ASSESSING THE CHANGES OF SOIL HUMUS CONTENT IN ZALA COUNTY

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Abstract

In previous decades agricultural lands have been deteriorating in terms of soil organic matter (humus) decline as a consequence of non-sustainable agricultural practices. The assessment of humus content of arable lands in Zala County is based on measured humus content (weight%) data of the Hungarian Soil Information and Monitoring System (TIM) collected from 1992 to 2010. As a result of soil sampling methodology change in 2000, 3-3 measured data of 39 sampling points were available by sampling method. Taking into consideration the small number of measurements and the different soil characteristics, changes were analysed within soil subtypes. Categorization of humus content was based on the classification system of The Handbook of the Large-Scale Genetic Soil Mapping (Jassó et al., 1989). We detected positive humus content changes during the sampling period I.

(1992-199) and declining humus content during the sampling period II. (2000-2010).

Keywords: sustainable agriculture, humus content, TIM, soil degradation, soil organic matter

Összefoglalás

Az elmúlt évtizedek során a mezőgazdasági talajok szervesanyag tartalmának csökkenése figyelhető meg, aminek egyik feltételezett oka a nem fenntartható talajművelési technológiák alkalmazása. Zala megye mezőgazdasági területeinek humusz tartalom változásait a hazai Talajvédelmi Információs és Monitoring Rendszer (TIM) 1992 és 2010 között mért humusztartalom (tömeg %) adatai alapján vizsgáltuk. 39 TIM mérőpontról, a 2000-ben megváltozott mintavételi eljárás miatt, mintavételi eljárásonként 3-3 mérési adat állt rendelkezésünkre.

Figyelembe véve azt, hogy kevés adat áll rendelkezésünkre, továbbá, hogy az egyes talajok eltérő tulajdonságokkal rendelkeznek, a humusztartalom változásokat talaj altípusonként vizsgáltuk. A Genetikus talajtérképezési útmutató kategóriarendszere alapján soroltuk be a humusztartalmakat (Jassó et al., 1989). Az első mérési periódusban (1992-1998) a humusztartalom pozitív irányba változott, a második periódusban (2000-2010) ezzel ellenkező irányú változást tapasztaltunk.

Introduction

Multifunctionality of agriculture has long been recognized but some functions were de-emphasized, i.e. food production was the main - if not the only - function of agricultural sector for decades. Non-sustainable land use threatens soils and leads to soil degradation. As a result of intensive agricultural practice, carbon loss from soils has been detected in many

European countries (SoCo Project Team, 2009; Janssens et al., 2004; Sleutel et al., 2003). Legal steps have been made both on European and national levels. The European Commission in the Thematic Strategy for the Protection of Soil emphasized that organic matter decline is a major threat to soils (COM(2006)231), and contribute to global warming. In order to maintain sustainable land use in the states of EU, according to the Common Agricultural Policy, the Commission proposed a new Good Agricultural and Environmental Conditions on organic matter protection (COM(2012) 46). In the Hungarian law Act No. CXXIX of 2007 on the Protection of Arable Land, Act No. XXXVII of 2009 on Forests, on the Protection and Management of Forests, Decree No. 90 of 2008 (VII. 18.) FVM of the Ministry of Agriculture and Rural Development laying down detailed rules of elaboration of soil conservation plans give legal background of humus protection of soils on national level.

Agri-environmental programmes have been operating in Hungary since 2002 requiring environmental agricultural management practices from farmers, e.g. soil protection. Well before the first agri-environmental programme was launched, a soil quality monitoring system was set up in 1991 and sampling started at 1992. One of the functions of the Soil Information and Monitoring System (TIM - acronym of the Hungarian name of the database) is to follow agri-environmental processes. Soil organic matter (SOM) plays a significant role in soil quality. Monitor the effects of agri-environmental programmes on soil, soil quality indicators have been introduced (Bindraban et al., 2000; McRae et al., 2000). Among these indices organic matter (OM), SOM or humus has the most generally recognised influence on soil quality, affecting physical, chemical and biological indicators (Doran and Parkin, 1996). Its presence in soils, in a satisfactory level, can positively influence various physical and biological processes beneficial for agricultural production (e.g. yields). Balanced humus content improves cation exchange capacity, buffering function, lessens surface compaction and changes in soil temperature, contributes to better soil water balance (Wolf and Snyder, 2003; Hülsbergen, 2003). If allowing SOM concentrations decrease too much, the productivity of agriculture will be at risk **(**Loveland and Webb, 2003**).**

The porosity (responsible for soil O_2 level), the degree of aggregation and the OM production (influenced by moisture and nutrients) are responsible for the differences of SOM content in different soil textural classes. Clays tend to have the highest, sands associated with the lowest SOM values. Agrotechniques introducing smaller amount of O_2 into the soil tend to preserve SOM (Wolf and Snyder, 2003). A great amount of studies have revealed that one of the consequences of conventional farm practices is reduced SOM content and that under sustainable farm management practices (e.g. minimum-tillage, mulching) humus concentration is significantly higher (Foissner, 1992; Edwards et al., 1999; Rusu et al., 2009). There is considerable concern that besides other factors (climate, vegetation, water recourse) excessive land use can contribute to global warming by accelerated SOM decomposition increasing the level of atmospheric CO_2 (Lal, 2009; Jenkinson et al., 1991; Khaledian et al., 2012). Agriculture has tools to mitigate global warming and protect SOM content by applying sustainable agricultural management practices and current agri-environmental policies seek to promote such efforts and goals.

The following study investigates the humus content change - as a recommended soil quality indicator - on agricultural land in Zala County based on TIM site data between 1992 and 2010.

Materials and methods

Soil Information Monitoring System of Hungary

Soil Information and Monitoring System in Hungary (TIM) was established in 1991 and consists of 1236 reference points (Várallyay et al., 2009). 864 TIM sites are situated in agricultural areas (coded as "I") countrywide and out of these, 40 TIM reference points are in Zala County. As for the location of TIM reference points, 189 are in areas with specific problems, e.g. heavily contaminated industrial areas (coded as "S" sites) and 183 are in forests (coded as "E"). TIM data are part of the Hungarian Detailed Soil Hydrophysical Database, MARTHA that is a representative database for Hungarian soils being under cultivation (Makó et al., 2010).

TIM network points were assigned to represent areas belonging to certain and smaller geographical areas; therefore they are realistic and nature-like descriptions of Hungarian soils. Besides representativeness other preferences were also taken into consideration in the TIM site designation process: areas of existing soil monitoring, long-term field experiences or of environmental monitoring systems (e.g. weather stations, groundwater level wells) were also favoured. Humus content is planned to be measured in every three year (Várallyay et al., 1995).

TIM sites of Zala County in agricultural areas

The base of our research was humus content data of agricultural areas measured on TIM sites ("I" points) in Zala County. The measurements were carried out in accredited laboratories and database was provided by the National Food Chain Safety Office- Plant Protection, Soil Conservation and Agri-environment Directorate.

The agricultural TIM network of Zala County consists of 40 sampling sites (Fig. 1) and out of these, 39 TIM sites data were analysed as there was no complete data set of one monitoring point.

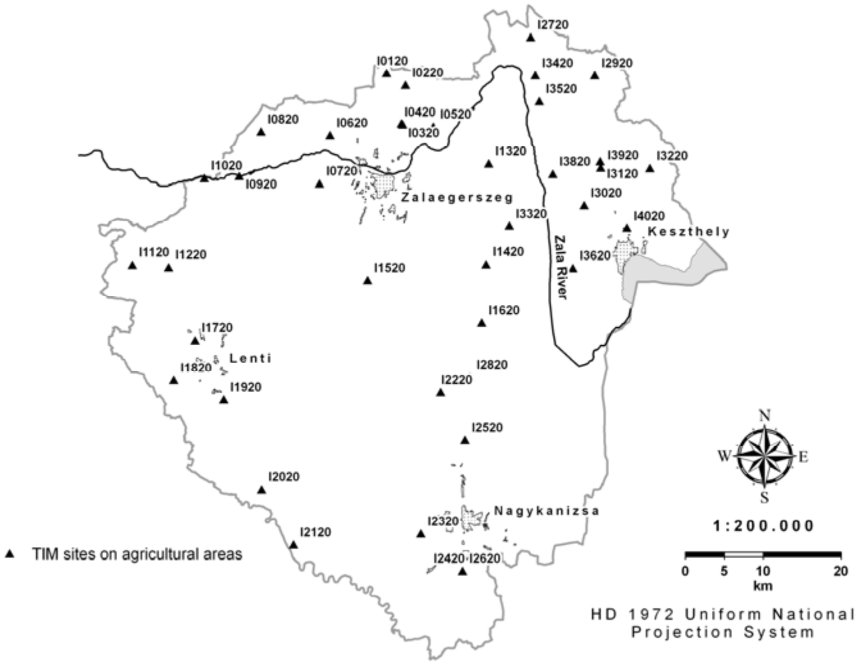

Figure 1. TIM points on agricultural lands in Zala County

TIM "I"- sampling sites are situated in ten different soil subtypes, according to the Hungarian soil category system (Stefanovits, 1963), detailed in Table 1.

Table 1. Number of TIM points in Zala County by soil subtypes

Soil subtypes code	Soil subtypes	WRB 2006 (soil types)	Number of TIM points
112	Non-podzolic brown forest soil with clay illuviation	Haplic Luvisol	15
122	Pseudogley with clay illuviation (Brown forest soil)	Stagnic Luvisol	7
132	Rustbrown brown forest soil	Eutric Cambisol	4
395	Meadow-like humous alluvial soil	Mollic Fluvisol	4
402	Slope deposits of forest soils	Colluvic Regosol	3
131	Typical brown forest soil (according to Ramann)	Eutric Cambisol	2
302	Non calcareous typical meadow soil	Haplic Gleysol	2
54	Non-calcareous multilayer humous sand	Haplic Arenosol	1
301	Calcareous typical meadow soil	Haplic Gleysol	1
321	Typical marshy meadow soil	Histic Gleysol	1

Between 1992 and 2010 humus content sampling and analysing was carried out six times from three different soil depths at each point. Qualitative determination of soil organic matter was performed according to Tyurin method, Hungarian Standard (MSZ: 08-0452-1980). In 1992, 1995 and 1998 point sampling method was used as sampling technique and from the year 2000 nine individual samples were collected randomly within a 50 m radius circle around the TIM point and cores were composited as one sample. By depths, three samples were taken independently from sampling method: one from the zone 0-30 cm; the second from the depth 30-60 cm and thirdly from the 60-90 cm layer. The main aim of the sampling methodology change was to produce data that can be comparable in time and space. Regarding to the different sampling method the first three-years (1992, 1995, 1998) and the following period of data (2000, 2004, 2010) cannot be compared.

In our research we focused on the samples of the upper 0-30 cm soil layers. Using the TIM soil data set, according to the soil texture and humus content data, soils were categorised into low- (LHCS), medium- (MHCS) and high humus content soils (HHCS) (Jassó et al., 1989). Humus category values may be different by soil subtypes which values may vary depending on soil texture. As a consequence of sampling methodology change samplings and data were divided into two periods: from 1992 to 1998 as period I. and from 2000 to 2010 as period II. Data were analysed with the SPSS statistical package (Version 20.0) and Microsoft Excel Analysis Toolpack. Results were expressed as mean, standard deviation (SD) or 95% confidence interval. The Kolmogorov–Smirnov test was used to analyse the normal distribution of measurements ($P > 0.05$). A P value less than 0.05 was considered statistically significant. Paired sample t-test was used to compare the humus content between two different years. Correlation analysis was used to test what extent the new sampling method changed the temporal homogenity of measured values.

Results and Discussion

The humus contents in 1992, 1995 and 1998 show a strong correlation (r≥0.998). The correlations in 2000, 2004 and 2010 varied between 0,78 and 0,98. After 2000 the strongest correlation was between 2000 and 2010 (r=0,98). A weaker correlation was observed between 2000 and 2004 (r=0,81), and between 2004 and 2010 (r=0,78). As a result of sampling methodology change in 2000 the standard deviation (SD) of humus content in the first three-year sampling period is differ from SD values of the other three-year sampling period (Fig. 2). In 35 TIM sites the SD of humus content were higher after 2000, in 28 TIM sites the SD of humus content increased more than 100%.

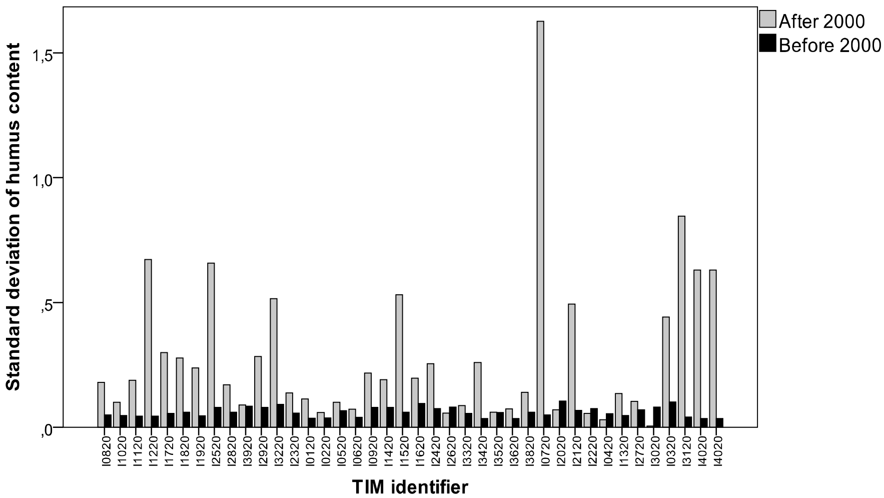

Figure 2. SD of humus content with the new and the old sampling method

Examining the last three years' data, at 31 sampling points the lowest humus contents, while at 4 sampling points the highest humus content were detected in 2004. These results lead us to exclude humus content data of 2004 and examine changes only between two years in the two sampling periods: 1992 and 1998; 2000 and 2010.

The examination of humus content changes at each sample points according to low- (LHCS), medium- (MHCS) and high humus content soil (HHCS) categories was followed by the analysis of measured values within soil subtypes during the two sampling periods. The proportion of LHCSs decreased 18% (7 TIM point) between 1992 and 1998, between 2000 and 2010 increased 12% (5 TIM points). Rate of MHCSs grew from 31% to 49% in the first sampling period and declined from 46% to 36% between 2000 and 2010. The number of TIM points characterized by HHCS is the lowest taking into consideration the whole sample. Between 1992 and 1998 the increase in this category was 2%, between 2000 and 2010 rate of HHCS dropped down 2%. TIM sites concerned in changes are shown on Table 3 and Table 4.

Table 3. Humus content changes at TIM sites in Zala County between 1992 and 1998

TIM identifier	**Soil Subtypes**	**Humus content 1992**	**Humus content 1998**
I0120	Pseudogley with clay illuviation (Brown forest soil)	low	medium
I1320	Typical brown forest soil (according to Ramann)	low	medium
I1520	Pseudogley with clay illuviation (Brown forest soil)	low	medium
I2120	Meadow-like humous alluvial soil	medium	high
I2720	Typical brown forest soil (according to Ramann)	low	medium
I3320	Pseudogley with clay illuviation (Brown forest soil)	low	medium
I3820	Pseudogley with clay illuviation (Brown forest soil)	low	medium

Table 4. Humus content changes at TIM sites in Zala County between 2000 and 2010

TIM identifier	Soil Subtypes	Humus content 2000	Humus content 2010
I1020	Pseudogley with clay illuviation (Brown forest soil)	medium	low
I1120	Pseudogley with clay illuviation (Brown forest soil)	medium	low
I1220	Pseudogley with clay illuviation (Brown forest soil)	medium	low
I1320	Rustbrown brown forest soil	medium	low
I1520	Non-podzolic brown forest soil with clay illuviation	medium	low
I2020	Meadow-like humous alluvial soil	high	medium

By 1998 seven sampling points were classified to higher soil humus content category, in contrast, by 2010 such positive change was not noticed, all the six changes represents decreasing humus content. No humus content category changes were detected at other sampling points.

The direction of changes were analysed within soil subtypes (Fig. 3). Non calcareous typical meadow soil and meadow-like humous alluvial soil are in the best status according to humus content, notwithstanding in the latter case, the rate of sites with high humus content decreased. Soils of slope deposits of forest soils and non-calcareous multilayer humous sand were classified as LHCS category during both sampling periods.

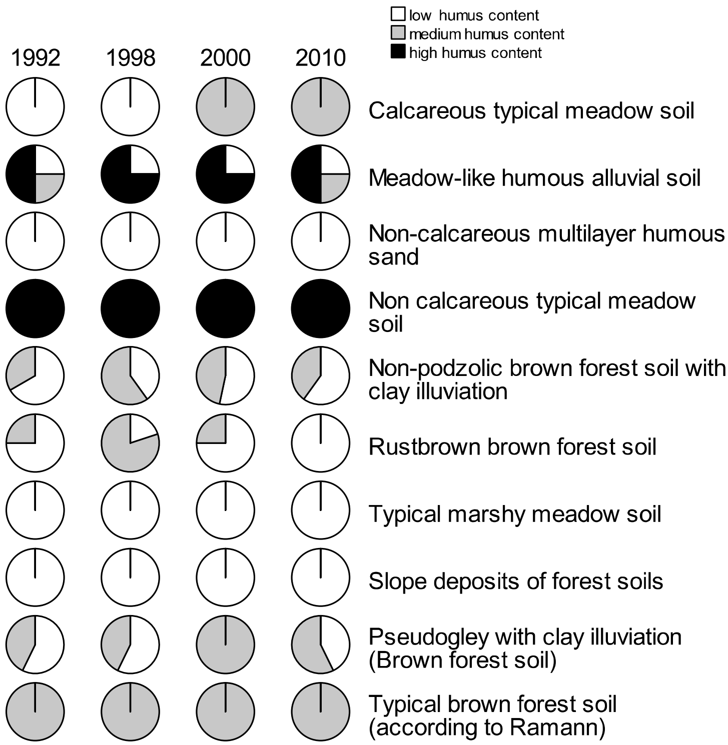

Figure 3. Humus content changes within soil subtypes by humus content categories

Taking into consideration the measured humus content values at the 39 sample points, from 1992 to 1998 the humus content decreased at one and grew at 38 TIM points. In 2010 the measured humus content values were lower at 33 TIM points and were higher at 4 TIM sites then in 2000. No significant change were registered according to the mentioned changes.

In the case of soils with minimum of four or more TIM sampling sites paired sample t-test was used in order to assess whether detected changes in humus contents in different years were significant. (Data of measured humus content show normal distribution thus paired sample t-test can be used.) Between the years 1992 and 1998 the growth of humus content was 7,6% ($p \leq 0{,}001$) at TIM sites of non-podzolic brown forest soil with clay illuviation, 6,2 % ($p \leq 0{,}001$) of pseudogley with clay illuviation (Brown forest soil) and 10% ($p \leq 0{,}004$) of rustbrown brown forest soil. No significant changes were detected at sampling points of meadow-like humous alluvial soil. During the sampling period II., between 2000 and 2010 significant 5,5% ($p \leq 0{,}007$) decline of humus content change was identified at TIM points of pseudogley with clay illuviation (Brown forest soil). The 3,2% ($p \leq 0{,}023$) decline was also significant at meadow-like humous alluvial soil sampling sites. Due to the low number of sampling sites (≤3) of other soil subtypes the significancy of humus content changes was not analysed.

Conclusion

Humus content data of the year 2004 was excluded as extreme values were detected in the highest proportion in the year 2004. The other reason for exclusion was that humus content data of 2004 showed a lower correlation between humus content values of 2000 and 2010. We need further investigation to explore the cause of extremity of humus content values of 2004.

During the sampling period I. – covering six years – changes we detected were positive. According to humus content categories 7 TIM sampling sites were classified into higher humus content category: from low- to medium-, and from medium- to high humus content category. Analysing humus content within soil subtypes changes were significant in three soil subtypes: non-podzolic brown forest soil with clay illuviation, pseudogley with clay illuviation (Brown forest soil) and rustbrown brown forest soil. During the 10 years of the sampling period II. the humus content changed towards negative direction: from medium- to low- and from high- to medium humus content category at 6 TIM points. Within soil subtypes significant decline of humus content change was identified in the case of pseudogley with clay illuviation (Brown forest soil) and meadow-like humous alluvial soil.

Although the humus contents of arable lands have been monitored at TIM network from 1992, the humus content database is not suitable for long time-series analyses. In the case of TIM sampling sites where changes were detected other factors should be considered (e.g. meteorological variables, applied agrotechnique, sampling thechnique) to reveal the cause of humus content changes.

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