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# VARIABILITY OF SOIL PROPERTIES IN CONDITIONS OF THE SUSTAINABLE SOIL UTILIZATION IN CARPATHIAN REGION*

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Key words: Carpathian region, ecological agriculture, soil properties, sustainable utilization.

Abstract

The work deals with the assessment of the basic physical and chemical soil properties in the conditions of ecological farming system in chosen area of Carpathian region. The aim of this work is based on time variability of soil properties to consider sustainability of ecological farming management and its role in sustainable agriculture and development. The observation was carried out in 1996–2000, 2013–2015 in the farm with the ecological farming system in north-east of Slovakia. The paper confirmed that ecological agriculture has positive influence on chemical and physical soil properties and enables its sustainable utilization.

## ZMIENNOŚĆ WŁAŚCIWOŚCI GLEBY Z UWZGLĘDNIENIEM ZRÓWNOWAŻONEGO WYKORZYSTANIA GLEB W REGIONIE KARPACKIM

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Słowa kluczowe: region karpacki, rolnictwo ekologiczne, właściwości gleby, zrównoważone użytkowanie.

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Abstrakt

Praca dotyczy oceny podstawowych fizycznych i chemicznych właściwości gleby w systemie rolnictwa ekologicznego na wybranym obszarze Karpat. Celem pracy jest analiza zmienności czasowej właściwości gleb z uwzględnieniem zrównoważonego zarządzania ekologicznym gospodarstwem rolnym i jego roli w zrównoważonym rolnictwie i rozwoju. Obserwacje przeprowadzono w latach 1996–2000 i 2013–2015 w gospodarstwie z systemem rolnictwa ekologicznego w północno-wschodniej Słowacji.

W badaniach potwierdzono, że rolnictwo ekologiczne ma pozytywny wpływ na chemiczne i fizyczne właściwości gleby oraz umożliwia jej zrównoważone wykorzystanie.

## Introduction

There is a need to assess the impact of different farming methods on soil quality and fertility in specific ecoregions. Many authors have been investigated the impact of different managements on soil properties, mainly biological, such as enzyme and microbial indices (BOBUĽSKÁ et al. 2015, CASTILLO and JOERGENSEN 2001, HOSSAIN et al. 2002). Sustainable farming systems in Slovakia is mainly represented by the incorporation of organic fertilizers and crop residues that not only increase soil quality and fertility, but also affect soil organisms (ZAHARIA et al. 2010). Application of organic fertilizers can also significantly increase the level of plant-available nutrients and soil chemical and physical properties that affect soil health and quality. The sustainable soil utilization responds to concrete soil-ecological conditions and is realized in a specific way and intensity that does not affect any negative changes in the soil and on soil properties. The basic principle of the sustainable soil utilization philosophy is in its protection against any nature degradation and human impact (FAUCON et al. 2017, LI et al. 2017, DARWISH et al. 2015). The sustainable development of soil utilization involves protection of the land area at the scale that follows the needs to sustain all soil functions. From the ecological farming point of view on the soil, information about quality changes or soil degradation are very important (JIANG et al. 2017).

To the soil development evaluation, the basics characteristics of the natural environment (physical, chemical and biological) are employed. As the physical soil properties are involved bulk density, porosity, water holding capacity, soil temperature, etc. The chemical properties are characterized by total carbon and nitrogen content, soil pH and nutrients availability.

The paper contributes to knowledge within the problems of changes of soil properties in ecological farming system in time horizon. Therefore, the main objective of this work is a) to determine selected soil properties (physical and chemical) in the long-term monitoring in less favourable soil-climatic conditions and b) to assess the ability of ecological farming system influence the quality and health of soil ecosystems.

## Material and Methods

The research was carried out in 1996–2000 and 2013–2015 at the production conditions on the model farming enterprise Liptovská Teplička (48°57'N; 20°05'E), which has been in the system of ecology agriculture since 1996. The study period was performed at the very beginning of ecological management application on this site with due to show the impact of this system on soil properties after almost 20 years. The studied territory is a part of the National Park Low Tatras. The altitude of the area is 846 till 1492 m a.s.l. From the geomorphologic point of view, the area comes under sub-unit Kráľovohoľské Tatry. Climatic conditions are relatively homogenous. The whole site belongs to mildly cold area, the average daily temperature is higher than 10°C ranging from 1600–2000 mm and average precipitations of 800–1100 mm. The soil conditions are relatively homogenous. The biggest land area is formed by Cambisol, medium heavy, heavily skeleton mostly under topsoil. The second widespread soil type is Rendzina soil, medium heavy, shallow and skeleton. There is some Histosol in the territory. Mostly of the soil in the area are located on the slopes. The soil samples for determination of physical properties were collected two times per year from six sites, in spring (connected vegetation) and in summer (before the harvest), from the layer 0,5–0,15 m in three replicates.

Bulk density [t $m^{-3}$] and total porosity [%] were determined in Kopecký cylinder (Fiala et al. 1999) during years 1996–2000 and 2013–2015. The soil samples for chemical properties determination were collected once a year. Soil pH, humus content [%], available Mg, K, P [mg $kg^{-1}$] (analysed during years 1997–2000 and 2013–2015), total nitrogen content [mg $kg^{-1}$] (analysed during years 1998, 1999 and 2013–2015) were observed using the common available laboratory methods (Fiala et al. 1999). For time and spatial demonstration of soil properties, the results in 1996–2000 are compared to the results in 2013–2015.

Obtained soil physical and chemical data were tested by mathematical-statistical methods from which analysis of variance and regression analysis were used (the Statgraphics software package).

## Results and Discussion

Table 1 and Table 2 show the basic physical and chemical properties of soil in farming system in Liptovská Teplička. Bulk density and total porosity are closely related to each other. Values of porosity correspond with the values of bulk density and there was a strong negative correlation (Table 3) between those two parameters that correspond with several authors (Paul Obade and Lal 2014, Liu et al. 2013, Kotorová 2007). Higher bulk density changes ratio between water and air capacity in behalf of water capacity. Also porosity is lower and in parallel capillary pores ratio is higher. That induce favourable water mode and plant water supply during vegetation (Kotorová 2007). Therefore, bulk density and porosity values increase. Average values of bulk density in 1996 were higher (1.48 t m$^{-3}$ in spring and 1.46 t m$^{-3}$ in summer) than over than 10 years later (1.07 t m$^{-3}$ in spring and 1.09 t m$^{-3}$ in summer). This parameter stabilized its values over the time horizon and increased total porosity (ranged from 44.18–63.33% in spring and 44.86–59.01% in summer).

Table 1

Basic soil physical properties in the farming system in Liptovská Teplička

| Year | Season | Ho* [t m$^{-3}$] | P** [%] |
|---|---|---|---|
| 1996 | spring | 1.48 ± 0.11 | 44.18 ± 5.40 |
| | summer | 1.46 ± 0.13 | 44.86 ± 5.35 |
| 1997 | spring | 1.15 ± 0.09 | 56.68 ± 6.05 |
| | summer | 1.22 ± 0.10 | 53.92 ± 5.96 |
| 1998 | spring | 1.15 ± 0.08 | 56.65 ± 5.25 |
| | summer | 1.12 ± 0.08 | 57.71 ± 6.10 |
| 1999 | spring | 1.18 ± 0.09 | 55.68 ± 5.55 |
| | summer | 1.28 ± 0.11 | 51.94 ± 5.20 |
| 2000 | spring | 1.10 ± 0.06 | 63.33 ± 6.32 |
| | summer | 1.15 ± 0.05 | 56.78 ± 5.84 |
| 2013 | spring | 1.12 ± 0.09 | 57.75 ± 5.39 |
| | summer | 1.14 ± 0.10 | 56.90 ± 5.98 |
| 2014 | spring | 1.06 ± 0.05 | 59.76 ± 5.95 |
| | summer | 1.09 ± 0.06 | 59.01 ± 5.87 |
| 2015 | spring | 1.20 ± 0.09 | 54.78 ± 5.34 |
| | summer | 1.22 ± 0.10 | 54.06 ± 5.67 |
| Mean 1996–2000 | spring | 1.21 ± 0.15 | 55.30 ± 6.90 |
| | summer | 1.25 ± 0.13 | 53.04 ± 5.12 |
| Mean 2013–2015 | spring | 1.12 ± 0.07 | 57.43 ± 2.50 |
| | summer | 1.15 ± 0.07 | 56.66 ± 2.48 |

* bulk density; ** porosity

Table 2

Basic soil chemical properties in the farming system in Liptovská Teplička

| Year | pH | Humus [%] | Mg [mg kg$^{-1}$] | N [mg kg$^{-1}$] | P [mg kg$^{-1}$] | K [mg kg$^{-1}$] |
|---|---|---|---|---|---|---|
| 1997 | 6.3 ± 0.06 | 5.34 ± 0.50 | 246 ± 25 | – | 57 ± 4 | 306 ± 11 |
| 1998 | 6.3 ± 0.06 | 5.26 ± 0.46 | 240 ± 22 | 2932 ± 211 | 57 ± 6 | 327 ± 10 |
| 1999 | 6.4 ± 0.00 | 5.07 ± 0.53 | 227 ± 34 | 3023 ± 200 | 54 ± 6 | 261 ± 10 |
| 2000 | 6.3 ± 0.06 | 5.06 ± 0.54 | 274 ± 40 | – | 64 ± 9 | 260 ± 13 |
| 2013 | 6.3 ± 0.04 | 6.24 ± 0.33 | 283 ± 35 | 3680 ± 263 | 64 ± 8 | 254 ± 15 |
| 2014 | 6.6 ± 0.00 | 5.87 ± 0.41 | 284 ± 45 | 2223 ± 199 | 59 ± 5 | 233 ± 20 |
| 2015 | 6.4 ± 0.03 | 5.66 ± 0.26 | 295 ± 44 | 2085 ± 155 | 66 ± 8 | 271 ± 18 |
| Mean 1996–2000 | 6,3 ± 0.05 | 5,48 ± 0.21 | 247 ± 20 | 2978 ± 64 | 58 ± 4 | 289 ± 33 |
| Mean 2013–2015 | 6,4 ± 0,15 | 5,9 ± 0.29 | 287 ± 7 | 2662 ± 884 | 63 ± 4 | 253 ± 19 |

Table 3

Correlation coefficients ($r$) for relationship of soil physical and chemical parameters

| Parameter | Bulk density | Porosity | pH | humus | Mg | N | P | K |
|---|---|---|---|---|---|---|---|---|
| Bulk density | – | -0.99** | -0.13 | -0.54** | -0.06 | -0.13 | -0.14 | -0.14 |
| Porosity | -0.99** | – | 0.13 | 0.53** | 0.06 | -0.13 | 0.14 | 0.14 |
| pH | -0.13 | 0.13 | – | 0.16 | 0.42* | -0.15 | 0.54** | 0.29 |
| Humus | -0.54** | 0.53** | 0.16 | – | 0.26 | 0.05 | 0.61** | 0.38* |
| Mg | -0.06 | 0.06 | 0.42* | 0.26 | – | -0.12 | 0.37* | 0.08 |
| N | -0.13 | -0.13 | -0.15 | 0.05 | -0.12 | – | -0.13 | 0.12 |
| P | -0.14 | -0.14 | 0.54** | 0.61** | 0.37* | -0.13 | – | 0.56** |
| K | -0.14 | -0.14 | 0.29 | 0.38* | 0.08 | 0.12 | 0.56** | – |

** $P < 0.01$, * P < 0.05

Long-term research has shown that ecological farming system regulates bulk density in the soil ecosystem during the years and within the seasons. Soil reaction, which ranged between 6.3 and 6.6, is one of the most important factors of soil fertility, in spite of the fact, that its value is dynamic and changes in dependence on external and internal factors (SHEAHAN et al. 2012). During the research, soil reaction changed on model area only minimally due to ecological agriculture without application of acid mineral fertilizers. On the other hand, application of organic material significantly affects soil reaction and thus maintain soil ecosystem to become sustainable (LI et al. 2014). In acid soil, calcium, magnesium, potassium, phosphorus, or molybdenum may be deficient, and the decomposition of the soil organic matter is slowed down, causing a decreased mineralization of nitrogen (WYSZKOWSKI and SIVITSKAYA 2016, MAGDOFF and VAN ES 2009). Soil reaction also affects the availability of some nutrients (Table 3) and content of heavy metals in soil systems which was also shown in our study.

Organic matter positively influences soil buffer capacity and thus, soil reaction changed only minimal. It is important continuously pay attention on soil reaction, because soil naturally change due to acid atmospheric fallout and calcium taking off by crops. It is less probable that the increase of total nitrogen (2223–3680 mg kg$^{-1}$) would positively influence the soil fertility. For soils with low productivity, to which also our researched area belongs, non-directly comparable relationship between total nitrogen content and fertility is typical. In soil-ecological conditions of researched area mineralization of nitrogen runs little intensively (optimal temperature for intensive process is 28–30°C). Therefore, within high content of total nitrogen, content of mineral – nitrogen immediately available for plants does not have to be high. Phosphorus is relatively firmly fixed (54–66 mg kg$^{-1}$) and its content is relatively stable and depends on soil reaction. Therefore content of available phosphorus changed minimally and within the common interval. Content of potassium (233–327 mg kg$^{-1}$) and magnesium (227–295 mg kg$^{-1}$) was relatively high during focused period. With the regard to soil granularity, these nutrients can be firmly fixed on soil particles and therefore are not flowed out from plough-land in spite of high rainfalls during the year. Content of humus is changing markedly during the long time period in comparison of two time periods (Table 4).

Table 4

Analysis of variance of soil physical and chemical parameters

| Parameter | Source of variability | Degree of freedom | F-value calculated | *P* significance |
|---|---|---|---|---|
| Bulk density | year | 7 | 8.33 | ** |
| Porosity | year | 7 | 8.24 | ** |
| pH | year | 6 | 0.82 | - |
| Humus | year | 6 | 1.99 | * |
| Mg | year | 6 | 17.52 | ** |
| N | year | 6 | 12.77 | ** |
| P | year | 6 | 2.06 | * |
| K | year | 6 | 5.87 | ** |

** $P < 0.01$, * $P < 0.05$

Percentage of humus has increased from 5.06 to 6.24%. The concentration of soil organic matter is corresponding with the average values for Cambisols (Barančíková et al. 2016) and their study also shows the positive effect of ecological farming system on soil ecosystem. Our research confirmed suitability of the area for ecological farming, at the same time the positive influence of the applied system on humus balance in soil during the long term ecological farming management.

## Conclusion

Research confirmed that physical soil conditions have positively changed in ecological system of agriculture. Measured values of bulk density and porosity are continuously modified and stabilized during the focused time period. Chemical soil properties (soil reaction, humus, available nutrients, nitrogen) were also markedly changed. Based on the introduced results we can conclude, that stability and sustainable utilization of agroecosystem can be achieved thought biodiversity of maintained areas and by returning of organic matter into soil.

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