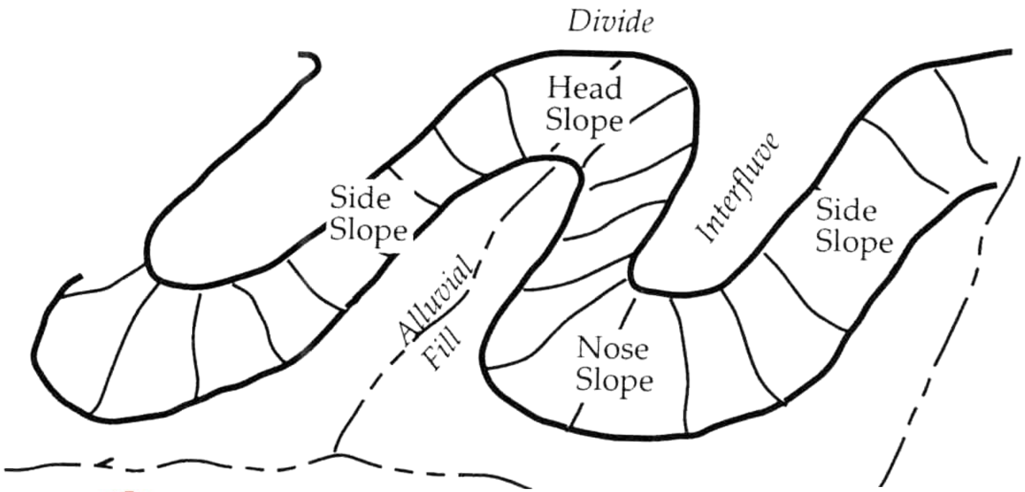


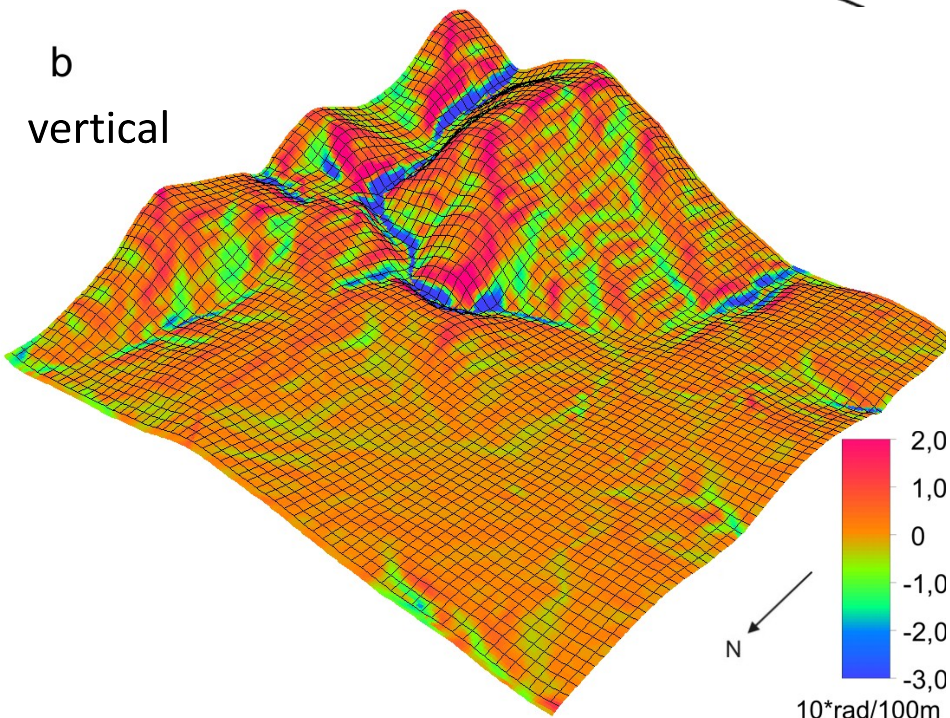


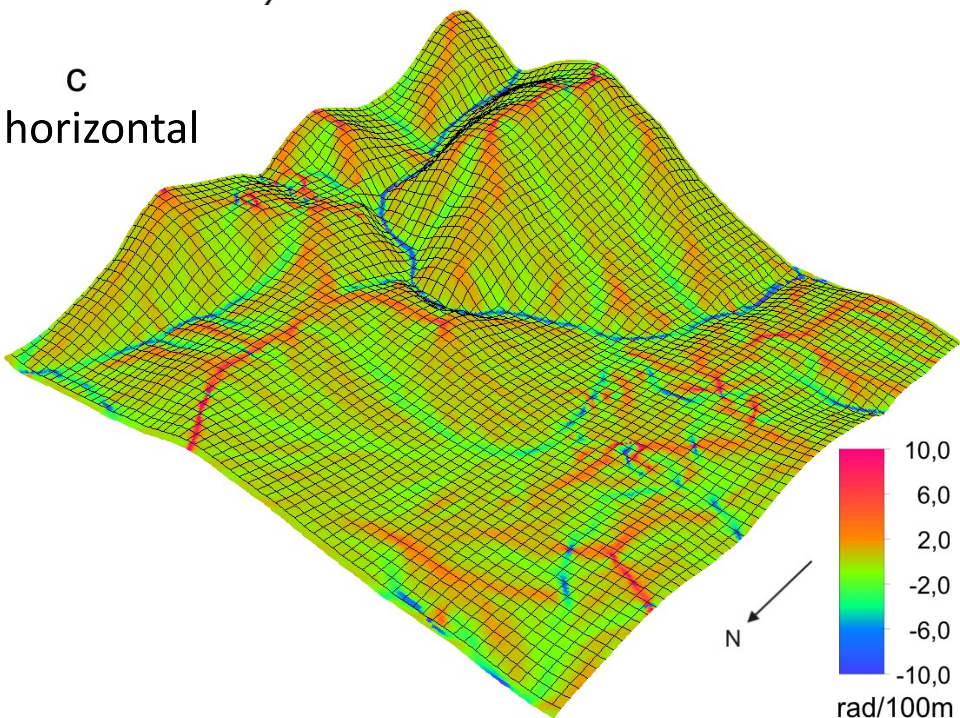
- Influence convergency or divergency of the slope

- Drives the direction of the water flow in the landscape

Slope shape (slope curvature)

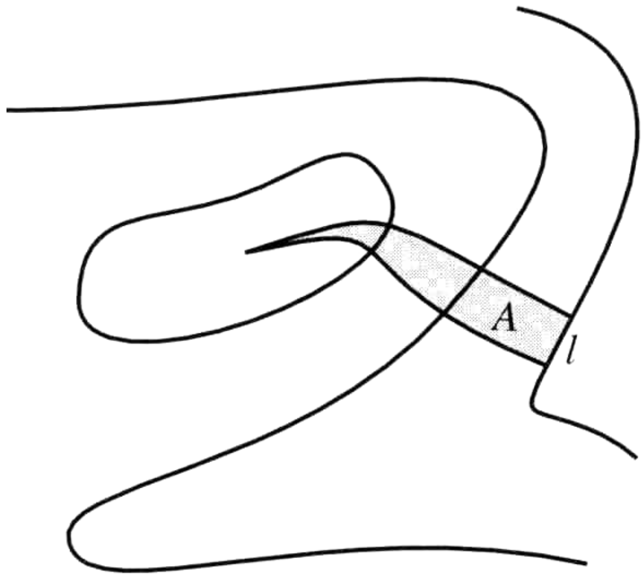


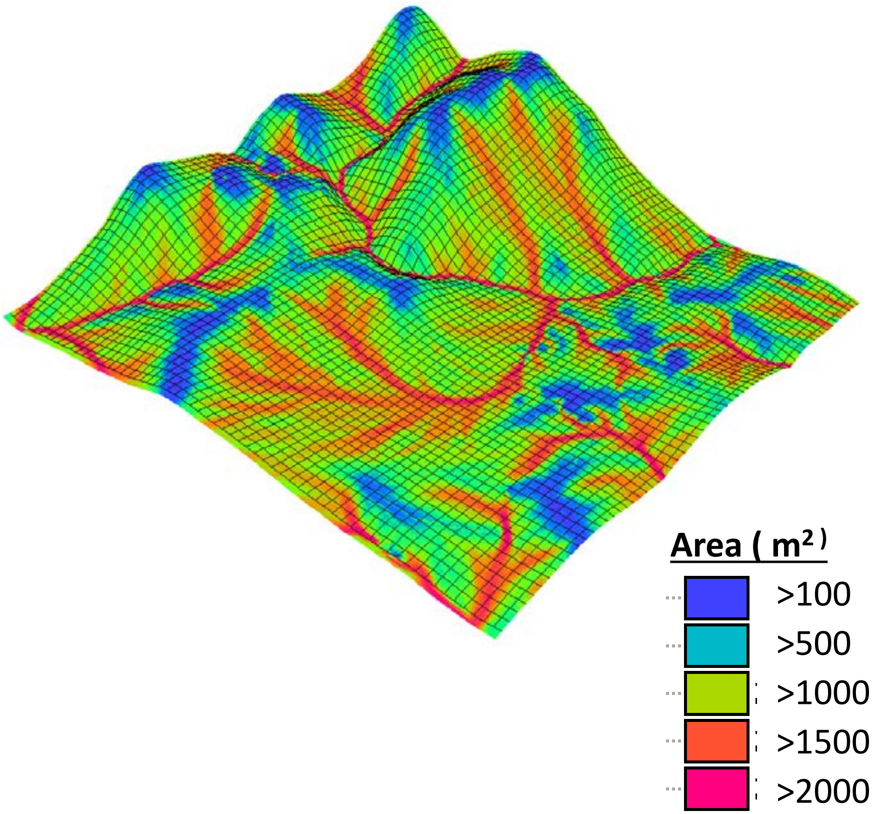




SPECIFIC CATCHMENT AREA

- Ration of an area (*A*) above certain lenght of contour (*l*), from where the water flows over this contour part
- Important for TWI calculation





Flow calculations in terrain modelling

Calculating flow directions from a DEM (steepest slope)

58	52	55	53	56	58
55	40	42	45	51	55
48	33	35	33	48	52
33	23	28	27	25	38
17	17	17	22	17	12
12	10	15	18	16	14

Output flow direction map

?	?	?	?	?	?
?	S	S	S	SW	?
?	S	SW	S	S	?
?	S	S	SE	SE	?
?	S	SW	E	E	?
?	?	?	?	?	?

Calculating flow accumulation

1	1	1	1	1	1
1	1	1	1	1	1
1	2	2	3	1	1
1	5	1	4	2	1
1	6	2	1	6	9
1	9	1	1	1	1

Output flow accumulation map

1	1	1	1	1	1
1	1	1	1	1	1
1	2	2	3	1	1
1	5	1	4	2	1
1	6	2	1	6	9
1	9	1	1	1	1

Secondary characteristics

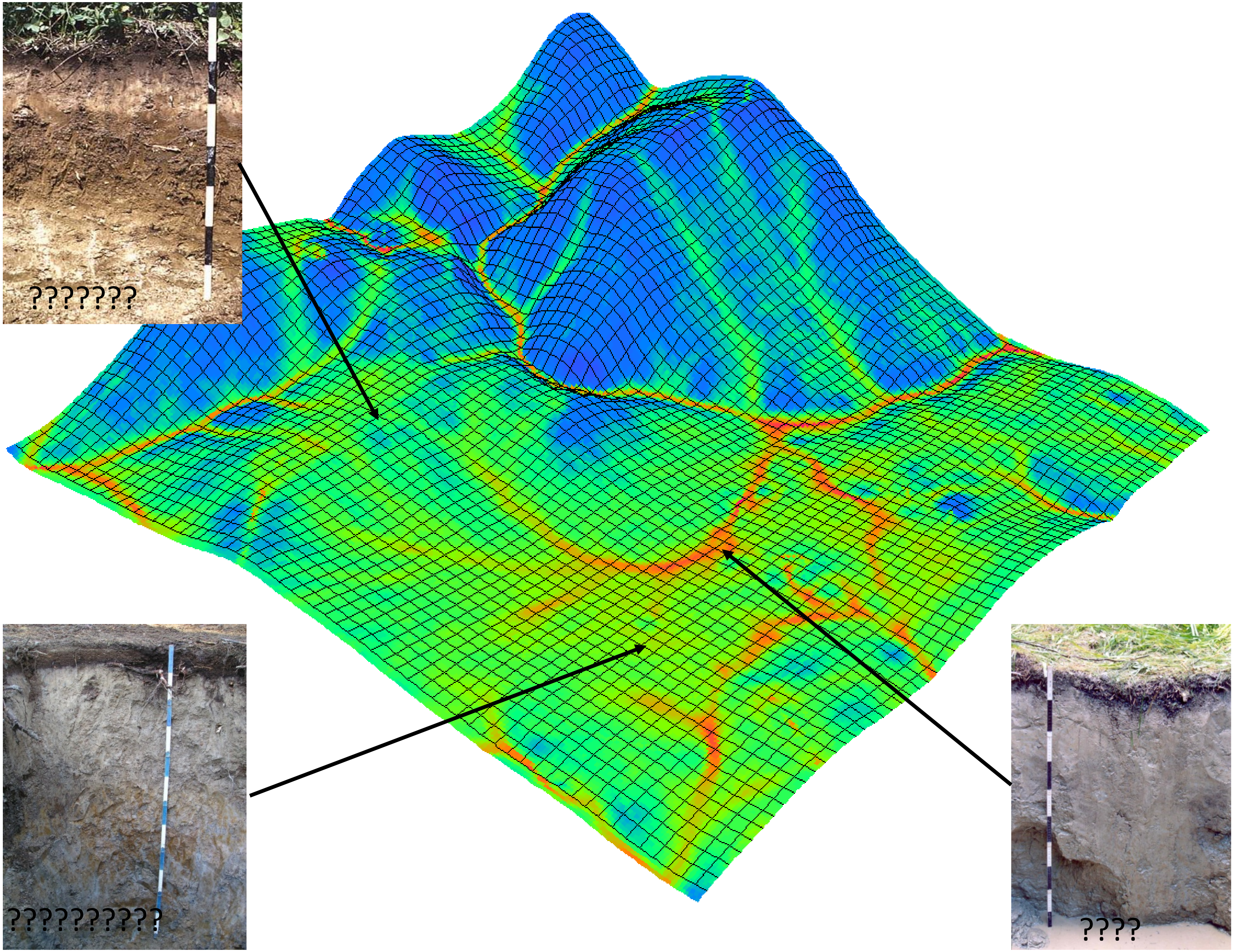
TOPOGRAPHIC INDEX

(topographic wetness index, wetness index)

$$TI = \ln\left(\frac{A_c}{\tan\beta}\right)$$

where A_c is *contributing area* and *b* is slope

- This index describes potential wetness of the point in the landscape



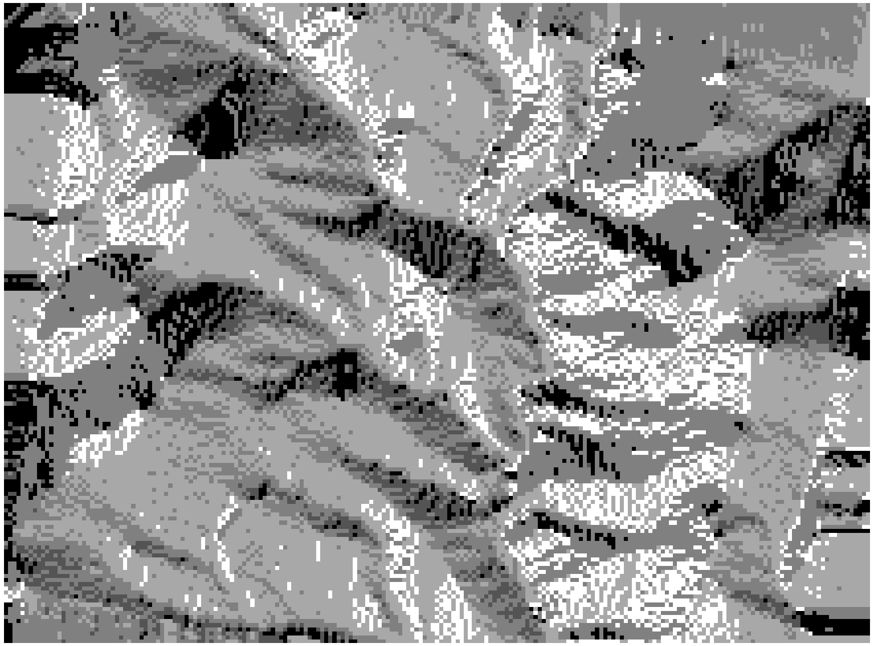
POWER STREAM INDEX

$$PSI = A_c \tan b$$

- Indicator of power of the water flow (connection to erosion)
- Power of the flow is directly dependent on the size of specific catchment - *Ac*
- Determines potential size of erosion and sedimentation according to slope shape

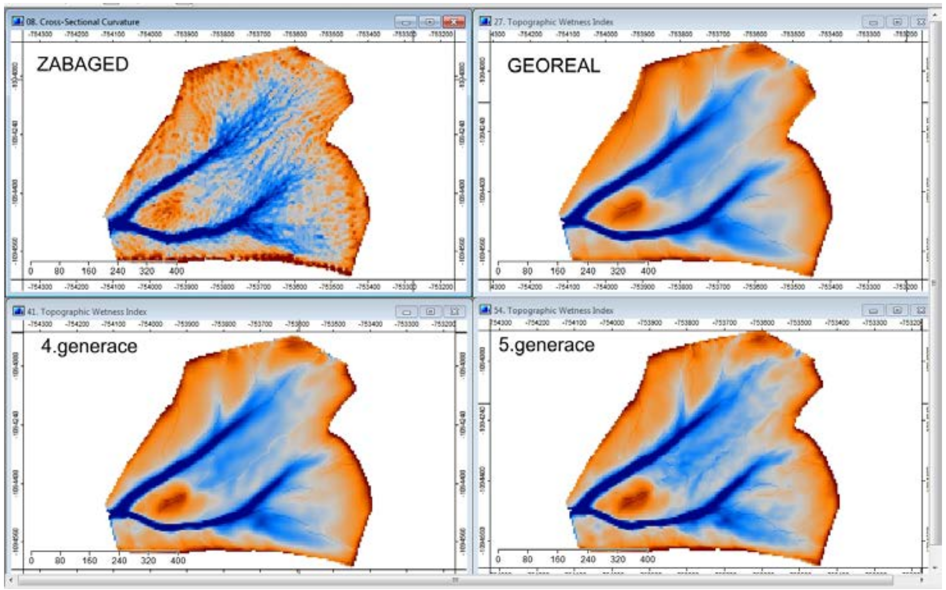
SOLAR INDEXES

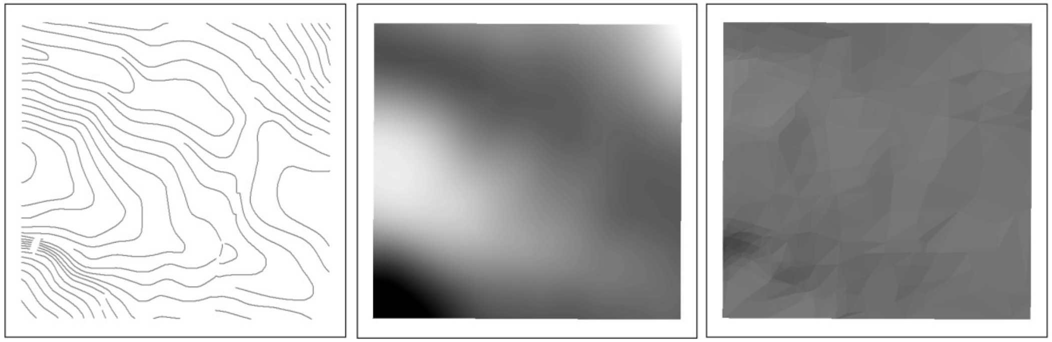
- Describe amount of the solar energy received
- Driven by aspect and elevation



Digital terrain models

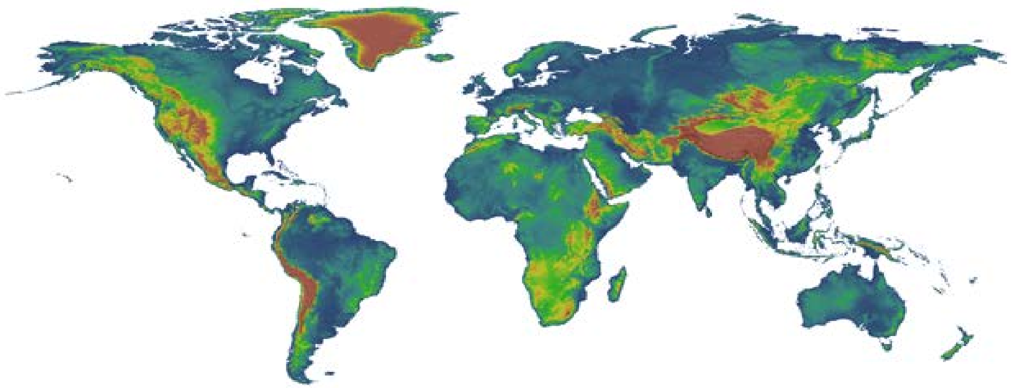
- Source:
  - Contours
  - Stereoscopic images (aerial, satellite)
  - Radar/Lidar
- DEM quality
  - Horizontal resolution
  - Vertical resolution
  - General accuracy
- Model type
  - Contours
  - Raste
  - TIN



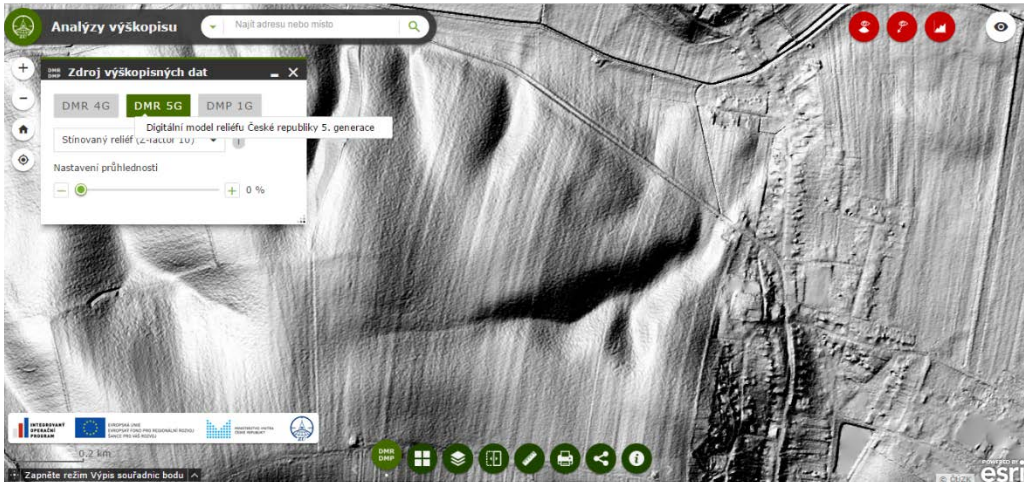


Digital terrain models

- Global
  - SRTM
  - Aster GDEM

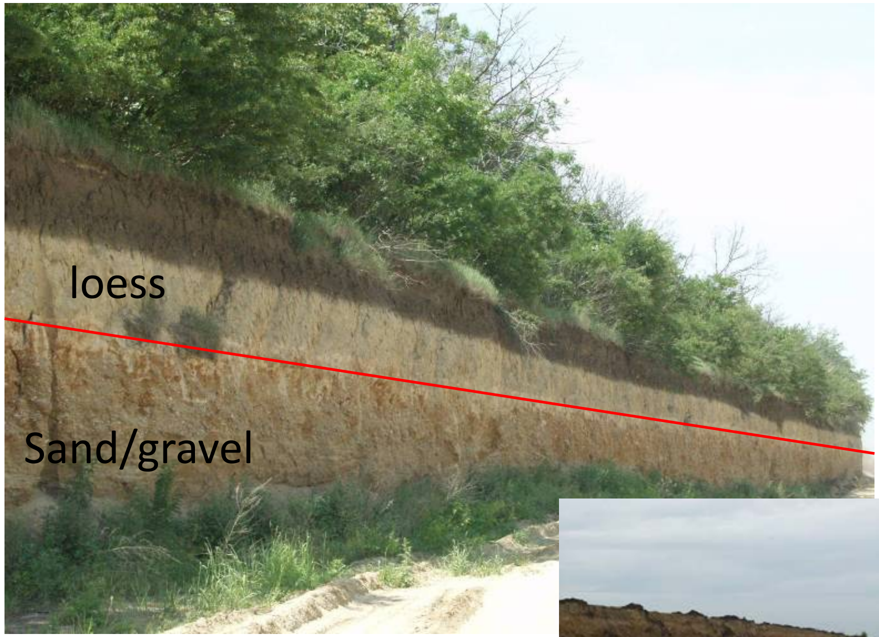


- Local
  - National products
  - Case studies



Auxiliary data - parent material

- More data sources available then for soil resources, but….:
  - Not reflecting quaternary sediments
  - Not reflecting the very top surface layer (only if thickness > 2m)
- Source:
  - Geological maps
  - Satellite images

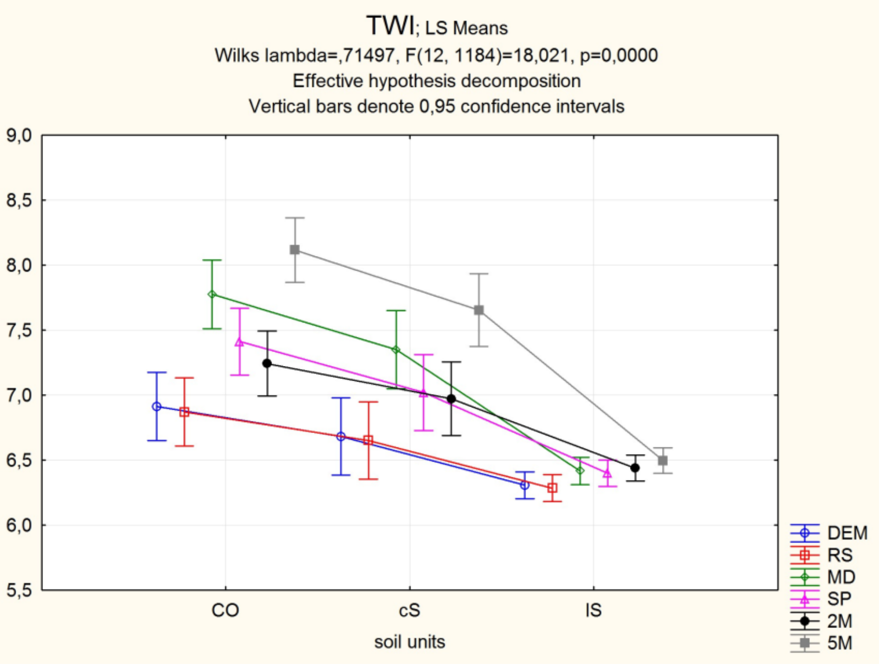


Auxiliary data - time

- ???

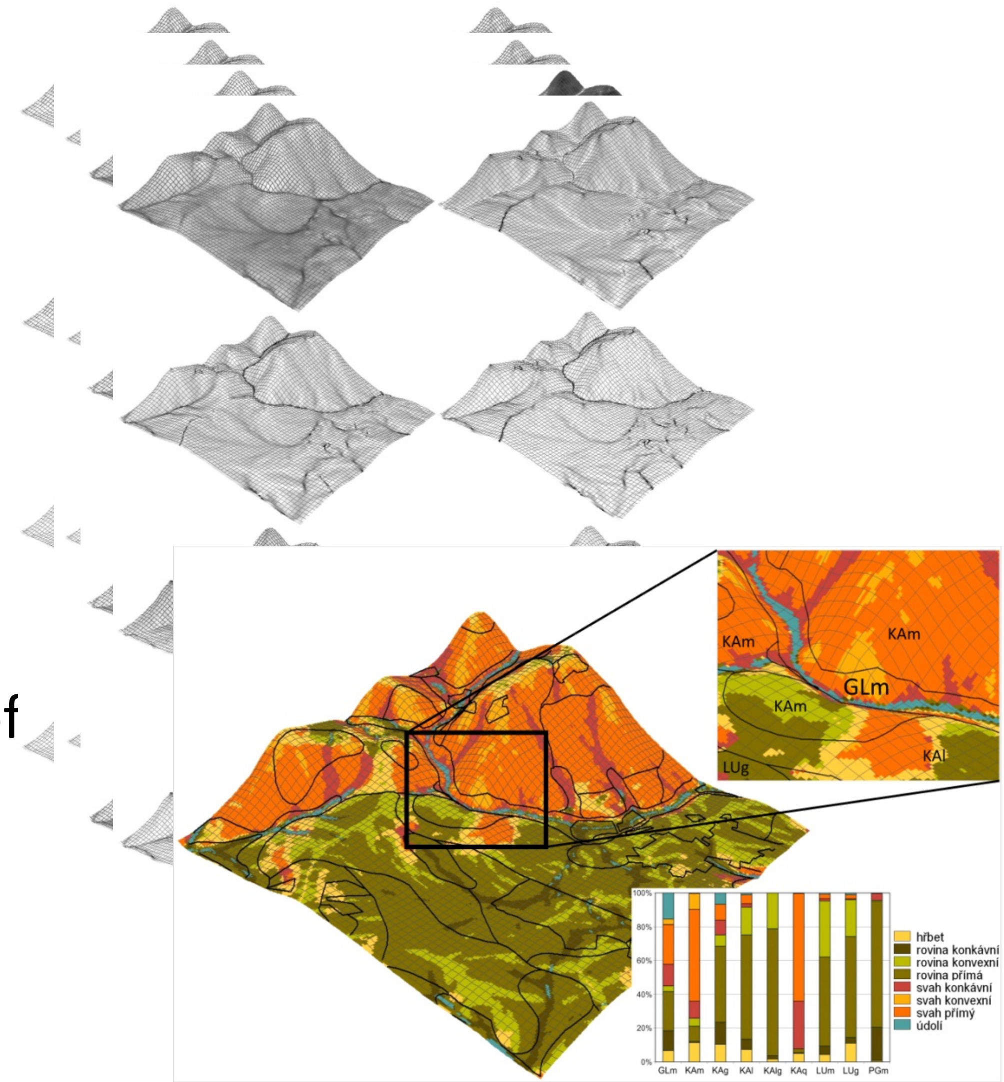
Auxiliary data - resolution

- Resolution influences the quality of the product
- Increased resolution leads to increased computational capacities
- Common resolution:
  - local applications 1-20m
  - National /Regional 5-50m
  - Global 30-1000 m
- **Higher resolution does not neccesarly means better results**



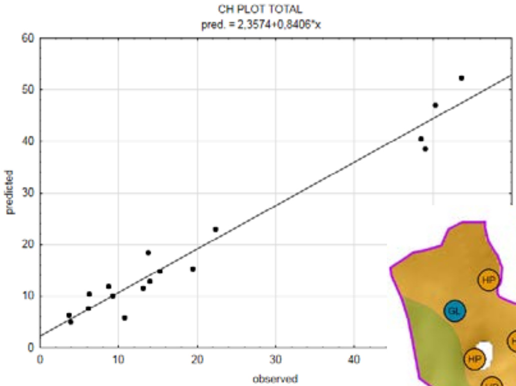
Data visualisation - crispy x fuzzy format

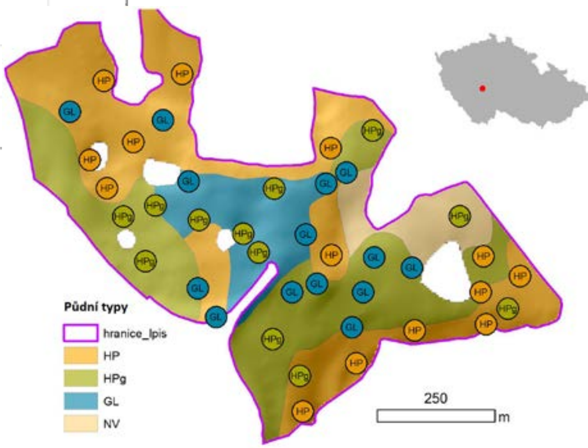
- Traditional soil survey products – polygons
  - Easy to understand
  - No spatial variability described
- Fuzzy logic
  - Probability of membership to some class
  - Better representation of natural features
  - …but often turned into crispy classes when producing final product



Validation

- **Validation methods to asses produced map accuracy**
  - confusion matrix
    - Kappa coefficient
    - total accuracy
    - User's accuracy
    - Producer's accuracy
  - Purity of delineated map units
  - Coefficient of areal correspondence





	Overall accuracy	User's accuracy		
		HP	HPg	GL
KPP	**50%**	**86%**	**42%**	**21%**
0mBT_Z	45%	64%	8%	57%
0mNN_Z	38%	100%	0%	7%
0mSVM_Z	35%	100%	0%	0%
0mCRT_Z	**50%**	64%	0%	79%
0mRF_Z	35%	100%	0%	0%
30mBT_Z	43%	43%	0%	79%
30mNN_Z	**55%**	86%	0%	71%
30mSVM_Z	50%	64%	8%	71%
30mCRT_Z	30%	86%	0%	0%
30mRF_Z	35%	93%	0%	7%
50mBT_Z	50%	93%	25%	29%

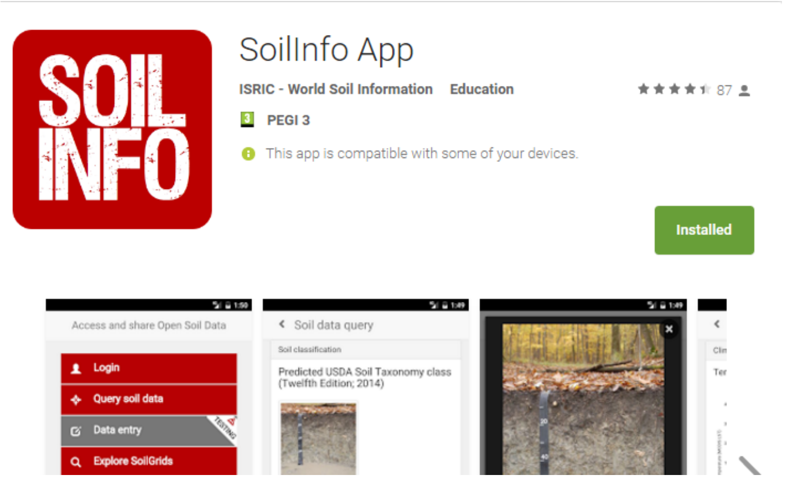
Validation

- **Validation data**
  - cross-validation
  - Validation subdataset
    - 20-30% of the total input data
  - Independent validation set

  - More detail data
    - High resolution soil maps

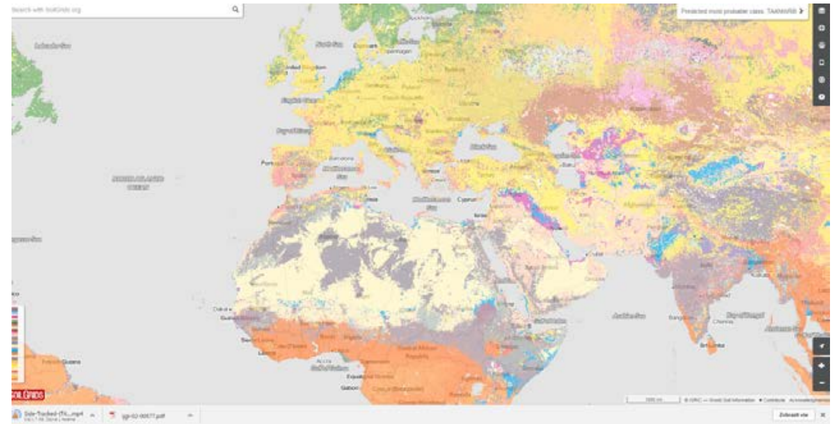
Software for DSM

- Common (GIS) software
  - ArcMAP
  - ILWIS
  - SAGA
  - R
- Special software/applications
  - SoLIM
  - Smart mobile Apps



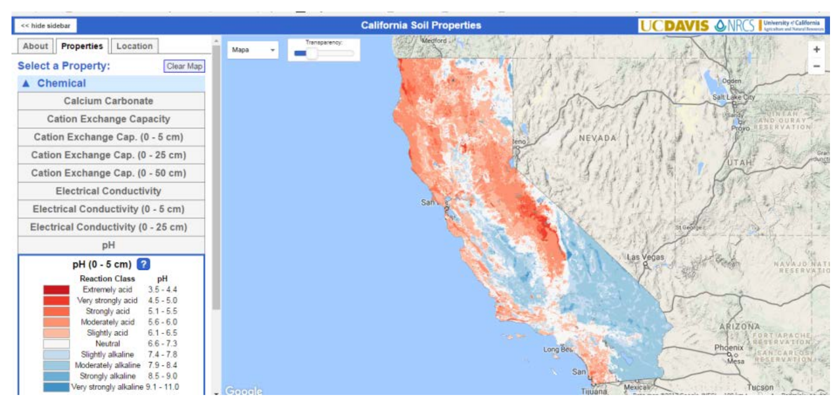
Application / projects

- Global project
  – GlobalSoilMap
  – SoilGrids
  – eSOTER



- Regional projects
  – LUCAS (EU)

- National/local projects
  – https://casoilresource.lawr.ucdavis.edu/soilweb-apps/



“Pros” and “Cons” of Digital Soil Mapping

+ Very consistent product due to the way it is created.
+ The soil landscape model is explicit. Updates can be completed more efficiently over large areas.
+ We can use this information to make predictions of soil properties including dynamic soil properties.
+ The variability or inclusions can be represented (in some cases)

– In some locations, the soil-landscape relationship is difficult to determine and represent. Examples are areas with heterogeneous parent materials.
– Can be misused (It makes really pretty maps and a bad map is worse than no map at all)
– Learning new software can be very frustrating

Key Points

- The DSM products always relay on soil survey data
- It is impossible to use these products and create good maps if you do not know your soil-landscape relationship.
- Knowledge about accuracy is important
- It is complex process – interdisciplinarity needed!