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Spatial Variability of Soil Properties on Kame Field of Poznań Lakeland

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Spatial variability of soil

Spatial variability in soil systems belongs to two broad categories (Wilding et al., 1994)

- **Systematic variation(structural)**
- **Random variation (unstructural and unknown causes)**

✐**Large-scale spatial variability of systematic nature:(e.g . Shrink-swell phenomena)**

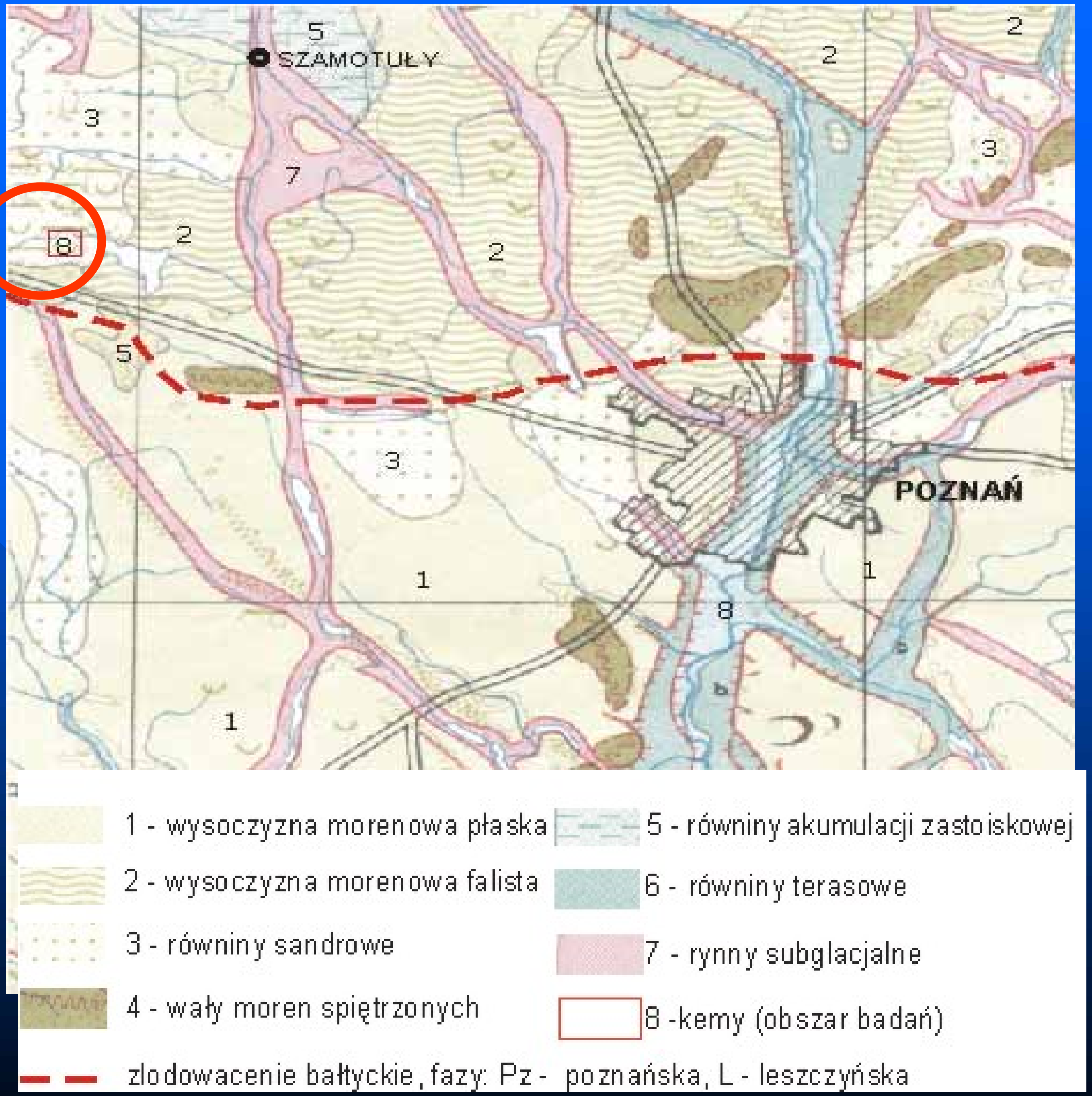
✐**Fine scale spatial variability: occur in aggregate ped units**

Location of the study area

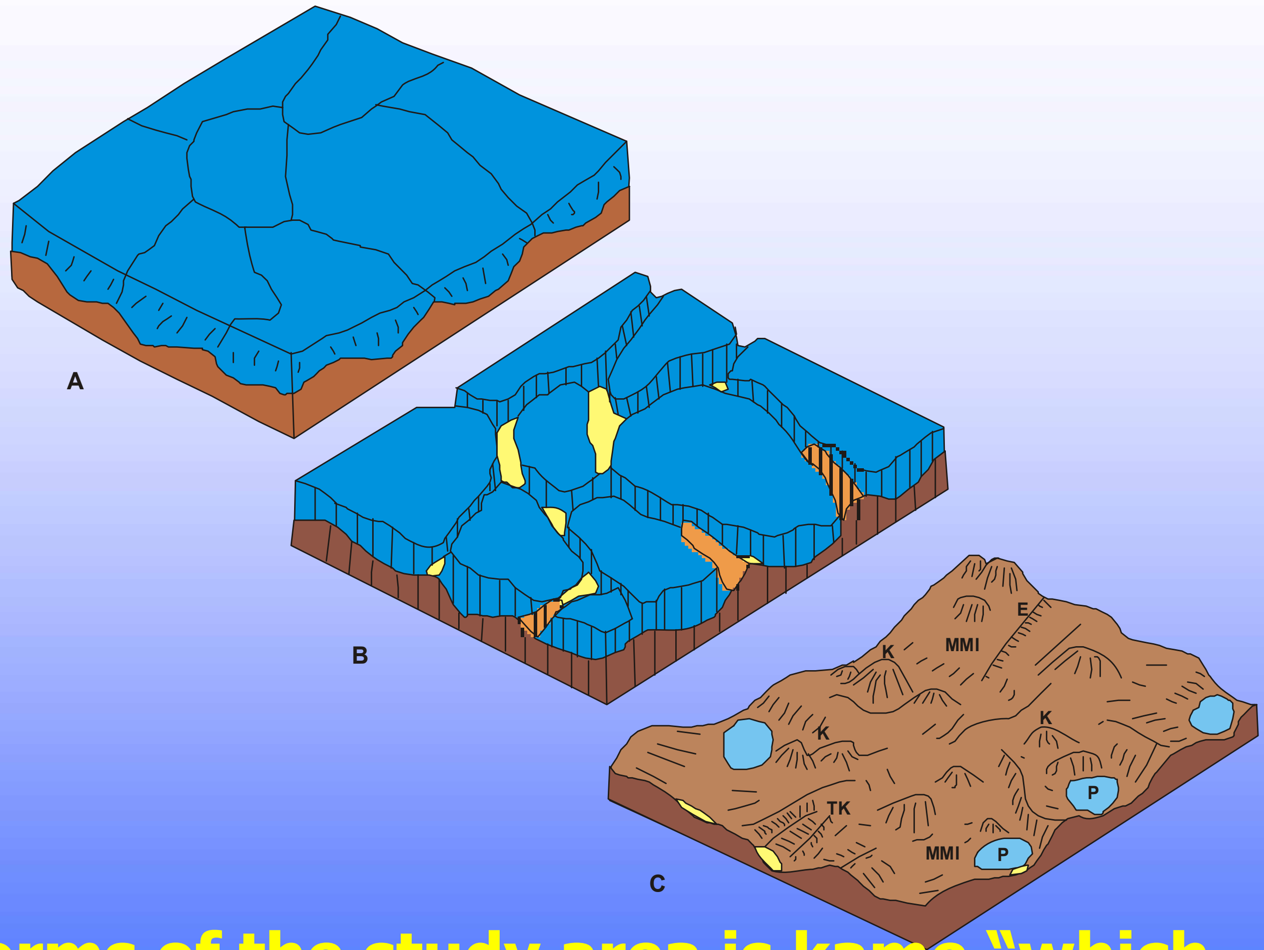
The study area of 100 hectares, is located in the Poznań Lakeland, western side of Bytyń lake at the hamlet of Pólko (approximately 32 km from Poznań city), in the province of Wielkopolska.

The field is a gently undulating area covered with glacial and glaciofluvial deposits. It is characterized by gentle slopes, running slightly from the West to the East, heading towards Bytyń lake. The elevation ranges between 90 to 100 m a.s.l.; the highest point is 100.4 m a.s.l and the lowest point is 90.2 m a.s.l. The area coordinates range from Latitude of 52030`67`` to 52031`14``N and from Longitude of 16027`30`` to 16028`27``E.

According to Starkel's map (made by Karczewski et al. 1987), the study area is located in the front of ice -marginal zone. The glacial and glaciofluvial deposits in this area are materials produced by areal deglaciation process; these materials were carried, sorted and deposited by water which originated mainly from melting glacial ice.



Areal deglaciation process

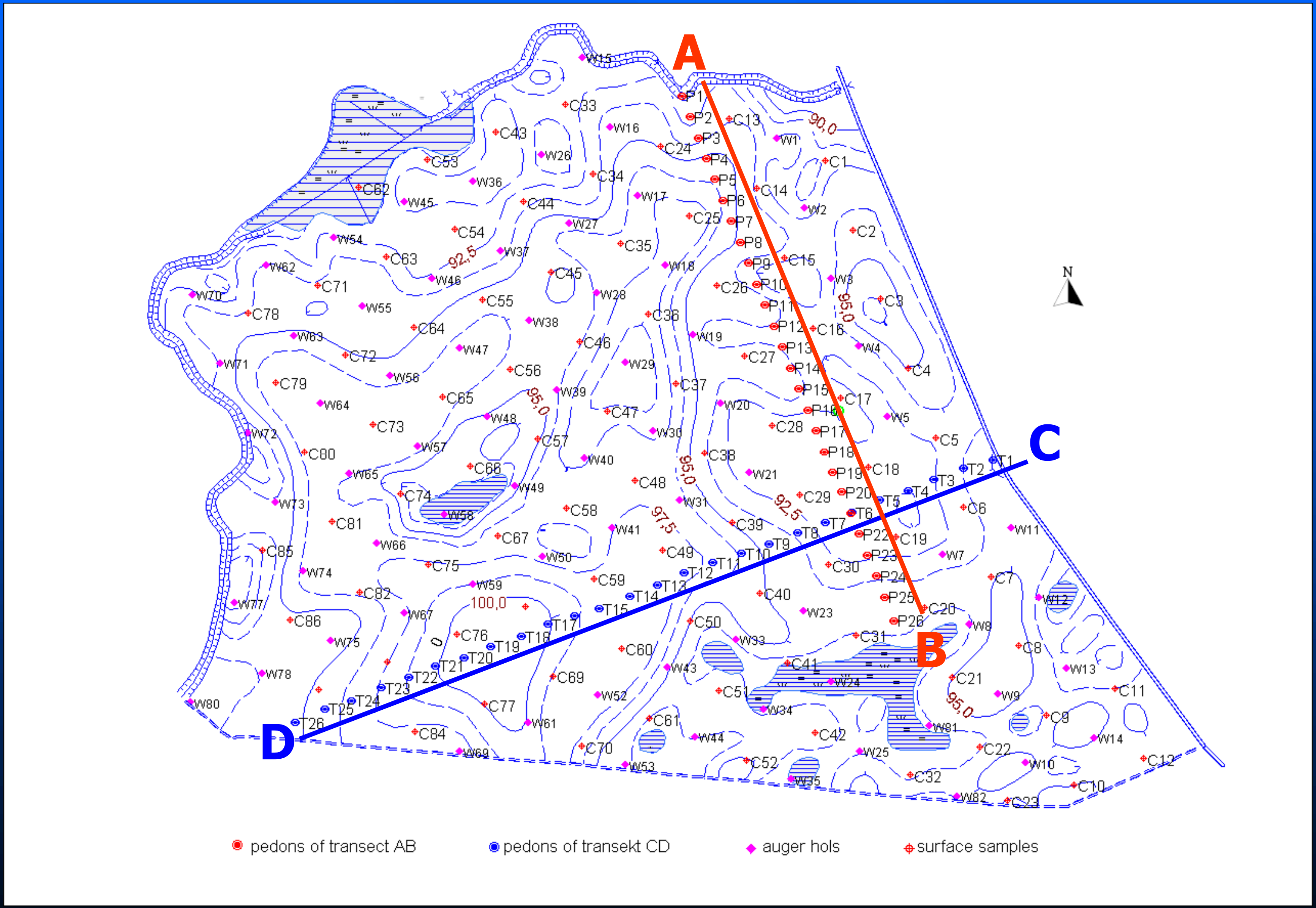


The landforms of the study area is kame "which defined as a steep-sided small isolated hills" with kettle holes, which are covered with glacial till materials by areal deglaciation proces

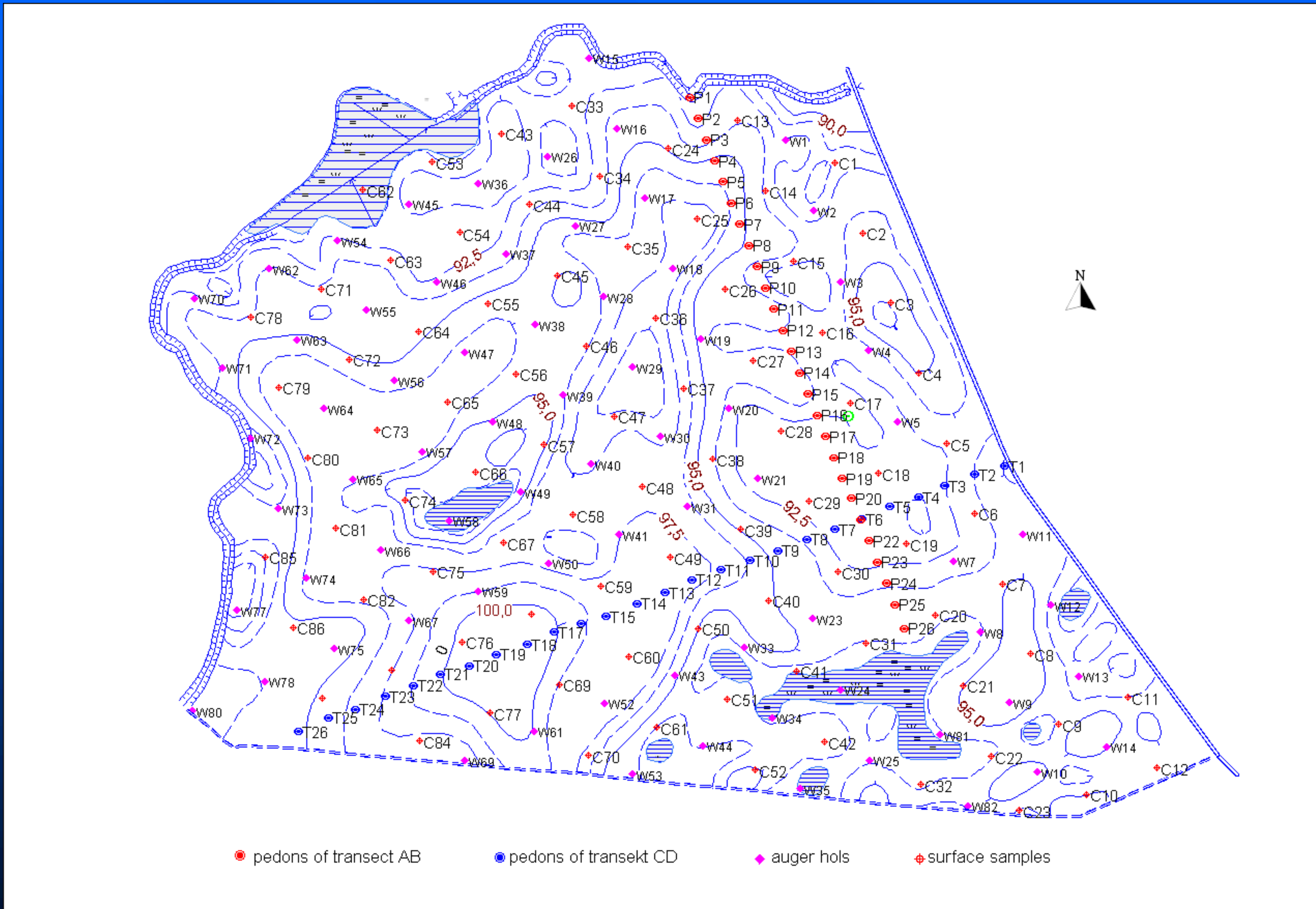
Field work

- systematic survey was carried out over the study area, based on two main transects: AB of NNW-SSE direction and CD of ENE–WSW direction, have been made with an intervals of 30 m between one observation point and the other. Along of 750 m across the field for transect AB and with intervals of 40 m along 1 000 m for transect CD.
- In order to increase the precision of survey, the rest of the area was subdivided into a square grid pattern. Each square area is 100 x 100 m. 73 points on the intersections of the grid square lines were considered as an observation points. Intense field surface investigation on one more inserted square grid was carried out in order to investigate properties of soils surface and to obtain samples from the soil furrow slice for 123 investigated points (where these squares intersects are the grid cells center of the first one).
- The GPS device was used to restrict:
- 51 points along two transects,
- 73 sites on the intersections of the main grid square,
- As well as 123 points on the inserted grid.

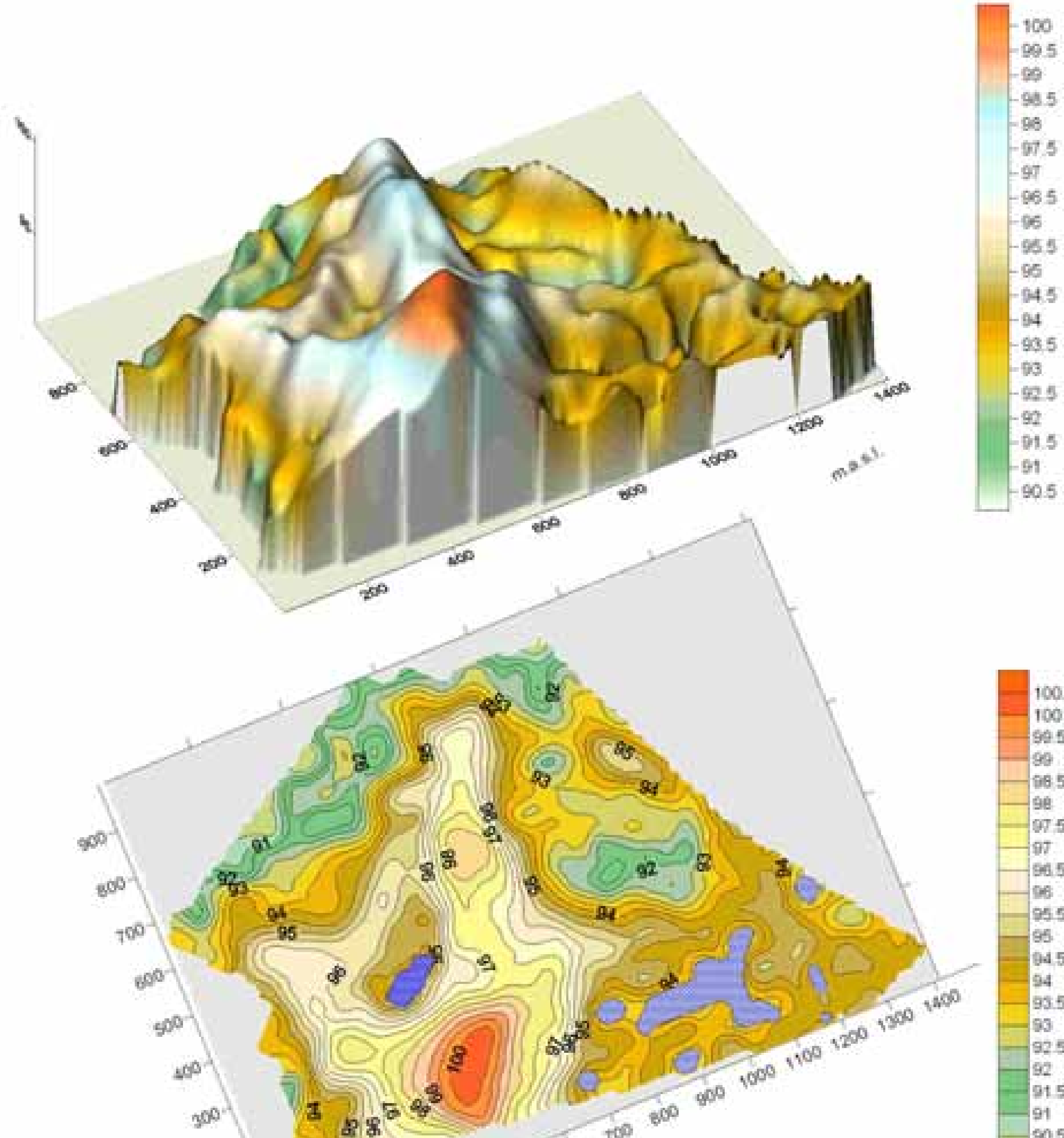
Outline of study area with the design of soil survey methods



Sampling of topsoil



Digital elevation Model



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Physical and chemical analyses

- Hygroscopic water was measured by using of (40 g) air dried soil samples and to dry it in the oven at 1050C.
- Organic carbon was determined by a modification method of the **Walkley-Black** procedure (1934), **Nelson** and **Sommers** (1982), which is based on the oxidizing the sample by application of 1N potassium dichromate and concentrated sulfuric acid, then exposed to external heat.
- Organic matter content was calculated by multiplying of organic carbon values by constant of (1.724). For few samples that had high organic matter content, organic carbon was determined by loss on ignition (**LOI**) at 4200C in the furnace for 6 hours; **Soil Survey Laboratory Staff** (1992).

- Particle-size analysis was performed on bulk soil samples by hydrometer method with application of sodium-hexametaphosphate (**Na6P6O18**) as a chemical dispersion agent. Sands fraction were separated on hole sieves **1 – 0.5 – 0.2 – 0.1** mm, respectively; method of **Polski Komitet Normalizacyjny**, 1998. Polska Norma PN-R-04032. Then soil texture was established according to Polish standards **BN-78/9180-11** (1978), **PN-R-04033**(1998) as well as **Soil Survey Staff** (1975).
- Soil reaction (**pH**) was measured in suspension of H2O (**1:1**), (**0.01M**) CaCl2 (**1:2**) and (**1M**) KCl (**1:2**), according to **Soil Survey Laboratory Staff** (1992).Using Microcomputer pH/ Ion meter Cl-316.
- Exchangeable cations (**Ca++, Mg++**, **K+**, **N+**) were estimated by **Mehlich** method (**BaCl2-TEA, pH=8.2**), modified by **Kocialkowski** and **Ratajczak** (1984). Cations were measured by using atomic absorption spectrometer (**Spectr AA 10**).
- Exchangeable **Al+++** and **H+**; were estimated by potassium chloride (**1M KCl**); method from **Soil Survey Laboratory Staff** (1992).

- Soil Surface Area (**SSA**) was estimated for 220 horizons from 42 pedons, by the technique method of the Ethylene Glycol Mono-Ethyl Ether (EGME), from **Soil Survey Laboratory Staff** (1992), which was modified for the purpose of this study. The modification was based on the procedure of soil drying to constant weight in an evacuated desiccator over P2O5 for no more than 72 h. Then to replace the sample an evacuated desiccator over EGME for one day. At the beginning of the next working day, the desiccator is pumped under 12.2 cm (Hg) pressure and allowed to equilibrate 30 minutes, then the sample is weighed and the desiccator re-evacuated under lab-suction for 1 minute. The procedure is repeated every day work till the sample attains a constant weight.
- The Carbonate content in the soil samples which have shown reaction to applied dilute HCl (10%) in the field. First were estimated by **Scheibler** method (1982), then the estimates were checked by applying method of loss on ignition (**LOI**) in the furnace at 8500C.
- The contents of mineral substances were estimated by loss on ignition (**LOI**) in the muffle furnace at 4500C, **Soil Survey Laboratory Staff** (1992).
- Total Soil Nitrogen was estimated for 178 samples by **Kjeldahl** method **Mc Rae** (1988).
- Electrical Conductivity (**EC**) was measured in suspension of H2O (**1:2**) by **Solu bridge microcomputer conductivity meter CC-317**. **Soil Survey Laboratory Staff** (1992).

Statistical and geostatistical analyses

Spatial variability of soil properties was assessed through the analysis of semivariograms of the selected individual variables. Experimental semivariograms were obtained from the omnidirectional semivariances, (h), as a set of spatial observations, Z(xi), which were calculated as (**Komisarek** 1994, **Warrick** et al. 1989):

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[z(x_i) - z(x_i + h)\right]^2$$

Where: and are experimental measures of any two points separated by the vector h and N(h) is the number of experimental pairs separated by h.

A cross-variogram extends this approach into the multivariate analysis. Cross-variogram is defined as the variance of the difference between two variables of different types or attributes at two locations (**Bailey** and **Gartell** 1995):

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[z_1(x_i) - z_1(x_i + h) \right] \bullet \left[z_2(x_i) - z \quad (x_i + h) \right]$$

SPATIAL VARIABILITY OF SOIL COVER

a) Spatial variability of soil properties within ploughed horizon

b) Spatial variability within pedological cross-sections

The study of spatial variability of soil cover pointed to several soil forming processes which are acting both on topsoil and subsoil of this kame field:

1- accumulation of organic matter

2- leaching of calcium carbonates and other bases

3- reduction and transformation of iron

4- migration of clay particles either from up to down in one horizon or from one horizon to another.

In most sites these processes are overshadowed by erosion, which is a result of accelerated water runoff as well as anthropogenic denudation. All these processes in addition with some soil properties such as aquic conditions, epi- or endo-saturation, were taken into consideration while classifying soils at Suborders and Great groups categories.

Classification of soil

The following soil categories have been established on the basis of field studies and laboratory analyses:

- Three Soil Orders: Alfisols, Mollisols and Histosols. Histosols occur in tiny depression, which are ponding most time of the year; therefore it has been excluded from the present study.
- Three Soil Suborders: Udalfs, Aquolls and Saprists.
- Three Soil Great Groups: Hapludalfs, Endoaquolls and Haplofibrists.
- Seven Soil Subgroups: Typic Hapludalfs, Glossic Hapludalfs, Glossaquic Hapludalfs, Typic Endoaquolls, Cumulic Endoaquolls, Fluvaquentic Endoaquolls and Typic Haplofibrists.

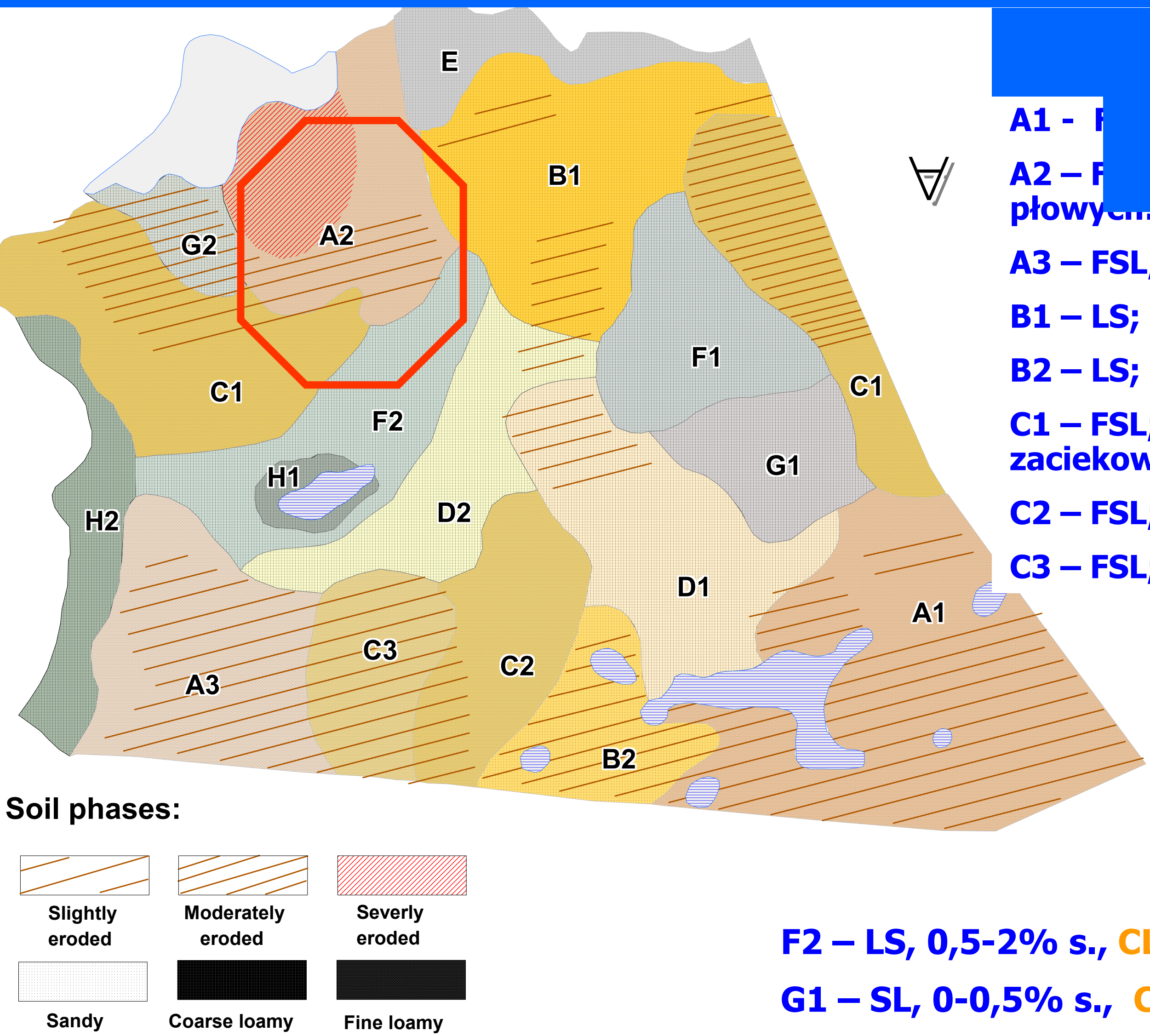
Soil families were defined according to criteria of the **Soil Survey Staff** (1993):

1- Particle-size distribution in horizons of major biologic activity below plough depth (control section); surface layers were generally excluded and Bt horizons are given special emphasis,

2- Mineralogical classes are defined on the basis of the approximate mineralogical composition of the control section. According to previous studies of mineralogy of the Poznań Lakeland soils (**Komisarek** 2000), the mineralogical class is mixed and consisted of quartz and all other kaolinite, illite, smectites, chlorite, representing less than 40 percent of any of these minerals,

3- Soil temperature regime was identified in as a mesic.

Soil map of kame field of „Pólko”



A1 - F

A2 – F
płowych: typowych i opadowo-glejowych

A3 – FSL; 2-5% s., FL, gleby płowe typowe,

B1 – LS; 2-5% s., S, gleby płowe zaciekowe,

B2 – LS; 0,5-2% s., S, gl. płowe zaciekowe,

C1 – FSL; 0,5-2% s., FL, gleby płowe zaciekowe opadowo-glejowe,

C2 – FSL; 2-5% s., FL, jak wyżej

C3 – FSL; 5-10% s., FL, jak wyżej

D2 – LS, 0-0,5% s., CL, jak wyżej,

D1 – LS, 2-5% s., CL,jak wyżej,

E1 – LS, 2-5% s., S, gleby deluwialne próchniczne

F1 – LS, 0-0,5% s., CL, czarne ziemie zbrunatniałe,

F2 – LS, 0,5-2% s., CL, czarne ziemie zbrunatniałe,

G1 – SL, 0-0,5% s., CL, czarne ziemie właściwe,

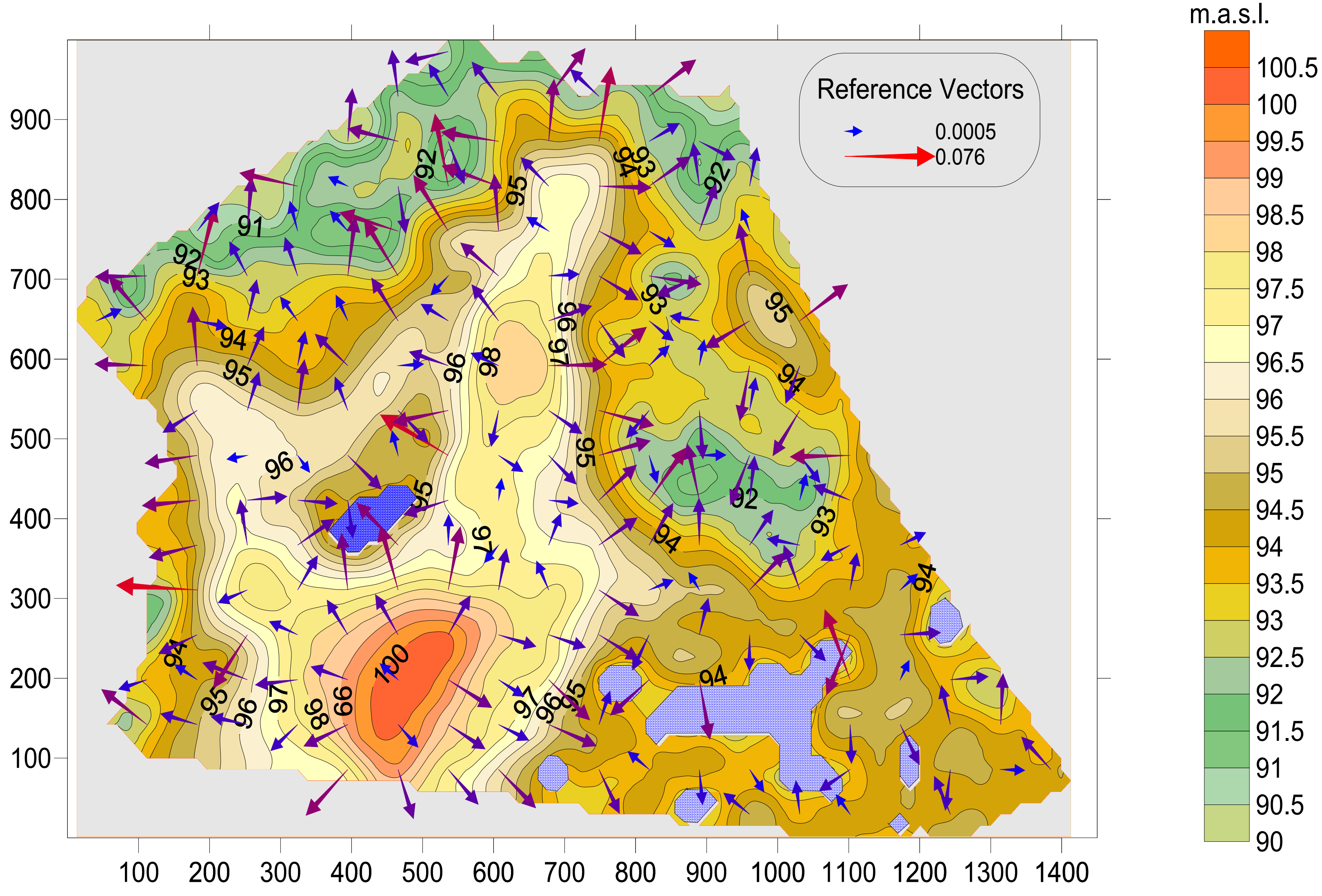
G2 – SL, 0,5-2% s., CL, czarne ziemie właściwe

H1 – SL, 5-10% s., CL, czarne ziemie akumulacyjne

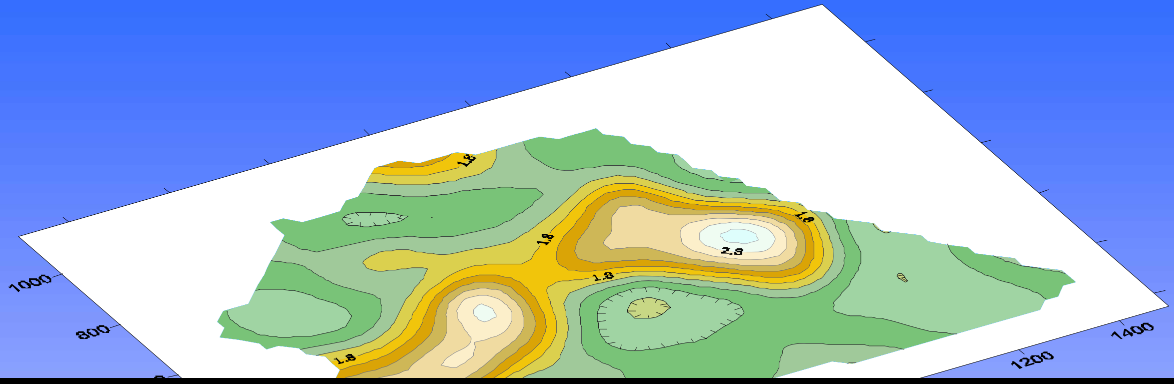
H2 – SL, 0,5-2% s., CL, czarne ziemie akumulacyjne

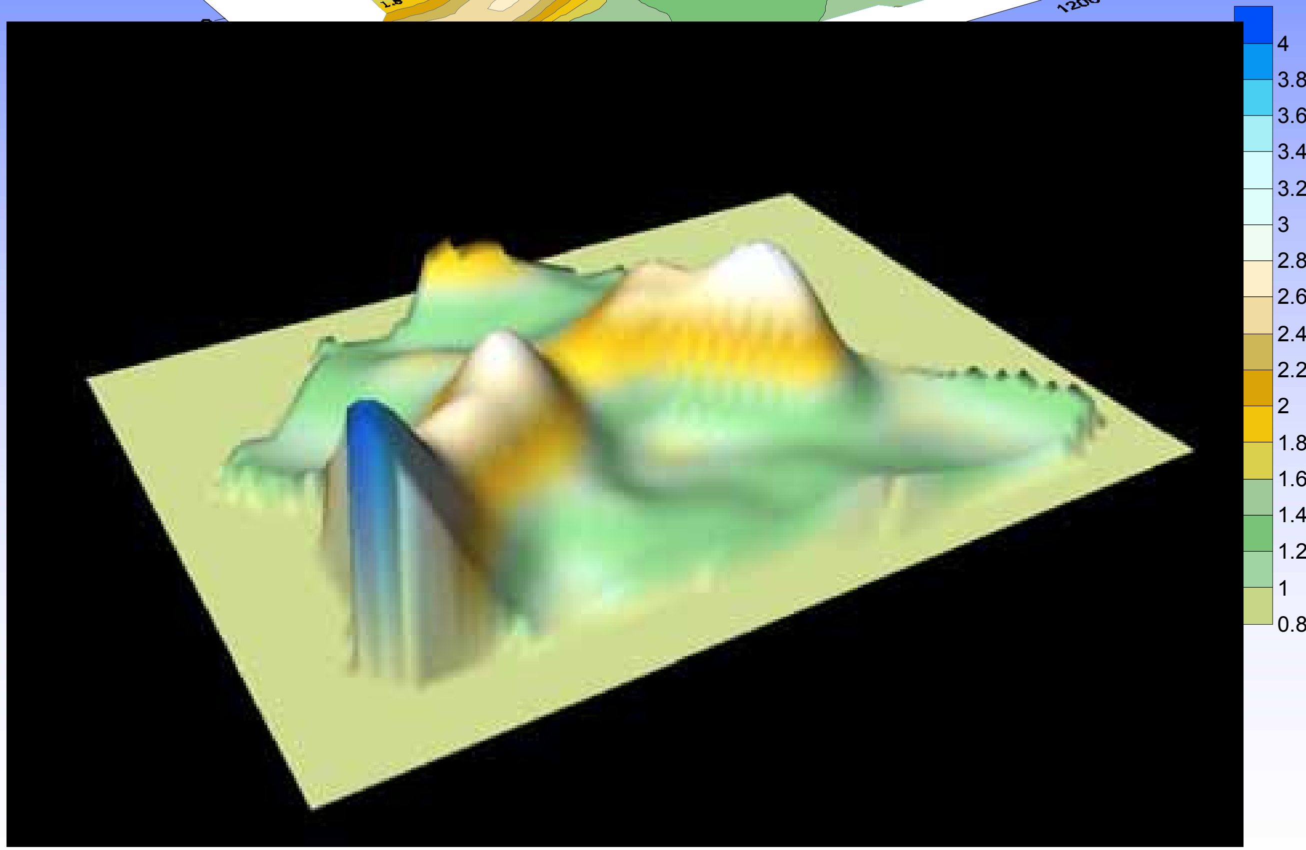
S CL FL

Detailed topographic map of studied area with reference vectors of slope



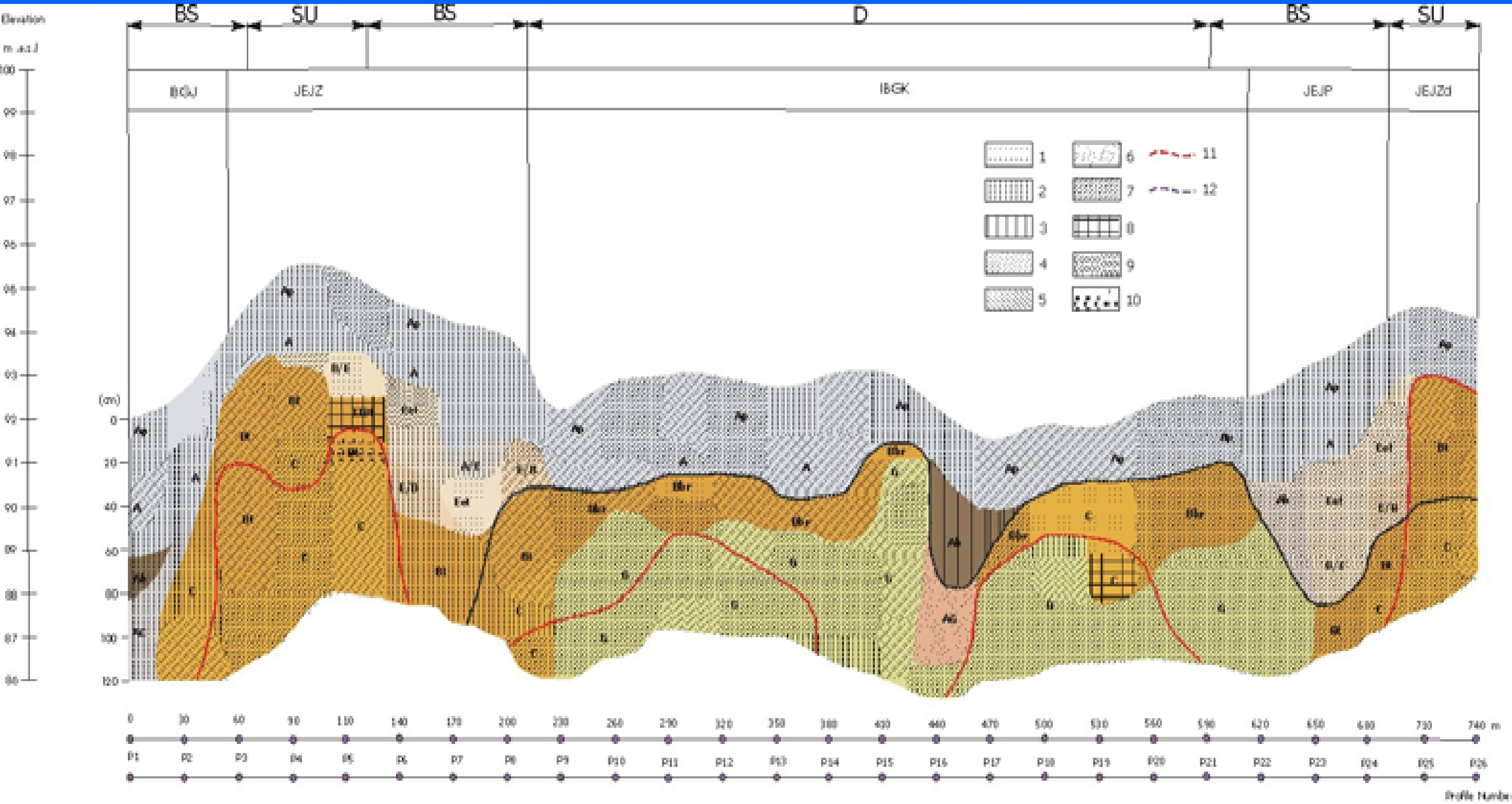
Relation between microrelief and epipedons color





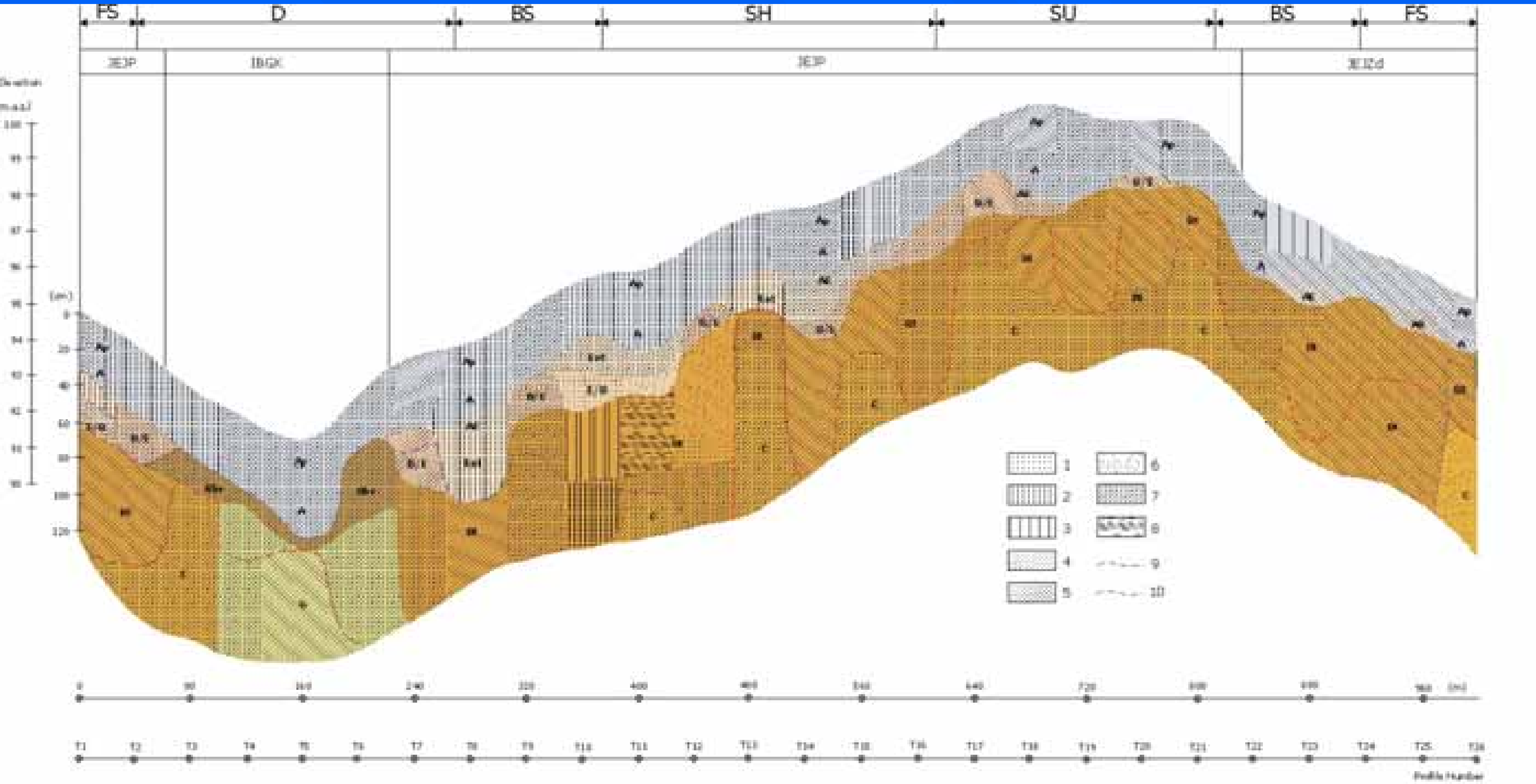
Distribution of Pedon Darkness Index PDI values of Ap horizons on studied area

Pedagogical Cross-Section AB



Pedological cross-section AB - Pólko: 1 - sand, 2 - loamy sand, 3 - loamy fine sand, 4 - sandy loam, 5 - sandy clay loam, 6 - loam, 7 - fine sandy loam, 8 - coarse sand, 9 - very fine sand, 10 - coarse sandy loam, 11 - top of calcium carbonate accumulation, 12 - top of gley spots, P - profile, D - depression, BS - backslope, SU - summit, IBGK - Typic Endoaquolls, IBGJ - Fluvaquentic Endoaquolls, JEJZ - Glossic Hapludalfs, JEJP - Glossaquic Hapludalfs, JEJZd - Typic Hapludalfs

Pedagogical Cross-Section CD

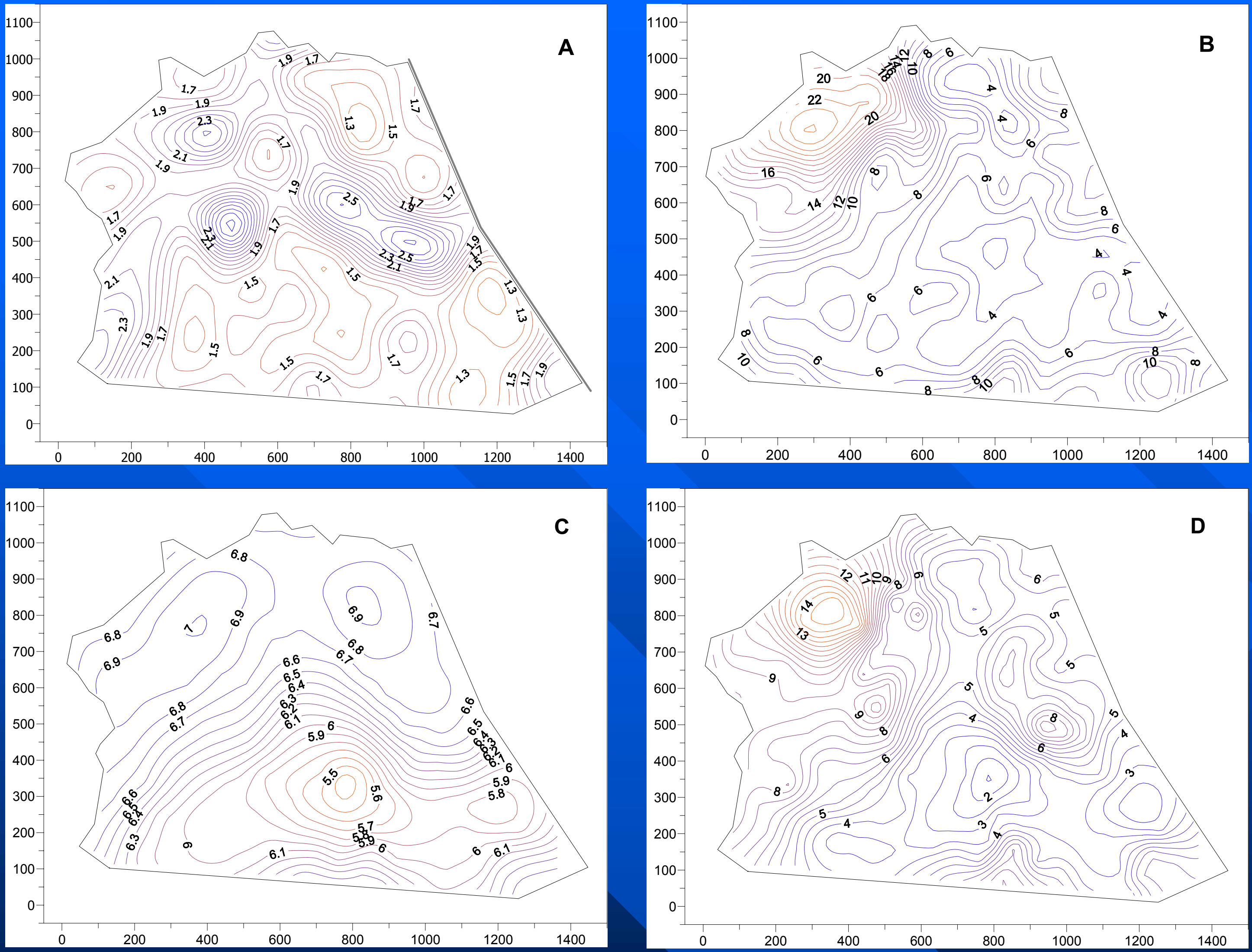


Pedological cross-section CD - Półko: 1 - sand, 2 - loamy sand, 3 - loamy fine sand, 4 - sandy loam, 5 - sandy clay loam, 6 - loam, 7 - fine sandy loam, 8 - clay loam, 9 - top of calcium carbonate accumulation, 10 - top of gley spots
FS - footslope, D - depression, BS - backslope, SU - summit, SH - shoulder, JEJP - Glossaquic Hapludalfs, IBGK - Typic Endoaquolls, JEJZd - Typic Hapludalfs

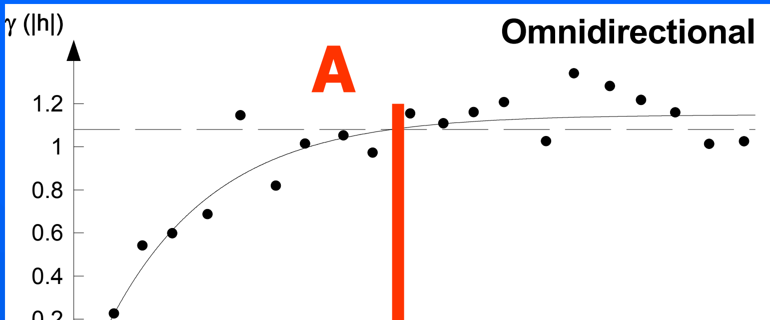
Spatial variability of soil properties within ploughed horizon

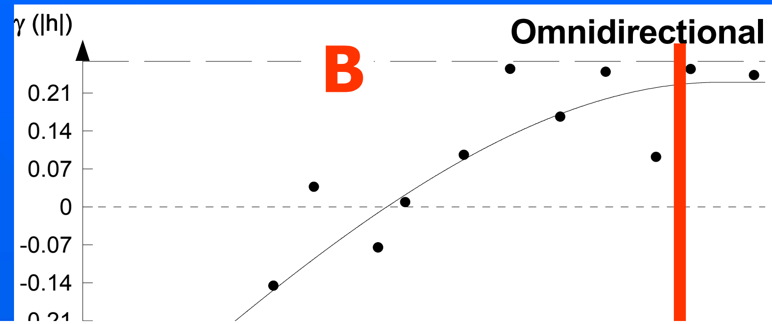
The tested soil properties demonstrate average and high values of the variability coefficient, the spatial analysis indicates that they exhibit a high systematic variability and low random variability. The content of organic matter is correlated to a distance of 220 m, the content of clay fraction to 368 m, and exchangeable calcium to 410 m.

Sc … nt
(A … in
$CaCl_2$ (D) in plough layer.



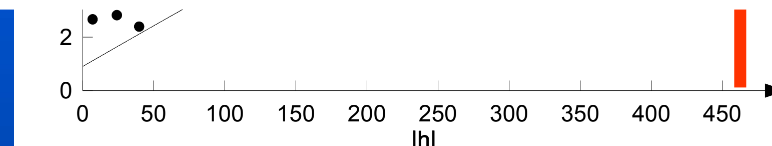
Contour maps of spatial variability of organic matter (%) (A), clay content (%) (B), pH in $CaCl_2$ (C), exchangeable Ca (cmol+/kg) (D) on soil plowed layer.





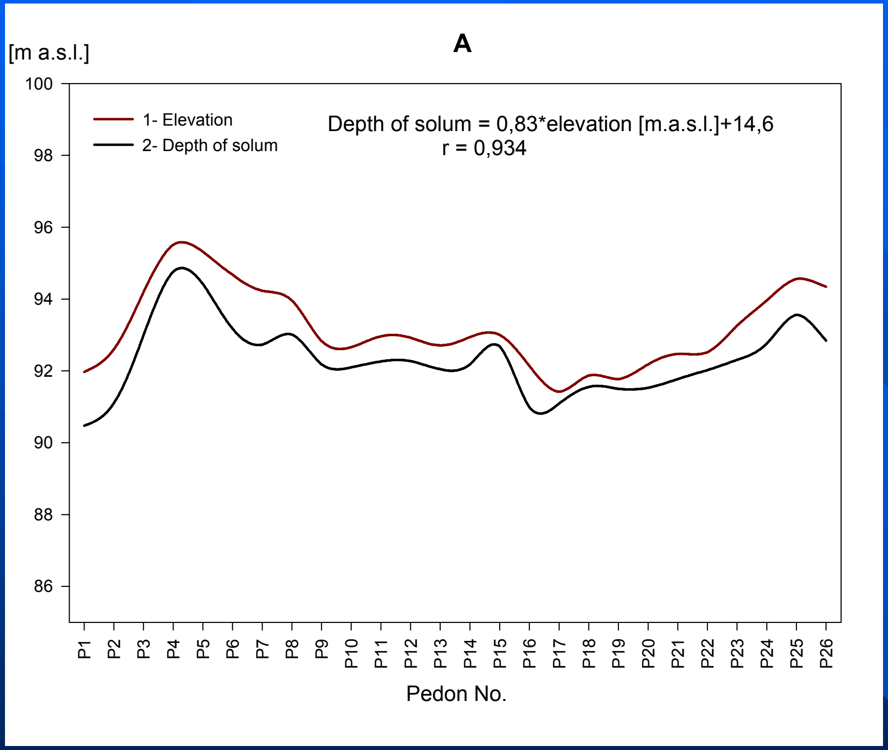
cross-variogram shows the same diagram like semivariogram

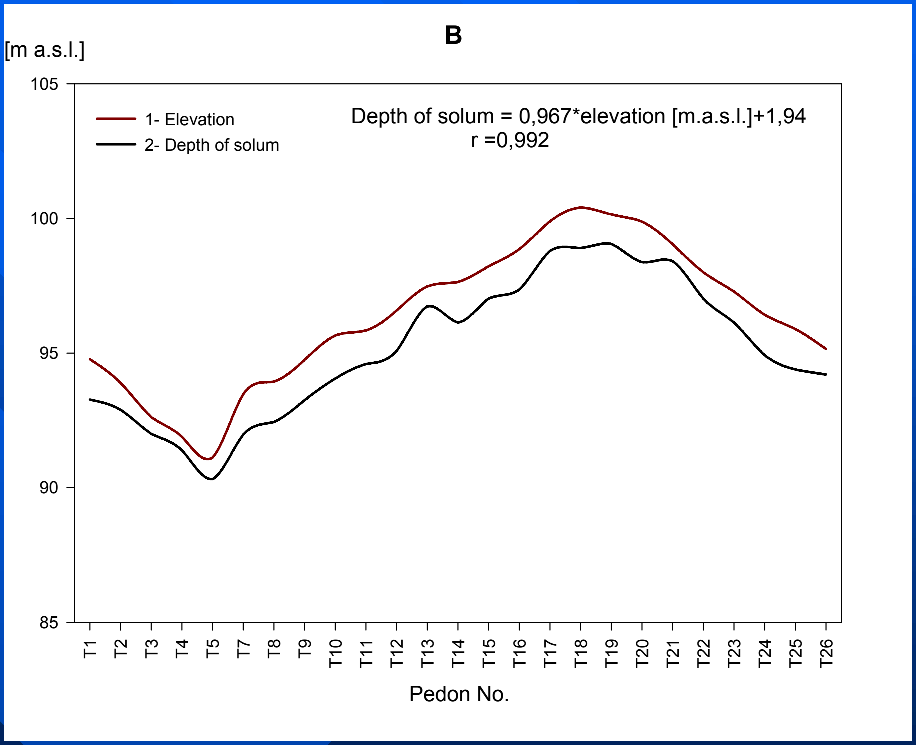
Experimental cross-variograms show the same results



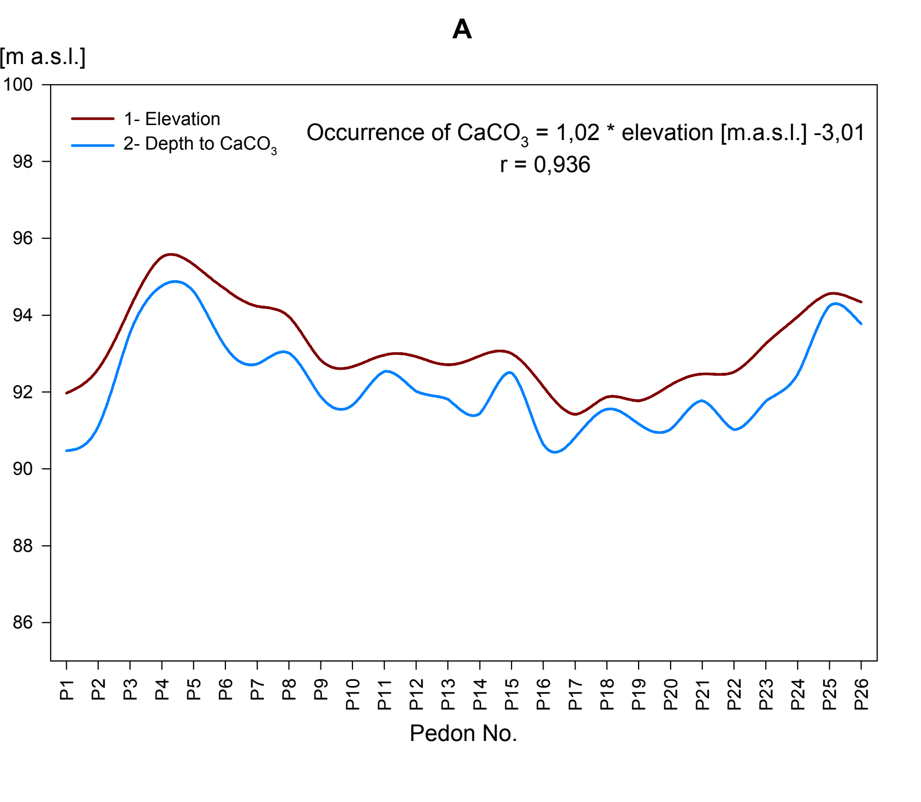
cross-variogram: organic matter content – exchangeable Ca content (A), organic matter content – clay content (B), organic matter content – **pH** in $CaCl_2$ (C), clay content - exchangeable Ca content (D).

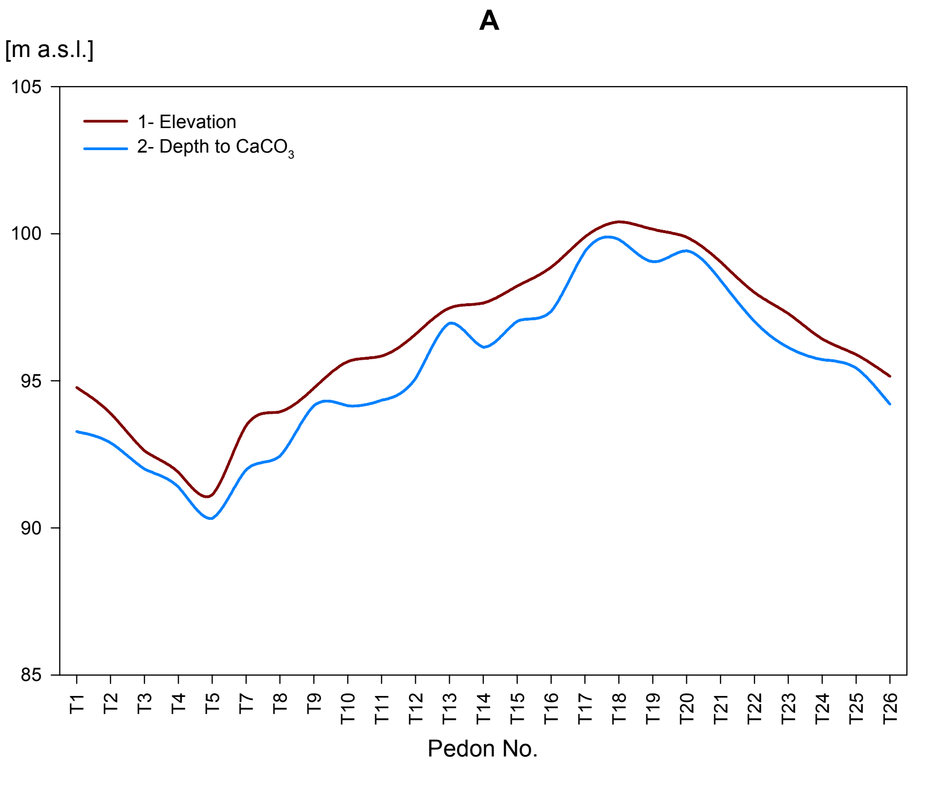
Spatial variability within pedological cross-sections



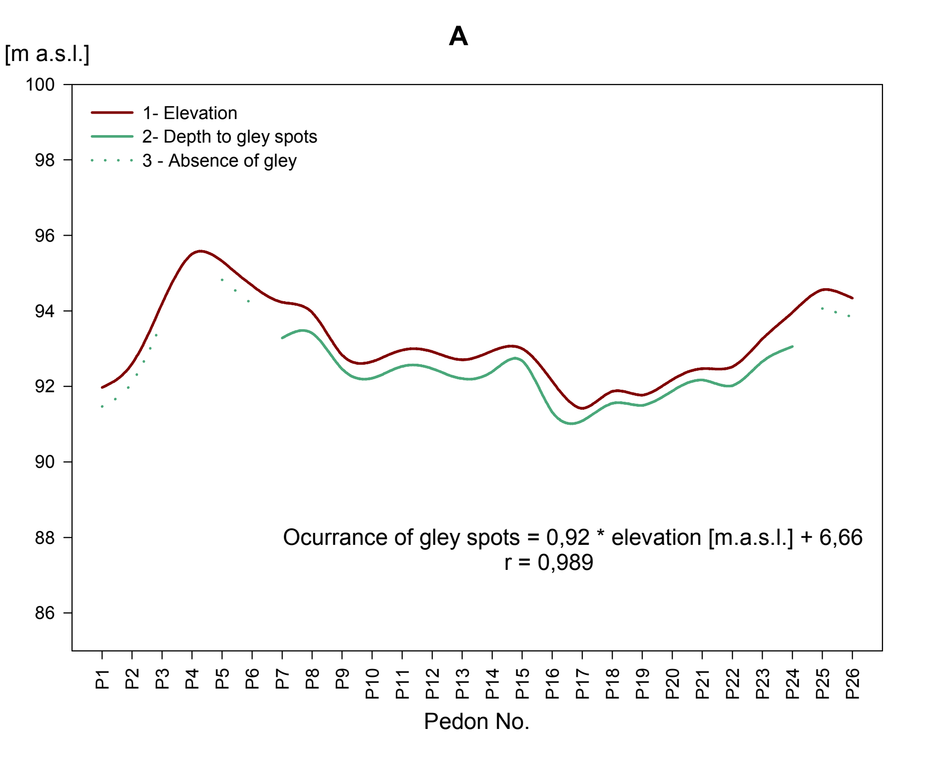


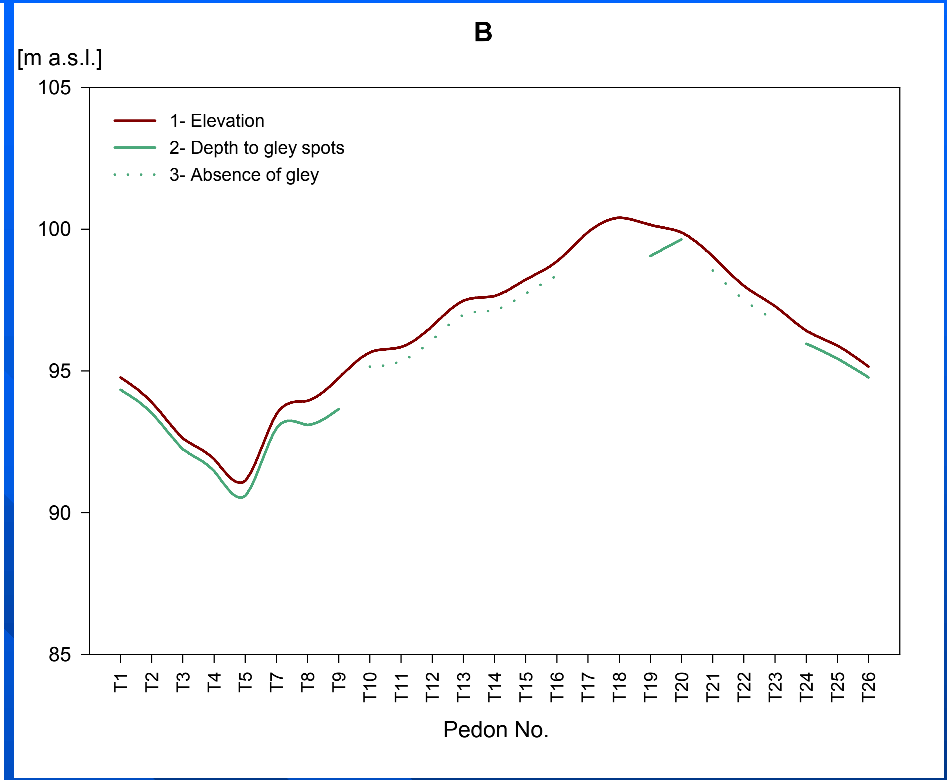
solum thickness : transects A-B (A) and C-D (B)





Leaching of CaCO3: transects A-B (A) and C-D (B)





Occurrence of gley spots : transects A-B (A) and C-D (B)

CONCLUSIONS

1. Studied soils are formed from highly diverse parent materials of glacial and glaciofluvial deposits affected by series of soil forming processes and natural drainage conditions. However, the differences in the soil cover are due to both pedogenic and geogenic processes. Pedogenic is responsible for the formation of specific vertical sequences of genetic horizons, whereas the vertical and horizontal assorting of the parent textural material and moreover weathering of its components are attributed to the geogenic process.

2. Variations of parent materials, microrelief and soil moisture conditions are responsible for the occurrence and development of two soil orders located side by side: Alfisols are mostly cover uplands and backslopes whereas Mollisols are found on remaining areas of pediments and footslpoes.

3. A clear top-sequential consociation of soil series connected together by interaction through geochemical processes is found on this kame field as follows:

a) Alfisols are found on the summits, shoulders and backslope, which are mainly formed from the action of eluvial and illuvial processes. The water status in subsoil as well as the occurrence of glossic horizon had key role in the classifying soils into subgroups,

b) Mollisols are found on footslopes and closed depressions; where organic matter accumulates eventually in epipedons accompanying with the occurrence of epi or endo-saturation conditions within subsoils, thicknesses of mollic horizon, water status and the irregular decrease in organic carbon content from a depth of 25 cm to 125 cm are used to classify soils into subgroups,

c) On concave toeslopes, the intensive accumulation of organic matter is overthickening mollic horizon to the extend that these soils meet the requirements of Cumulic Endoaquolls,

d) On kettle holes and around ponds Typic Haplosaprists are found, which are periodically submerging. However, theses soils are excluded from study.

4. On the basis of numerous results and statistical studies of spatial variability of soil cover, the distribution probability of soil properties revealed that:

- most soil properties exhibit skewed, non-Gaussian distributions and,
- each soil property can follow different distribution probability for various materials and sites and therefore the probability characteristics and the shape of the distribution function have to be estimated for each case.
- relative stable soil characteristic such as: clay content, organic matter content, cation exchange capacity and total organic matter accumulation shows small random variability (<25 %) and large systematic variability which is correlated at transects AB of 740 m and CD of 1 000 m in a liner dimensional measurement.

- although the tested soil properties demonstrate average and high values of the variability coefficient, the spatial analysis indicates that they exhibit a high systematic variability and low random variability. The content of organic matter is correlated to a distance of 220 m, the content of clay fraction to 368 m, and exchangeable calcium to 410 m.
- spatial relationship between the content of organic matter and exchangeable calcium in the soil and between the soil reaction and clay fraction and the content of exchangeable calcium, determined on the basis of positive cross-variograms, is modified by agrotechnical cultivation measures.

5- There are high variability of cation exchange capacity (CEC) and total exchangeable cations in the ploughed horizons (Ap) as a consequence of clay fraction and organic matter distribution in the studied soil. Alfisols have mean total exchangeable cation capacity varying from 4 to 6 cmol(+)*kg-1. These values are 2-3 times lower than those obtained for illuvial horizons and are also lower compared to those found in Mollisoils epipedons, amounting to 10-16 cmol(+)*kg-1. Although the horizons contain 2-3 % organic matter and about 10 % clay fraction, they have a moderately aggregated structure.

6- The diversities of physico-chemical and morphological properties among observation sites are so high, that the level of liner measurement or even the level of two-dimensional measurement does not represent major practical significance in relation to the characteristics of soil cover; liner and two dimensional accompanying with individual measurements particularly for polypedons seem to be more beneficial.


Thank you