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MAIN FEEDBACKS BETWEEN OXIDIZABLE CARBON CONTENT AND SELECTED SOIL CHARACTERISTIC OF CHERNOZEM

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Abstract

VLČEK VÍTĚZSLAV, HLADKÝ JAN, KYNICKÝ JINDŘICH, BRTNICKÝ MARTIN. 2015. Main Feedbacks Between Oxidizable Carbon Content and Selected Soil Characteristic of Chernozem. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 63(2): 471–476.

Anthropogenic pressure on our agricultural land is culminating last hundred years, especially after 1948, not only because of only massive application of mineral fertilizers but also because of land consolidation and subsequent accelerated water and wind erosion and use of mechanization. This article focuses on main demonstration of feedbacks especially with oxidizable carbon which can negatively affect soil as a homeostatic system. Oxidizable carbon, as the basis of soil humus, is crucial for maintaining soil fertility and for its resistance to further degradation factors affecting the soil. 35 chernozem sites were selected in South Moravia region. These soils had been probably used for their fertility and availability before the turn of the AD. Unfortunately, their long-term agricultural use has resulted in adverse impact on their quality.

This way, shallower forms of erosion were often formed. These erosion forms are omitted for the purposes of our study there. For this work, locations with preserved chernic (i.e. diagnostic) horizon, as the horizon with less anthropogenic influence, were selected. Relations between a grain size (clay, silt and sand particles), exchange reaction in soil, sorption capacity, oxidizable carbon content, total nitrogen content and content of selected potentially acceptable elements (Ca, Mg) were monitored.

Keywords: chernozem, feedback, oxidizable carbon

INTRODUCTION

In the Czech Republic, chernozem has been used since the beginning of agriculture. It is a fertile soil in hot and dry areas usually up to an altitude of 300 m. They were probably used for agriculture at the turn of AD. The limiting factor of these soils, however, has always been water. Anthropogenic pressure and duration of chernozem use causes gradual degradation. This degradation culminates especially in the last hundred years, especially after 1948, when smaller fields of chernozem land were gradually joined to larger areas, thus water and wind erosion was accelerated. Additionally, the use of high doses of mineral fertilizers without adequate crop rotation and without use of manure or green manure brings additional risks of gradual loss of ecological and production functions of these soils.

Excessive fertilization with mineral nitrogen, known mainly from the 80's of the 20th century, had led for example to increased yields, but on the other hand, it had led to reduce of e.g. exchangable magnesium pool (Pokorný, 2012). With decrease of magnesium, but also e.g. by changing the ratios of other elements and other physical and chemical properties of soil, quality and content of soil organic matter had been subsequently decreasing. The reduce of organic matter content in soil and its quality then usually leads to a decrease of the soil sorption capacity, to higher susceptibility to erosion and to other negative consequences associated.

In this manuscript, we try to find some feedbacks between selected soil characteristic in chernozem soil type and to suggest a potential risk of negative anthropogenic impact on these characteristic.

MATERIAL AND METHODS

In South Moravia, 35 sites of chernozem were selected. Samples were taken from chernic, i.e. diagnostic, horizon from a depth of 30–60 cm. Chernic diagnostic horizon was chosen because it is assumed to be minimum anthropogenically influenced. All properties of arable land lying above are supposed to be influenced with e.g. used farming techniques (plowing, minimization), the level of fertilization and erosion etc. Horizon lying below the latter largely removes these differences and thus natural feedbacks of soil characteristic can be seen. For the evaluation, all chernozems were selected regardless their subtype or variety. Nonetheless, erosion forms with shallow chernic horizon were excluded. In the Fig. 1, sample sites are indicated.

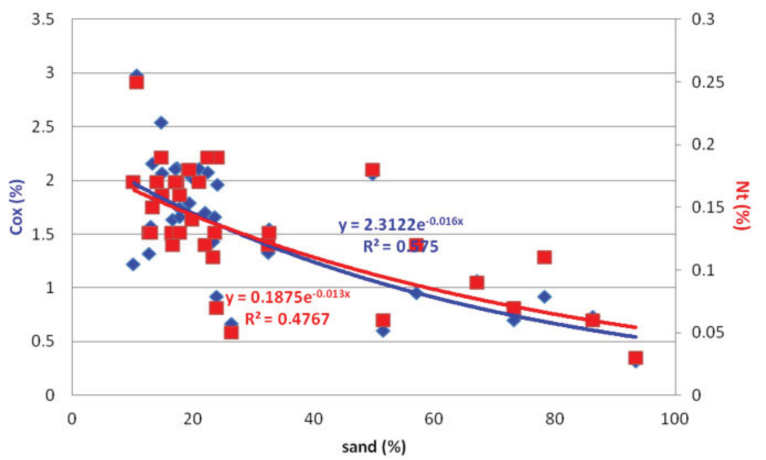
Samples were collected using a soil chamber bit with Edelman head. Immediately after sampling, quartering of collected material was processed. Samples were dried then and analyzed by standard methods: **Particle size analysis:** used the conventional "pipette method" (Gee et Bauder, 1986), **soil exchange reaction**: used method ISO 10390, **cation-exchange capacity** (CEC) (ISO 13536), **oxidizable carbon** content (ISO 14235), **total nitrogen content** (ČSN ISO 11261) **and content of selected potentially acceptable elements** (Mehlich III).

RESULTS AND DISCUSSION

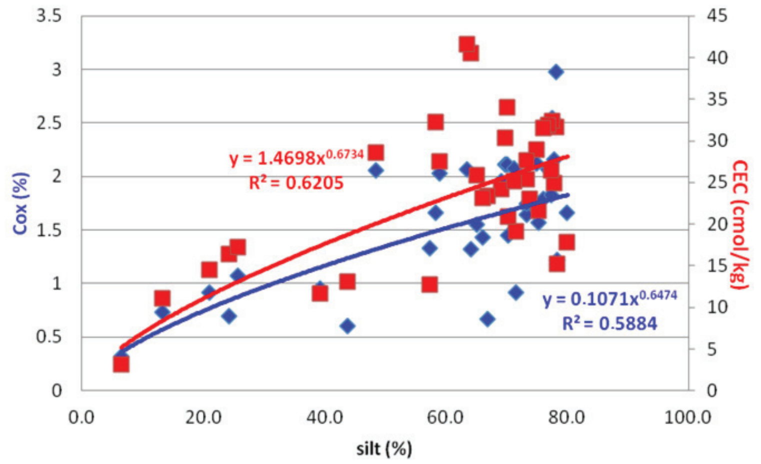
Particle size analysis: average content of clay particles (< 0.002 mm) is 8.10 ± 1.00%, average content of silt particles (0.05–0.002 mm) is 61.17 ± 3.45%, average content of sand particles (0.05–2.00 mm) is 30.73 ± 3.93%. In average, it is evaluated as a silty clay. Average soil exchange reaction is 6.98 ± 0.11 which is estimated as neutral. Average **cation-exchange capacity** (CEC) is 23.84 ± 1.44 cmol/kg which we evaluate as medium high. Average **oxidizable carbon content** (Cox) is 1.57 ± 0.10% which is evaluated as medium humic. Average **total nitrogen content** is 0.14 ± 0.01%. Average **C/N ratio** is 11.66 ± 0.30. Average **potentially acceptable calcium content** is 11748 ± 2128.6mg/kg and average **potentially acceptable magnesium content** is 477.03 ± 47.19 mg/kg.

Before becoming familiar with the feedbacks, it is worth to remind the soil acts as a homeostatic system (i.e. the system maintained in balance). That is allowed by feedback between particular

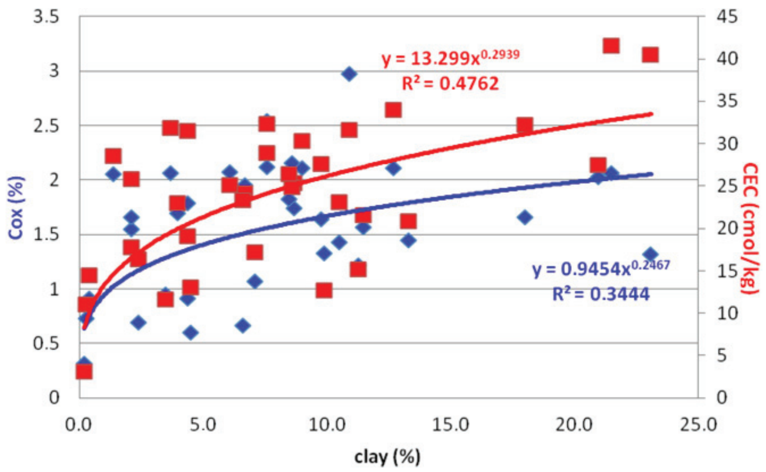
1: *Sample sites*



2: *Influence of sand content (%) on Cox content (%) (blue) and on total nitrogen content Nt (%) (red)*



3: *Influence of silt particles (%) on Cox content (%) (blue) and sorption capacity (cmol/kg) (red)*



4: *Influence of clay particles (%) on Cox content (%) (blue) and CEC (cmol/kg) (red)*

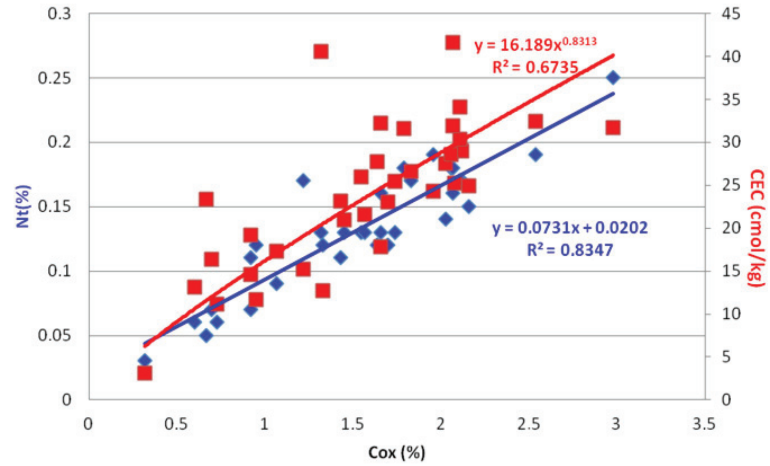
elements of the system. Soil reaction while buffering after acidification is often cited as the most striking example. After acidification as acid rain or physiologically acidic fertilizer, solubility of calcium carbonate increases and soil reaction returns to the original state. The described process is called a negative feedback (i.e. acting against the process). But if in biological systems positive feedback appears (e.g. pests without predators, disease without adequate reaction of the organism), it can lead to serious disturbances or the collapse of the entire system (Pawlowski, McCord, 2009). Therefore, occurrence of the positive feedback should be eliminated up to minimum in any of the system (Míchal, 1994).

As seen in Fig. 2: while increasing content of sand particles (0.05–2.00 mm), oxidizable carbon content is decreasing. The reason is probable increased respiration of soil microorganisms within excessive aeration. That leads to increased organic matter decomposition and total nitrogen reduce (Kong *et al.*, 2009). Correlation coefficient between sand content and Cox is high (R = –0.76), correlation coefficient between sand content and Nt is high as well (R = –0.69).

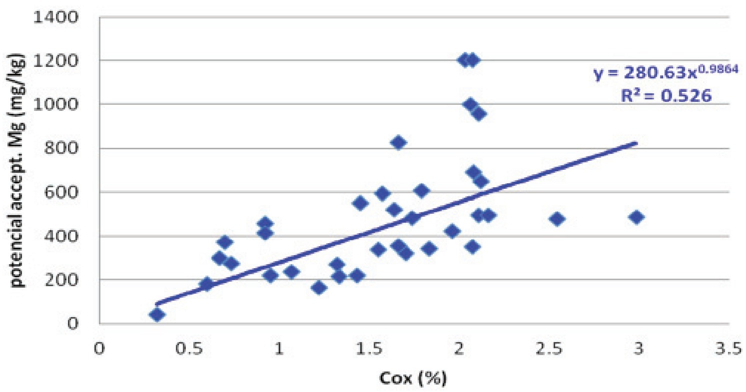
As seen in Fig. 3: while increasing silt particles (0.002–0.05 mm), content of oxidizable carbon and sorption capacity (cmol/kg) is increasing. Correlation coefficient is high in both cases: Cox R = 0.77 and CEC R = 0.79. Similar relation between organic carbon and silt fraction were found by Zhao *et al.* (2006).

As seen in Fig. 4: while increasing clay particles content (< 0.002 mm), oxidizable carbon content and sorption capacity (CEC) is increased. Correlation coefficient is high again in both cases: Cox relation (R = 0.59) a CEC relation (R = 0.69). Relation between sorption capacity value and clay content completely correlates with results of Adamu *et al.* (1989), who state correlation between CEC and clay content R = 0.70.

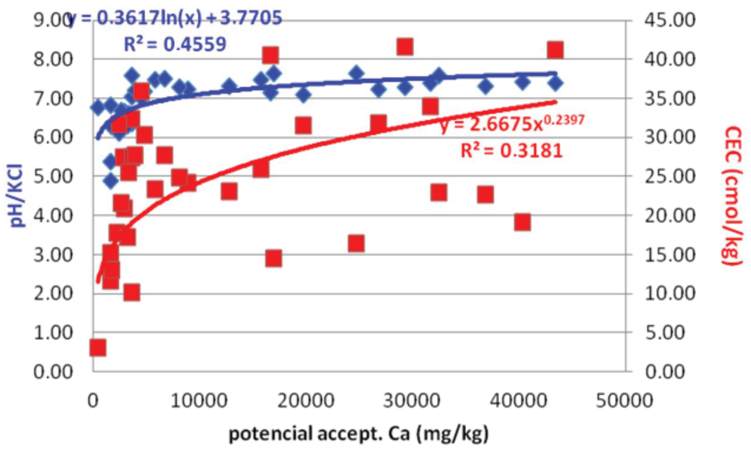
As seen in Fig. 5: Decrease of oxidizable carbon content is followed by reduce of cation-exchange capacity (CEC). The result is in full correlation with the conclusion that soil organic matter is one of the main factors affecting soil sorption. In the study



5: *Influence of Cox content on cation-exchange capacity (CEC) cmol/kg (red) and total nitrogen content Nt (%) (blue)*



6: *Influence of oxidizable carbon content Cox on potentially acceptable magnesium content (mg/kg)*



7: *Influence of potentially acceptable calcium content (mg/kg) on cation-exchange capacity (cmol/kg) (red) and exchange soil reaction (blue)*

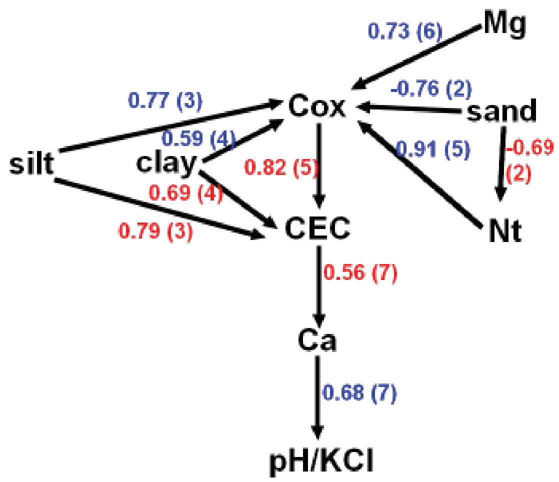
of the 444 samples of tropical soil, Aprile et Lorandi (2012) state correlation between Cox and CEC R = 0.84 (our samples 0.82). With reduce of Cox, total nitrogen content Nt is reduced. Usually, optimum C/N ratio is considered to be 10. In our samples, average C/N ratio was estimated to be 11.7 and considered to be normal. Reduce of C/N ratio leads to increase of basal respiration and organic matter is more easily decomposable by microorganisms (Manzoni *et al.*, 2010). In this case, increasing doses of nitrogen addition (therefore reduce of C/N ratio) can lead to loss of total organic matter reserves in soil which is considered to be positive feedback. C/N ratio involves organic matter quality (Paračková, 2001). Correlation coefficient is high in both cases: CEC (R = 0.82), Nt (R = 0.91).

As seen in Fig. 6: Decrease of oxidizable carbon content is followed by reduce of acceptable magnesium. As study of Pokorný *et al.* (2012) indicates, with its lower content, humus content and quality is decreased. As the authors state, reduce is caused by inadequate saturation of humic acid by magnesium and by decrease of particular humates formation. There is also a decrease of the colored coefficient, and figuratively, also reduce of the sorption capacity and other negative phenomena. The correlation coefficient is high (R = 0.73).

As seen in Fig. 7: decrease of potentially acceptable calcium content leads to reduce of exchangeable pH. Decrease of sorption capacity means that potentially acceptable calcium decreases as well. Correlation coefficient is high in both cases pH/KCl (R = 0.68) and CEC (R = 0.56).

In the Fig. 8, all statistically significant feedback of selected physical and chemical characteristic are summarized. Numbers between particular soil characteristic indicate correlation coefficient, number in brackets and its color indicate number and color shown in the Figs. 2–7.

Anthropogenic influence of monitored factors is relevant for nitrogen, calcium and magnesium input. Increase of mineral nitrogen addition doses leads to reduce of exchange magnesium reserves which affect not only the content but also the quality



8: *Summary of the results*

of soil organic matter (Pokorný *et al.*, 2012). This way, other physical, chemical and biological properties of soils, its buffer ability, resistance to soil compaction and erosion are changed (Balesdent *et al.*, 2000; Lützow *et al.*, 2002).

Other possible anthropogenic input to the system is the addition of calcium and magnesium. Nevertheless, saturation of the sorption complex is not currently being adjusted by adequate doses of calcium resp. magnesium. Partly, that condition for this type of soil is slowed by accelerated erosion which usually strips the land to the carbonate parent material.

CONCLUSION

On the basis of results from 35 chernozem sites obtained by monitoring of physical and chemical properties, main feedbacks between selected soil characteristics were assessed:

Particle size analysis: average clay particle content is 8.10 ± 1.00% with variation range 0.2–23.1%, average silt content is 61.17 ± 3.45% with variation range 6.5–80.1% and average sand content is 30.73 ± 3.93% with variation range 10.2–93.5%. Generally, it is considered to be silty clay. Average **soil exchange reaction is** 6.98 ± 0.11 with variation range 4.9–7.65 which is considered to be acidic to alkalic. Average **cation-exchange capacity** (CEC) is 23.84 ± 1.44 cmol/kg which is estimated as medium high with variation range 3.12–41.56 cmol/kg and sorption capacity is estimated from very low to very high. Average **oxidizable carbon content** is 1.57 ± 0.10% which is estimated as medium humic with variation range 0.32–2.98% (very low to very high content). Average **total nitrogen content** is 0.14 ± 0.01% with variation range 0.03–0.25%. Average **C/N ratio** is 11.66 ± 0.30 with variation range 7.2–14.5. Average **potentially acceptable magnesium content** is 477.03 ± 47.19 mg/kg with quite wide variation range 41–1203 mg/kg. Average **content of potentially acceptable calcium** is 11748 ± 2128.6 mg/kg again with quite wide variation range 1061–45332 mg/kg.

Several types of feedbacks can be distinguished. Reduce of oxidizable carbon content (humus as well) in soil is followed by:

- decrease of exchangeable magnesium (and conversely),
- decrease of total nitrogen content,
- decrease of sorption capacity (CEC),
- decreased sorption capacity (CEC) is followed by reduce of exchange calcium reserves,

resulting in decreasing exchangeable soil reaction. Negative feedback is applied there. While acidification, calcium is released from pedogenic substrate and it slows the decline of soil reaction.

Soil organic matter content is influenced by physical properties: positively by silt particles (R= 0.77) and negatively by sand content (R= –0.76).

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