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EFFECT OF SCRAPING ON HUMUS CONTENT OF HEAVY TEXTURED SOIL DEGRADED BY EXCESS WATERS

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On low-lying soils with a high clay content and poor water conductivity, excess water regularly appears after almost every rainy winter causing soil degradation, which leads to yield failures and/or losses. To outlet the harmful excess surface, waters needs appropriate ameliorative and agrotechnical operations. Among them, scraping represents a suitable intervention into soil structure involving the complete conversion of the micro-topography of the land. The humus content of the soil is a determining factor in terms of soil fertility; therefore, it must be preserved even when drastic tillage operations are carried out on a plot. Our research aimed to assess the effect of scraping on the humus content of the soil on three plots with a heavy textured Vertisol endangered by excess waters. Scraping was used on these plots to create a homogeneous topography and surface with a slight slope to get rid of excess water when it appears. It was established that scraping did not cause humus loss on a plot scale, and it resulted in an even organic matter distribution, hence a potentially more homogenous yield within the ameliorated plots.

Keywords: Vertisol; soil fertility; organic carbon; surface levelling

Hungary is located in an area threatened by both drought and excess water. The latter originates from Hungary's hydro-geographically determining basin nature that often results in excess water formation as a general problem in the Great Hungarian Plain (Szesztay, 2000). According to Pálfi (2001), excess (inland) water is a periodic, but rather permanent phenomenon, a specific type of water in flat regions extended over relatively large areas. Inland water, which appears sometimes several times a year, is a unique problem in international comparison, unique to Hungary (Bárdos and Muhoray, 2012). In Hungary, the size of the area strongly and very strongly threatened by excess water is about 530 thousand ha (Körösparti et al., 2022). Due to climate change, extreme weather conditions are becoming more frequent, and the proportion of areas affected by local water damage is increasing. The aggregate arrangements in soil develop a strong structural influence on the ability of soil to absorb and hold water during irrigation and rainfall events (Abou Najm et al., 2021). On low-lying soils with a high clay content and poor water conductivity of the Great Hungarian Plain, especially if close-to-surface clogged, almost impermeable layer has formed as a result of many years of improper tillage. In such cases, excess water regularly appears after almost every rainy winter (Birkás et al., 2009).

Soil structure is a key attribute of soil quality and health that significantly impacts water infiltration (Basset et al., 2023). Infiltration rate is also affected by the type of technology deployed within the control traffic farming

system (Godwin et al., 2015), while water retention capacity depends on soil properties and the possibility of irrigation (Jobbágy et al., 2019).

According to Thyll et al. (1983) and Ligetvári (2011), the drainage of harmful excess surface waters can only be achieved by the complex application of appropriate ameliorative and agrotechnical operations (soil reclamation, proper tillage system, deep loosening, mole drainage, etc.). Scraping involving the complete conversion of micro-topography, surface levelling, and the creation of a slope in the desired direction can be such an ameliorative intervention.

Scrapers are self-propelled or towed soil moving and transporting machines including a working tool of a cutting box (scraper box) equipped with a cutting edge. During extraction, the cutting edge cuts into the soil, swallows a layer of it, and conveys it to the scraper box. After the box is full, the machine lifts the cutting edge and transports the crushed soil to the installation site, where it empties and spreads the material (Faur and Szabó, 2011). Scrapers are primarily used for the construction of large-scale embankments, mine reclamation, humus recovery, and the removal of contaminated soil (Barry Phelps and Holland, 1987; Ghose, 2001; Miyahara et al., 2020; Sweigard, 2007).

The humus content of the soil is a determining factor in terms of soil fertility since organic matter content strongly influences soil properties, such as water infiltration rate, water retention capacity, and nutrient supply capacity (Ding et al., 2002; Campbell et al., 1996). Humus, the organic

matter of the soil, is the organic remains found in the soil that have been more or less transformed. Some of them have already undergone a specific transformation called humification, during which a group of high-molecular carbon-containing compounds is created, which turn into dark-coloured, relatively stable new compounds, so-called humic substances. Forming a colloidal system with clay minerals, humic substances provides plants with nutrients and water that can be absorbed and has a favourable effect on chemical and biological properties, water, air and heat balance of the soil (Hargitai, 1993; Füleky and Filep, 1999). The humus content is a characteristic of the type of soil and naturally changes only over a very long time.

Vertisols (meadow soils) are the most typical in the areas endangered by the formation of excess waters in Hungary. Generally, Vertisols have an average organic matter content between 0.5% and 5% (sometimes 10%), depending on climatic conditions and land use systems, and usually they have a higher content of organic matter in a wetter, humid climate and in natural, undisturbed conditions, such as in cultivated fields (Coulombe et al., 1996; Chan, 1997). Beyond the effect of the soil and climatic conditions, the applied agro-technics and land preparation also significantly influence soil fertility (Huzsvai et al., 2020). Nevertheless, there is a shortage of knowledge about the effect of topsoil handling techniques like scraping in agricultural relations beyond industrial and hydrological ones. The novelty of our research is in assessing the effect of scraping on the humus content of the soil as the main fertility indicator on Vertisol endangered by excess waters near the village of Zsadány.

Material and methods

Description of the investigated area

The area with the investigated 3 plots (T8, T9, T10) is located near the village of Zsadány (46.92421, 21.48911), in the Berettyó-Körös region of the Great Hungarian Plain. The climate of this region is moderately warm, with an average annual rainfall of 540–560 mm. In terms of topography, it is a low-lying plain. The ground cover is made up of hydromorphic soils, about 44% of its soils are saline, 34% are meadow, and 14% are alluvial soils (Dövényi, 2010). The investigated area has been utilised as a cropland for decades. The plots were ploughed conventionally until 2014 when reduced (conservation) tillage was introduced. The goal of the introduction of conservation tillage was to mitigate the loss of the organic carbon stock of the soil which was justified by several studies e.g., Kovács et al. (2023) and Ibrahim et al. (2024). Since 2015, two main tools have been used for soil cultivation: a Horsch Tiger stubble cultivator working to a depth of 30–35 cm before growing spring crops, and a Vaderstadt TopDown multipurpose cultivator working to a depth of 25–30 cm before sowing winter cereals. Due to intensive fertilisation with high doses of NPK, high yields (150–180% of the county average) are characteristic of each crop grown on the investigated plots.

Soil of the investigated plots

Before scraping, 9 samples were taken from the 0–30 cm layer of the soil on plot T8, 21 samples on plot T9,

and 16 samples on plot T10, respectively. The laboratory testing of the soil samples was carried out in the “Felső-Bácskai Agrolabor” laboratory accredited under the number NAH-1-1125/2019. The humus content (organic carbon content) of the soil was determined according to the Hungarian standard MSZ-08-0210 (1977). Table 1 shows the averages of the main test results for the three investigated plots.

Table 1 Selected soil parameters of the investigated plots (T8, T9, T10) before scraping

Parameter/Plot	T-8	T-9	T-10
pH _(KCl)	5.85	6.17	5.60
Plasticity index by Arany	59	56	58
Total soluble salt (m·m ⁻¹ %)	0.06	0.07	0.07
CaCO ₃ (m·m ⁻¹ %)	0.87	0.83	0.47
Humus (m·m ⁻¹ %)	2.67	2.55	2.78
P ₂ O ₅ (mg·kg ⁻¹)	89	145	109
K ₂ O (mg·kg ⁻¹)	207	203	282
NO _x -N (mg·kg ⁻¹)	7.66	8.26	1.97
Na (mg·kg ⁻¹)	40.0	71.2	53.0
Mg (mg·kg ⁻¹)	629	667	776
SO ₄ ²⁻ -S (mg·kg ⁻¹)	25.4	27.5	8.6
Mn (mg·kg ⁻¹)	285	190	91
Zn (mg·kg ⁻¹)	2.7	1.9	2.4
Cu (mg·kg ⁻¹)	7.2	6.7	7.0

Source: “Felső-Bácskai Agrolabor” (NAH-1-1125/2019)

Based on the laboratory test results, the soil of all the three plots is slightly acidic and calcareous with clay texture. The humus content is medium-high, its N-supplying capacity is medium, and it is moderately supplied with phosphorus and weakly with potassium. Based on its Al-soluble Na content, the soil is at the risk of salinisation. The magnesium content is high. Its manganese and copper supply capacity is good, for zinc it is poor.

Classification of sampling points into height categories

Topographic heterogeneity also affects soil properties and yield, so the variance between laboratory results and yield data from sampling points at different heights was very high. To mitigate this variability, we defined height categories according to topography. When determining the height categories, the location of the sampling points was considered so that the areas represented by the individual points, i.e., the totality of the height categories defined by the set of points with nearly the same height (within 0.5 m), covered approximately the entire plots. On the other hand, it was also taken into account that each height category must contain a statistically evaluable number of elements (n). Accordingly, the sampling points of the plots were classified into categories by their height above sea level, which is summarised in Table 2.

Table 2 The number of sampling points of the investigated plots (T8, T9, T10) classified into height categories

T8		T9		T10	
height category	number of points (n)	height category	number of points (n)	height category	number of points (n)
102.0–102.5 m	3	97.0–97.5 m	8	90.0–91.0 m	3
103.0–103.5 m	4	97.5–98.0 m	6	91.0–91.5 m	10
103.5–104.0 m	6	98.0–98.5 m	7	91.5–92.0 m	3
104.0–104.5 m	6	–	–	–	–

Scraping on the plots

Since the risk of inundation could not be eliminated by deep loosening on the soil with a high clay content, in 2020 a complete levelling and scraping of the surface was carried out. The purpose of scraping was to create plots with a homogeneous topography and a surface with a slight slope in one direction so that in the event of an excessive amount of water, the soil could not absorb it, and excess water flows down to an area from where it can be easily drained into the channels bordering the plots. The intervention was performed with a GPS-controlled (Trimble Ag Software) precision machine. The main part of the machine consists of a cutting box, which cuts soil shavings from the ground as it moves and collects them in the box. There is a cutting-edge holder on the bottom plate of the cutting box, to which the steel cutting edge is screwed. The cutting box (bowl) is an uncovered container with a swing door at the front. The swing door can be opened and closed hydraulically. The cutting box itself is surrounded by the walking mechanism, which is fixed to the box on both sides with two large pins. The crate can be raised and lowered with hydraulics fixed between the walking structure and the crate. The front of the undercarriage is shaped like a swan's neck, and it is connected to the front member or the tractor. In the investigated area, a towed cutting box was used, which was operated by a tractor of 287 kW performance (Fig. 1).

The area of plot T8 is 23.3 ha, its topography and soil were extremely heterogeneous. Before scraping, the average height of the plot above sea level was 103.6 m, and the largest difference in level within the plot was 2.3 m. Plot T9 covers 27.8 ha, the topographical heterogeneity was less than on plot T8 with its average height of 97.8 m and the largest level difference of 1.2 m. The plot T10 of 19.1 ha has the lowest location, its average height above sea level was 91.2 m, and the difference in level was 1.4 m. All the three examined plots are characterised by the fact that there were several large and small depressions and low-lying non-drained areas on which excess water regularly formed. The fields were loosened several times in the past decades, but the danger of excess water could not be eliminated and inundation reappeared every rainy spring. The relief maps of the plots before (left) and after (right) scraping are illustrated in Fig. 2.

Data processing and analysis

Trimble Ag software was used to produce topographic maps, interpret, and display spatial data. For creating the height categories and sorting the geological data into categories, Microsoft Excel program was used. The two-sample paired *t*-test was used for statistical evaluation, which is suitable for comparing the pairs of samples from the same sampling point in consecutive years, thereby showing what kind of change the intervention has caused. The results were checked with the LSD test.

**Fig. 1** Scraping set used

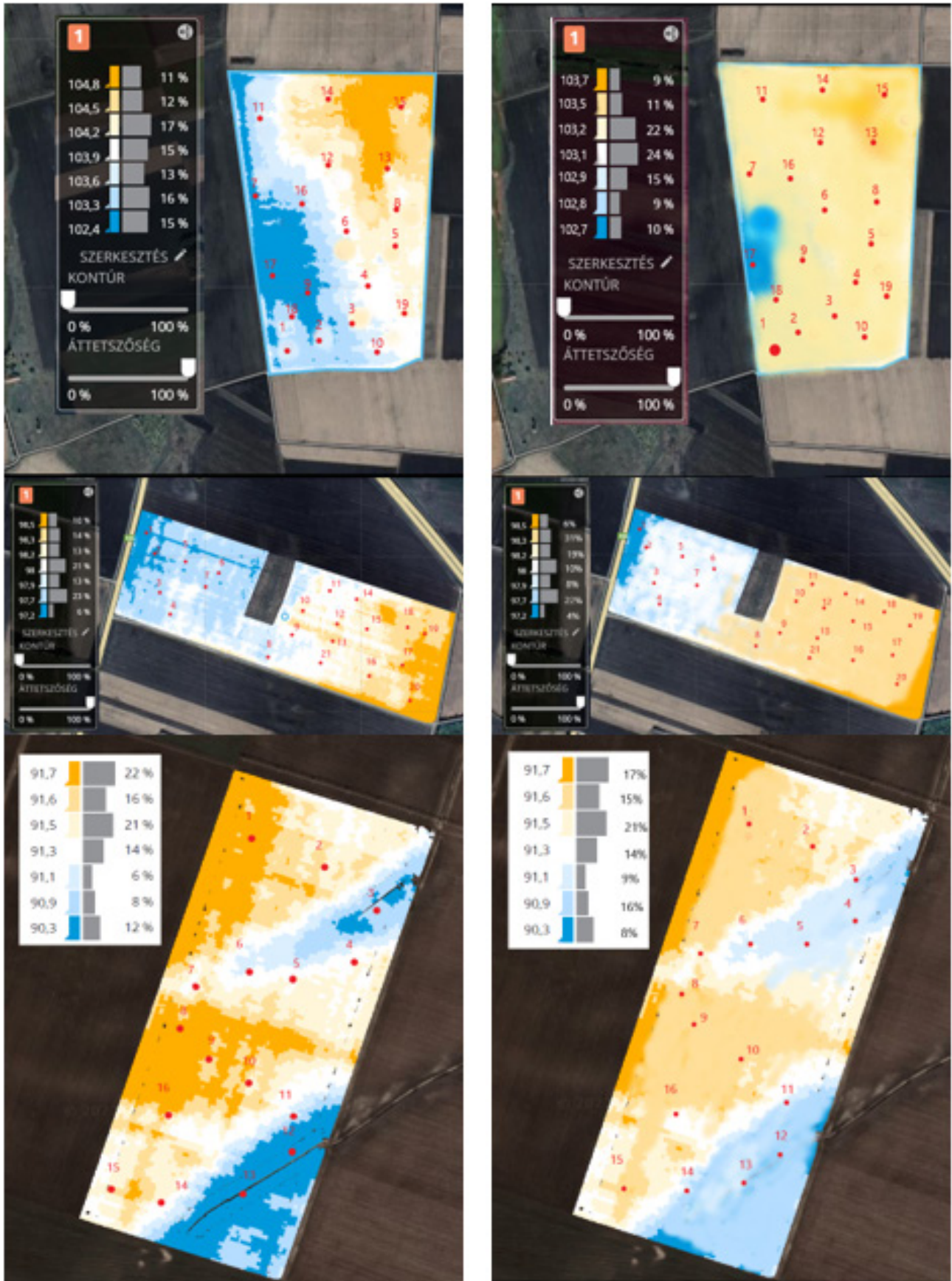


Fig. 2 Topographical maps of the investigated plots (T8, T9, T10) before and after scraping

Results and discussion

As a result of the scraping operation carried out on the investigated plots, their topography changed significantly and became more homogeneous (Fig. 2). Compared to the initial state before soil mass movement, the largest level difference within these plots decreased by 0.7 m, and the standard deviation of the height data changed from 0.68 m to 0.37 m. At the edge of the fields, low-lying areas were created, where the excess water from the entire surface of the fields can flow onto and can be outlet.

One of the main causes of soil degradation which damages the upper layer of the soil the most is the formation of excess water resulting in local waterlogging, which compacts, silts up, deaerates the soil, and changes the biochemical processes (Ferronato et al., 2019). The formation of excess water is influenced by many factors, among

which soil conditions, geological peculiarities, and topographic features can be considered constant (Bozán et al., 2008). Waterlogging is a significant obstacle to crop production worldwide in areas with high rainfall and/or poor drainage, only in Russia about 9 million hectares are considered to be wet, of which 5 million hectares are agricultural land (Tsaregorodtsev et al., 2020).

The most economical way to deal with the problem is appropriate plant selection, and if it is not effective, combined agronomic and engineering solutions are necessary (Manik et al., 2019) like scraping. In our case, theoretically, excess water cannot form on the surface of those newly created, gently sloping fields freed from topographical heterogeneity, but in the years after the intervention, weather conditions did not result in considerable excess water formation, so we could not check the effectiveness of scraping in this respect.

The effect of scraping on the humus content of the soil

The average humus content of the samples taken from the upper 0–30 cm soil layer at 19 test points on plot T8 changed as a result of scraping carried out in 2020 according to the height categories as described in Fig. 3. We hypothesised that the humus-rich topsoil of higher areas was moved to deeper areas.

The results from the analysis of the data with a two-sample paired *t*-test are summarised in Table 3. It can be concluded that the average humus content became higher (from 2.73% to 3.09% and from 2.22% to 2.64%) in the two, originally deeper (102–202.5 m and 103–103.5 m above sea level) areas, while it slightly decreased in the soil of the higher (103.5–104 m) sampling points (from the average of 2.89% to 2.85%). Nevertheless, these differences cannot be verified statistically contrary to the area with the highest elevation (104–104.5 m) where the humus content decreased significantly (from 2.7% to 2.34%, $LSD_{5\%} = 0.266\%$).

The average humus content of the samples taken from the upper 0–30 cm soil layer at 21 test points on plot T9 changed according to the height categories as a result of scraping carried out in 2020, as illustrated in Fig. 4.

Table 4 shows the results of the two-sample paired *t*-test for the humus content data of plot T9. In the originally deepest (97–97.5 m) area, the average humus content increased significantly (from 2.34% to 2.61%, $LSD_{5\%} = 0.225$). The humus content of the soil increased slightly (from 2.59% to 2.66%) in the medium-deep area

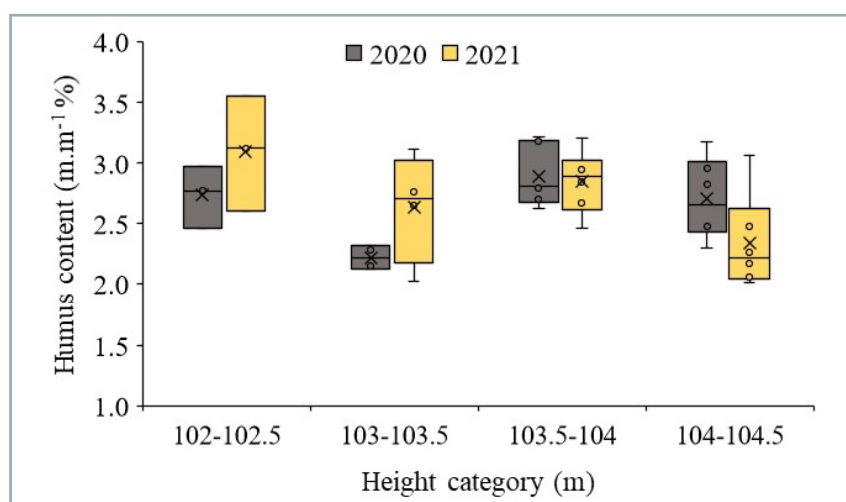


Fig. 3 Humus contents on plot T8 before and after scraping (2020–2021) (number of points = 3, 4, 6, 6)

Table 3 Results of the paired *t*-test for the humus content data of the soil on plot T8

Height category (m)	102.0–102.5		103.0–103.5		103.5–104.0		104.0–104.5	
	2020	2021	2020	2021	2020	2021	2020	2021
Mean	2.73	3.09	2.22	2.64	2.89	2.85	2.70	2.34
Variance	0.065	0.221	0.010	0.207	0.062	0.067	0.111	0.152
Observations	3	3	4	4	6	6	6	6
<i>t</i> Stat	-2.855		-1.804		0.366		2.783	
<i>P</i> (<i>T</i> <= <i>t</i>) two-tail	0.104		0.169		0.729		0.039	
<i>t</i> Critical two-tail	4.303		3.182		2.571		2.571	

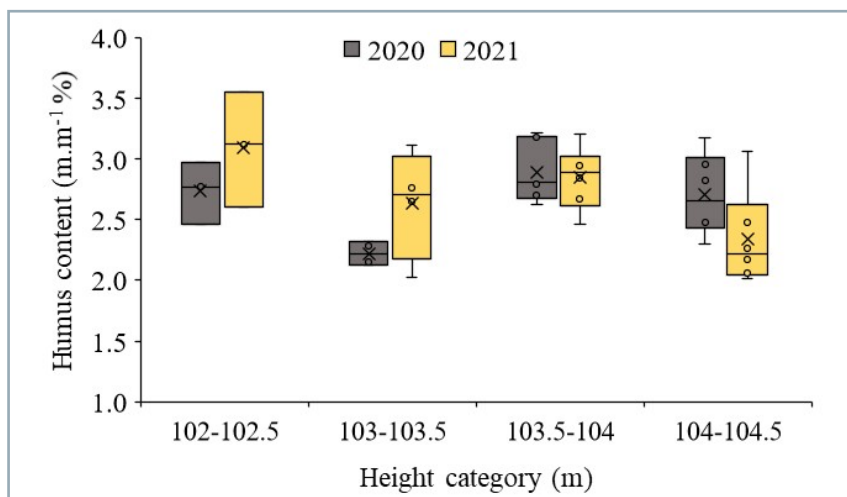


Fig. 4 Humus contents on plot T9 before and after scraping (2020–2021) (number of points = 8, 6, 7)

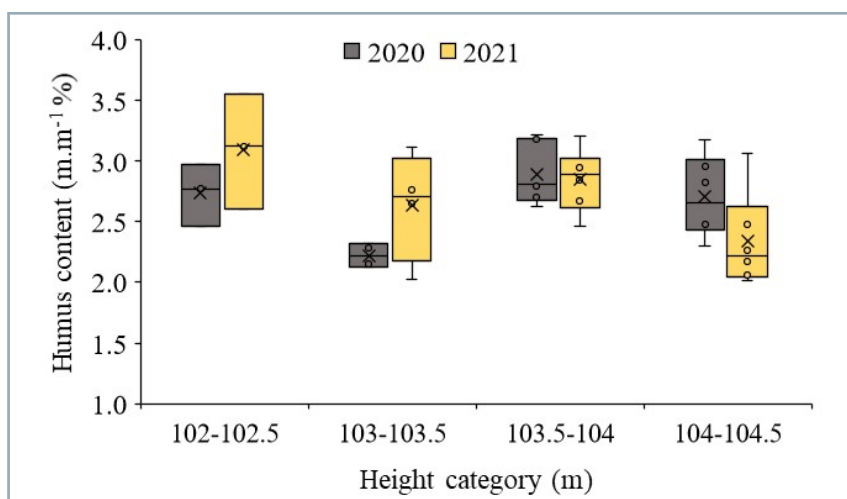


Fig. 5 Humus contents on plot T10 before and after scraping (2022–2023) (number of points = 3, 10, 3)

(97.5–98 m), but this difference cannot be verified statistically. At the highest points (98–98.5 m), the average humus content decreased to a statistically significant extent, from 2.75% to 2.30% ($LSD_{5\%}$ 0.16%).

The change of the average humus content of the samples taken from the upper 0–30 cm soil layer at 16 test points on plot T10 due to scraping carried out in 2022 is illustrated in Fig. 5.

The results of the two-sample paired *t*-test of the humus content data calculated for plot T10 are listed in Table 5. In contrast to the other two examined plots, on plot T10, the average humus content of the soil slightly decreased only (from 2.78% to 2.66%) in the originally deepest (90–91 m) area. The reason for this is that the low-lying part of this field forms a natural excess water outlet (probably an old stream bed covered due to regular ploughing), which the owners considered useful to be maintained as a drainage channel. Therefore, they mined the humus-rich topsoil from there and transported and spread it on the surface of the two higher-lying areas. Hence, the average humus content of the soil increased slightly (from 2.67% to 2.78% and from 2.74% to 3.05%, respectively) in the medium (91–91.5 m) and the highest (91.5–92 m) parts; however, these differences were not statistically significant either.

Table 4 Results of the paired *t*-test for the humus content data of the soil on plot T9

Height category (m)	97.0–97.5		97.5–98.0		98.0–98.5	
	2020	2021	2020	2021	2020	2021
Mean	2.34	2.61	2.59	2.66	2.75	2.30
Variance	0.078	0.185	0.085	0.174	0.092	0.022
Observations	8	8	6	6	7	7
<i>t</i> Stat	2.488		-0.385		3.663	
<i>P</i> (<i>T</i> < <i>t</i>) two-tail	0.042		0.716		0.011	
<i>t</i> Critical two-tail	2.365		2.571		2.447	

Table 5 Results of the paired t-test for the humus content data of the soil on plot T10

Height category (m)	90.0–91.0		91.0–91.5		91.5–92.0	
	2022	2023	2022	2023	2022	2023
Mean	2.78	2.66	2.67	2.78	2.74	3.05
Variance	0.044	0.084	0.165	0.200	0.313	0.467
Observations	3	3	10	10	3	3
t Stat	0.492		-0.673		-0.464	
P(T<= t) two-tail	0.671		0.518		0.688	
t Critical two-tail	4.303		2.262		4.303	

Soil is the largest terrestrial reservoir of organic carbon and plays a central role in mitigating climate change, containing more carbon globally than the atmosphere and vegetation combined (Jobbágy and Jackson, 2000; Georgiou et al., 2022). Many researchers have observed a decrease in the humus content of the soil during field production (Raiesi, 2021; Loke et al., 2019; Gelybó et al., 2022). In the examined area, we found a lower humus content than expected for the investigated soil type (Vertisol), which was formed due to long-term cultivation and unfavorable soil structure, as well as unfavorable, easily soluble, and leachable forms of humus (Na-humates) due to the high Na content. Just like in the case of the studied plots, the loss can be particularly significant in sloping areas, where erosion by water can wash away dissolved organic matter from the topsoil (An et al., 2024). Landscaping and leveling of topographical conditions eliminated the risk of erosion on the tested plots, we could not detect a significant loss of humus, and the humus content of the soil increased slightly in the filled-up plot parts.

Conclusion

On the investigated plots, the main purpose of scraping was to create a homogeneous topography with a slight slope to outlet excess water. Nevertheless, scraping involves soil movement from one place to another, which means the transportation of all soil ingredients. Among them, from a fertility point of view, humus (organic matter) is the most important. In the investigated area, fodder maize is often grown to fulfil the feed needs of a large-scale animal farm. Maize is demanding on the soil, we can expect a large yield on soils with a deep fertile layer, rich in humus and nutrients, with good nutrient supply capacity (Kátai, 2021). Significant loss of humus due to scraping would impede the maintenance of original soil fertility, hence the high level of maize production. Therefore, we surveyed the effect of scraping on the redistribution of the soil humus stocks within the examined plots. We established that scraping is an effective operation to get rid of the harmful effects of excess water without humus loss on a plot scale, and it results in an even organic matter distribution, hence a potentially more homogenous yield within the ameliorated plots.

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