Journal of Central European Green Innovation 11(2), 86–92. (2023) DOI: 10.33038/jcegi.4855

EFFECT OF CONSERVATION TILLAGE ON EARTHWORMS IN A LONG-TERM FARM EXPERIMENT (HUNGARY)

TALAJKÍMÉLŐ MŰVELÉS HATÁSA A FÖLDIGILISZTÁKRA EGY ZALA MEGYEI TARTAMKÍSÉRLETBEN

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Abstract

Conventional ploughing tillage is associated with significant soil degradation. Erosion is increasing while soil organic matter is decreasing and life circumstances of soil biota are deteriorating. Non-inversion conservation tillage tends to provide better conditions for soil fauna due to less disturbance, more organic matter and higher soil moisture content. In our study, we investigate the effects of 18 years of conservation tillage on earthworm abundance and biomass. Our study was carried out on a 90 ha area divided into 10 pairs of plots in Southern Hungary close to Dióskál. Samples were taken in spring and autumn during the first 3 years after the shift from conventional to conservation tillage (2004–2006) and then after 15 years the sampling was repeated in the 3-year-period of 2019–2021. Samples were collected with a soil sampler of 10 cm diameter and height. Our results show that the number of earthworms increased explosively after the shift. However, their abundance do not increase after years, but their number and biomass are significantly higher in all periods of the study in conservation tillage areas.
Keywords: *conservation tillage, reduced tillage, non-inversion tillage, cover crop, long-term experiment*
JEL code: *Q10*

Összefoglalás

A hagyományos, szántásos talajművelés jelentős talajdegradációval jár. Növekszik az erózió, miközben csökken a talajok szervesanyagtartalma és romlanak a talaj élővilágának életfeltételei. A forgatás nélküli, talajkímélő művelésű rendszerek a kisebb zavarás, több szervesanyag és magasabb nedvességtartalomnak köszönhetően többnyire jobb körülményeket biztosítanak a talajfauna számára. Tanulmányunkban azt vizsgáljuk, hogy milyen hatása van egy 18 éves talajkímélő művelésű terület a földigiliszták egyedszámára és biomassza tömegére. Vizsgálatainkat Dióskál település határában 10 parcellapáron 90 ha-on végeztük. A mintákat az átállást követő első 3 évben (2004–2006), illetve a 2019–2021 közötti 3 évben, tavasszal és ősszel vettük egy 10 cm átmérőjű és ugyanekkora magasságú talajszaggatóval. Eredményeink azt mutatják, hogy a földigiliszták egyedszáma az átállást követően gyorsan megnő, felszaporodásuk robbanásszerű. Azonban számuk az évek elteltével nem növekszik, de egyedszámuk és biomassza tömegük szignifikánsan magasabb a vizsgálat minden periódusában a talajkímélő művelésű területeken.
Kulcsszavak: *talajkímélő művelés, csökkentett művelés, forgatás nélküli talajművelés, takarónövény, tartamkísérlet*

Introduction

The negative effects of conventional ploughing, rotational tillage (PT) (increased erosion, soil structure degradation, poor of water management properties, reduction of biodiversity, etc.) are widely known (BIRKÁS et al. 2011). Although land quality is not a negligible factor (JUHOS - MADARÁSZ 2016), intensive tillage has led to a loss of biodiversity, significant erosion and chemical pollution in the modern agricultural landscape (KELLER et al. 2019, SZABÓ et al. 2001). The loss of biodiversity threatens the long-term stability of ecosystems and the maintenance of their 'services' (BÁLDI 2005, MASOUDI et al. 2023). For this reason, soil health and soil biota have received increasing attention in the last decade (KOVÁCS et al. 2020, KOTROCZÓ - FEKETE 2020, KOTROCZÓ et al. 2022, JUHOS et al. 2023).

Several attempts of sustainable arable farming are known (CENTERI et al. 2021). Soil conservation tillage (CT) systems are no-till, minimum-till, reduced tillage, etc., and we can also include regeneration farming as well. They have in common the abandonment of rotation and the reduction of soil disturbance to varying degrees, thus supporting soil biota. Despite their almost half-century-long history (KASSAM et al. 2017, 2019, RIEDER et al. 2018), their role in Hungary is still subordinate (MADARÁSZ et al. 2021). Earthworms constitute a very significant fraction of the beneficial soil fauna and their role is essential for soil fertility and ecosystem functioning (DARWIN 1840, BIRKÁS 2001, KASZA et al. 2015). Their role as indicators of good soil condition makes them excellent bioindicators. Soil cultivation affects the abundance, habitat and activity of earthworms in two ways. The direct effect is caused by mechanical damage, while the indirect effect is caused by the lack of organic matter due to the removal of stem residues and due to soil erosion. Besides, the negative effect of the less favourable soil moisture conditions caused by the lack of soil cover is also unfavourable for the earthworms.

The impact of low-tillage systems on earthworms has been investigated by several authors (EMMERLING 2001, BIRKÁS et al. 2004, KUNTZ et al. 2013, ROARTY et al. 2017). These studies often only present data from a few years, and the results are highly variable. Moreover, there are very few data available in the Central and Eastern European region for reduced tillage, which is probably the most commonly used in Hungary (DEKEMATI et al. 2020). Therefore, the aim of our study was to investigate the effects of CT reduced tillage on the number of earthworms and biomass in a long-term experiment.

Materials and methods

The sample area

Our investigations were conducted in the western catchment of Lake Balaton, at the border of Dióskál in Zala County (46°42'15" N, 17°02'50" E, 176–206 m asl). The average annual temperature in this area is 11°C, the average precipitation is 650–700 mm (MADARÁSZ et al. 2021). In 2003, 12 pairs of plots were established on 107 ha, ranging in size from 3 to 5 ha (KERTÉSZ et al. 2007). The alternating PT and CT (no rotation, reduced number of passes, with at least 30% cover of crop residues) plots were designed according to the requirements of the ornithological observations started in 2003 (FIELD et al. 2007). The two types of plots differed only in terms of tillage, with the same crop species sown, the same amount of fertiliser and the same crop protection applied by the farmer. The rotation included winter wheat, maize, oilseed rape and spring barley. Yield differences between the two tillages were described in detail in MADARÁSZ et al. (2016). The area has a significant relief, with the slope of the hilly landscape varying between 0–15%. Accordingly, the soil properties are diverse, mainly with eroded brown forest soils with low humus content (Haplic Luvisol (loamic, humic) (WRB 2014)).

Sample collection

The earthworm surveys were conducted on 10 pairs of the 12 pairs plots (1–6 and 9–12 pairs of plots; 90 ha) twice a year, in spring (April) and in autumn (October) at the beginning of the experiment (2004–2006) and during the last 3 years (2019–2021). Sampling was carried out using the HARPER ADAMS UNIVERSITY COLLEGE (2003) method. Soil samples were collected with a soil sampler of 10 cm diameter and the same height (from 0–10 cm depth) at 9 points per plot. After sampling, each soil sample was sorted manually and the earthworms were counted and measured by weight to two decimal places (BÁDONYI et al. 2008).

Statistics

Data were processed using MS Excel and SPSS Statistics 22. After the distribution tests, the data pairs were analysed using a T-test and one-factor variance analysis.

Results

The amount of earthworms that can be sampled is influenced by a number of factors, such as soil water potential, temperature or excessive tillage (CHAN 2001). The first two factors are the reason for the larger differences between some samples, although the data did not show significant seasonal variabilty. However, the effect of tillage was found to be significant. To eliminate the effect of seasons, the aggregated annual data were used. Averaging the data from the first and last three years of the experiment, the average earthworm abundance in CT plots was 93.2 pcs/m^2, while the same factor was 29.7 pcs/m^2 for PT. There was also a significant difference in the weight of earthworms, which was 0.42 g/individual for CT and 0.25 g/individual for PT samples (Figure 1). For the quantity of earthworms, the ratio CT/PT was 3.2, with a significant variability between 1.4 and 5.5. In terms of weight, the annual ratios showed a smaller variability (1.3–3.2) with a mean value of 1.7. It is worth noting from the ratios that already in the spring of the first year (2004) there was a significant difference between the two areas with different cultivation. For earthworms, the ratio was 2.6 in terms of their number and 1.4 in terms of weight. It is surprising, however, that the same values to one digit were measured in autumn 2021. This implies that after the rapid change following the changeover, the CT/PT ratio has remained essentially unchanged over the last 17 years with respect to these two parameters.

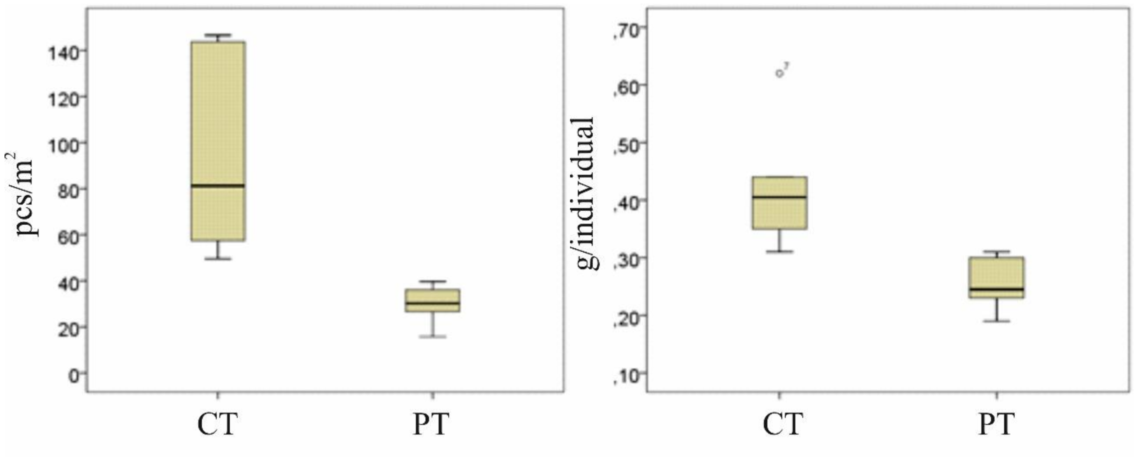

Figure. 1. Numbers and biomass of earthworms in soil conservation (CT) and conventional/ploughing (PT) plots in Dioskál, averaged over the years 2004–2006 and 2019–2021.

These results are in agreement with the ratios between 2 and 9 found in the literature (CHAN 2001, DEKEMATI et al. 2020). Interestingly, the highest CT/PT ratio (5.5) was measured in the second year of the experiment (spring 2005). Similar results were reported in a nearby study (MADARÁSZ et al. 2021), where we found a stagnation of the ratios after a rapid change until the introduction of cover crops. This resulted in a further increase in earthworm numbers. This draws attention to the importance of cover crops and regenerative, soil renewal management (ROARTY et al. 2017).

If we look at the absolute number of earthworms in the first and second sampling periods (2004–2006 and 2019–2021), we see a decline not only for PT but even for CT (Figure 2). Nevertheless, a significant surplus of CT was still present (62 pcs/m2 for PT and 23 pcs/m2 for CT). However, in terms of average weight of earthworms, we measured a clear significant increase for CT plots (2004–2006: 0.35 g/individual; 2019–2021: 0.49 g/individual). For PT plots, no significant change in earthworm weight was found over the 17 years (2004–2006: 0.26 g/individual; 2019–2021: 0.24 g/individual).

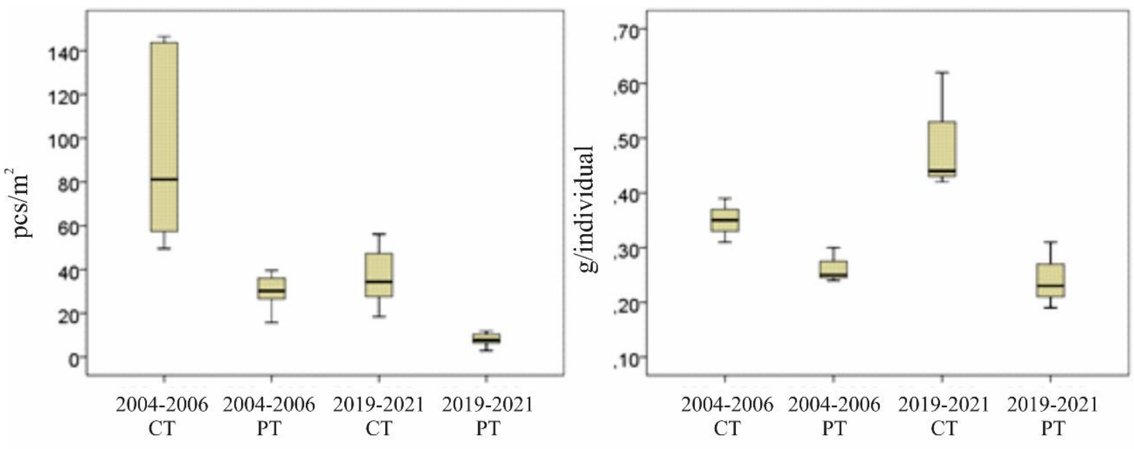

Figure. 2. The number and biomass of earthworms in the soil conservation (CT) and conventional (PT) plots in Dioskál, 2004–2006 and 2019–2021.

In the samples collected in the field, 6 species were isolated (Aporrectodea caliginosa, Aporrectodea rosea, Allolobophora chlorotica, Octolasium lacteum, Lumbricus rubellus, Proctodrilus tuberculatus), which reside in the upper 20 cm of the soil in their active state. In summary, the 3x more in number and 2x larger earthworm masses occurring on CT form an abundance of macropores, which greatly increase infiltration, thus reducing runoff and erosion (MADARÁSZ et al. 2021).

Conclusions

Conservation tillage has a positive effect on the number of earthworms and their biomass. Their life activity enriches the soil humus, improves soil structure, and forms stable tunnels, while the absence of rotation, less number of passes (less disturbance), more organic matter and more favourable soil moisture conditions favourably influence the living conditions of earthworms. As a result, after the transition from PT, there is a large increase in the number of earthworms in the CT plots, but this increase stops after the jump and subsequently stagnates. If further soil improvement and an increase in earthworm numbers and soil life are to be achieved, the use of cover crops is recommended.

Acknowledgements

The research was supported by EU-Life, Syngenta Ltd. and the National Research, Development and Innovation Office (K143005).

References

BÁDONYI K. – HEGYI G. – BENKE S. – MADARÁSZ B. – KERTÉSZ Á. (2008): Talajművelési módok agroökológiai összehasonlító vizsgálata. *Tájökológiai Lapok* 6, 145–163.
BIRKÁS M. (Ed.) (2001): Talajművelés a fenntartható gazdálkodásban. Gödöllő, SZIE, Mezőgazdasági és Környezettudományi Kar. 292 p.
BIRKÁS M. (2002): Környezetkímélő és energiatakarékos talajművelés. Budapest, Akaprint Nyomdaipari Kft.
BIRKÁS, M. – JOLÁNKAI, M. – GYURICZA, C. – PERCZE, A. (2004): Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. *Soil Tillage Res*. 78, 185–196. https://doi.org/10.1016/j.still.2004.02.006
BÁLDI A. (2005): Az agrár-környezetvédelmi programok ökológiai kutatásának szükségességéről. *A Falu* 20, 61–65.
CENTERI, C. – SALÁTA, D. – SZILÁGYI, A. – OROSZ, G. – CZÓBEL, S. – GRÓNÁS, V. – GYULAI, F. – KOVÁCS, E. – PETŐ, Á. – SKUTAI, J. et al. (2021): Selected Good Practices in the Hungarian Agricultural Heritage. *Sustainaability* 13, 6676. https://doi.org/10.3390/su13126676
CHAN, K.Y. (2001): An overview of some tillage impacts on earthworm population abundance and diversity – implications for functioning in soils. *Soil Tillage Res*. 57, 179–191. https://doi.org/10.1016/S0167-1987(00)00173-2
DARWIN, C. (1840): On the formation of mould. Tranc. Geol. Soc., London, 5. 505–509. https://doi.org/10.1144/transgslb.5.3.505
DEKEMATI, I. – SIMON, B. – VINOGRADOV, S. – BIRKÁS, M. (2019): The effects of various tillage treatments on soil physical properties, earthworm abundance and crop yield in Hungary. *Soil Tillage Res*. 194, 104334. https://doi.org/10.1016/j.still.2019.104334
EMMERLING, C. (2001): Response of earthworm communities to different types of soil tillage. *Applied Soil Ecology* 17, 91–96. https://doi.org/10.1016/S0929-1393(00)00132-3

FIELD, R.H. – BENKE, S. – BÁDONYI, K. – BRADBURY, R.B. (2007): Influence of conservation tillage on winter bird use of arable fields in Hungary. *Agric. Ecosys. Environ*. 120, 399–404. https://doi.org/10.1016/j.agee.2006.10.014

HARPER ADAMS UNIVERSITY COLLEGE (2003): Earthworm Soil Core Standard Operating Procedure. Newport UK, Crop and Environment Research Centre. 4 p.

JUHOS, K. – MADARÁSZ, B. (2016): Interpretation and integration of pedological data in land evaluation systems. *Bulgarian J. of Agricultural Sci*. 22, 209–215.

JUHOS, K. – NUGROHO, P.A. – JAKAB, G. – PRETTL, N. – KOTROCZÓ, ZS. – SZIGETI, N. – SZALAI, Z. – MADARÁSZ, B. (2023): A comprehensive analysis of soil health indicators in a long-term conservation tillage experiment. *Soil use and Management*, https://doi.org/10.1111/sum.12942

KASSAM, A. – BASCH, G. – FRIEDRICH, T. – GONZALEZ, E. – TRIVINO, P. – MKOMWA, S. (2017): Mobilizing greater crop and land potentials sustainably. *Hun. Geogr. Bull*. 66, 3–11. https://doi.org/10.15201/hungeobull.66.1.1

KASSAM, A. – FRIEDRICH, T. – DERPSCH, R. (2019): Global spread of conservation agriculture. *Int. J. Environ. Stud*. 76, 29–51. https://doi.org/10.1080/00207233.2018.1494927

KASZA, G. – BÓDI, B. – SÁRKÖZI, E. – MÁZSA, Á. – KARDOS, L. (2015): Vermicomposting of sewage sludge – Experiences of a laboratory study. *Int. J. of Bioscience, Biochemistry and Bioinformatics* 5, 1–10. https://doi.org/10.17706/ijbbb.2015.5.1.1-10

KELLER, B. – SZABÓ, J. – CENTERI, C. – JAKAB, G. – SZALAI, Z. (2019): Different land-use intensities and their susceptibility to soil erosion. *Agokémia és Talajtan* 68, 14–23. https://doi.org/10.1556/0088.2018.00004

KERTÉSZ, Á. – BÁDONYI, K. – MADARÁSZ, B. – CSEPINSZKY, B. (2007): Environmental aspects of conventional and conservation tillage. In: GODDARD, T. – ZOEBISCH, M. – GAN, Y. – ELLIS, W. – WATSON, A. – SOMBATPANIT, S. (Eds.), No-till Farming Systems. Bangkok, World Association of Soil and Water Conservation. pp. 313–329.

KOVÁCS, B. – DOBOLY, C. – SEBŐK, F. – KOCSIS, L. (2020): Effect of vineyard floor management on seasonal changes of cultivable fungal diversity in the rhizosphere. *Agriculture* 10, 534. https://doi.org/10.3390/agriculture10110534

KOTROCZÓ, Z. – FEKETE, I. (2020): Significance of soil respiration from biological activity in the degradation processes of different types of organic matter. *DRC Sustainable Future: Journal of Environment, Agriculture and Energy* 1, 171–179. https://doi.org/10.37281/DRCSF/1.2.10

KOTROCZÓ, Z. – KOCSIS, T. – JUHOS, K. – HALÁSZ, J. – FEKETE, I. (2022): How Does Long-Term Organic Matter Treatment Affect the Biological Activity of a Centre European Forest Soil? *Agronomy* 12, 2301. https://doi.org/10.3390/agronomy12102301

KUNTZ, M. – BERNER, A. – GATTINGER, A. – SCHOLBERG, J.M. – MÄDER, P. – PFIFFNER, L. (2013): Influence of reduced tillage on earthworm and microbial communities under organic arable farming. *Pedobiologia* 56, 251–260. https://doi.org/10.1016/j.pedobi.2013.08.005

MADARÁSZ, B. – JUHOS, K. – RUSZKICZAY-RÜDIGER, Z. – BENKE, S. – JAKAB, G. – SZALAI, Z. (2016): Conservation tillage vs. conventional tillage: long-term effects on yields in continental, sub-humid Central Europe, Hungary. *Int. J. of Agric. Sustainability* 14, 408–427. https://doi.org/10.1080/14735903.2016.1150022

MADARÁSZ, B. – JAKAB, G. – SZALAI, Z. – JUHOS, K. – KOTROCZÓ, ZS. – TÓTH, A. – LADÁNYI, M. (2021): Long-term effects of conservation tillage on soil erosion in Central Europe: A random forest-based approach. *Soil and Tillage Res*. 209, 104959. https://doi.org/10.1016/j.still.2021.104959

MASOUDI, M. – CENTERI, C. – KARLIK, M. – JAKAB, G. (2023): Extracted samples and in situ soil investigations to assess the effects of different land use and tillage management practices on soil organic matter composition. *Land Degradation & Development* 34, 2560–2572. https://doi.org/10.1002/ldr.4629
RIEDER, Á. – MADARÁSZ, B. – SZABÓ, J.A. – ZACHÁRY, D. – VANCSIK, A. – RINGER, M. – SZALAI, Z. – JAKAB, G. (2018): Soil organic matter alteration velocity due to land-use change: a case study under conservation agriculture. *Sustainability* 10, 943. https://doi.org/10.3390/su10040943
ROARTY, S. – HACKETT, R.A. – SCHMIDT, O. (2017): Earthworm populations in twelve cover crop and weed management combinations. Appl. Soil Ecology 114. 142–151. https://doi.org/10.1016/j.apsoil.2017.02.001
SZABÓ M. – BARCZI A. – TURCSÁNYI G. (2001): A környezet állapota és használatának néhány szempontja Magyarországon. In: ÁNGYÁN J. – PODMANICZKY L. – SZABÓ M. – VAJNÁNÉ MADARASSY A. (Eds.) Az Érzékeny Természeti Területek (ÉTT) rendszere. Tanulmányok Magyarország és az Európai Unió természetvédelméről. TEMPUS Institutional Building Joint European Project. ELTE-TTK, SZIE-KGI, KöM-TvH, Budapest-Gödöllő-Berlin-Madrid-Thessaloniki. pp. 19–87.
WRB (2014). World Reference Base for Soil Resources 2014. FAO, Rome

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