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THE CASE STUDY OF THE SPATIAL NITROGEN VARIABILITY OF SOIL ENDANGERED BY EROSION ON LOESS MATERIAL

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Abstract

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The erosion impact on the spatial variability of selected soil properties was picked for the purpose of the research. The chosen locality is situated close to Křenovice (Vyškov district). Sites with soil type chernozem are exploited as arable land almost everywhere in this region. The agricultural production, however, has had staggering impact during last 80 years and has caused many degradation changes of soil properties of chernozems. This work aims to point out the water erosion impact on the spatial variability of total nitrogen, total organic carbon and C/N ratio, at steep grounds with no soil protection from erosion on loess parent material.

chernozem, Nt, Cox, C/N ratio, erosion, loess

Nitrogen, as a part of protein, is a limiting factor of live on the Earth. Nitrogen is also important deterioration agent of living environment (Vilček, Hronec, Berdna, 2005). Even though, 99 % of nitrogen is not available for more than 99% of organisms. Despite of relatively high volume of nitrogen in the nature, the reason for this obvious contradiction is molecular form of nitrogen which is not utilizable for most of organisms. The cleavage of the triple bond, which connects both atoms of nitrogen, requires a lot of energy. The energy can be obtained only in the processes under high temperatures or by few specialized species of microorganisms that can fix air nitrogen. Primary source of soil nitrogen is atmosphere containing 77.5 % of N_2. This form of nitrogen, although it occurs in high amounts in soil, is not utilizable by higher plants if it is not previously ionizated and transformed to NH_4^+ a NO_3^- ions. One of the possibility to isolate air nitrogen is electrical discharge while storm. Molecules of N_2 are oxidized to nitrogen oxides alternatively up to nitric acid. On the base of mentioned information, 10–40 kg N per ha are transferred to the soil annually.

In topsoil, total nitrogen content (Nt) usually is mainly about 0.1 to 0.2 % but it can vary from 0.03 to 0.5 %. It is possible to calculate that there is probably 3 000–9 000 kg N per ha in topsoil but only 1–2 % of this amount is present in form of NH_4^+, NO_3^- ions and therefore utilizable by plants. Biomass of microorganisms, metabolites of organisms living in soil, plant and animal residues etc. are part of soil nitrogen sources as well.

Evaluation of the correlation between total nitrogen suggests that there is a relative high correlation between slope, soil moisture and crop yield (Vaněk, *et al.*, 2008; Persson, Pilesjö, Eklundh, 2005).

Total nitrogen content is relatively constant value in soil because it is formed by hardly degradable compounds as aromatic nuclei of humic and fulvo acids etc. For this reason, soil total nitrogen content is put into relation with Cox and is expressed as a ration of C/N. The ratio usually varies from 10 to 12:1. Nevertheless, ratio 18:1 is still considered as sufficient. The ratio can be considerably narrowed in over-fertilized soil. Long-term and excessive encumbrance by nitrogen results in exhaustion of accumulative capacity of ecosystem (Galloway *et al.*, 2003) and loss of ecosystem stability (Bobbink and Roelofs, 1995). It is attended by enhanced amount of nitrogen in form of gas emissions and nitrates coming out of ecosystem.

Vilček, Hronec, Bedrna (2005) show consequences of nitrogen abundance in soil, especially in form

of nitrates, to its quality and biota: decrease or absence of nodulating symbiotic bacteria, decrease of nitrogen-fixing bacteria in soil, extension of growing time, weak blossoming, insufficient formation of crop and excessive growth of vegetative parts of plants, freezing of perennial plants because of insufficient preparing plants before winter, weaker resistance to fungal disease, wind or longer rain, negative consequences for organisms while penetration of nitrates to groundwater or drinkable water which may lead to cancer.

The aim of this study was to show spatial variability of total nitrogen on sloping parcel with unresolved erosion protection of our most fertile soils, on selected parcel near the village Křenovice (county Vyškov).

MATERIAL AND METHODS

The study compares changes of selected soil parameters in locality Křenovice (county Vyškov district – see Picture 1) within present results (2011–2012) and results from the same locality 40 years ago. In 1965, the Soil Survey was done and one of the typical selected soil pit was opened there (soil analysis Tab I). From taken present samples, maps of soil spatial variability were done for monitored parameters.

Characterization of area of interest

Sloping parcel with southern exposition is located at an altitude of 220–260 m above sea level. According to agro-climatic zones (Kurpelová, Coufal, Čulík, 1975), locality is ranged to warm climatic area, zone A3 which is warm, moderately dry climate and with mild winters. From the point of agronomic categorization, parcel is considered as a corn production area. Annual temperature average is 8.5 °C, annual precipitation average is 540–600 mm. Number of days with 0.1 to 10.0 mm precipitation is 90 and 15 days with precipitation above 10.0 mm.

Evaluation of soil according Soil Survey

Erosion form of carbonated chernozem, on loess, number of soil pit 9/366/V3

0–28 cm brown-grey Ap horizon (topsoil) with slightly developed crumbly loam structure and visible border,

28–52 cm transitional horizon A/Ck, fair-brown with dark humus particles, structureless, compacted and without visible border,

52 cm and deeper: parent material (loess), fair, structureless, loam, wet and slightly compacted, casual root penetration, pseudomycelia.

Results are summarized in Table I.

Sampling collection

The aim area is approximately 10 ha, it was divided into square nets (squares 40 × 40 m with 37 sampling sites). In addition, soil pit was opened. In advance, areas associated with the boundaries of the parcel were excluded. From the monitoring sites, sampling was done only from the topsoil layer (depth 0–15 cm, mixed sample). Sampling from the soil pit was done from all the described horizons. The samples were then dried.

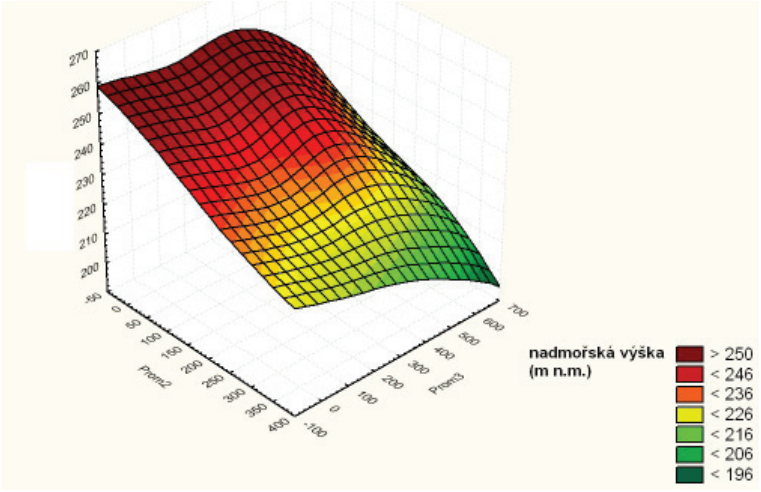
Soil analysis

Collected samples were dried at room temperature and sieved through strainer mesh with 2 mm sieve mesh for the separation of skeletal particles (ČSN ISO 11464). Resulted fine-grained soil was subjected to standard physical and chemical analysis, see below. The aim of the analysis was to evaluate spatial variability of the parcel on loess, endangered by erosion.

From the chemical characteristic, content of Cox and total nitrogen (Nt) respectively their ratio were determined.

Oxidimetric titration according Nelson et Sommerse (1996) was used for the determination of Soil organic matter (SOM), Cox respectively.

1: *Aerial map of Křenovice locality (Vyškov district) with marked area of interest (© GEODIS BRNO, s r. o.)*



2: *Orographic model of terrain of Křenovice locality, orientation of X and Y axis is the same as at other figures (3D surface graph, toughness 0.25, Statistica 8.0.)*

For the determination of total nitrogen content (Nt), standardized Kjeldahl method was used according ČSN ISO 11261 (836415): „Quality of soil – determination of total nitrogen content – modified Kjeldahl method".

Results were statistically set by analysis of variance.

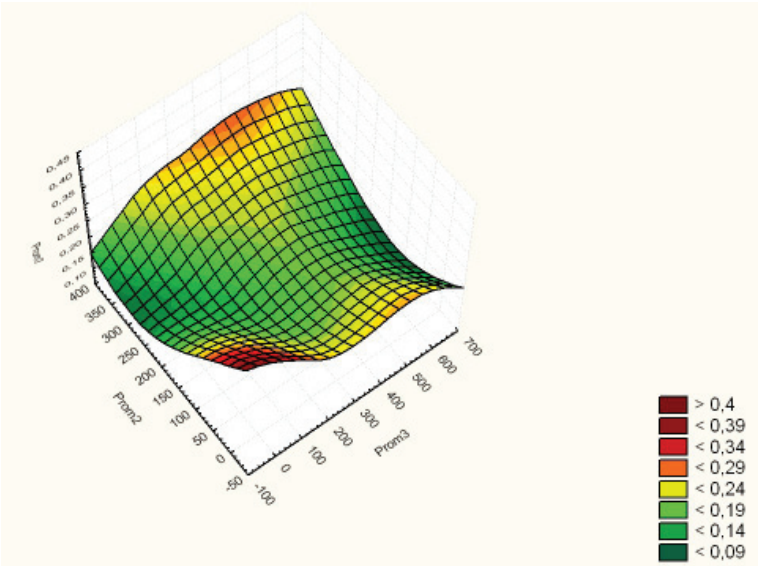
RESULTS AND DISCUSION

Spatial variability of total nitrogen content (Nt)

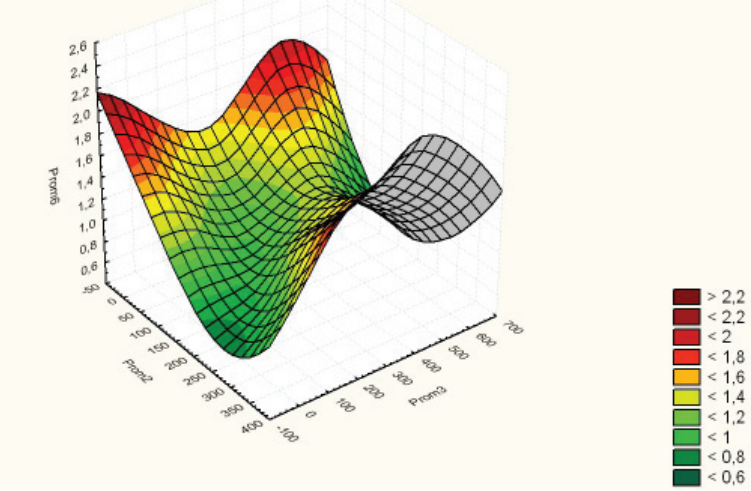
The average value of total nitrogen content was 0.19 ± 0.007% which approximately corresponds with the data for arable soil of the Czech Republic. Extreme values vary from 0.10–0.26%. Spatial variability is shown in Fig 3. Areas with the lowest content of Nt are concentrated in a center of the parcel. These areas are affected by the highest level of erosion. Contrarily, areas with the highest nitrogen content are found on the bottom and top of the hill. These places are partly affected by erosion or places where colluvisols and accumulated chernozem can secondarily originate on the cumulative basis. As evident, in this locality, average values of total nitrogen content are 0.19 ± 0.007%. In the area of interest (10 ha), there is incomplete 68 900 kg of nitrogen to the depth of 25 cm. Arrangement of spatial variability can be seen in Fig. 3.

Spatial variability of Cox content

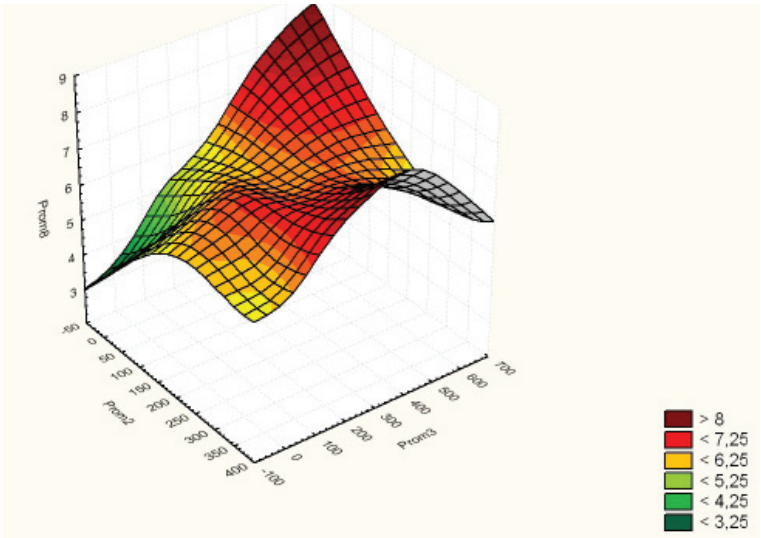
Average of Cox value is 1.23 ± 0.06% on selected field. These values calculated to content of humus can be evaluated as a medium content, nevertheless in extreme cases, values can vary from 0.89 to 1.98%



3: *Spatial variability of total nitrogen content (Nt) in % – axis Z (3D surface graph, toughness 0.25. Statistica 8.0.)*



4: *Spatial variability of the Cox content in % – axis Z (3D surface graph, toughness 0.25, Statistica 8.0.)*



5: *Spatial variability of ratio C/N (3D surface graph, toughness 0,25. Statistica 8.0.)*

Cox (low and high content). Spatial variability of oxidable carbon content is not regular there. Areas with the lowest content of Cox are concentrated approximately in the middle of the slope, as expected. On the sides of the most intense erosion, material of parent topsoil is mixed with deeper located loess parent material. Areas with the highest content of Cox are found on the bottom and top of the slope. Arrangement of spatial variability can be seen in Fig. 4.

Spatial variability of ratio C/N

Average value of ratio Cox/Nt is 6.59 ± 0.1 on selected field. Range of variation oscillates from 5.2 to 8.0. This ratio is rather narrow and refers to nitrogen reserves in whole locality. It probably results from erosion. Nitrogen is transferred also into loess materials, which contain small part of soil organic material (0.21% Cox) if compared to topsoil. Total nitrogen is likely to be partially adsorbed on the SOM and especially on clay particles. Whole profile, including nitrogen reserves in loess, is homogenized by ploughing. Arrangement of spatial variability can be seen in Fig. 5.

Křenovice locality, Vyškov district, typical selected soil pit 9/366/V3 in 1965 (Soil Survey) and comparisons with current situation:

According to older classification, it was ranked to eroded carbonated chernozem, on loess. To the depth of 28 cm, there is dark-grey humic chernozemic horizon which is affected by ploughing. Under humic horizon, there is transitional horizon with 24 cm of thickness (depth 28–52 cm). Lower, parent material (loess) was found (analyses see Tab. II).

As evident from both Tabs; loss by erosion is around 30 cm. In 1965, parent material was at the depth of 52 cm, currently, it is already at the depth

I: *Results from Soil pit No: 9/366/V3 during year 1965*

	Orh (ca)	h/Pca	Pca
depth (cm)	0–28	28–52	52 +
Content of particles sub 0.01 mm (%)	38.7	35.8	-
Cox (%)	1.01	0.31	-
pH/KCl	7.3	7.2	-
CEC (mmol/100g)	21.00	14.00	-
Nt (%)		N/A	
ratio C/N		N/A	

II: *Results from Soil pit No: 9/366/V3 during year 2011*

	Apk	Ck
depth (cm)	0–25	25+
Content of particles sub 0.01 mm (%)	38.6	34.4
Cox (%)	1.15	0.21
pH/KCl	7.3	7.2
CEC (mmol/100g)	17.1	16.8
Nt (%)	0.21	N/A
ratio C/N	5.5	

of 25 cm. Ploughing is currently done within transitional horizon with adding of pedogenic loess material. Classification is rather problematic because chernozem should show thickness of chernic horizon more than 30 cm which is not observed. One of the possible proposal would be to re-classification to carbonated regosol or eroded chernozem.

CONCLUSION

At the whole area of interest, evident sheet erosion was visible in the middle of the slope. In general, there was found out:

- average value of total nitrogen content was evaluated as medium content (0.19 ± 0.007 %). Range of variation oscillates from 0.10 to 0.26 (low–medium content). Spatial variability is not regular in the locality. Areas with the lowest Nt are concentrated in the middle of the parcel, that means areas are affected by the highest level of water erosion. Areas with the highest content are contrarily found on places related to base and top of the hill – places partly affected by erosion or places where colluvisols and accumulated chernozem can secondarily originate on the cumulative basis,
- content of oxidable carbon in topsoil is 1.23 ± 0.006 %, ratio C/N is then rather narrow: on average 6.59 ± 0.1 /1,
- spatial variability of monitored parameters corresponds with surface erosion effect. Generally, the lowest values/ratios are found in the middle part of the parcel, contrarily the highest ones on the base and top of the hill,
- texture is loam soil (38.6, resp. 34.4 % clay particles),
- classification according Taxonomic Classification of Soil of the Czech Republic is rather problematic. One of the possible suggestions would be re-classification as eroded chernozem partly carbonated regosol and modal colluvisol.

SUMMARY

The paper is evaluating spatial variability of total nitrogen and oxidable carbon content in Křenovice locality (Vyškov district) where sheet water erosion is proved. Results from two soil pits (years 1965 and 2011) were located on the same place and were compared. See the Tabs. I., II.
Sloping parcel of Křenovice land register is oriented to north-east. Altitude ranges from 220 to 259 m above sea level. It belongs to warm climatic area, zone A3. Annual temperature average is 8.5 °C (1961–1990), average annual precipitation is 540–600 mm. According data from Soil Survey, there is loam eroded chernozem, on loess (loam in topsoil according present classification). Total area of 10 ha was divided to square net approximately 40 × 40 m (37 sampling sites). In addition, one soil pit was opened. Sampling was done only from the topsoil from the depth of 0–15 cm (mixed sample). From collected present samples, map of spatial variability of total nitrogen content Nt (Fig. 3), content of oxidable carbon Cox (Fig. 3) and ratio C/N (Fig. 4) was made. At the whole parcel, sheet water erosion was proved although there is relatively low annual precipitation. Average of total nitrogen content is

0.19 ± 0.007 % which is evaluated as medium content. Extreme values vary from 0.10 to 0.26 %. Average value of oxidable carbon is 1.23 ± 0.06 % which is evaluated as medium content. Range of variancy oscillates from 0.89 % (low content of organic matter) to 1.98 % (medium content of organic matter). Ratio C/N is rather narrow, on average 6–7:1.

Spatial variability of monitored parameters corresponds with surface erosion effect. Generally, the lowest values/ratios are found in the middle of the parcel contrarily to the bottom (in terms of colluvial material) and top (places with less of erosion effect) of the hill.

At exposed parts of the slope, loss by erosion is approximately 30 cm (parent material was at the depth of 52 cm in 1965, currently it is only at the depth of 25 cm). Ploughing is currently done within transitional horizon with adding of soil forming material – loess. Soil reaction is alkalic because of erosion. Texture is classified as loam soil.

Soil classification of according Taxonomic Classification of Soil of the Czech Republic is rather problematic. Digital soil map (URL 1) at 1:100 000 scale shows parcel to be located in bloc of chernozem modal resp. modal pelic cambisols. Classification among chernozems is slightly problematic because on the eroded area, soil does not correspond with the definition of chernozem. Soil with chernic horizon Ac, which is thick more than 30 cm, is said to be chernozem. From the mentioned analysis it is evident that chernic horizon does not exist in some cases and transitional horizon is made from the topsoil. One of the possible suggestion is to partly classify this soil as chernozem washout/ eroded chernozem (although it does not observe parameters for chernic horizon) or it might be ranked among carbonated regosols with occurrence of colluvisols. Map arrangement among cambisols could not be explained.

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URL1: http://geoportal.cenia.cz/mapmaker/MapWin.aspx?M_Site=cenia&M_Lang=cs
(Digital map at 1:100 000 scale, from portal of the State Administration, 1. 7. 2012).

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