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SOIL AGGREGATE STABLITY, ORGANIC CARBON AND PLANT AVAILABLE NUTRIENT CONTENTS (N,P) IN SOILS OF PREHISTORIC MOUNDS AFTER ABANDONMENT OF CULTIVATION

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Abstract
Prehistoric mounds are valuable archeological and nature conservational sites of the Hungarian lowland. However, due to the machinery cultivation most of them were plowed during the 20th century. After setting new legislative frames of their preservation, former cultivated mounds were abandoned and spontaneous regeneration processes of vegetation and soil could initiate on the ex lege mounds. Four mounds situated within the National Park of Hortobágy were investigated after their cultivation were abandoned, regarding their most important soil properties such as aggregate stability, bulk density, nitrogenous and phosphorous content, pH, organic carbon content and secondary carbonates.

Keywords: prehistoric mounds, post-agricultural soil transformation, organic matter, aggregate stability, soil nutrients

1. Introduction

Although the number of prehistoric mounds in the Carpathian Basin could be estimated approx. 25 000, only about 2000 mounds are under protection in recent time on the Great Hungarian Plain, where the small round mounds rise from the environment like humps (Bede, 2014). Their average diameter is 30-80 m and average height is variable but none of them is higher than 11 meter. They are characteristic elements of the environment having nature-conservational, landscape-aesthetic, archeological and culture-historical values. They have important function in maintaining of biodiversity, since many of them hold valuable fragments of loess-grassland vegetation (Zelenyánszki, 1989).

Their number was dramatically reduced due to intentional/unintentional habitat alteration and the mechanization of agriculture. Extensive protection ("ex lege") of the mounds was declared by the 1996. LIII. law. In the cadastre survey they are listed as natural monuments (Tóth, 1999).

Before the legislative protection, most of the mounds were cultivated and therefore their number, height and natural value moreover, the traceability of valuable loess-grassland associations was reduced, which has not changed after the adoption of the law. The new legislative regulation (32/2010 III.30. FVM) prohibits the further cultivation of mounds and initiates to let them fallow, while the owners who lose profit are compensated in form of agricultural support. In case of numerous earlier cultivated mounds, a planned ecological reconstruction was started; while in other cases only spontaneous regeneration processes were observed. There are several methods for their grassland restoration (Tóth, 2004).

As a result of national legislation further disturbance of the mound's grasslands were stopped but seed propagule of weeds stratified in the soil, nutrient supply from earlier artificial fertilizers and isolated situation does not facilitate spontaneous regeneration processes. Invasive plant species are able to colonize as well. Moreover, after stopping the agricultural cultivation, there is a significant change in the soil's organic matter content, nutrient content and in soil structure. After their abandonment, further addition of artificial fertilizers, first of all N and P supply were stopped. To increase the soil organic material content, favorable conditions were created, which changed the coexistence of certain species as well (Camill et al., 2004). On abandoned fields the nutrient and weed-seed stock is relatively high, which can be explained by the long plough-land cultivation.

The reconstruction of grassland vegetation on mounds is an excellent opportunity to maintain biodiversity of landscapes, where agricultural cultivation definitely prevails. They offer possibility to enlarge the total extension of grasslands, create new patches and establish connections in form of stepping stones between existing ones (Miglécz – Tóth, 2011).

By resettling of grasslands, more and more mounds could recover their former valuable plant communities. In order to reestablish the native vegetation, there is a need for active intervention, direction and support of succession processes. To understand better the reestablishment processes, we investigated the changes in soil carbon and nutrient content after the abandonment of cultivation.

2. Materials and Methods

Study area

The study area is in Hajdu-Bihar County, on the Ágota-puszta which is the southern part of Hortobágy National Park. Ágota-puszta is a very flat plain area covered by native solonetzic grasslands (Kátai – Novák, 2010), where the average height is 86-87 m.a.sl. with several abandoned riverbeds (Kerülő, Tárkány) laying 0.5-1 meter lower and filled with temporary wetlands (Novák, 2010). Typical vegetation is pannonian alkaline grasslands, bogs and in very small extension loess grasslands (Novák, 2005; Tóth – Novák, 2003). The groundwater level is influenced by the riverbed of Kösely. The largest marsh is Kerülő creek (Barcsay, 2008).

Four mounds were investigated around Nádudvar and Püspökladány (Fig. 1.), three of which (Boda, Hegyes and Rév mound) were cultivated till 2011-2012 and another one (Lapos mound) was disrupted by former earth construction works but it was never plowed or cultivated in the last 300 years based on the land use data of historic maps. The characteristics of the mounds are showed in Table 1.

At the very top of Boda mound, there is

Table 1. Summary table of examined mounds of properties (Tóth – Tóth, 2003)

Name of mounds	Settlement	Boundary/field	Geographical coordinates	Absolute height (m)	Relative height (m)
Boda mound	Nádudvar	Boda-zug	47°23'29" 21°03'07"	91.7	4.7
Hegyes mound	Nádudvar	Laposszeg	47°23'42" 21°05'23"	94.0	4.8
Lapos mound	Nádudvar	Peresi legelő	47°23'57" 21°06'39"	91.0	4.1
Rév mound	Püspökladány	Bikalapos	47°22'03" 21°03'03"	90.1	3.0

a small patch of semi-natural vegetation because the top is protected from plough-land cultivation by its triangulation point. Hegyes mound became asymmetrical shape because of the meandering and lateral erosion of Kösely river. Earth roads can also be mentioned as they have negative influence on the mounds, on its vegetation and erosion processes as well. It was cultivated until to the top. Lapos mound was cut from north and south sites, and a significant amount of the material was taken away for the purpose of road and dyke construction. Consequently 50° difference can be observed considering the slope grade. This mound functioned originally as a residence for people (tell) because brick and sherd pieces were found in higher frequency on the north and on the south side (Tóth – Tóth, 2003).

In 2011, the detailed survey of Hortobágy National Park showed that there were attempts to reinstall the grassland on the study area with the exception of Boda mound. Although alfalfa was sown on Boda mound, grassland with the aim of natural protection was not established. The formerly ploughed land of Hegyes mound was also sown with alfalfa. During the reconstruction of these mound's grassland Festuca rupicola and Agropyron cristatum were sown. The southern side of Lapos mound, where disruption occurred but ploughing and cultivation not, was sown with Festuca rupicola. This area is surrounded highly alkaline and solonetzic grasslands. After the abandonment of alfalfa cultivation, Festuca rupicola and Agropyron cristatum were sown in Rév mound.

Field sampling and laboratory methods

The soil samples were taken during the summer of 2014. 100 cm^3 stainless metal cylinders were used for undisturbed soil sampling during the field work. Each mounds were sampled on their top, which were abandoned or never cultivated and in their surroundings, which are still under cultivation. Samples were collected in 10x, in case of Lapos mound 5x repetitions. In addition, we took three samples in the same way from loess grassland in the surrounding of Boda mound, which was regarded as reference sample, being in natural state and not disturbed by any cultivation process but situated not on a mound. Fig. 2. shows the general sampling design of collection of subsamples from cultivated and abandoned soils in case of all the investigated mounds. After the samples were transported into the laboratory, they were dried on 40 °C until constant weight for further analysis. Subsamples taken for assessing bulk density

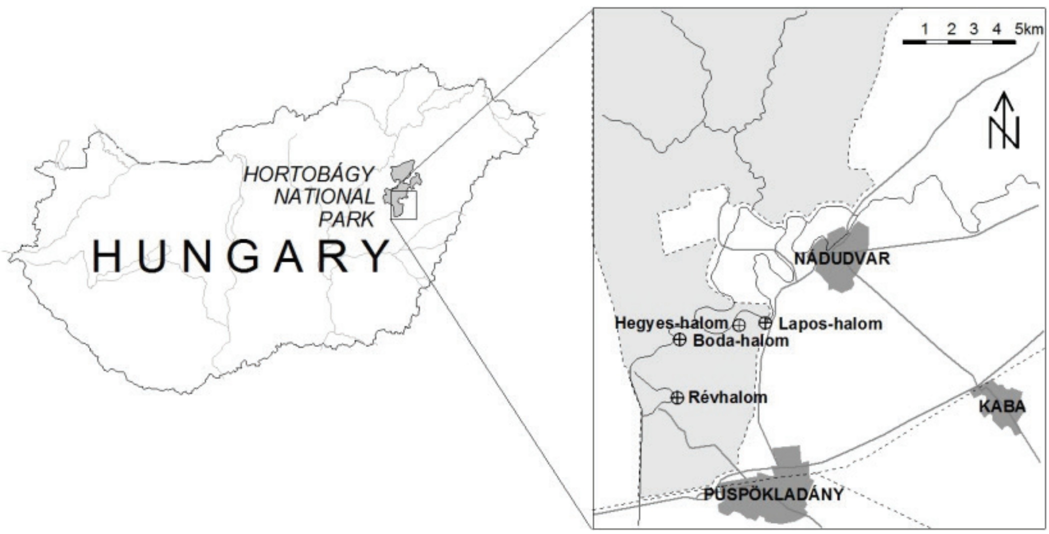

Fig. 1. Location of investigated mounds

in undisturbed cylinders were dried out at 100 °C for 24 hours. In laboratory the soil organic matter (%) total nitrogen (mg/kg), total phosphorus (mg/kg) content and the stability of the soil aggregates were determined.

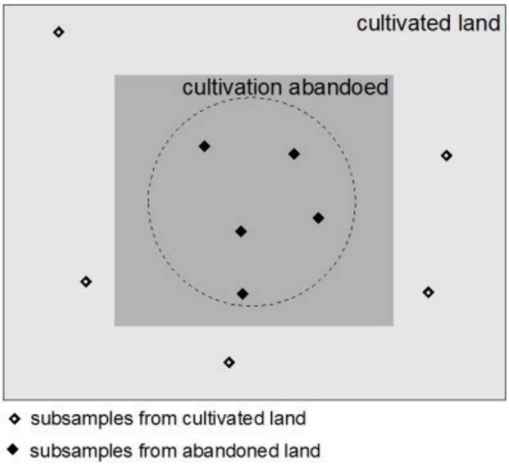

Fig. 2. Sampling design of collection of soil subsamples from cultivated and abandoned areas around investigated mounds

To estimate the aggregate stability, two different size classes of aggregates were separated by dry sieving (1-3 mm and 3-5 mm diameter aggregates). In case of both size classes, two methods were used to determine the stability of soil aggregate. The first one is based on the Hungarian standard (MSZ-08) (Table 2.), while the other one was measured considering the Sekera&Brunner-type (Table 3.) qualitative estimation.

The measurement of soil organic carbon content was carried out by wet oxidation, kaliumbichromatic humus-determining method (Ponomareva – Plotnikova, 1980), soil organic carbon data were converted into soil organic matter, multiplying by 1.724. Measuring of slightly extractable phosphorous was extracted by ammonium-lactate extraction and analyzed by spectrophotometry according MSZ 20135:1999 standard method. Nitrogen extraction was carried out by KCl extraction method and was assessed by spectrophotometry. Totally 33 samples were analysed from cultivated, abandoned and reference sites, then the results were ordered into groups and statistically analyzed. Statistical methods for the examination of results were carried out to characterize their descriptive statistical parameters that belonged to nitrogen and phosphorous content. We calculated means, standard deviations, minimum, maximum, median, quartiles for every locations ie. mounds and we evaluated data considering land use groups (cultivated, abandoned, reference). In addition, water stability of soils was compared with Mann-Whitney test, which evaluates the degree of water stability of soils on the abandoned fields and surrounding

Table 2. Table for estimation of waterproofness of soil aggregates (MSZ-08)

Degree of collapse	Image during collapsing	Degree of water stability
1	The aggregates are not destroyed or they produce little amount of big debris.	good
2	Predominantly, the aggregates fall apart as big debris but in small amount.	appropriate
3	The aggregates fall apart as debris. The number of big and small debris is identical.	slightly deteriorated
4	The aggregates predominantly fall apart as small debris. There is only a little amount of big debris.	deteriorated
5	The aggregates fall apart exclusively as small debris.	very deteriorated
6	The aggregates flow away during the process of the soil becoming mud.	totally deteriorated

Table 3. Table for estimation of water stability of soil aggregates (Sekera&Brunner)

Image during collapse of aggregates	Degree of water stability	Degree of water stability
There is no falling apart or just as big debris.	very high	AS1
Predominantly fall apart into big debris in little amount	high	AS2
Fall apart into the same amount of big and small debris, slightly muddy.	medium	AS3
Predominantly small and a little amount of big, muddy debris.	trifling	AS4
Only small debris with significant muddiness.	low	AS5
Absolutely falling apart and strong muddiness.	very low	AS6

plough-land of two mounds (Boda and Hegyes mound) . The results of statistical analysis were illustrated with R-statistic software.

3. Results

The main texture class of the investigated soils proved to be loam in every case, which was varying between loam, silt loam and silt clay loam.

Average soil organic matter content proved to be highest in the natural loess-grassland, the reference site (8.71 %). Among the abandoned sites, the general humus content was the highest on Lapos mound (5.43%) and the lowest in Rév mound (2.70%). Generally the abandoned soils showed slightly higher median with wider standard deviation of organic matter but the difference between cultivated and abandoned sites is not significant, comparing with the reference site, where soil organic matter content is significantly higher (Fig. 3.).

Regarding the soil nitrogen content, the highest value can be measured in the soil of Rév mound (27.73 mg/kg), while the lowest was in Hegyes mound's soil (10.54 mg/kg). Average nitrogen content is the lowest in the Boda mound's loess-grassland (10 mg/kg) and the highest is in the soil of the still cultivated site of Boda mound (19.75 mg/kg). The results spread in very wide range considering the nitrogen content between still cultivated and abandoned areas at the same site. In case of Hegyes mound, the nitrogen content of abandoned field is slightly lower, than the still cultivated surrounding area; however this difference is not significant. In other cases, e.g. on Boda mound's average

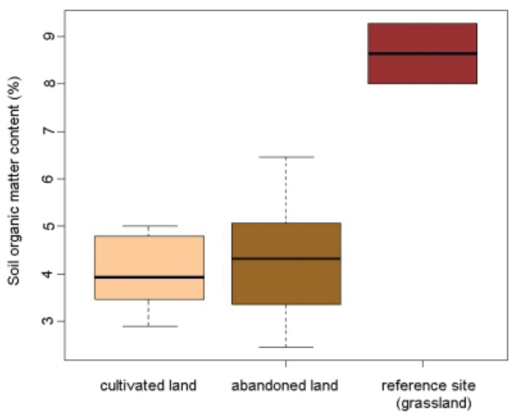

Fig. 3. Average soil organic matter content (%) on the cultivated, abandoned sites and the reference grasslands

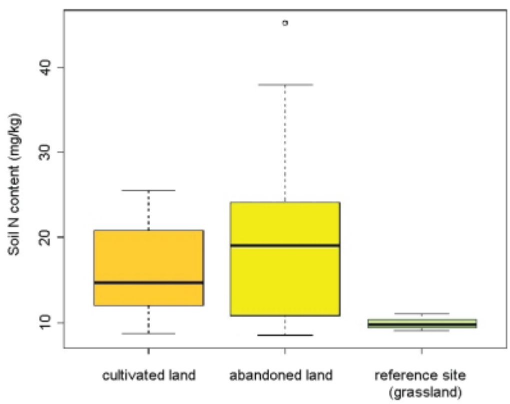

Fig. 4. Average nitrogen content (mg/kg) on cultivated, abandoned sites and the reference grasslands

nitrogen content is significantly lower on the abandoned places. Due to the very different nitrogen contents varying between sites, there is no significant difference between cultivated and abandoned samples, only the referential site showed significantly lower nitrogen content (Fig. 4.).

The phosphorous content of soil was the highest on the still cultivated sampling site of Boda mound (99.2 mg/kg). The lowest amount was measured in the soil of reference site's loess-grassland soil (29.89 mg/kg). On the analyzed abandoned places, the highest average content of phosphorous was on Boda mound (88.39 mg/kg). In the case of Lapos mound, it was the lowest (52.44 mg/kg). The variance among mounds was wider than in case of the nitrogen. On the abandoned sites of Hegyes mound, the average phosphorous content was higher than in the surrounding cultivated land. Due to the cultural layer (bones and other anthropogenic layers) that came to the surface as a result of ploughing and erosion, the phosphorous content is high on the surface of the mound. In case of Boda mound, the phosphorous content is lower in the abandoned sites than in the soil of still cultivated environment. The differences between the three types of sampling sites with their average phosphorous content can be seen on Fig. 5. Similarly to the nitrogen, no significant difference was found between still cultivated and abandoned mounds soils but reference site is significantly lower considering phosphorous content.

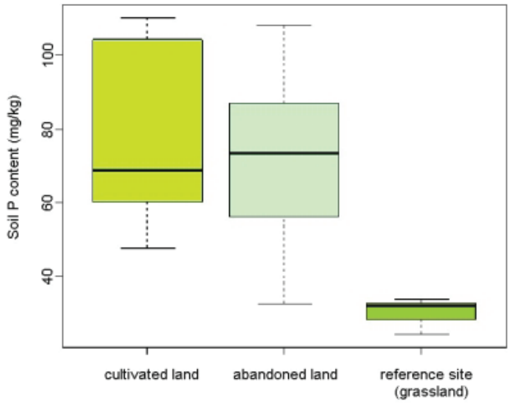

Fig. 5. Average phosphorus content on the arable land, on the uncultivated field and the natural lawn

Comparing the stability of aggregates (Table 4.) the lowest soil aggregate stability could be measured in the soils of Rév mound resulting the highest degree of soil aggregate deterioration. The soils of Lapos mound was found with the highest stability of cultivated and abandoned soils. The soils of the natural loess-grassland reference site around Boda mound have the best condition as the degree of degradation of soil aggregate stability is negligible. Comparing the abandoned site samples with the still cultivated ones, in case of Hegyes mound the abandoned soils stability proved to be better, than the cultivated ones. In case of Boda mound, the situation is reversed because the stability of the soil aggregates of plough land is in better condition

Table 4. Aggregate stability (means) of the sampled sites

Sampling site	Land use type	Aggregate stability by MSZ (10 min)		Aggregate stability by Sekera&Brunner (0.5 min)	
		Aggregate size (mm)			
		1-3	3-5	1-3	3-5
Hegyes mound	abandoned field	3.4	4.2	3.0	3.8
Boda mound	abandoned field	3.0	3.4	2.4	3.4
Rév mound	abandoned field	4.0	4.8	3.4	4.8
Hegyes mound	cultivated	3.4	3.8	2.8	3.8
Boda mound	cultivated	4.2	4.4	3.0	3.6
Boda mound	grassland	3.0	3.0	2.0	2.0
Lapos mound	grassland	3.2	4	2.0	3.0

than soils of the abandoned field.

In case of Hegyes mound, the result of Mann-Whitney test, was W=44 and p=0.6445. It means that the ranknumbers of the analyzed groups are close to each other. Therefore, the stability of aggregates in ploughed land and abandoned field does not differ significantly from each other. In case of Boda mound, the result is W=93 and the value of p=0.0005. It means that the ranknumbers of the examined groups are not close to each other. In this case the difference between water stability of aggregates in ploughed and abandoned sites is significant.

4. Discussion

Highest organic matter content was measured in the natural loess-grassland (8.71%). Comparing with soil organic matter content of ploughed and abandoned fields – which were long time cultivated as well – it can be said that actually the average organic matter content is in average less than half of the values from the native grassland.

The organic content of soils in abandoned fields has slightly higher variance than the values from still cultivated fields, but the means don not differ significantly. Obviously the 1-2 years after the abandonment was not enough for significant carbon accumulation in these soils.

Among the mounds, Lapos mound has the highest amount of average humus content (5.43%) because there was no agricultural cultivation thus humus content did not decrease as much as in ploughed land. The lowest average humus content can be seen in the soil of Rév mound (2.70%), which was several hundreds of years cultivated.

The lowest amount of nitrogen stock can be found in the natural loess-grassland (10 mg/kg), since it was not influenced by addition of any organic or artificial fertilizer. It is remarkable that the average nitrogen content is higher on ploughed lands but it differs from the degree of abandoned places just slightly. During the cultivation, the nutrient content was constantly resupplied but after abandonment the spontaneous regeneration of abandoned fields stops the further addition and utilization. Moreover, as these abandoned places are covered by closed vegetation, the permanent plant covering can prevent nitrogen forms from erosion. As a consequence of slow regeneration, the loess-grass species that like nutrient supply will be in a disadvantageous position in relation to weed. The succession can get stuck. Hegyes mound is in the best situation concerning the average nitrogen content (10.54 mg/kg). Despite the field was not cultivated, Lapos mound has an exceptionally high amount of average nitrogen content (26.40 mg/kg), which could be because of frequent grazing of sheep and the sheep's manure, since the sheepfold is located in the direct neighborhood of the mound.

The plant available phosphorous content is the lowest in natural loess-grassland (29.89 mg/kg). The average amount of phosphorous on certain type of territories can be related to the use of artificial fertilizer or to the abandonment of its usage, as it was the case with nitrogen. On the territory where the mounds were withdrawn from cultivation, the amount of phosphorous was generally lower because the supply was stopped. However, the abandoned field of Hegyes mound showed outstanding result. The phosphorous content was much higher (87.47 mg/kg) than on plough-land. On this field, probably early historic-archeological, anthropogenic soil layers were excavated by cultivation and erosion, which could be responsible for higher phosphorous contents. The high amount of phosphorous promotes the breakthrough and further spreading of several weed. Furthermore, it inhibits the process of the succession's later phases, until nutrient surplus in soils are occur. In this case, Lapos mound is in the best condition because the average phosphorous content is 52.44 mg/kg.

The soil aggregate's stability of the analyzed sites were given by two methods. The results are similar to the expected. The best soil aggregate stability is in the case of loess-grassland 3 (slightly deteriorated) and the stability of soil aggregates is perfect AS2 (highy). The highest stability of aggregates is observed in the soils under natural vegetation (Table 4.). As a consequence of regular ploughing and cultivation, the degree of stability becomes worse. Its lower limit is made by the stability of artificial aggregates. Our results show that the stability plough-lands have a lower degree (higher values) and the soil structure is deteriorated. The comparison of abandoned and cultivated sites was based on statistical test. The stability of the soil aggregates of abandoned and cultivated site in Hegyes mound does not differ significantly while the results of Boda mound show that the deterioration of the stability of the soils is not as strong as in case of the Rév mound.

Summarizing after 1-2 years of abandonment, there is no significant difference regarding the soil organic matter content, nitrogen and phosphorous stocks, and aggregate stability between the cultivated and abandoned sites. Compared with undisturbed native grassland sites, the mound's soils has less organic matter, higher nitrogen and phosphor content and less stable aggregates, which could be evaluated as a result of long time cultivation.

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