https://doi.org/10.34101/actaagrar/150/1741

Evaluation of mineral element content of beetroot during the different stages of the growing season

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Summary

In modern nutrition, bioactive materials of different vegetables are especially important to be researched. The experiment was carried out on March 30, 2016 (sowing date). Mineral element content (B, Ca, Cu, Fe, K, Mg, Na, P, S, Zn) was evaluated on the 60th, 85th and the 105th day of the vegetation period. The data are presented as the mean of five varieties which can give the real state of these parameters of beetroot grown on lowland chernozem soil.

In the young beetroot leaves (60 days) the mineral element content was higher than in the older ones (85 days). The calcium and magnesium content of the leaves was much more favourable (10 times higher) than in the root. The potassium content of leaves has reached the amount of 5000 mg kg^{-1}, but at the same time more than 3000 mg kg^{-1} was detected in the improved root. This value is favourable for the potassium supply of the human organism.

The sulphur content (1300 mg kg^{-1}) of the leaves was the highest on the 85th day of vegetation period. Similar tendency was detected for boron content (2.45 mg kg^{-1}), while for iron content it was higher (28.23 mg kg^{-1}) in the younger leaves (60 days).

Finally, it can be concluded that the increased element content of beetroot leaves will be a favourable source of mineral element supply of the human organism.

Keywords: beetroot leaf, beetroot root, mineral element content, spring time cultivation

Introduction

The beetroot (*Beta vulgaris* ssp. *esculenta* var. *rubra* L.) belongs to the *Chenopodiaceae* family. Its progenitor the wild form of *Beta vulgaris* L. var. *maritima* which is originated from the Mediterranean Sea region.

Varieties with short vegetation have small or middle leaf lengths which can promote the intensive root development. The size of foliage has connection with the possibility of mechanical harvest. Between the varieties there are important differences in the lengths of leaf petiole and its colour content. Small leaf varieties have thinner petiole and deep

purple colour, while the long leaf varieties have orange petiole with purple stripes.

Several researchers suppose connection between the petiole and root colour intensity. In our earlier experiment we have detected, that the short season varieties had smaller leaves and faster root improvement (Takácsné Hájos et al., 1999).

The beetroot has very good colour intensity, which is determined by the ratio of red *betacyanins* and yellow *betaxanthine* content. It is influenced by genetic (variety) and environmental (growing circumstance) factors as well (Takácsné Hájos, 1999).

This vegetable contains high amount of phenolic components, which can work as antioxidant and take part in prevention against tumour and cardio vascular disease (Yao et al., 2004). Its moderate and long-time consumption can prevent several diseases (Nyirády et al., 2010).

The carotenoids and ascorbic acid content of beetroot can increase the antioxidant capacity (Wootton-Beard and Ryan, 2011).

Compering with other vegetables, beetroot has rather high folic acid content in raw material and processed product as well. The daily folic acid need can be supplied by 200 g beetroot consumption. This favourable effect is connected with dark green leaves and higher *betanine* content.

According to Hoppner and his co-workers (1972), there are high differences between the varieties in this parameter (3.8-15.2 µg per g solids content). The folic acid or folate (vitamin B_9) has neuroprotective effect and favourable against heart attack and several tumour disease (Maison, 1994).

The oxalate content of table beet leaves is not too high and it can be eliminated by cooking or fermentation (Ninfali and Angelino, 2013).

The high nitrate content can be unfavourable; however, Presley et al. (2011) proved that till 1000 mg kg^{-1} nitrate content can cause favourable effect to decrease the progress of dementia. Furthermore, it plays an important role (with folic acid) in the protection against *Alzheimer* disease. Moreover, Bryan and Pierini (2013) stated that it can increase the efficiency among athletes as well.

The root of beetroot can store rather high amount mineral element. The core of the root has higher mineral element than the inner part, so the beetroot should be peeled thinly to avoid the loss of bioactive compounds (Takács-Hájos, 2011).

Researchers have found 336 mg per 100 g potassium content and 25 mg per 100 g magnesium content in the root on meadow silt soil (Takács-Hájos, 2009).

The insufficient mineral and trace element supply has a relationship with the development of several diseases. Beetroot has rather high macro and micro element content.

The physiological importance of ion ratio $(Ca^{2+}+Na^{+})/(Mg^{2+}+K^{2+})$ is optimal in the human organism when it is about 1.0. Experiments have proved that the Mg, Ca, Mn, Fe, Cu and Zn content of the lamina is multiple of the values measured in the petiole. The ion ratio was lower in the petiole in all varieties which were tested. According to this result the consumption of petiole has as much importance as the lamina in the fresh consumption (Takacs-Hajos et al., 2009). This seems to explain the reason why beetroot leaves were used for healing in ancient times.

The aim of the experiment was to evaluate the mineral element content during the vegetation period (60^{th}, 85^{th} and 105^{th} day), and to suggest the proper time of harvest in case of fresh consumption.

Material and methods

The experiment was carried out at the University of Debrecen, Farm and Regional Research Institute in its Botanical and Exhibition Garden. In order to have representative results about the species, five varieties were observed. The sowing date was 30 of March, 2016. The space between rows was 40 cm, the size of parcels were 5 m×0.8 m with 2–2 rows on it.

The genotypes were grown which are propagated by seed (clusters holding from 3 to 5 seeds). Therefore, it is necessary to thin the beets when they are young (2 to 4 leaves). Besides the thinning, weeding and plant protection was done during the growing period.

The daily temperature (*Figure 1*) range has reached the 20 °C at the beginning of the vegetation period. Because of the tolerance to cold, no damage was found in the development of beetroot.

According to data, in the second half of May the daily maximum temperature rarely was decreased to 25 °C which helped the synthesis of bioactive compounds.

During the vegetation, the natural precipitation was not uniformly distributed. In order to complete the water need of plants, drop irrigation was applied with 20–25 mm amount of water occasionally.

The experiment was performed on lowland chernozem soil type, which data is presented on *Table 1*. As the data shows, the plasticity, the mineral element content and the pH of the soil is good for growing beetroot.

The sampling was done 3 times during the vegetation (30 of May, 23 of June and 13 of July), which were at the stage of 60, 85 and 105 days of vegetation. For the sampling, 10 representative plants were chosen from each variety to have an average sample.

Figure 1. *Minimum and maximum temperature values during the vegetation period (Debrecen, 2016)*

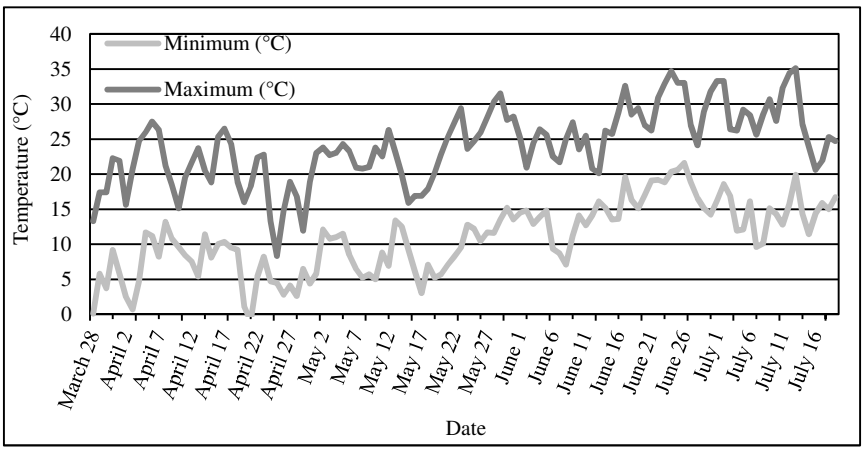


Table 1. *The soil analysis of experimental field (Debrecen, 2016)*

Analysed parameter (unit of measurement)	Amount
pH (KCL)	6.83
Plasticity index of Arany K_A	38
Total water soluble salt% (w/w)	0.04
$CaCO_3$% (w/w)	0.99
Humus% (w/w)	2.91
AL-soluble P_2O_5 (mg kg^{-1})	481
AL-soluble K_2O (mg kg^{-1})	309
KCL-soluble NO_3^- + NO_2^- - Nitrogen (mg kg^{-1})	2.16

Regarding to measurements, they were performed at the Agricultural Laboratory Centre, University of Debrecen and were the following:

Total dry matter content (%) by the standard of MSZ-08-1783-1:1983 chapter 2.

Mineral element content (mg kg^{-1}) – B, Ca, Cu, Fe, K, Mg, Na, P, S Zn with ICP-AES, the preparation of the samples was with cremation at 550 °C by the standard of MSZ-08-1783:1983

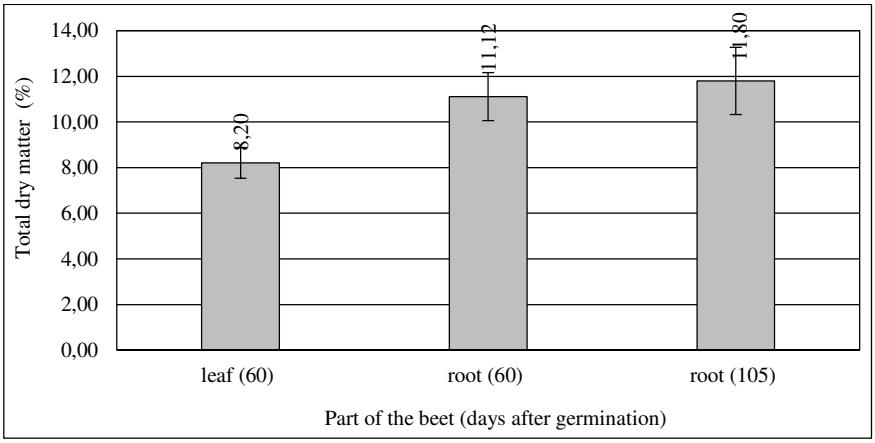
The main object of this work was to evaluate and to compare the bioactive compounds as dry matter content and total solids content of the beet in the root and in the leaf when they are consumable.

Results and discussion

Total dry matter content

One important quality parameters of vegetables is the total dry matter content. In the different part of the beetroot plant we have found great differences in it (*Figure 2*).

Figure 2. *Total dry matter content (%) of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*



In the leaves its content is about 8% comparing to the same improved root, where this amount is higher (11.12%). According to earlier experiment (Raczkó et al., 2015), this parameter was higher (16%) by the second crop production where the sowing time was at the end of June.

We can state that the root of spring time production was fresher and younger than the one which was harvested in October.

Mineral element content

The potassium has one of the highest amount in the vegetables. It was proved in the case of beetroot as well by the analysis of potassium content which was the highest at the age of 85 days of the leaves (*Figure 3*).

Lower amounts were measured in the root not only for the potassium, but for the sodium as well. Similar result was found by Csikkel-Szolnoki et al. (2002). Beetroot at the age of 60 days has soft and consumable leaves. In this stage the potassium content was more than 4000 mg kg^{-1}.

This is the main reason that the potassium intake of the human organism can be complemented with fresh beetroot leaves as component of green salad mixes. In the older leaves (85 days) the potassium content

is higher. However, the fiber content of leaf stalk is higher. The sodium content is rather low in the beetroot which is even less amount in the root.

More attention has to be paid for the regular supply of calcium and magnesium which importance is rather high in the human organism. For these elements 8–10 times higher amount was detected in the leaves than in the root (*Figure 4*).

Figure 3. *K and Na content of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*

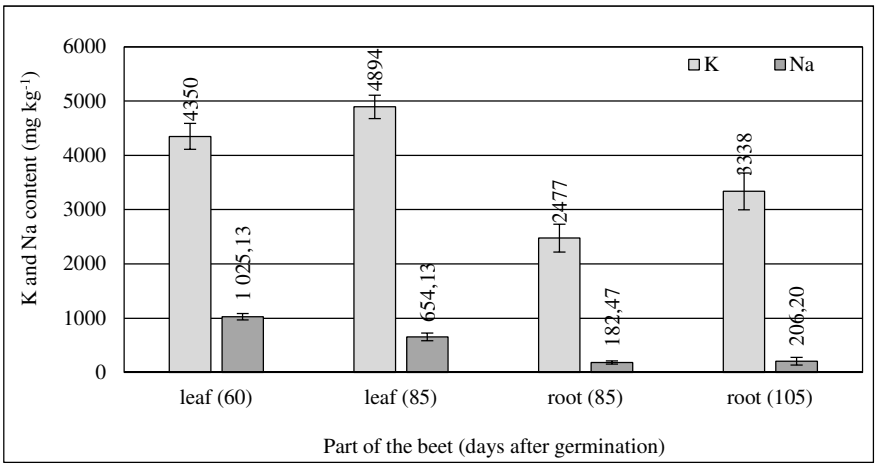
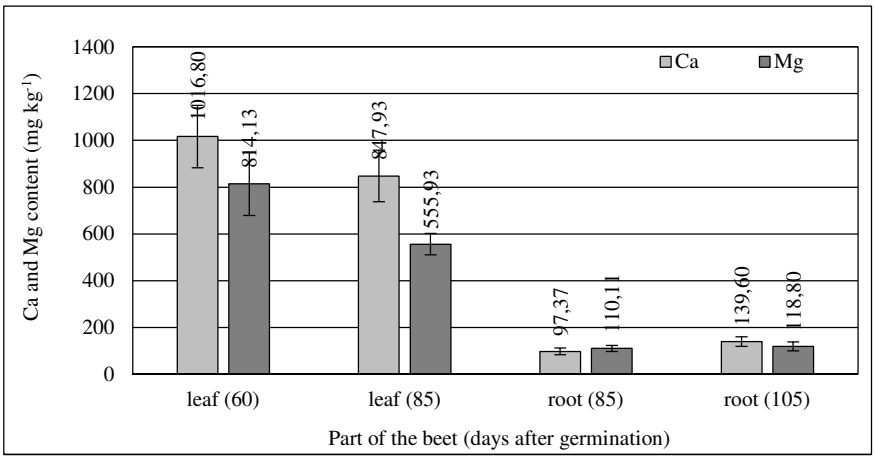


Figure 4. *Ca and Mg content of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*



The younger leaves (60 days) had higher calcium and magnesium content than the older ones (85 days).

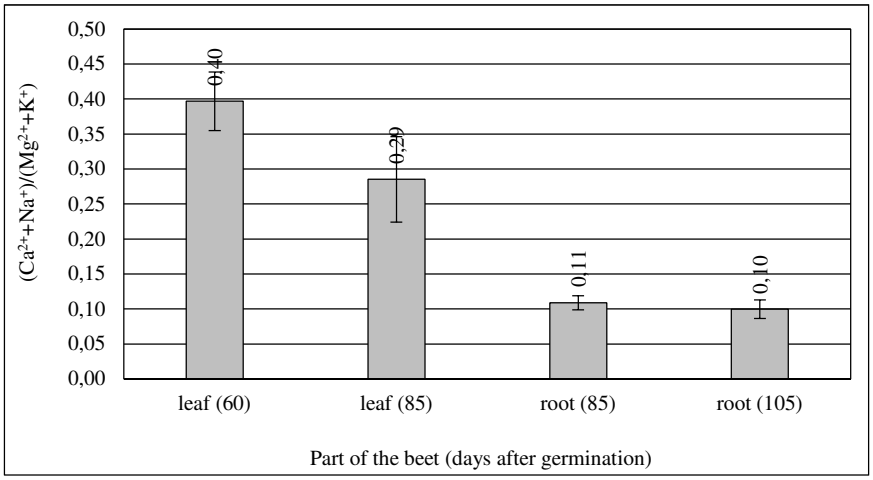
The evaluation of mineral element content is influenced by the soil element content and the growing method as well. Earlier experiments (Takácsné Hájos and Szőllősiné Varga, 2004) have proved that the beetroot can accumulate higher calcium and magnesium content (for Ca 1820 mg kg^{-1} and for Mg 1480 mg kg^{-1}) by second crop production on silty loam soil. This study has proved the negative effect on the calcium and magnesium accumulation by spring time sowing and drip irrigation.

The calcium, magnesium, potassium and sodium have great role in the ion ratio – $(Ca^{2+}+Na^{+})/(Mg^{2+}+K^{+})$ – in the human organism. The optimal value is 1.0, however, most of the cases it is between 2.0 and 2.5. Explanation can be found in higher sodium intake (salt consumption).

The vegetables, such as beetroot has an important role to have an optimal ion ratio in the human organism. This value as usual is lower than 1.0 in the vegetable species.

Similar tendency was detected in our experiment where the leaves and roots have very low ratio (*Figure 5*).

Figure 5. *$(Ca^{2+}+Na^{+})/(Mg^{2+}+K^{+})$ ion ratio of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*



Finally, we can summarize that the increased potassium, magnesium content and rather high calcium supply can ensure favourable nutrition physiological effect.

The sulphur is the 6th important element in the physiology which role lies in the synthesis of protein and several vitamins (as B_1 vitamin) and it

takes part in different redox systems. The highest sulphur content was detected in the leaves at the age of 85 days of vegetation period *(Figure 6).*

The same element content was rather low in the root. Significant differences were not found in the phosphorus content between the leaf and the root at the different growing stages.

Data of Cu, Fe and Zn content has shown on *Figure 7*.

Figure 6. *P and S content of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*

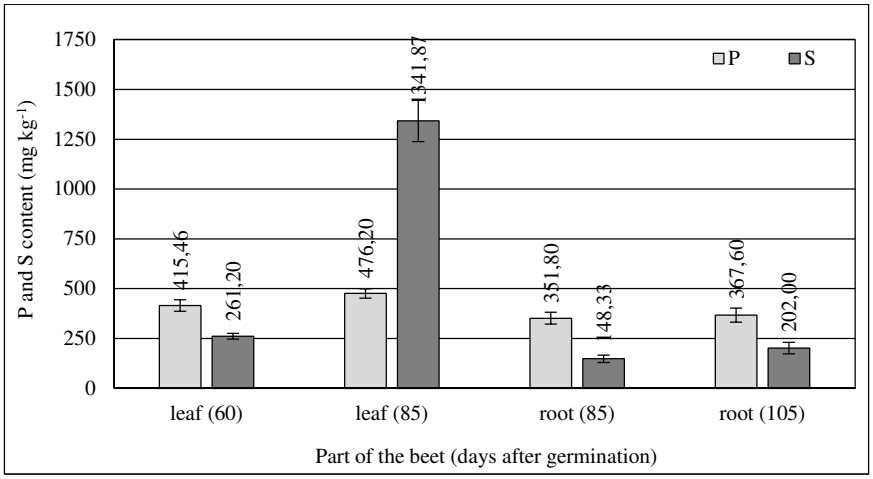
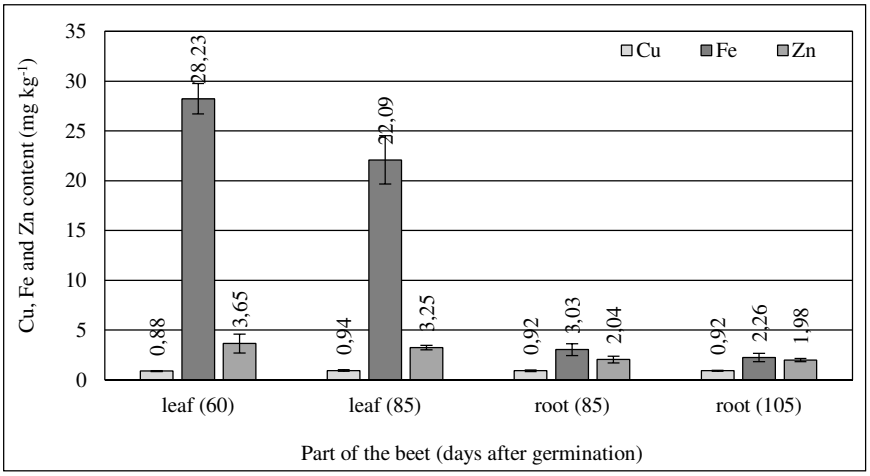


Figure 7. *Cu, Fe and Zn content of beetroot in leaf and in root at different growing stages (Debrecen, 2016)*



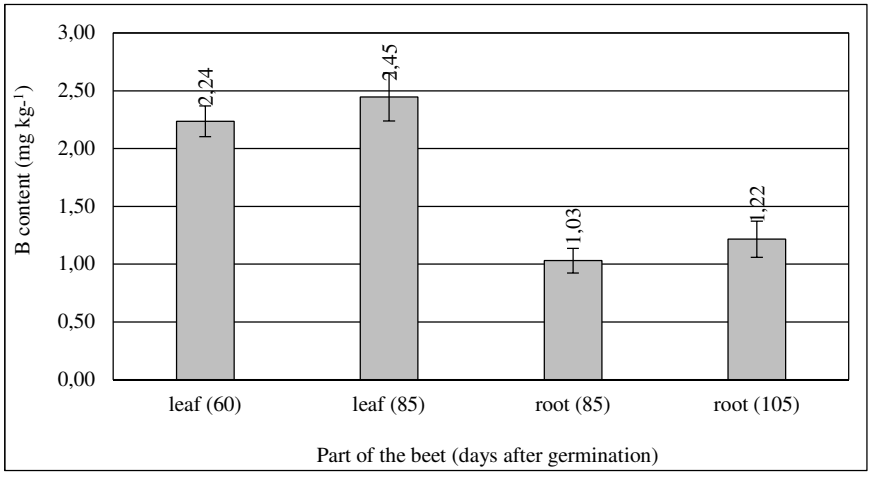
Among the evaluated elements the iron has exceeded with high concentration in the leaves. Besides, the 60 days old leaves have shown the highest amount (28.23 mg kg^{-1}) in the mean of varieties. The values of the iron content in the root was about one-tenth of the values measured in the leaves.

However, it is well known that in the human organism the iron absorption is much lower from the vegetables which can be explained with higher organic acid content.

The zinc has important role in the enzymatic activity, insulin synthesis and carbohydrate metabolism. In our experiment the zinc content was higher in the leaves than in the root. These data are in synchronous with earlier measurements (Csikkel-Szolnoki et al., 2002). The copper content was nearly similar in the different part of beetroot. The boron is an essential microelement which is important in the nutrition element uptake, transport of carbohydrate and other assimilate. This element is accumulated meanly in the vegetative parts of the plant.

Its content is higher in the dicotyledon plants than in the monocotyledon ones (Loch and Nosticzius, 2004). In the human physiology it has an important part in the vitamin D activation. Two times higher boron content was detected in the leaves than in the root in our experiment (*Figure 8*). The older plant parts (85 days old leaf and 105 days old root) showed higher boron content.

Figure 8. *B content of beetroot at the different stages of growing period (Debrecen, 2016)*



Conclusion

The experiment was carried out on lowland chernozem soil, with spring time sowing date (30 March of 2016). The data are presented in the mean of five varieties. The aim was to evaluate the mineral element content during the vegetation period (60th, 85th and 105th day) to determine the proper time of harvest when the bioactive compounds are available in high amounts for fresh consumption.

The measurements have proved that the 60 days old leaves have higher calcium and magnesium content than the older ones. The leaves have shown more favourable mineral element content compare to the root for nearly every parameter. The ion ratio was between 0.1 and 0.4 for the leaves and the roots which is recommended for human consumption. Among the microelements the iron was found in the highest amount (25–30 mg kg^{-1}) in the leaves (60 days).

Extremely high sulphur content was detected on the 85 days of the vegetation period in the leaves. The publication of boron content of beetroot is not satisfactory. The boron supply of the leaves (2.3–2.5 mg kg^{-1}) were nearly two times higher than in the root in our circumstances. The elder leaves (85 days) have shown the highest boron content.

Acknowledgments

This study was supported by the EFOP-3.6.3-VEKOP-16-2017-00008.

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Review of research on salt-affected soils in the Debrecen agricultural high educational institutions, with special focus on the mapping of Hortobágy

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Summary

The history of the research of Debrecen scholars on salt-affected soils of Hortobágy and the region is very rich and diverse.

Focusing on mapping, the following stages can be distinguished, indicating the completeness of the maps and the purpose of the performed work

- First, quantitative maps (Arany, 1926) for the utilization of the lands at 1:75,000 (*Figure 1*).
- Second, quantitative map (Kreybig, 1943) for the utilization of the lands at 1:25,000.
- Third, category map (Kreybig et al., 1935) testing the suitability of the classification system at 1:75,000.
- Fourth, partial category map (Szabolcs, 1954), showing the reasons of unsuccessful management at 1:10,000.
- Fifth, partial quantitative map (Csillag et al., 1996), showing the utility of digital sampling at 1:25,000.
- Sixth, partial quantitative map (Tamás and Lénárt, 2006), showing the capacity of multispectral remote imagery at 1:100.
- Seventh, partial quantitative map (Douaik et al., 2006), showing the usefulness of geostatistical mapping at 1:10,000.
- Eight, national quantitative maps (Pásztor et al., 2016), showing the applicability of geostatistics for administrative purposes at 1:10,000.
- Ninth, partial quantitative/category map (authors, 2019), finding the optimal methods at 1:10,000.

Keywords: salt-affected soils, solonetz, sodic soils, mapping, soil type

Introduction on soil mapping

The history of soil mapping (see Várallyay, 1989 on earlier developments in Hungary), with particular emphasis on salt-affected, soils is a history of competition between two paradigms, one of quantitative appraisal of

soil properties, mainly salinity and the other, of categorical delineation of patches of similar pedons. In short, mapping categories, such as soil types, orders, etc are abstract terms, which are difficult to elucidate in a few words for the uninitiated. Although quantitative maps deliver directly understandable message for the users, such maps are suited only for a limited number of soils, among which salt-affected soils are the most prominent, since their main features: salinity, sodicity and alkalinity are all easily quantifiable characteristics (Arany, 1956). During the history of soil science first categorical maps were compiled, but salt-affected soils were the first being spatially represented by quantitative maps. Later, due to technological advances, categorical maps lost ground, but still thrive parallel to quantitative maps.

History of the study of salt-affected soils in Debrecen

The history of research and management of salt-affected soils was well documented during the history of high agricultural education in Debrecen, partly covered by the review of Blaskó (2012). Research on salt-affected soils in Hungary was always active, but after the Versailles peace treaty, following the First World War it became more concentrated on the remaining national territories, since large areas of the old country, among the newly defined borders were salt-affected. Such research lasted until the nineteen-eighties and then slowed down to the current pace.

During the last 63 years in the Debrecen agricultural academy/ college/university and the closely collaborating institutions (Debrecen University of Sciences, Hortobágy National Park, Soil Reclamation Station, etc.), several professors of the Soil science and other departments of the agricultural institution graduated as chemists in the Debrecen University of Sciences (under several names) and technical collaboration was easy to organize.

Often the professors and docents of the agricultural academy/ college/university carried out precious research. The main activity of Sándor Arany, one of the leading scientists of salt-affected soil research was multifold ranging from mapping to laboratory analysis and reclamation (e. g. Arany, 1926, 1934; Arany and Babarczy, 1937).

Scientific debate was frequent in those days and two cases deserve special attention. Professor Ferenc Szelényi installed a field reclamation experiment in Hortobágy with multiple deep plowing of sodic soils under standing water (Szelényi, 1956, 1957), thereby intending the washing away of salts, but his research received rather critical reviews (Károly Páter and others). Another special event for the domestic specialists of salt-affected soils of those times (and that time there were many!) was the paper of the invited Austrian soil scientist (zoologist), Herbert Franz on the formation of the solonetz soils of Hortobágy (Franz,

1964), using the concept of Székyné et al. (1959) among others. Two hotshots of the Hungarian school, Katalin Darab, (1967) and György Várallyay (1967), analyzed his ideas very critically.

Later György Filep (Filep, 1999ab, 2001; Filep and Wafi, 1992, 1993; Filep and Rédly, 1992), an eminent researcher and professor was working on the details of chemistry of salt-affected soils.

During the nineteen-seventies "complex amelioration", that is drainage of salt-affected fields prone to waterlogging, combined with reclamation was the most typical costly investment in the affected areas, recruiting researchers from several university departments, such as Gusztáv Sziki (1961). Grazing studies were always evident in the grassland (e. g. Milkovich and Bánszky, 1962). József Fekete (1968) studied the salt and water cycle of related slightly salt-affected soils. Lajos Ábrahám (1957) worked on the effect water bodies on the salt-affected soils among other topics.

The foundation of the Hortobágy National Park provided new opportunity for the study of the vegetation and soils of salt-affected grasslands, and in this work the researchers of Debrecen University of Sciences had greater role, Júlia Varga (1984, 1986) carried out botanical studies, Lajos Varga (1960) and András Szabó (1996) studied microfauna in the national park.

In recent years Lajos Blaskó, János Tamás and co-workers carried out important research on salt-affected soils (Blaskó et al., 2003, 2006ab; Tamás et al., 2014). These are closely related to the long research activity of the Karcag Research Institute, which is not covered by this short review. We must also skip the long recent activity of the Research Station of Afforestation of Salt-affected lands at Püspökladány (e. g. Leszták and Szabolcs, 1959; Jassó, 1962; Tóth, 1972) due to lack of available space in this journal.

The fellow scientists and alumni in other faculties of the now united Debrecen University continue research in the Hortobágy on geomorphology, vegetation, erosion, tumuli, such as Albert Tóth and Csaba Tóth, Tibor Novák (Tóth 1988, 1997, 2001; Kovács and Tóth, 1988; Novák et al., 2016), but also the Gödöllő based Attila Barczi (Joó et al., 2003) attract students in large numbers. Pál Sümegi with his interest in the reconstruction of ancient landscapes also contributed to soil knowledge in the region (Bede et al., 2015). Albert Tóth directs a summer camp in the Hortobágy for students with a soil research section (e.g. Tóth, 1996 among many volumes) every year already for 44 years.

History of the mapping of soils in Hortobágy

Regarding the mapping of such soils a special condition for that was, that the City of Debrecen was the historic owner of large parts of the

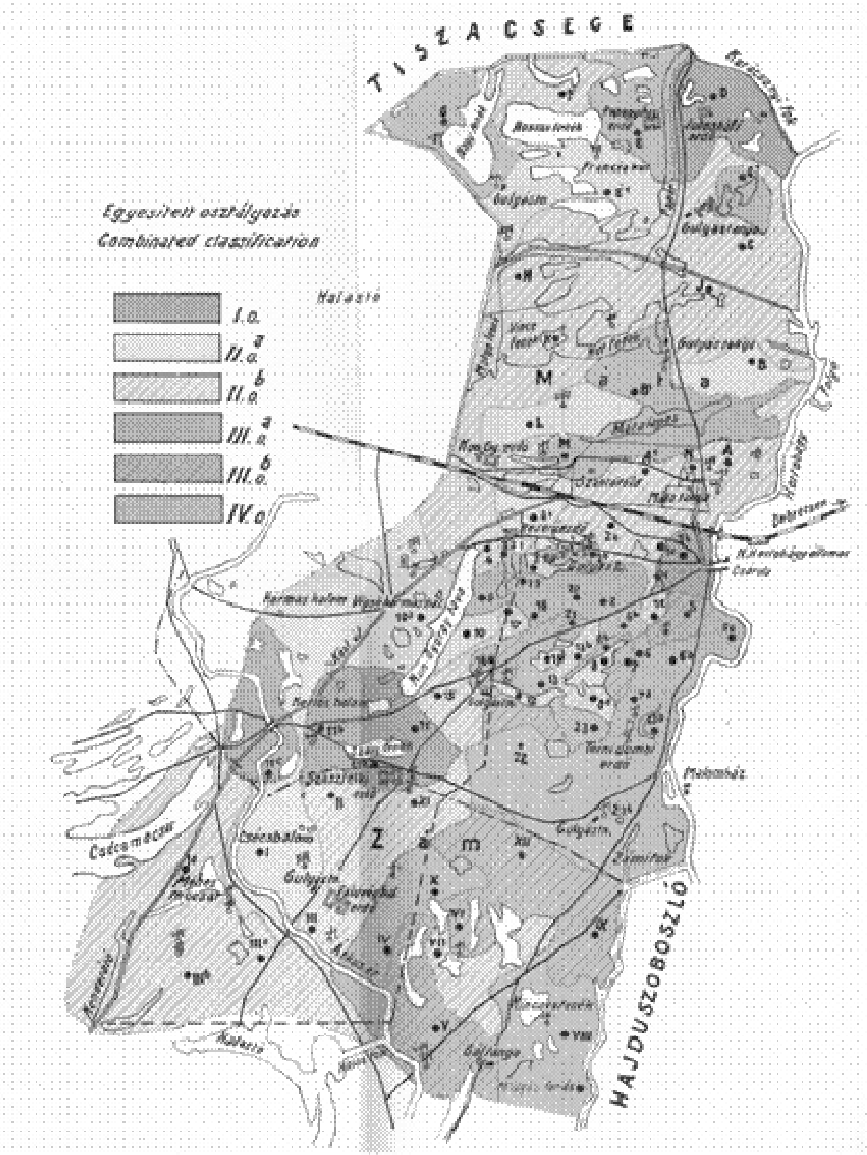
Hortobágy Puszta, a mainly treeless mosaic of salt-affected dry grasslands, sparse croplands, meadows and marhes. When the first method of medium-scale mapping (1:75,000) of salt-affected soils was developed, Pál Magyar, a forester, sharing the concepts of the botanists Raymund Rapaics (1927) and Rezső Soó (1934), worked together with the chemist Sándor Arany. On large part of Hortobágy P. Magyar (1928) compiled a vegetation map, whereas S. Arany (1926) a soil map. P. Magyar later established the Research Station of Afforestation of Salt-affected lands on 1 October 1924. The soil salinity and alkalinity classes distinguished by them were defined by *Table 1*, showing the classification of Alexis De Sigmond (1927). It was based on the properties of soil samples taken from 0–30 cm and 30–120 cm depths (*Table 1*). De Sigmond defined his scheme as a "practical botanical classification". This is a typical artificial classification system based on the ranges of total salt concentration and soda (Na_2CO_3), being dominant components of the Hungarian sodic soils, which are so much widespread in Hortobágy. This quantitative soil classification system was, and is still actively used by botanists and foresters. Since the appearance of this classification in Hungary, the lower threshold of a soil, qualified as "true salt-affected soil" is 0.1% salt content. The threshold value for a saline soil, Solonchak, in the genetic classification is 0.25% salt content in the topsoil. The system shows similarities to the practical classification of salt-affected soils of Hayward and Wadleigh (1949).

Table 1. *Classification of salt-affected soils by De Sigmond (1927)*

A) Based on one characteristic only		
Class	Salt % (salt)	Soda % (soda)
Class I	<0.1	0. –0.05
Class II	0.1–0.25	0.05–0.1
Class III	0.25–0.5	0.1–0.2
Class IV	>0.5	>0.2
B) Based on the combination of the two Classes of Class_salt and Class_soda		
I = Isalt/Isoda IIa= IIsalt/Isoda or Isalt/IIsoda, IIb=IIsalt/IIsoda or IIIsalt/Isoda IIIa=IIIsalt/IIIsoda or IIsalt/IIIsoda, IIIb=IIIsalt/IIIsoda or IVsalt/IIsoda IVa=IVsalt/IIIsoda or IIIsalt/IVsoda, IVb=IVsalt/IVsoda		

The patches delineated by the two researches showed great coincidence and represented one of the first quantitative soil maps, directly showing the salt or soda concentration of the soil (see Table 7 in Tóth and Várallyay, 2002). On the other hand the vegetation map remained category map.

Figure 1. *Map of the area of Hortobágy which was owned by the city of Debrecen showing the combined salinity/soda content (see Table 1B) according to the categories defined by De Sigmond (1927) as published by Arany (1926)*



The second large mapping in the area, the national soil mapping project initiated and led by Lajos Kreybig was unique for being a national survey based on field and laboratory soil analyses and at the same time serving practical purposes (Kreybig, 1937). It was carried out between

1935 and 1951 in several stages. These maps still represent a valuable treasure of soil information. The soil and land use conditions were presented together on the map sheets. Chemical (soil calcareousness/ alkalinity/acidity on a continuous grade) and physical soil properties (texture classes) of the soil root zone were identified inside croplands and grasslands/meadows, but not in forests. This map series did not introduce mapping categories and used quantitative classes of soil chemical and physical characteristics, being a typical quantitative map serving clearly practical purposes.

By that time Alexis De Sigmond, the greatest person of the Hungarian salt-affected researches, compiled a new theoretically based universal soil classification system, covering also the salt-affected soils and this system was put on map in the Hortobágy, creating the only map of his unique soil classification (Kreybig et al., 1935). The types of his soil map, together with the current equivalent categories are shown in *Table 2*.

Table 2. *Salt-affected soil types in the "Soil order 12. Sodium soils" of De Sigmond (1938)*

Main types	Interpretive name based on the Russian names
1: Saline soils	Solonchak
2: Saline alkali soils	Solonchak-Solonetz
3: Leached alkali soils	Solonetz
4: Degraded alkali soils	Solod
5: Regraded alkali soils	Soil salinized again

After the Second World War the new paradigm was the "genetical soil mapping" based on the Russian school, following the Dokuchaev principles. A system was elaborated by Hungarian soil scientists, soil surveyors and soil-mapping specialists for large-scale soil survey, to satisfy the practical needs of soil information for large farming units (state and co-operative farms), which characterized the Hungarian agriculture between 1950 and 1990. Such maps were prepared for about one-thirds of the area of Hungary (about 35,000 km^2). The system consists of four main parts: (i) genetic soil map, indicating categorical genetic soil taxonomy (type, subtype) units and parent material; (ii) thematic soil maps of the most important physical and chemical soil properties; (iii) thematic maps, indicating recommendations for rational land use, cropping pattern, soil improvement, tillage practice and fertilization; (iv) explanatory booklets, including a short review on the physiographical conditions; description of soils, recommendations for their rational utilization, field description of soil profiles and results of field observations or measurements and data of laboratory analyses (Sarkadi et al., 1964; Szabolcs, 1966). One of the first such published maps showed

a part of Hortobágy by István Szabolcs (1954), an alumnus of the Debrecen University, who later became world class scientist of salt-affected soils. The mapping followed a failed irrigation project of the grasslands and showed the high sodicity of the areas. The mapping categories of Hortobágy were discussed by Szabolcs and Máté (1955).

During the last decade of the last century the novel methods of satellite remote sensing, geographical information system, geostatistics, spatial sampling and digital image processing provided new opportunities as foreseen already by Várallyay (1989) in his review. A team of researchers from the Budapest Soil Institute of the Hungarian Academy of Sciences (under several names) performed several sampling and mapping experiments in Hortobágy with the participation of several authors of this report. First the correlation between relief, soil and vegetation was analysed under the leadership of Kálmán Rajkai (Rajkai et al., 1986; Oertli and Rajkai, 1988ab; Tóth and Rajkai, 1994; Tóth and Kertész, 2002), then a medium-scaled map of vegetation and soil properties was compiled based on a sophisticated sampling design, derived from a satellite image (Csillag et al., 1996; Tóth and Kertész, 1996).

The modern techniques of multispectral mapping were applied by the Debrecen Agricultural University staff. János Tamás and Csaba Lénárt, (2006) and Pechmann et al. (2003) tested multispectral mapping northeast from the contiguous Hortobágy area.

Another approach was carried out in the eastern part of Hortobágy, where several papers focussed on soil variability (Tóth and Kuti, 1999ab; Tóth et al., 2001; Tóth and Jozefaciuk, 2002). Douaik et al. (2007) analysed the spatio-temporal variability of surface soil salinity at 400 points, measured 19 times with instrumental technique for the assessment of topsoil salinity.

In recent years Szabó et al. (1999) and Pásztor et al. (2016) created country-wide maps of several characteristics, most importantly of soil salinity and sodicity. The reason for this map series is that inside the European Union a new delineation of Areas with Natural Constraints was performed based on a set of unified biophysical criteria. Farmers will receive financial compensation when their land is affected by such constraint, salinity and sodicity. The method for delineating such areas is strict (Terres et al., 2016) and has such threshold values for each criterion which were never used before. Therefore new maps of salinity and sodicity, with one hectare accuracy, were compiled with digital techniques for this purpose, evidently covering our area of interest.

Authors of this report are currently working on a project that intends to find the best mapping technique of salt-affected soils, thereby combining the best experience of the above predecessor researchers. The

project will be carried out inside the Hortobágy grasslands/meadows as the most typical salt-affected area of the country. The concepts and approaches used by the above researchers will be tested. Again the category and quantitative maps will be compared. During the research five alternative survey strategies (A-E) are tested.

Survey Strategy A, traditional profile-based survey as performed by Szabolcs (1954), complemented with proxy survey. In this survey profile locations will be allocated based on *digital terrain model (DTM) (α) and vegetation map (β) weighted by spatial extension*, then 2nd (already collected) profile data will be *extended by Electromagnetic induction transects* covering each rastercell, 3rd spatial interpolation will be used to predict each variable in the all rastercells.

Survey Strategy B is survey based on biomass. In this survey 1st with the combination of *biomass map* (estimated by an indicator such as Normalized Difference Vegetation Index [ε]) by DTM (α) 4–6 large sampling strata will be distinguished for selecting the profile locations, and 2nd based on (already collected) profile data spatial interpolation (with the proxies of biomass and DTM) will be used to predict each variable in all rastercells.

Survey Strategy C is based on theoretical salinization model. 1st using national *watertable level and salinity maps* (γ) *combined by DTM* ((α) salinization maps will be prepared, 2nd from which 4–6 large sampling strata will be distinguished for selecting the profile locations and 3rd spatial interpolation (with the two proxies) will be used to predict each variable in the all rastercells.

Two Land use-specific survey strategies (D and E) will be realized depending on the typical land uses.

Survey Strategy D will be followed in arable lands *via calculation of salinity index*. 1st *0–10 cm soil sampling*, 2nd *multicopter hyperspectral survey* (δ) *of bare surface*, 3rd *spectral and chemical (Electrical Conductivity as proxy of salinity, Sodium Adsorption Ratio, pH*) analysis of surface samples, 4th *calculation of salinity index*, 5th *matching of field and laboratory spectra, 6th calculation of salinity index for the field hyperspectral values*, 7th selection of profile locations based on extremes and spatial distribution of salinity index values, 8th direct surface salinity prediction based on salinity index, 9th interpolation of profile data to predict each variable in all rastercells.

Survey Strategy E is developed for salt meadows and steppes and is *based on the distribution of vegetation categories*. 1st based on the combination of 3–4 strata of DTM (α) and 3–4 strata of vegetation category map (β) 4–6 survey strata will be selected to assign the profile locations, 2nd spatial interpolation using DTM and vegetation classes will be used to predict each variable in all rastercells.

The preliminary results show promising results. *Figure 2* shows the result of applying the salinity index (mentioned in Survey Strategy D) in a sodic pan (Szappanszék). The UAV-based image capturing system consists of a Cubert UHD-185 hyperspectral snapshot camera (http://cubert-gmbh.com/uhd-185-firefly/), a Compulab Fitlet mini PC (http://www.fit-pc.com) and a CarbonCore octocopter UAV. The Cubert camera simultaneously records 125 bands in a spectral range of 450–950 nm with a sampling interval of 4 nm. *Figure 3* shows the clear border of very saline patch indicated by red colour.

As a proxy of clay content a novel method of using gamma dosimetry was applied in an experimental transect covering 70 m transition from an interdune valley to the sand dune using InSpector™ 1000 dosimeter. Fig 3 proves the possibility of using a simple device to infer on the clayiness of surface soil. The method can be useful to interpolate clayiness in Survey Strategy A.

The initial testing exercises show promising results and the project participants look forward to a new wave of modern mapping activity to satisfy the data need of farmers, domestic and EU administrators, scientist as well. This is the motivation for our team.

Figure 2. *Map of Salinity Index of a ca 2.5 ha sodic pan as defined by the combination of reflectance values as √(436 nm*630 nm) of hyperspectral camera carried by UMV, according to the equation of Kumar et al. (2015)*

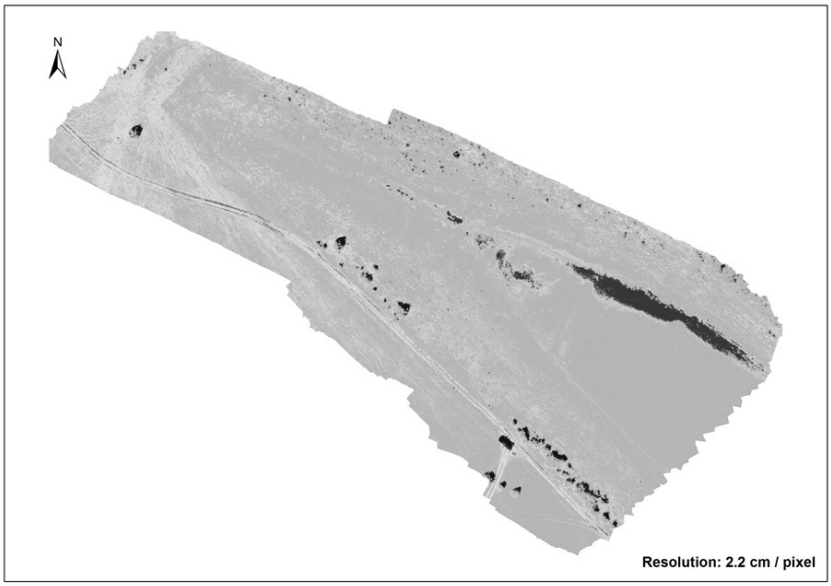
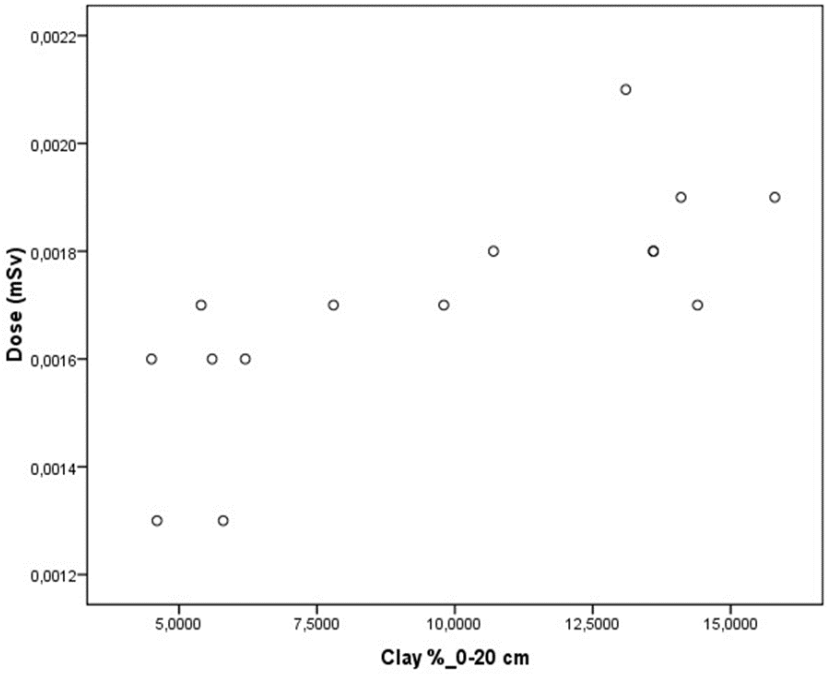


Figure 3. *Scatterplot of in situ surface gamma dose during 3 minutes measurement time (Y axis) versus laboratory determined clay percent of the surface soil layer (X axis) in a sand dune – interdune valley transect.*



Acknowledgment

This short review cannot be full and authors apologize for any shortcomings and mistakes. Authors appreciate the support of the OTKA grant K-124290 for the described research project.

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New and innovative consumer demands and expectations on the Hungarian food market

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Summary

Food and eating have always encompassed more than the simple intake of nutrients; therefore, when thinking about food consumption, we need to examine several groups of influencing factors whose correlations from the aspect of the consumer are described by a complicated matrix. This paper focuses on the selection of signs indicating new and innovative consumer behaviours, and on the megatrends that are the driving forces of transitions and that lead to the consequences of strikingly reconsidered consumer decisions nowadays. The authors stress that there are qualitative and structural changes in food consumption in Hungary, with an increasing quantity of differentiated consumer demands appearing, a few of them influencing our everyday decisions even at the concept level. The findings of primary research originated from a personal questionnaire survey consisting of 2001 respondents, in which we also focused on the attitude towards eating and media consumption related to gastronomy.

This paper is an introduction to the market segments detectable in the present Hungarian population aged 15–74 in the topics concerned.

Keywords: food consumption behaviour, food consumption trends, gastro-media consumption

Introduction

The study of food and eating is an issue during the analysis of any segment of which we find several imprints of the lives of the people living in the respective time. Foods have an outstanding significance, in addition to experiencing everyday routine, in the appearance of the well-being, of satisfaction. If we focus on the nutrition behaviour and the shopping decisions of a group, we can see their position in society, their values, the relationships that they have towards each other, the frameworks determining their decisions, their lifestyle and the contents and emotions communicated with foods (Karmasin, 2001). The consumption of foods also has a huge impact on the economy, just think of the fact that the second largest proportion of the expenditure of households is in this area, with an average value of 24.1% in 2016 in

Hungary, measured by the Hungarian Central Statistical Office, HCSO (HCSO, 2017).

Decision-makers of the economy are understandably also interested in the tendencies that can be seen in consumers' decisions and in what will be competitive products and technologies in the future (Lehota, 2004; Szakály, 2017). This outlook is especially exciting when we are witnessing a paradigm shift in several fields of the economy, coming from the changes in the consumer behaviour; previous decision-making patterns transform and force producers/service providers and dealers to adapt to the new phenomena (Törőcsik, 2016).

In our paper, aware of the importance of the issue and keeping the complexity of its concept of approach, we focus on the emphasis of signs indicating new and innovative consumer behaviours. We concentrate on those megatrends that are the driving forces of transitions and that lead to the consequences of strikingly reconsidered consumer decisions nowadays (Hauser et al., 2015; Rützlers, 2018). We conflict elements of the expected processes with the facts and statistics, and with the relevant findings of our related representative primary research.

Accordingly, we examine current consumption data, the major trends influencing the food market, how important eating is for the Hungarian population, what main gastro-channels they use to get information and communication, and what attitudes the respective consumers' segments show.

Material and methods

Food and eating have always been more than simple intake of nutrients, it is not accidentally the object of the interest of academics from different areas (Forgács, 2004), but during its examination we must not forget about its basic function of satisfying biological needs. Evidently, as long as our physiological needs are not satisfied, we are unable to think of food culture and the aesthetics of foods, the sophisticated ingredients and the variations of the experience offered by eating (Pich, 2014). Food phenomena are not only analysed from the aspect of consumer behaviour (Törőcsik and Pál, 2014); academics of other disciplines look at e.g. the environmental impacts of food consumption (Kerekes and Csutora, 2012; Notarnicola et al., 2017; Wunderlich et al., 2018), but researches related to disgust have also been made (see e.g. Egolf et al., 2018). The topic of gastronomy has also caught a growing media attention, and in public conversations it is a reliable and neutral issue suitable for creating a contact with everyone (Balázs et al., 2012), which is interpreted by Kapitány and Kapitány (2013) as a new phenomenon of the new millennium. Recently, cooking at home has been appreciated, which is

also supported by the media, as it is promoted not only by academic researchers but also by celebrities and opinion leaders. The growing popularity of cooking at home is closely related to healthy nutrition (Smith Taillie, 2018). Of course, another side of the issue has also been growing in popularity: foods ordered to our homes, street food and the consumption of convenience foods.

When talking about our thinking of food, several groups of influencing factors must be examined, whose correlations from the aspect of the consumer are described by a complicated matrix. Eating is influenced by *ingredients* (access, supply, transport etc.), *possibilities* offered by *technology* (deep freezing, simmering, baking etc.), the *knowledge* possessed by a community (family tuition, books, shows, courses etc.), and also the *lifestyle* of a group that is also typical of the individuals, due to their membership in the group. These broad categories shape eating culture that can be examined at the level of groups and individuals, completing all this with the related emotions.

Taking different indicators into consideration allows us to find several variations, evoking useful or only interesting behaviours in this huge market.

Food consumption data

Looking at data series of longer periods of food consumption reveals that both quantitative and structural changes are taking place simultaneously in Hungary *(Table 1)*, the saturation of the consumption of cereals and carbohydrates is finished, while the consumption of vegetables and foods is still increasing (Vetőné, 2014).

The examination of the consumption data of Hungarian households over the last ten years, using the data published by the HCSO, reveals a rather mixed picture. Let us focus on the data relevant for us from the 2017 HCSO data on the expenditure of the households and their living conditions, reflecting the findings of the consumption of 7485 households questioned (HCSO, 2017). *Figure 1* demonstrates a considerable restructuring from 2010 to 2016, and within this the proportion of expenditure on foods increased from 22.8% to 24.1%.

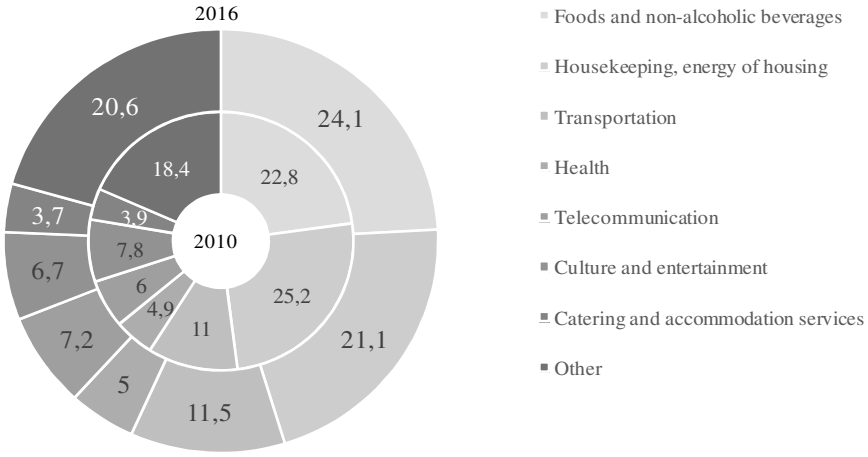
For the interpretation of the data we must remember that the consumption of households significantly decreased in quantity as an effect of the crisis starting in 2008, the effects of which were still palpable in the early 2010s, i.e. consumption was stagnating until 2012 and started to grow afterwards. In addition to the quantitative changes we could also see changes in the composition of the consumption.

Table 1: *A comparison of European and Hungarian trends (1990–2007)*

	Europe		Hungary	
Consumption category	Quantitative change (kg person^{-1} year^{-1})	Proportion from total of food consumption (%)	Quantitative change (kg person $^{-1}$ year^{-1})	Proportion from total of food consumption (%)
Cereals	138 kg → 131 kg decreasing	19.3% → 17.6% decreasing	110 kg → 88 kg decreasing	16% → 13% decreasing
Meat	81 kg on the average, but the tendency is increase	11%, no change/increasing	73 kg → 63 kg decreasing	9% – 11%, no change
Dairy products	210 kg → 221 kg, increasing	29%, no change	169 kg → 163 kg decreasing	25%, no change
Fat	28.5 kg, no change	3.8%, no change	38.6 kg → 37.4 kg decreasing	6%, no change
Fruits	73 kg → 93 kg, increasing	10.2% → 12.4%, increasing	155 kg → 194 kg, increasing	23% → 31%, increasing
Vegetables	107 kg → 117 kg increasing	15% → 15,6% increasing		
Proportion of import products in consumption	meat +120% cereals +83% vegetables +174%	increasing	increasing	7–10% → 30%, increasing

Source: by Vetőné (2014) using FAOStat Database (2012) and HCSO (2012)

Figure 1: *Breakdown of the expenses of households, 2010–2016*



Note: edited by the authors, Source: HCSO (2017)

"*The amount of the consumption of certain foods by the households is decreasing, which also reflects the qualitative change in the consumption habits. From 2010 to 2016 for example the quantity of bread consumed in a household decreased by 7.5 kilograms, but the purchase of crescents, rolls and other bakery products grew by 4.7 kilograms. Similarly, during the period examined the population consumed less animal fat (by 1.8 kilograms), but the consumption of vegetable oil and olive oil grew by 1 litre. In 2016, the costs of eating outside the household were HUF 34.5 thousand per person, half of this was meals in the workplace, school and kindergarten; the other half was meals in catering industry facilities and the consumption of beverages. The amounts paid in catering facilities have tripled since the start of the new millennium, and have grown to one and half since 2010. The most dynamic growth could be seen in the amount of per person expenditure on foods delivered home.*" (HCSO, 2017) Naturally, the respective groups show different consumption patterns within these general data (Bakucs et al., 2017).

These processes have brought about a critical situation for the market actors in production and sales, and not all of them have been able to successfully adapt to the changes. In comparison to the changes caused by the crisis, the recent changes in the demand seem less drastic, but they are still a continuous challenge, not last due to the pressure by the consumers who come up with ever mode diverse, always new demands.

Trend impacts in the food market

It is an evident decision then to also involve the *trend connections* of food/eating in our examinations, as the knowledge of these bears the chance of market success as well as it promotes the understanding of the decisions of consumers. In order to make right decisions we have to understand the operation of recent *megatrends* (Bosshart and Frick, 2003; Horx, 2015). We can state that within the megatrends, trends promote *acceleration/speeding up*, technological changes and rationality, a certain concentration of which is already hard to tolerate for people, and so after a while they are seeking the chance of *slowing (themselves) down*, showing a preference for the solutions of the counter-trend. Slowing down (the world and ourselves) contains emotional elements, even with some possible romantic touch, some affection for idyllic, human-scale "former life", but its recent manifestation is already adapted to the new frameworks. The dynamism of megatrends is given by the movements of trends and counter-trends, and they also give thrill and ever new business opportunities with the new combinations. The harmony of the two directions leads to stability; this may secure balance in societies (Hauser, 2016). As the frameworks of this study do not allow the detailed discussion of the respective megatrends that we have identified (for more

information see Törőcsik and Csapó, 2018), only references are made to them.

The issue of food is comprehensible in the cross-section of any megatrend; it is visible in everyday life, in cutting edge industrial practice that foods show up in the interconnections of different megatrends, especially in the field of health, body, ethical considerations, digitalisation, eco-paradigm and transparency (Törőcsik, 2014). In our examination a new feature to be highlighted is that in food industry and food trade, actions related both to trends (innovations with ICT technologies, convenience) and counter-trends (sustainability, sharing) can lead to successful solutions. We can see a growing popularity of bio-, vegetarian and vegan products, ones that can be consumed by people with food intolerance, and of fair trade products. We can also see a growing expectation by sustainability and transparency, impulses basically coming from the direction of slowing down. Functional foods are becoming important, as are digital developments related to eating, food porno is spreading fast, and all these promote acceleration. Of course only a smaller proportion of the population reacts to the total of the trend effects with modified shopping habits, but the new trends are more and more palpably filtering into the decisions made by the majority of consumers. This (among other things) makes it important to see what is typical of the Hungarian consumers, how much these phenomena are present in their everyday lives.

Research method

The basis of the primary research of our examination was a *personal questionnaire survey including 2001 persons*, conducted in April and May 2018 in order to analyse the behaviour and the opinion of the Hungarian population, among other things, as regards their eating habits. The questionnaire was representative of the Hungarian population aged 15–74 by gender, age groups (10-year intervals) and the region of the place of residence. The processing of the results took place with mathematical-statistical methodology, and also using the SPSS software for analysing data. During the processing of the findings we also made demographic background examinations, the findings of these are used to demonstrate the statistically justifiable deviations. The variables included in the analyses were as follows: gender, generations, health condition, level of schooling, subjective evaluation of the income positions, settlement category of the place of residence, and economic activity.

The project allowing the primary research is implemented with the support of the European Union, in co-financing of the European Social Fund, see EFOP-3.6.1-16-2016-00004 project called "*Comprehensive*

developments at the University of Pécs for the implementation of intelligent specialisation".

Results and discussion

The importance of foods, gastro-media behaviour

The first question that we asked of the respondents in our research was *how important role food had* in their lives. The respondents had to tell us their opinions on a Likert scale ranging from 1 to 10. The results indicate that food is important in the lives of the respondents, as 78% of them agreed with this statement to an extent above 5. We could not find significant differences across generations, whereas we think we found weak correlations according to settlement category, health condition, schooling and gender. We can say that the ones who more typically agreed with this statement were inhabitants of large villages or cities with county rank, and also people with college degree and secondary grammar school education. Respondents less typically agreeing with this statements included ones with more limited financial incomes, i.e. the ones struggling with problems of day-to-day living, and also those who stated that their incomes were not enough for a mere living, or those who reported to have definitely bad health condition. In the lives of male respondents, food plays a more important role than in the lives of their female counterparts, but the disparity was a few percent, only.

We also examined *how much respondents liked eating and cooking*. Our finding is that respondents more typically agreed with the statement that they liked eating (with 66 percent indicating values of 4 and 5), and also the fact that they were fond of cooking (with 53 percent indicating values of 4 and 5) on a Likert scale ranging from 1 to 5. We did not find significant correlations between how much somebody liked eating and what school education they had. We found weak correlations according to gender, generations, the settlement category of the place of residence, income level evaluated, and health condition. The results demonstrate a higher level of agreement with this statement by males, the young, the dwellers of the capital city or large villages, and a lower level of agreement by those with low income levels and having definitely bad health condition.

As regards whether somebody likes cooking and how they judge their own income levels, no significant correlation was found. We observed a weak correlation in accordance with generations, the settlement category of the place of residence, school education and the condition of the respondent's health. We can state that *the older somebody is, the more they agreed with the statement "I like cooking"* (among the elderly respondents, the proportion of those indicating value 4 or 5 was 62%). This statement

was rather agreed with by those possessing secondary grammar school or higher qualifications, and also those whose health condition was in some respect, or in all respects, a limiting factor in their own opinion.

People less typically agreeing with this statement were the inhabitants of the capital city, more typically agreeing were those living in smaller towns. A medium strong correlation (Cramer's V value=0.443) was detected between gender and whether they like cooking, i.e. results indicated that a much higher proportion of women agreed with this statement.

We also asked respondents about *illnesses that prevented them from eating any food.* Almost 13.24% of respondents (265 persons) declared that they had some disease of this kind, and 3% did not wish to answer this question. Another question of ours was *whether they had some special eating restriction, if they followed any special diet*. What we found is that slightly more people follow special diets than the number of those who have special diseases preventing them from food consumption, but this value was still low, only made 14.23% (285 persons) in the sample. Most of those who are restricted from eating just anything and follow special diet omit sugar from their foods (almost 50%), but many of our respondents do not eat white flour (28.6%), or are on a general slimming diet (25.5%).

Besides the diets listed above, a relatively large proportion of respondents mentioned other things, which that indicates the complex nature of the issue and the diversity of diets currently followed. We also wanted to know if those respondents who followed special diets had some illnesses. Findings show that 68% of those who are on a diet (194 persons) suffer from diseases influencing their food consumption. This reveals, on the one hand, that the rest follows special diets not due to illnesses but some other reasons, and we can say, on the other hand, that there are some respondents who, despite suffering from some disease, do not follow any kind of diet.

Dealing with gastronomy may be a recreational activity and a form of pastime, but this – primarily – content consumption does not have the same significance for each of the consumers' groups. We conducted a K-means cluster analysis in order to examine whether it was possible to define groups different from each other on the basis of media consumption and involvement in gastronomy. During the processing of our database, within the total of the sample (n=2001) we could identify three clusters *(Figure 2).* The first one is called "simply eaters", the second one is the "modern gastro-maniacs", while the third group was dubbed as "traditional gastro-maniacs".

Figure 2. *Clusters defined on the basis of gastronomy-related media consumption and gastro-involvement*

Note: edited by the authors

Members of the cluster of *simply eaters* (who are 35% of the sample) show a below-average interest in the consumption of media, eating is of medium importance for them, and their interest in gastronomy is no more than simply the love of eating. The group is characterised by dominance of males, and with above-average proportion of those with skilled worker qualification, residents of the capital city, the young and the middle-aged. Members of the cluster of *modern gastro-maniacs* (25%) show a broad interest in gastronomy, be that eating, cooking or watching cooking programmes. Members also showed an above-average agreement as regarded activities taken as more modern, such as watching and sharing food videos. Within the group we can see an over-representation of those with secondary grammar school qualification and a below-average proportion of those who had only completed 8 classes of primary school.

They are a typically urban group. As regards generation groups, middle-aged are over-represented. The largest group (40%) is made by *traditional gastro-maniacs* who show an average interest in the consumption of traditional media content related to eating (watching cooking programmes, reading recipes), and a below-average interest in consuming modern media content (watching and sharing food photos/videos). They like eating and cooking. It is a group with female dominance and typically with urban place of residence, with an over-representation of elderly members.

Segments defined by eating orientation

As another important element of our empirical research, we looked at, with cluster and factor analysis, the possibility of identifying consumer segments of the present Hungarian society aged 15–74 on the basis of their *attitude to eating*. The factor analysis was made for the following variables: the importance of eating (1 variable, 10 grade scale), attitudes towards cooking (6 variables, 5 grade scales), attitudes towards eating habits and gastronomy (15 variables, 5 grade scales). Using 19 scale variables 5 factors were identified which, as latent variables, describe the attitude of the respondents of the survey towards eating and gastronomy: the love of cooking; sophistication and variety; scarcity; routine/usual; and importance of eating. Attitude statements related to the factors and their weights are demonstrated in *Table 2*.

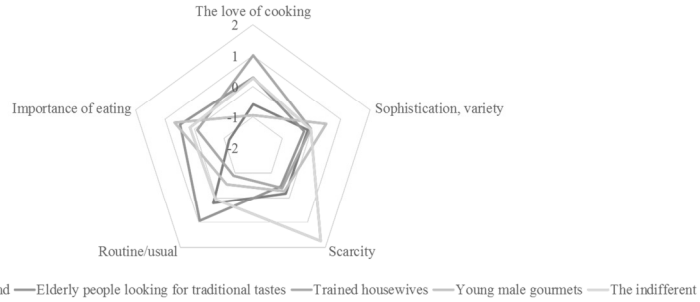
Table 2. Result of the cluster analysis: 5 factors of eating-related issues, according to the rotated component matrix

Rotated Component Matrix[a]						
	K					Specifi-cations of factors
	1	2	3	4	5	
I like reading about foods and watching recipes.	.884					
I like watching cooking programmes.	.836					The love of cooking
I like watching photos and videos made of foods.	.813					
I like cooking.	.740					
I make and share many photos/videos of foods.	.591					
It is very important for me that food is served in an elegant way.		.685				
My diet is varied.		.669				
I consume foods made from high quality ingredients.		.668				Sophisti-cation, variety
I have a preference for local products.		.642		.361		
I like eating in company.		.624				
I like the cuisines of other countries.		.530		-.531		
I often eat in catering facilities or order food.		.448		-.487		
It often happens that I cannot eat enough, because I cannot afford it.			.781			Scarcity
I often get food from others.			.751			
What I can afford is the cheapest foods.			.735			
I like eating familiar dishes.				.743		Routine/ usual
The Hungarian cuisine is the real one.				.722		
How important role does eating have in your life?					.810	Impor-tance of eating
For me eating is a leisure activity.	.345				.765	

Note: edited by the authors; Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalisation; a. Rotation converged in 7 iterations.

For the identification of consumer segments dominant for our research topic a cluster analysis was conducted, using these factors, with a K-means cluster analysis. The result of this analysis was the distinction of 5 clusters of the Hungarian population aged 15–74 (n=1975). The correlations of the respective clusters and factors are demonstrated in *Figure 3*.

Figure 3. *Cluster features on the basis of the factors examined*



Note: edited by the authors

The respective clusters were interpreted on the basis of their attitudes demonstrated by factors, and of their demographic background. As regards the respective demographic attributes, the following show significant differences among the clusters: gender ($\chi2=209.712$; $\lambda=0.132$, $\varphi=0.326$, Cramer-V=0.326; $p<0.000$), generations ($\chi2=195.151$; $\lambda=0.039$, $\varphi=0.314$, Cramer-V=0.222; $p<0.000$), settlement category of the place of residence ($\chi2=49.923$; $\lambda=0.006$, $\varphi=0.159$, Cramer-V=0.079; $p<0.000$), marital status ($\chi2=172.552$; $\lambda=0.048$, $\varphi=0.296$, Cramer-V=0.148; $p<0.000$), and subjective judgement of income position ($\chi2=182.465$; $\lambda=0.070$, $\varphi=0.304$, Cramer-V=0.152; $p<0.000$). In case of highest school education ($\chi2=119.917$; $\lambda=0.0396$, $\varphi=0.246$, Cramer-V=0.142; $p<0.000$) and economic activity ($\chi2=287.431$; $\lambda=0.055$, $\varphi=0.382$, Cramer-V=0.191; $p<0.000$) it was the response Does not know/Does not answer where the minimum expected cardinality of 5 for the respective values was not met.

The clusters identified by the analyses above are characterised by the following features:

The indifferent (21.6%): Members of this segment are less interested in cooking, they are not so much fond of sophistication and their enthusiasm for traditional foods is not particularly high, either. They are not likely to suffer from financial problems. In this group males are above-average represented; group members are older and have primary school education. Their incomes are limited, just enough for a living. As

regards economic activity, pensioners are in an above-average proportion among them.

Elderly people looking for traditional tastes (23.9%): Members of this cluster show an outstanding interest in traditional foods, eating is important for them, but sophistication is not typical for them at all. Their incomes do not particularly limit their possibilities. Their interest in cooking is not outstanding. Looking at their demographic background we can see an above-average proportion of people over 60, females, married and widows/widowers. Their highest school education is typically only primary school. An above-average proportion of them indicated that their incomes were hardly enough for a living. A significant share of them is pensioners.

Trained housewives (18.9%): Their interest in cooking is outstanding, in comparison with the other clusters. They do not show affinity to traditional foods, at the same time they strive for sophistication – even though there are segments that they lag behind in this issue. Financial considerations are not typical for the members of this group. The cluster shows a definite dominance of females. The elderly are below-average represented. They are more likely to live in countryside towns and cities.

Their highest school education is at least secondary school. Their income positions are good; they are even able to save smaller or larger sums of money. They typically have intellectual professions.

Young male gourmets (19.2%): The member of this segment consider eating as important, but their interest in cooking is by far less intensive.

Striving for sophistication and variety is most typical for this group, but they do not show any particular interest in traditional cuisine. The group is definitely of masculine character. As regards their age, they are more typically young, and residents of the capital city have a proportion slightly above the average. Their highest qualification is at least secondary school, but highly schooled members are also strongly represented among them. As regards their marital status, singles and those living in non-marital partnership have shares above the average, and their income positions are the best among all segments. As regards their economic activity, above-average proportions of them learn or are active earners (both white- and blue-collars).

Self-caterers falling behind (16.3%): What is most typical of this group is the limitations of their financial means. Their interest in traditional foods is measurable, and at the same time they strive for sophistication as well.

Their interest in cooking is not outstanding, but they are likely to regularly practice that as part of the daily routine. In this segment, the smallest one of all, the proportion of males and females is balanced.

There is not one generation that is dominant in the age composition, and the share of those living in the smallest settlements has a somewhat

above-average proportion. As regards the highest school qualification, many of them indicated primary school, only. They have financial problems; their incomes are enough for a day-to-day living at the best.

The proportion of blue collars among them is above the average, as is the share of unemployed.

Conclusions – (acknowledgements)

After the crisis, food consumption has started to grow again recently in Hungary, but with a changed composition and with more and more differentiated demands appearing.

We have found that in the lives of the Hungarian adult population eating has an admittedly important role. The importance of eating is more definitely approved by inhabitants of large villages and cities with county rank, and also by those who have college degree and secondary grammar school certificate. Interestingly, eating is less important for those struggling with problems of day-to-day living, and also for those who have reported to have definitely bad health condition. Eating is slightly more important in the lives of male respondents than in the lives of their female counterparts. The reasons should definitely be discovered why eating is valued as less important by those that have problems of living and struggle with illnesses – one would expect them to find it as an issue of vital importance. Another ex-post research should be devoted to the issue why males more intensively agree with the importance of eating, although stereotypes would make us expect that of women.

Media contents related to gastronomy are not interesting at all for 35% of respondents, 40% of them have a preference for traditional media, while 25% like new media solutions as well.

We have identified segments on the basis of attitude to eating, among which the groups of trained housewives and young male gourmets, i.e. approximately 38% of all respondents, are standing our positively.

Trained housewives show an active interest and like creating, whereas young male gourmets are active in consumption. Other analyses in the future can reveal whether making further, smaller groups of them will demonstrate trend groups that are statistically also verifiable.

We found that approximately 14% of respondents are on a slimming diet or follow a special diet. The ones that follow a special diet mentioned in a relatively large proportion, in addition to slimming diets, other diets – this demonstrates the diversity of habits and concepts. This 14% also contains patterns of eating behaviour related to trends.

It is a definitely new phenomenon that many extend their concept chosen for the change of their eating habits to other product areas as well, like clothing or tourism. Just think of clothes, shoes or car accessories

chosen by the vegans, and slow tourism. It has become typical to create a life philosophy from the consumption of foods.

On the whole we can summarise that the consumption of foods is more and more shaped by the impacts of trends, which forces food industry actors to carry out an analysis of the trends before making their longer term decisions, keeping in mind that the behaviour of the majority of consumers is evidently not characterised by the following of the trends.

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Livestock production development in AP Vojvodina

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Summary

The aim of this paper is to present the effects of breeding program implementation on the development of animal breeding in Vojvodina since 2010. Data from the Main breeding organization (controlled population) and data from the Statistical Office of the Republic of Serbia (total population) were used as a basis for this research. The main breeding organization is the Departmant of Animal Science, Faculty of Agriculture, University of Novi Sad that implemented the main breeding programs in cattle, pig, sheep, goat, horse and poultry production. The milk yield in a recorded population of Holstein Friesian and Simmental cows shows evident phenotypic increasing trend as opposed to a population that is not controlled. The results of the selection measures in Vojvodina show that pig breeding has an upward trend and that we have an increasing number of small and medium (family) farms. Interest in sheep and goat production is increasing primarily because of the high demand for products made from sheep meat and goat milk and meat. In the recent decades, Vojvodina has been faced with a decrease in the number of horses. At the same time, there is an increasing interest in sports horses and recreation. According to poultry production results of parental flocks, an increasing tendency was observed in the production of controlled flocks recently, while the number of breeding stock breeders was reduced.

Keywords: livestock production, breeding programs, population size

Introduction

In the Republic of Serbia livestock breeding is the leading branch of agriculture. 77.5% of the total number of agricultural holdings are engaged in livestock production (Popović, 2014). According to his research, almost eight out of ten farms have at least one livestock line in the production structure, while farms with livestock production lines use 70% of agricultural land and the dominant share of other resources, such as labor and mechanization. The author also points to the regionalization of livestock production in the Republic of Serbia. Pig farming is mostly concentrated in Vojvodina, with 41% of the animals. Cattle production is mostly located in the central part of Serbia, while in the territory of

Vojvodina, 27.8% of the cattle are bred. The number of sheep bred in the Vojvodina is 20%, the goat 31%, and the poultry 45% of the total number of animals. Novković et al. (2011) in the research related to livestock production in Vojvodina from 2001 to 2009 included the economically significant types of livestock (cattle, pigs, sheep and poultry) with the aim of quantitative analysis of production changes and comparisons of them with Hungary. The authors calculated a tendency of slight decrease of basic herd of pigs (-0.69%), stagnation of cows and heifers as well as poultry (0.12% and -0.11%), while in sheep farming they calculated a high growth rate due to import of breeding animals (7.87%). Compared to Hungary, the authors point to an unfavorable situation that is reflected in a lower concentration of almost all species of livestock. The biggest differences are in cattle and sheep breeding, and the smallest in pig breeding, while the concentration of poultry is even slightly better than in Hungary. Aleksić et al. (2009) assessed the state of livestock in Serbia as not viable, pointing out that the number of animals of all species is constantly decreasing, which is especially noticeable for female animals used in reproduction (pregnant cows and heifers, pregnant sows and gilts, breeding sheep and goats).

To make livestock production economically viable, it is necessary to have clearly defined breeding goals to be achieved, as well as programs for their realization (Bogdanović et al., 2005). Selection of livestock in Vojvodina institutionally started with the establishment of the Provincial Livestock Institute in 1950. Over the years, the organizational structure has been changed several times, and finally by entering into force of the Livestock Act (Official Gazette of RS 41/09), Department of Animal Husbandry, Faculty of Agriculture in Novi Sad, in 2010, received "Decision on enrollment in the Register of Breeding Organizations of the Ministry of Agriculture, Forestry and Water Management" as the Main breeding organization for the Autonomous Province of Vojvodina (AP Vojvodina) and the same year started the implementation of the Main breeding programs.

The aim of this paper is to present the effects of breeding programs implementation on the development of animal breeding in Vojvodina since 2010.

Material and methods

As a material for this research data from Main breeding organization (controlled population) and data from Statistical Office of the Republic of Serbia (total population) were used. Main breeding organization collects, process and analyzes data related to population size and productivity in controlled population of animals. Data were collected from primary and

regional breeding organizations, through quarterly reporting documentation and annual selection review which is obligatory event defined in the main breeding programs.

Results and discussion

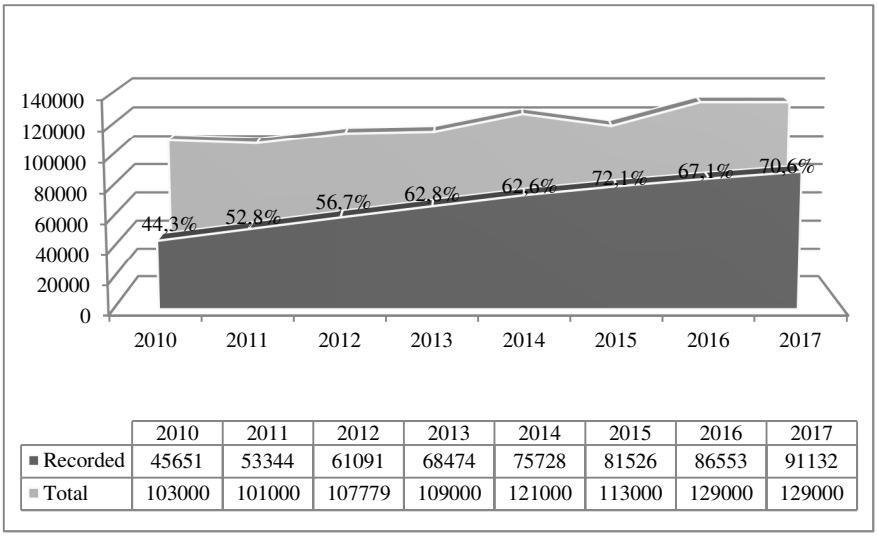
Cattle production

The dominant breed in controlled cattle population in Vojvodina is Holstein-Friesian (HF). According to the Main breeding organization, the Holstein-Friesian (HF) breed in 2005. constituted 98% of the controlled cattle population in Vojvodina (Main breeding organization, 2011), but over the last ten years, the breed structure has changed and there is an increasing interest in dualpurpose (Simmental and Brown Swiss) and fattening breeds of cattle (Hereford, Angus, Limousine and Sharoles). In 2017 the breed structure of the controlled cattle population in Vojvodina constituted 76% HF breed, 21% Simmental and 3.16% other breeds.

The size of the total and controlled population of Holstein-Friesian and Simmental cows and heifers since 2010 is increasing, as well as the proportion of the controlled in relation to the total population of cows and heifers in Vojvodina (*Figure 1*). The aim of increasing the controlled population was achieved for both breeds, given that the population of Holstein-Friesian cows in 2017 increased by 81.90% compared to 2010, and Simmental by 204.27%. The proportion of the controlled in the total population of cattle in Vojvodina in 2017 increased by 26.32% compared to 2010 and reflects the interest of farmers for the implementation of breeding programs on their farms. It is also the result of increased incentives for genetic improvement of livestock by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. In some other countries of Central and Eastern Europe share ranges from 77.8% in Austria to 93.9% in Czech Republic, while in the Poland is 30.5% (Bucek et al., 2014). Considering the total and controlled cows and heifers population size, there is room for further increase of the ratio of controlled in relation to the total cattle population.

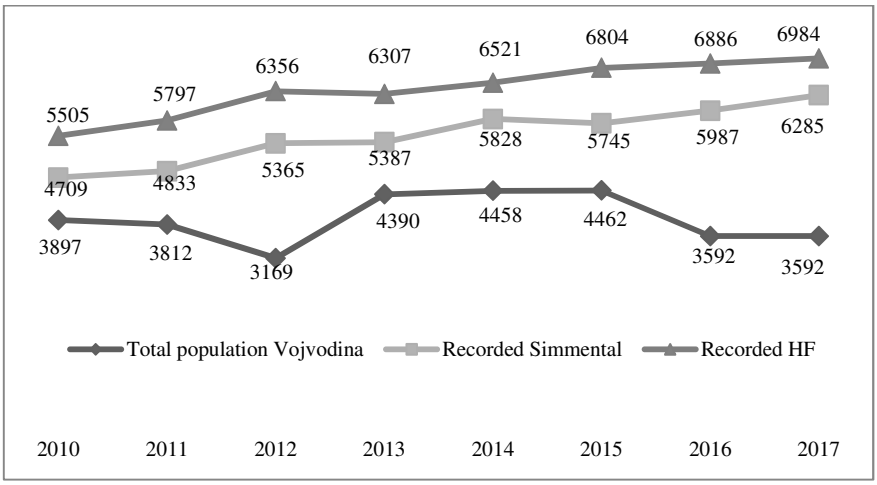
The average milk yields in a recorded (HF, Simmental) and total population (*Figure 2*), shows an increasing phenotypic trend of this very important production trait in recorded population, as well as higher absolute values, in contrast to total population, indicating the impact of implementation of breeding programs. However, although the average milk yield of HF population increased by 10%, the goal of 7500 kg of milk in 305-d lactation has not been achieved. The yield of more than 5000 kg of milk for the Simmental breed has been achieved in the last year of breeding program implementation.

Figure 1. *Size of the total and recorded cows and heifers population and share of recorded relative to the total population in the period 2010–2017*



	2010	2011	2012	2013	2014	2015	2016	2017
Recorded	45651	53344	61091	68474	75728	81526	86553	91132
Total	103000	101000	107779	109000	121000	113000	129000	129000

Figure 2. *Phenotypic trends for 305-d milk yield of Holstein Friesian, Simmental and total population in the period 2010–2017*



Increase of milk yield in the period 2010–2017 is 1479 kg for the HF and 1580 kg for the Simmental cows. Milk fat yield and content also shows increasing phenotypic trend in both breeds; milk fat yield was increased by 50 kg in the HF (fat content, 3.78% vs. 3.36%) and by 55 kg

in the Simmental (fat content 3.92% vs. 3.52%) (Main breeding organization, 2018).

Given the genetic potential of the HF cows for milk production, determined average milk yield in the HF population in Vojvodina is not satisfactory. The average milk yield and milk fat content of HF cows are lower in relation to Croatia (7889, 4.0%) (CAA, 2018), as well as in relation to Slovenia (8042, 3.97%) (Kmetijski Institut Slovenije, 2018). But, we need to know that the HF population in Vojvodina is very heterogeneous in many parameters (herd management, selection activities, herd size, etc.). In the former large state farms, for example, the average milk yield of HF cows are 8500 kg. The average milk yield of Simmental cows in Vojvodina is higher in relation to Croatia (5030 kg, 4.01%), as well as in relation to Slovenia (5873 kg, 4.10%).

Dairy production is a significant branch of agriculture and the overall economy in Vojvodina. As well as previously analyzes (Trivunović et al., 2015), this article shows significant positive effects of implementation of breeding programs for HF and Simmental cattle on the overall performance of dairy cattle. In the region of ex-Yugoslavia, the share of the recorded relative to the total population is increasing, as well as the average milk yield, while the total population size is decreasing, (Stoković et al., 2007).

Beginning of the beef cattle recording system and the establishment of a database for the selection and further improvement of beef cattle is related to the Department of Animal Husbandry, Faculty of Agriculture in Novi Sad, for the second half of 2013. In 2013, a total of 1223 heads of beef cattle were raised in Vojvodina: Hereford-1038, Limousine-45, Sharole-44, Angus-96. In 2017, the number of recorded beef cattle was 2063: Hereford 1064, Sharole-266, Limousin-109, Angus-587.

Pig production

Controlling the productivity of sows is a measure aimed at tracking production results (conception, farrowing rate, fertility, maternal effect, and others production traits) in order to perform an appropriate selection of parents to produce the next generation. The number of sows under productivity control is still on the rise and has a positive trend line (*Table 1*).

The control of the productivity of the boars are a selection measure that follows the production indicators of boars (bore efficiency, litter size, piglets with anomalies, quality of sperm and others production traits), where the aim is to choose boar which according to their production characteristics correspond to the aim of production. Also, due to the purchase of seeds from artificial insemination centers, in order to avoid breeding animals who have common ancestors and to improve

productivity by using the highest quality boars, the number of boars under control additionally oscillates.

Table 1. *Number of animals under productivity control*

Year	Control of sow productivity	Control of productivity boars	Number of sows in Vojvodina (Statistical Office of the Republic of Serbia)	Sows under control in population (%)
2010	37,915	843	139,000	27.28
2011	38,476	827	121,000	31.80
2012	27,547	388	-	-
2013	34,001	461	103,000	33.01
2014	28,714	584	115,000	24.97
2015	32,809	552	119,000	27.57
2016	40,686	504	110,000	36.99
2017	38,193	578	108,000	35.36

The traits that measured by performance test and traits that are included in the calculation of the selection index are: backfat thickness and side fat thickness, depth of musculus longissimus (MLD) and life gain. The results of the performance testing of boars are shown in *Table 2*. We can see that the number of tested boars are decreasing, which is also recorded by Trivunović et al. (2014). One of the consequences of the decreasing the number of tested animal is increased import of animals, and the use of semen from artificial insemination centers. The results obtained by the performance test are shown in *Table 2*. Based on the data of the test results (weight gain, feed conversion, back fat thickness, % of meat in carcasses, number of tits, constitution, size and number of litter from which originates), the best boars should be selected (Yoo and Lee, 2011).

The data are encouraging, since the effect of the continuous implementation of the Main Breeding Program, and the last 10 years state stimulation of farmers in the production of quality breeding material, gives positive results. It should also be said that the life gain and MLD are also increasing, while the backfat thickness and side fat thickness are in decline. Radović et al. (2015) also recorded a positive results (increasing) life gain and MLD in performance test gilts. Selection pressure should be increased to economically important traits. Also, it is necessary to test breeding methods and improve them. In order to achieve the appropriate selection success, continuity is needed, which can be achieved by stable market and production without major oscillations.

Table 2. *Results of the performance teste of boar*

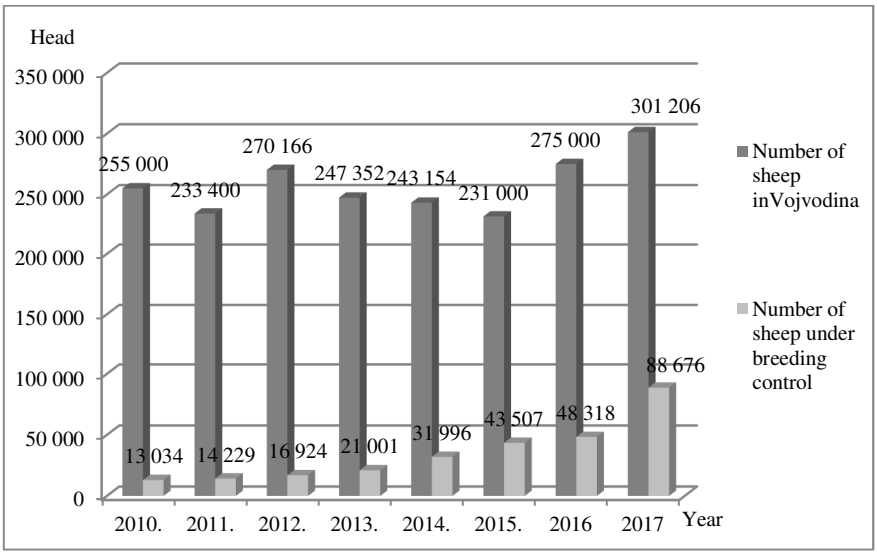
Year	Number of tested boars	Age at the end of test, days	Body weight	Life gain, (kg days^{-1})	Backfat thickness (mm)	Side fat thickness (mm)	MLD (mm)
2010	1294	196	111	0.556	11.1	8.1	68.2
2011	872	199	112	0.552	13.0	12.8	69.8
2012	883	187	114	0.609	17.2	16.9	74.3
2013	812	170	113	0.665	17.6	18.1	77.1
2014	987	191	112	0.585	15.92	16.38	76.69
2015	827	188	107	0.569	13.9	13.7	72.6
2016	724	186	112	0.603	12.81	13.02	74.82
2017	594	180	110	0.615	11.03	11.44	75.14

Sheep production

Intensive sheep production is based on genetic potential and life cycle of animal. It is mainly oriented towards increase of biologic bases for sheep reproduction. Most intensive mating activity is during October and November and then fertility rate is highest (highest number of successful pregnancies is achieved with the highest number of lambs per sheep) (Mekić et al., 2011, 2017).

Of the estimated 275,000 sheep in APV in 2017. (Statistical Office of the Republic of Serbia), only 29.44% were under the breeding programme (*Figure 3*).

Figure 3. *Total numbers of sheep in APV and numbers of sheep under breeding controlled*



Sheep breeding is controlled through the monitoring of fertility, birth weight of lambs, body weight of ewes and wool production (*Table 3*). In APV most popular breeds were: Merino ladschaf and ile de france, which together make up more than 88% of controlled population of sheep. The average herd size under the breeding programme in 2017 was 55.7 heads, while most breeders had 30–120 heads.

Table 3. *Findings from sheep monitoring under the APV breeding programme, 2017*

Breed	Fertility	Birth weight (kg)	Weaning weight (kg)	Woll production (kg)	Body weight of ewes (kg)
Bergamo	1.34	4.12	30.98	3.41	71.41
Tsigai	1.32	4.12	30.08	3.43	74.51
Choka tsigai	1.20	3.59	28.07	3.41	66.60
Ile de France	1.47	4.07	30.66	3.55	68.63
Man meet merino	1.18	5.39	34.55	4.43	82.59
Suffolk	1.53	4.28	31.36	3.04	69.06
Charollais	1.33	4.19	31.66	3.41	71.47
Texel	1.66	4.11	31.24	3.29	72.77
Merino ladschaf	1.31	4.19	31.02	3.57	70.95
British milk sheep	1.76	3.46	29.11	2.78	63.42
Romanov sheep	2.40	2.26	19.00	1.87	55.74

Goat production

In Serbia goat breeding started to develop with imports of Saanen and Alpine goats for crossing with Balkan goats to improve milk production (Pihler, 2014). As in other European countries, in Vojvodina, goats are bred mainly for milk production, and milk yield per head is the most important production traits. Of the estimated 46,393 goats in Vojvodina in 2017. (Statistical Office of the Republic of Serbia), only 16.09% were under the breeding programme (*Figure 4*).

In Vojvodina, three breeds are under controlled breeding – Alpine, Saanen, and Balkan – of which Alpine goats are the most numerous. The average herd size under the breeding programme in 2017 was 44.17 heads, while most breeders had 30–120 heads. Goat breeding is controlled through the monitoring of fertility, birth weight of kids, body weight of goats and milk yield of Alpine and Saanen goats (Table 4).

Figure 4. *Total numbers of goats in APV and numbers of goats under breeding controlled*

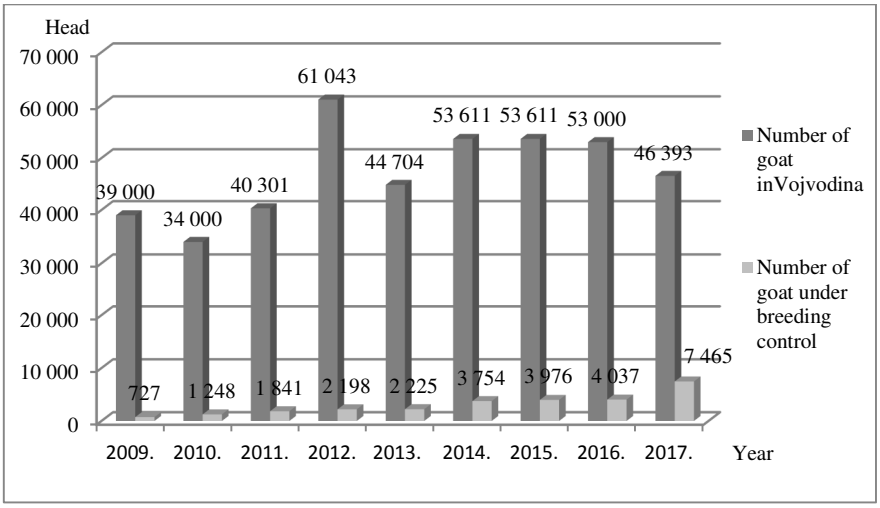


Table 4. *Findings from goat monitoring under the APV breeding programme, 2017*

Parameter	Alpine	Saanen
Days of lactation	217.34	241.20
Fertility (%)	1.62	1.54
Milk (kg)	592.31	754.56
% fat content	3.51	3.22
% protein content	3.12	3.20
Birth weight (kg)	3.19	2.81
Body weight of goats (kg)	54.80	61.52

Horse production

In the last decades Vojvodina has been faced with a decrease in the number of horses. At the same time, interest for sports horses and recreation is increasing. Taking into account the geographical position of our country, available pasture area, food production, labor force, and other suitable factors, we can conclude that much more has to be done to improve this livestock branch. The number of horses within controlled population from 2010 to 2016 recorded a positive trend, which is the result, first of all, implementation of the breeding programs. In 2017 there is a decrease of number of horse compared to 2016 by 2%. If we compare the number of horses in the controlled population with the data of the Statistical Office of the Republic of Serbia from 2017, which tell us that there are about 6000 head of all categories in the AP Vojvodina, we obtain a percentage of horses that are within the controlled population and which is 28%.

From the moment when man domesticated the horse before the 5000–6000 years until today, horses are subject to many forms of selection which resulted in gradual genetic changes and the creation of many breeds. Within the controlled population it is mostly bred Lipizzaner, Thoroughbred and Nonius horses. The Lipizzaner breed is most represented in the controlled population. The number of horses in 2017 is 1.497. In the AP Vojvodina, two stud farms are distinguished: Karađorđevo and Kelebija, but the breeding is also largely represented by individual breeders. The next breed that is most represented is Nonius. Because strength of the skeleton, strong muscles, good walking and calm temperament Nonius are used primarily for agricultural works, while today it is mainly used for riding and for harness. This change in the role resulted in a drastic decrease in the Nonius population, so under the control of productivity in the Stud Book there are only 68 horses. In order to prevent further reduction in the number and loss of genes that may be of major importance in the future, the Ministry of Agriculture has included Nonius in the program for the conservation and sustainable use of genetic resources of domestic animals. Except in Serbia, Nonius is breeding in Hungary, Slovakia and Romania (Mihok et al., 2004; Maftei et al., 2011; Bene et al., 2014). The gallop sport in Vojvodina does not have such a long tradition, but quickly raises the reputation of horse breeding in one country. The specific rules of breeding Thoroughbred horses date from the 18th century. The selection criterion has remained unchanged to date, and this is the result of the races. Controlled population of Thoroughbred horse is mostly represented on the stud farms Pik Bečej and Karađorđevo.

Poultry production

Breeding program in poultry is applied to the control the population of parents flock of meat type hybrids and parents flock hybrids for eggs production. The following meat type hybrids are represented: Ross 308, Cobb 500, Hubbard. Under control there is a flock of light hybrids – Tetra SL. In the area covered with our main breeding program in poultry is parents flock turkey – hybrid But Big 5. The main breeding program in poultry is also planned to monitoring the production results chickens breeds of the following races: Amrock, Silver Italian Chickens, Sasex, New Hampshire, Brahma, Wyandotte, Australorp and Marans.

Continual control of the production of imported flocks is necessary with aim to exclude from the production those hybrids that give worse production results comparing with others in the region, and give to producers recommendation which hybrids to use. Production results are according with the technological norms of breeding hybrids, and the

production results of individual hybrids indicate their end of usage on the territory of AP Vojvodina.

Table 5. *Eggs production results parents flock of poultry in the period from 2010 to 2017 years*

Para-meters	Ross 308	Cobb 500	Hubbard F15	Hubbard Red bro	Hubbard Classic	Tetra SL	Isa Brown	But Big 5	Year
Number of birds in the flocks	213,663	53,334	8,163	0	97.218	14,267	0	2,335*	2010
	137,938	82,726	8,719	0	43.351	0	0	2,322*	2011
	217,006	103,195	0	0	0	13,315	11,941	2,388*	2012
	143,933	23,001	63,402	0	0	15,369	0	2,273	2013
	104,623	24,493	8,088	0	0	0	0	2,414	2014
	137,804	90,913	8,047	2,889	0	15,391	0	2,340	2015
	110,176	50,630	0	2,899	0	15,817	0	2,207	2016
	150,179	52,065	0	0	0	15,471	0	2,207	2017
Total number of eggs	138	136	159	0	135	240	0	96	2010
	146	128	71	0	117	0	0	120	2011
	161	142	0	0	0	232	173	98	2012
	158	153	145	0	0	188	0	103	2013
	163	179	130	0	0	0	0	100	2014
	158	168	188	168	0	215	0	96	2015
	173	140	0	131	0	255	0	78	2016
	182	146	0	0	0	266	0	92	2017

Note: * But Big 6

Conclusion

The milk yield in a recorded population of Holstein Friesian and Simmental cows shows evident phenotypic increasing trend as opposed to a population that is not controlled. It actually indicates the great importance of implementation of breeding programs on the development of dairy cattle production in Vojvodina. There are significant resources for the development of beef cattle production in Vojvodina. However, despite that, as well as preferential quotas for export of beef meat, and the opening of new markets, although demanding, but which have high payment power and where is a demand for beef, this branch of cattle production was not sufficiently developed.

The results of the selection measures in Vojvodina show that pig production has an upward trend and that we have more and more small and medium (family) farms.

Interest for sheep and goat production is increasing. This is primarily because of the high demand for products made from sheep meat and goat milk and meat, due to state subsidies and because of the geographical position and terrain of AP Vojvodina, which allow the breeding of highly productive goats. However, although sheep and goat production is rising, in general sheep and goat numbers remain very

small. In future years, the main herd is expected to grow slightly more quickly as the number of young farmers opting for intensive sheep and goat breeding is increasing.

In the future, the horse breeding could be orientated in three directions: racing horses (trotter and Thoroughbred); sport horses and horses for recreational purpose; horses for tourism which would enable the preservation of locally adapted breed. Breeding of warmblood horse for sport could become the most important branch of horse breeding.

According with production results of parental flocks, covered with Main Breeding Program in the past period, we noticed increasing of the production of controlled flocks, and in same time reducing the number of breeding stock breeders.

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Long-term effect of soil management on the carbon-dioxide emission of the soil

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Summary

CO_2 emission from soils is one of the most important elements of the global carbon cycle, thus it has crucial rule in climate change. Each soil cultivation operation intervenes in the microbiological life of the soil, hence tillage is a factor through that the processes taking place in soil can be controlled. During the last decades, the organic material content of agricultural soils decreased to the half due to the intensive management resulting in the degradation of natural soil fertility. While intensive, plough-based tillage can cause soil degradation and erosion, the physical, chemical and biological status of the soil can be significantly improved through the application of conservation tillage methods. The results of long-term experiments prove that soil protective tillage enhances the enrichment of organic matter in the top layer of the soil. In order to reveal the role of tillage systems in CO_2 emission from the soil, regular measurements were carried out in the plots with conventional and reduced tillage of the soil cultivation experiment of Research Institute of Karcag. Anagas CD 98 and Gas Alert Micro 5w infrared gas analysers were used to measure CO_2-concentrations, and a specially developed method (consisting of a frame and a bowl) was applied to delimitate the measuring area. Most of the measurements were done on stubbles after harvest in order to exclude root respiration. The weather conditions of the examined 10 years were very changeable providing a good chance to compare them to each other. We found the tillage operations resulting in higher emission values in both tillage systems. On stubbles higher and more even emission was characteristic to reduced tillage due to the lower degree of soil disturbance and higher soil moisture content.

Keywords: long-term experiment, soil cultivation, CO_2 emission, stubble, microbiological activity

Introduction

CO_2 emission from soils is one of the most important elements of the global carbon cycle, thus it has crucial rule in climate change. Each soil cultivation operation intervenes to the soil microbiological life hence tillage is a factor through that the processes taking place in soil can be controlled. During the last decades the organic material content of

agricultural soils decreased to the half due to the intensive management resulting in the degradation of natural soil fertility. While intensive, plough-based tillage can cause soil degradation and erosion, the physical, chemical and biological status of the soil can be significantly improved by the application of conservation tillage methods. The results of long-term experiments prove that soil protective tillage enhances the enrichment of organic matter in the top layer of the soil.

International research results prove that the highest carbon-dioxide loss from the soil is due to the regular ploughing of the soil (Tracy et al., 1990; Giuffré et al., 2003). Land use under field conditions is sum of various crops with different biological needs and production technologies. Land use is the tool that can harmonize the agroecological conditions and growing technology (Birkás et al., 1999). Soil cultivation is an element of land use that can influence the biological activity of the soil.

Conventional tillage can contribute to climate changes. The regular turning of the soil by ploughs considerably increases the carbon-dioxide emission of croplands (Reicosky, 1995). Disturbing the soil by tillage results in looser soil structure, changing air regime, fast gas exchange.

The increased oxygen content of the soil induces intensive microbiological activity. The carbon-dioxide generated from the decomposition of organic materials is emitted into the atmosphere, consequently it can be one of the direct causes of the global climate change (Gyuricza et al., 2005). Since the increased microbiological activity is in conjunction with intensive organic material consumption, direct correlation can be observed among the aeration of the soil, the carbon-dioxide emission and the humus content (Szabó, 1986). The humus materials of the soil are generated along several decades or centuries therefore even a decrease of a few percentages can hardly be turned back.

By the application of good agricultural practice the carbon-dioxide fixing ability of the soil can be increased, the organic carbon loss can be reduced, and humification can be strengthened. All these result in the increase of the organic matter content of the soil (Németh, 2004; Koós and Németh, 2007).

Shallow soil cultivation with no turning results in lower aeration and drying therefore the microbiological activity is poorer, but longer lasting (Birkás, 1993), while the organic material content available for the microbes is higher in undisturbed soils (Tóth et al., 2009).

Zsuposné (2003) also carried out microbiological examinations in the log-term soil cultivation experiment at Karcag. By comparing the conventional and conservation tillage systems she established that there was no significant difference in the activity of certain enzymes (urease, catalase), while higher activity of phosphatase could be figured out in the

case of conventional tillage. The annual average of carbon-dioxide production in conservation tillage system was 7.8% higher compared to the conventional one.

On the base of data originating from the examination of conventional and reduced tillage Zsembeli and Nagy (2004) established that higher carbon-dioxide emission to the air is characteristic to the plots of reduced tillage, although the differences are not considerably big every time. They figured out that root respiration has the major role in soil respiration; measured data proved that root respiration is the source of 70–80% of the total emitted carbon-dioxide in the case of an active, growing crop stand.

In this paper the results gained from the measurement on stubbles are published, as we consider stubbles the most suitable state when the effects of different soil cultivation systems on the microbiological activity of the soil can be compared. In stubble state, obviously after the harvest of the crop), root respiration is not characteristic, therefore the carbon-dioxide gas emitted from the soil is purely due to the microbiological activity, so more precise comparisons can be done.

Material and methods

The objective of the complex soil tillage experiment, launched in 1997, was to establish capabilities and effectiveness of a soil conservation tillage system, which stops the physical degradation the of soil among agro-ecological and arable ecosystems in the Trans-Tisza Region and to develop an environmental friendly energy-saving cultivation system. The long term cultivation experiment includes: reduction of the regularly cultivated layer, leaving the ploughing tillage method, application of reduced tillage and no tillage and direct seeding, application of mulching technology, and use of deep loosening to eliminate the physical defects of the soil and the factors limiting soil fertility. The total size of the plots of the experiment is 16 ha, the conventionally cultivated (plough based) plot was set on 3.5 ha, and the reduced tillage plot is 12.5 ha (*Figure 1*). Two plants were growing in crop rotation in the four plots. The plants (wheat, maize, peas, sunflower, and barley) represent the structure of crop production characteristic to Nagykunság region.

In order to reveal the role of tillage systems in CO_2-emission from the soil, regular measurements were carried out in the plots with conventional and reduced tillage of the soil cultivation experiment.

Three similar infrared gas analysers (*Figure 2*) were used to measure CO2 concentrations: an Anagas CD 98 (2006–2010), a Gas Alert Micro 5w (2011–2015), and a Testo 535 (2016–). A specially developed measuring set consisting of a frame and a bowl was applied to delimitate the measuring area. The volume of the plastic bowl is 2800 cm^3, the diameter

of the metal frame is 20 cm. In order to have perfect isolation, the metal frame is inserted into the soil (sharpened bottom edge) down to 5.5 cm and the trough around the frame is filled with water. This set was developed by the authors in 2005, as it was realised it is more practical and suitable for CO_2-emission measurements on stubbles and can substitute the cylinder method that was used earlier (Zsembeli et al., 2005). To determine the actual soil moisture contents and temperature TTN-M type probes were used.

Figure 1. *The soil cultivation experiment at Karcag*

Figure 2. *The frame+bowl method with the gas analysers (Anagas CD 98, Gas Alert Micro 5w and Testo 535)*

To calculate the CO_2-emission from soil the following formula was used:

$$F = d * (V/A) * (C2-C1)/t * 273/(273+T)$$

where F: CO_2 flux (g m^{-2} h^{-1}), d: density of CO_2 (kg m^{-3}, 1.96 for CO_2), V: volume of head space of chamber (m^3) A: area of chamber (m^2), C1: CO_2 concentration at time of start (m^3 m^{-3}), C2: CO_2 concentration at time of end (m^3 m^{-3}), t: duration of measurement (s), T: air temperature (C°).

Most of the measurements were done on stubbles after harvest in order to exclude root respiration that can be 80% of the total emission. The weather conditions of the examined 10 years were very changeable providing a good chance to compare them.

Parallel to the carbon-dioxide concentration measurements samples from the upper 10 cm deep soil layer, which has the major role in soil respiration, were taken in order to determine the actual soil moisture contents by gravimetric method.

Results and discussion

In the investigated ten years the weather was very diverse so it created an excellent opportunity for comparison between years. *Figures 3–12* show the CO_2-emission data calculated from the CO_2-concentration measurements in the two cultivation systems.

The results gained from the soil cultivation experiment must be evaluated separately for each year as the weather, agrotechnical and soil status conditions were considerably different each crop year. Each measurement were done in at least three replications, the averages of the replications are illustrated in the figures. The weather conditions of the investigated ten years were very variable providing excellent opportunity to compare the years.

The data of 25th July, 2006 were measured on stubbles after harvest (*Figure 3*), significant difference could be figured out between conventional and reduced tillage in terms of carbon-dioxide emission: 0.304 and 0.463 g m^{-2} h^{-1} were measured under similar soil moisture conditions (18 and 19 m/m%, respectively).

Oilseed rape was the indicator crop in 2007; it was harvested on 21st June. The measurements were done 4 days after the harvest on stubble (*Figure 4*). Higher carbon-dioxide emission values were calculated (the mean value was 0.333 g m^{-2} h^{-1}) for conventional tillage, while significantly much lower (0.158 g m^{-2} h^{-1}) mean value was characteristic to the plot of reduced tillage. The crop year of 2007 can be considered extreme from several points of view: very high annual mean air temperature (12.0 °C) and extremely high maximum value of soil

temperature (31.4 °C measured at the depth of 10 cm) were characteristic to that year. These extremely high temperature values, together with the dry soil status, were not favourable for the microbiological activity of the soil. Root analyses showed deeper roots of higher mass in the soil of the conventional tillage plot providing more organic matter as the source of carbon-dioxide emission.

Figure 3. *CO_2 emission on wheat stubble, 2006*

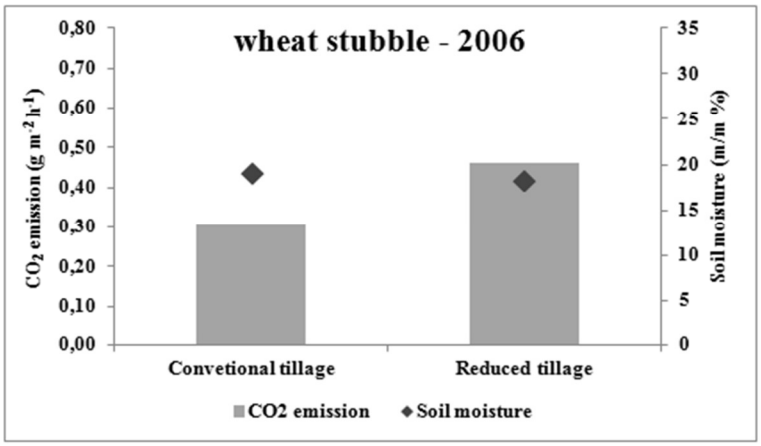
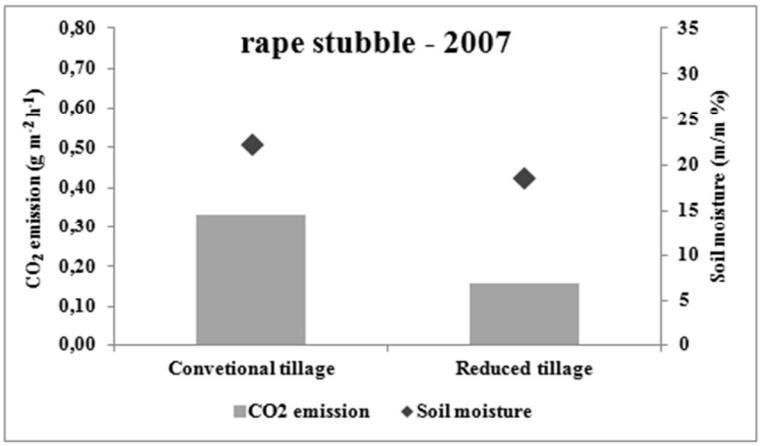


Figure 4. *CO_2 emission on rape stubble, 2007*



In 2008 the measurements were done on 24th June, after the harvest of winter barley. The soil moisture content at the date of the measurement was close to the value of field capacity. Under these conditions we determined higher carbon-dioxide emission (0.614 g m^{-2} h^{-1}) in the case of

reduced tillage compared to the conventional one with its 0.522 g m^{-2} h^{-1} mean value (*Figure 5*).

In 2009 the measurements carried out after the harvest of winter wheat showed significantly higher carbon-dioxide emission in the soil of the reduced tillage plot compared to conventional tillage (0.73 and 0.31 g m^{-2} h^{-1}, respectively) due to the higher soil moisture content and organic matter input characterising the reduced tillage system (*Figure 6*).

Figure 5. *CO_2 emission on barley stubble, 2008*

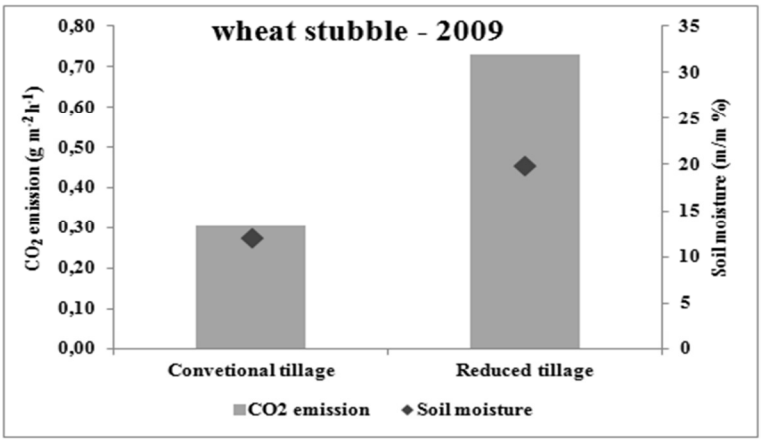
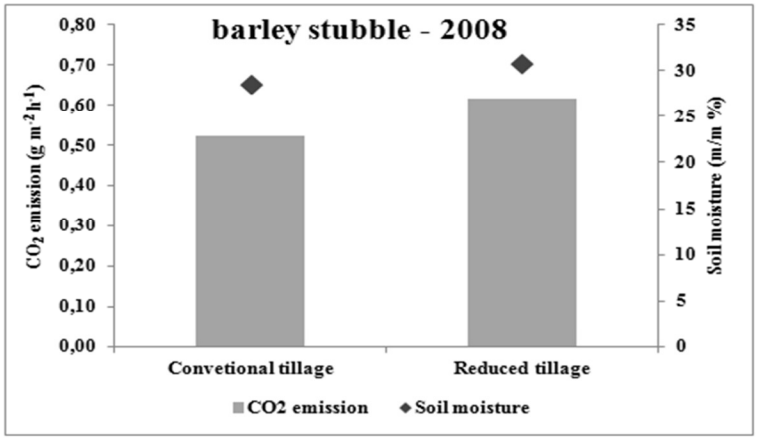


Figure 6. *CO_2 emission on wheat stubble, 2009*



In 2011 slightly higher values of carbon-dioxide emission was characteristic for reduced tillage (0.191 g m^{-2} h^{-1}) determined in

September after the harvest of sunflower. We calculated 0.143 g m^{-2} h^{-1} as a mean value for conventional tillage (*Figure 7*).

Extreme weather conditions characterized the year of 2012; but the plots of reduced tillage still showed higher carbon-dioxide emission on winter barley stubble (*Figure 8*). The mean values were 0.375 g m^{-2} h^{-1} and 0.250 g m^{-2} h^{-1}, respectively.

Figure 7. *CO_2 emission on sunflower stubble, 2011*

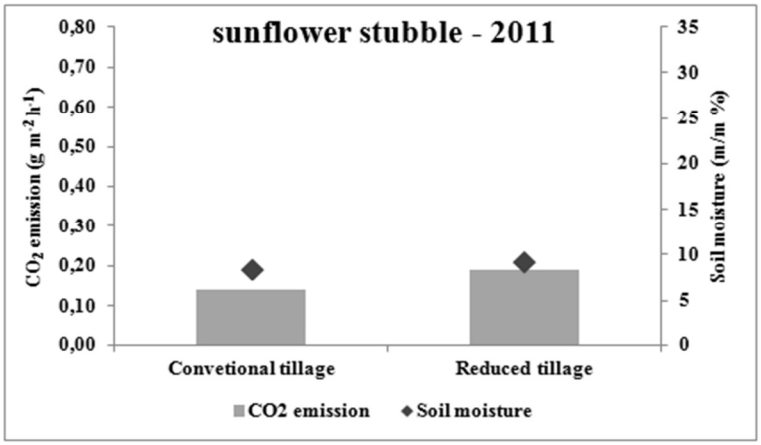
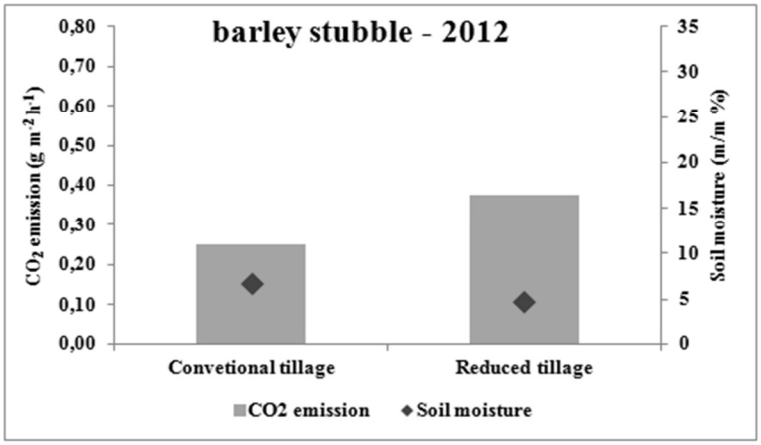


Figure 8. *CO_2 emission on barley stubble, 2012*



Winter fodder pea was the indicator crop in the soil cultivation experiment in 2013. Contrary to the previous years, the measurements carried out after the harvest showed higher carbon-dioxide emission

(*Figure 9*) from the conventional tillage (0.604 g m^{-2} h^{-1}) compared to reduced tillage (0.489 g m^{-2} h-1). We could not determine any reasons that led to this difference.

In 2014 winter barley was harvested from the plots of the soil cultivation experiment. The measurements were carried out on stubbles that year too (*Figure 10*), higher values of carbon-dioxide emission were found in the case of reduced tillage (0.246 g m^{-2} h^{-1}), but not significantly lower values were determined for conventional tillage (0.180 g m^{-2} h^{-1}).

Figure 9. *CO_2 emission on pea stubble, 2013*

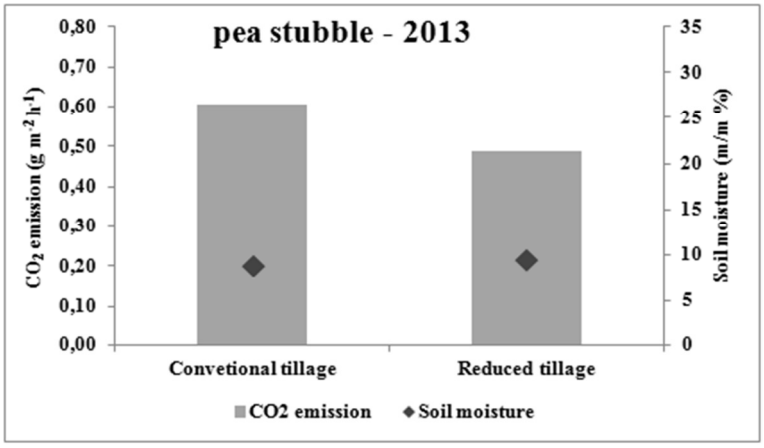
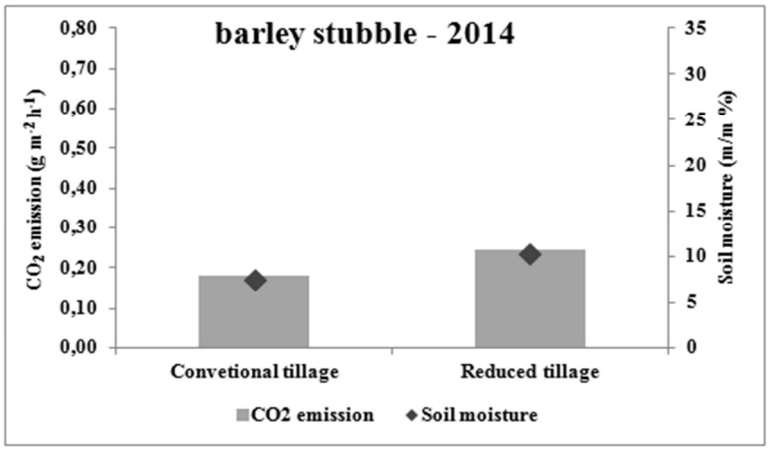


Figure 10. *CO_2 emission on barley stubble, 2014*



2015 was a droughty year, low carbon-dioxide values were characteristic due to the extensive microbiological activity of the soil (*Figure 11*). In such very dry conditions the effect of soil cultivation is not so expressive as soil moisture is a limiting factor for soil respiration. Similar values were characteristic for both tillage systems; we measured 0.202 g m^{-2} h^{-1} and 0.204 g m^{-2} h^{-1} on winter fodder pea stubbles.

In 2016, after the harvest of winter wheat, we measured low values for both treatments, but slightly higher values in the case of reduced tillage (0.281 g m^{-2} h^{-1}), while 0.239 g m^{-2} h^{-1} carbon-dioxide emission was calculated for conventional tillage (*Figure 12*).

Figure 11. *CO_2 emission on pea stubble, 2015*

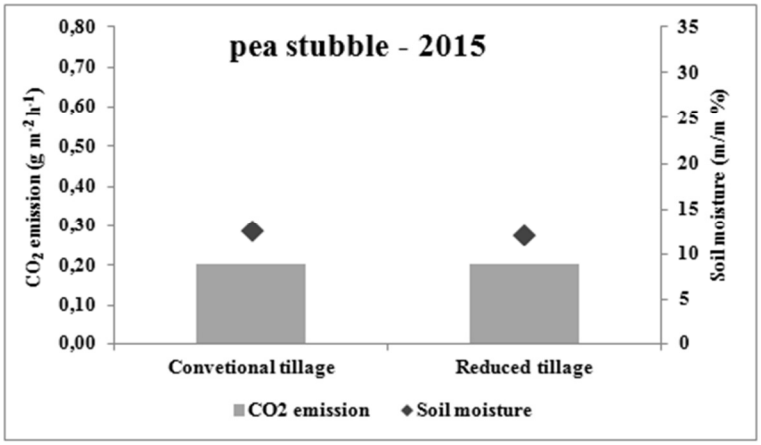


Figure 12. *CO_2 emission on barley stubble, 2016*

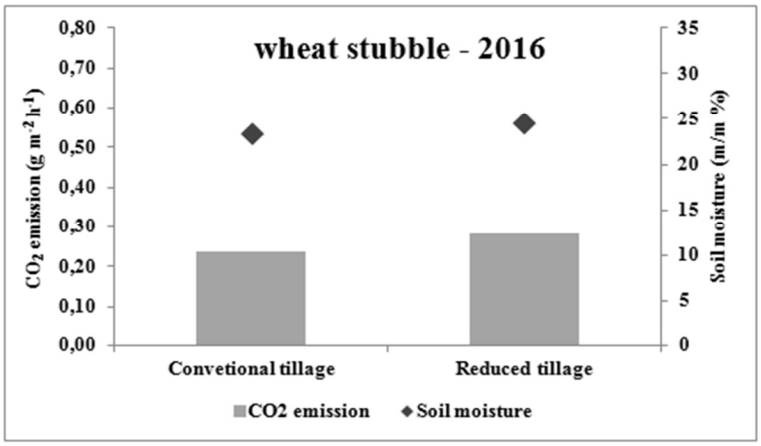


Table 1 contains the data of the statistical analysis of the carbon-dioxide emission values determined during the ten years of the investigation. The mean value of reduced tillage is higher, though the standard deviation is also high in that case. The minimum values are quite close to each other (0.143 and 0.158), the maximum value is much higher in the case of reduced tillage (0.730) compared to conventional tillage (0.604).

The CO_2 emissions of the soil are close correlation with the increasing soil moisture content. Hence environmental conditions (soil moisture content, temperature, pH, etc.) decisively influence the change of soil organic matter (accumulation or reduction) and the living conditions of the soil micro-organisms.

Higher emission values were characteristic on the stubble on the plot without disturbance in most cases. This proves that better conditions formed in the soil of reduced cultivation plot to the microbial processes. Based on the obtained results, direct correlation can be observed between the intensity of tillage and carbon dioxide emissions.

There is close correlation between the degree and intensity of CO_2-emission from the soil and the structural state and organic matter content of the soil. Applying alternative soil cultivation methods based on reduced disturbance of the soil more favourable conditions can be created in order to increase the organic matter content of the soil and the availability of the nutrients for the crops.

Table 1. *Descriptive statistics of the CO_2 emission values*

CO_2 emission (g m^{-2} h^{-1})	Conventional tillage	Reduced tillage
Mean	0.308	0.375
Standard error	0.047	0.061
Median	0.277	0.328
Standard deviation	0.148	0.194
Sample variance	0.022	0.038
Kurtosis	0.623	-0.669
Skewness	1.167	0.682
Range	0.461	0.572
Minimum	0.143	0.158
Maximum	0.604	0.730
Confidence level (95.0%)	0.106	0.139

Conclusions

Assessing all our data it can be concluded that reduced tillage showed higher carbon-dioxide emission values each of the 6 years when winter cereals (wheat, barley) were the indicator crops, the differences were significant in two years (2006 and 2009).

Only in one year out of ten was sunflower the indicator crop, in that case we could not figure out considerable difference between the two investigated soil tillage systems regarding the carbon-dioxide emission from the soil.

There were two years when the stubble of winter pea could be studied: in one of the two years no difference could be figured out, while in the other year the conventional tillage resulted in higher carbon-dioxide emission. Since fodder pea needs deeper cultivation of the soil, conventional tillage, where ploughing down to 30 cm was carried out, was more satisfactory to that indicator crop.

Oilseed rape was examined in one year: also conventional tillage with its deeper root zone resulted in higher carbon-dioxide emission from the soil.

As a summary it can be concluded that in seven years out of ten reduced tillage resulted in higher carbon-dioxide emission from the soil. We proved with field measurements that due to the moderate soil disturbance and the favourable soil conditions for microbial activity, reduced tillage system resulted higher CO_2-emission compared to the conventional tillage, though the emission was more balanced in time.

The application of reduced cultivation supported the soil in approaching its natural equilibrium state that manifested in the investigated factors of the soil carbon cycle. Under favourable soil moisture conditions microbiological activity (indicated by the level of CO_2-emission) was increased where reduced tillage system was applied.

Analysing the amount and fractional composition of the soil organic matters we found that reduced tillage produced an increased ratio of the stabile humic materials that bound to the soil minerals taking part in the formation of a more favourable soil structure. These data can characterise the resilience of ecosystems of arable lands.

There are several methods to measure the CO_2-emission of the soil, but none of them is universal, and can be used in any circumstances. The most problematic part is the spatial delimitation of the measurement area as the surface of the soil can be very various and proper isolation is a must. The tools (the infrared gas analysers and the frame+bowl set) we used for the in situ measurement were found effective and handy and recommended to be used to gain more information on the dynamics of CO_2-emission from the soil.

Studying the effect of different soil utilisation/cultivation methods on the CO_2 emission from soil is indisputably actual and needs more efforts as it can contribute to develop a more environmental friendly agricultural production.

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Impact of the integration of lupine (*Lupinus albus*) into crop rotation on the extent of soil compaction in the Westsik long-term field trial

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Summary

In order to reduce or eliminate soil compaction, rational crop rotation and appropriate sequence of crops have an increasingly important role in addition to mechanical and tillage solutions. In this respect, introduction of greening in recent years has been a major step, which focuses on aspects of environmentally conscious, soil conserving farming and the improvement of biodiversity. The cornerstone of this strategy is the cultivation of crops that have a beneficial effect on soil properties, such as the use of nitrogen-fixing plants and green manure plants in the cultivation system that have a beneficial effect on soil structure. In our examinations, penetrometer measurements were carried out in the second longest crop rotation-based field experiment in Europe in order to quantify the effects of green crops and crop rotation strategies on soil resistance. Our aim was to evaluate and compare the impact of lupine (*Lupinus albus*) on the penetration resistance of soil on sour sandy soils. At the time of the penetration resistance measurement, different crop rotations had a significant effect on the development of the parameter in the examined soil layer. The most favourable penetration resistance values were found in the crop rotation, which included lupine as a green manure. The favourable effect is dominant below the cultivated layer (0–40 cm), which is statistically verified. The values of penetration resistance of the cultivated soil layer of lupine sown as primary green manure did not differ significantly from the values measured in the case of the fallowing-based crop rotation. Therefore, the use of lupine green manure instead of fallowing could be worth considering by practical application due to its favourable effects on soil penetration resistance. The use of lupine green manure after the production of rye cultivation resulted in penetration parameters similar to fallowing, irrespective of the green crop and the applied amount of nitrogen fertilizer, which justifies the cultivation of the crop as green manure. In the case of potato cultivating, recorded compaction within the cultivated layer is an obvious consequence of mechanical compaction during harvest; therefore, machinery operations are decisive for the development of penetration resistance values of the cultivated layer. In addition to the beneficial effect of lupine as a green manure crop on soil condition, its nitrogen-fixing ability is also important; it stresses the utilisation of the crop of sour sandy soils for the sake of proper soil management.

Keywords: acidic sandy soil, soil compaction, lupine, crop rotation, penetration resistance

Introduction

Hungarian sowing structure is characterized by excess use of cereals, intensive cultivation systems have adapted to this. Disadvantages of this system have been emerged on global scale over the last few decades as increasingly limiting factors of cultivation. Such limiting factors are one-sided and extensive exploitation of the nutrient content of soils, non-environmentally conscious nutrient supply and soil degradation processes. Of the latter, there is a considerable degree of soil compaction, which is causing increasing problems worldwide. One of the most widespread, most damaging soil degradation processes is physical degradation of soil, more precisely the degradation and compaction of soil structure (Stefanovits, 1975). Based on the results of the soil compaction surveys carried out since 1987 on nearly 14 000 hectares, it was found that 73% of the examined areas have a solid barrier of tillage origin at different depths, which hinders plant growth and blocks the infiltration of precipitation (Birkás, 1997). Várallyay (1989) classified Hungarian soils into eight different categories based on their sensitivity towards physical degradation. According to expert estimates published in the publication "Environmental Prospects of Hungary", nearly 50% of our cultivated areas are concerned with harmful soil compaction (Bulla, 1994). Estimation and evaluation of the degree of harmful soil compaction in Hungary was carried out by MTA ATK TAKI. According to their calculations, the rate of harmful soil compaction in the majority of the Hungarian counties is 40–60%, while in Vas, Fejér and Békés counties the degree of compaction is lower (20–40%). In order to reduce or eliminate this harmful phenomenon, rational crop rotation and appropriate sequence of crops have an increasingly important role in addition to mechanical and tillage solutions. In this respect, introduction of greening in recent years has been a major step, which focuses on aspects of environmentally conscious, soil conserving farming and the improvement of biodiversity. The cornerstone of the strategy is the cultivation of crops that have a beneficial effect on soil properties, such as the use of nitrogen-fixing plants and green manure plants in the cultivation system that have a beneficial effect on soil structure. In the scope of impact assessments of crop rotations, Westsik (1928) observed that white lupine-based green manure significantly increased potato yield on acidic sandy soil. Bittera (1935) considered it as a great advantage of lupine that it is able to utilize the hardly soluble phosphorus content of the soil. Ajtay (1959) measured a threefold potato yield in the average of 8 years following lupine, compared to the control. In sand improvement crop rotation experiments, Szöllősi et al. (2001) examined the effect of different crop rotations on soil compaction.

Favourable effect of the crop rotation including lupine green manure could be detected in the lower soil layer below 35 cm. Their measurements confirmed that besides improving the fertility of sandy soil, soil structure could be improved by means of both green manure and livestock manure. The turned green mass and the added livestock manure improved soil structure, loosened the soil and reduced the degree of its compaction. In the case of green manuring, soil is loosened even by deep roots, thus their loosening effect is more profound and expressed. Since cultivation costs of soils in unfavourable compactness condition are higher and their yields are smaller, favourable soil conditions enable the achievement of higher profits during production; therefore the use of a rational crop rotation is an economically efficient intervention.

Material and method

In the course of our examinations, our aim was to evaluate and compare the impact of different plant sequences, cultivated crops and green crops on penetration resistance of soil on acidic sandy soil. The analyses were carried out on the Westsik long-term crop rotation field trial at the University of Debrecen, IAREF Research Institute of Nyíregyháza. The experiment was set up in 1929 on sandy soil with poor water and nutrient supply, which is able to represent various possibilities for the maintenance of soil fertility. In the scope of the experiment, there is no additional nutrient supply for one of the fifteen examined crop rotations; in this case periodic fallowing is used (I). In four crop rotations, green manuring is applied with lupine second crop (XII, XIII, XIV, XV). Lupine is found in the experiment as a subject for seed production, green forage production, primary and secondary green manuring. Out of the 15 crop rotations, 8 three-year crop rotations were selected for the analysis of penetration resistance. They share a common element: lupine is in some form included in all of the involved crop rotations (primarily sown lupine green manure, lupine seed production, lupine green forage production, spring ploughed, autumn ploughed and artificial fertilizer-free secondary sown lupine green manure crop rotations), and also – as a basis of comparison – non-manured, fallowed and livestock manured crop rotations (26 t ha^{-1} dose) were analysed.

The soil of the experiment is a low-humus, acidic, loose sandy soil. The sludge fraction is between 4.1 and 7.9%. Humus content of the soil varies between 0.45–0.77%. The pH of the soil measured in a diluted solution is 4.94–6.09, pH measured in potassium chloride is 3.89–5.15, Arany's plasticity index is 27–29. The AL-soluble P_2O_5 content is 29.39–202.00 mg kg^{-1}, the AL-soluble K_2O content ranges from 59.54 to 184.40

mg kg^{-1} in various treatments. At the time of the study, the area was used for rye production, with green crops according to the crop rotations. For each analysed crop rotation, measurements were performed during the rye stage for the sake of comparability and due to smoothness of the surface. At the time of the study, the area was in the agronomical condition appropriate to the production technology of rye. The long-term experiment (*Picture 1*) is currently maintained by the University of Debrecen, IAREF, Research Insitute of Nyíregyháza.

Picture 1. *Westsik's long term crop rotation experiment*

During the period preceding the date of the examination, the amount of precipitation was in conformity with the multi-annual average; it fell in a relatively balanced distribution. The year 2017 was characterized by a relatively rainy summer, thus soil moisture content was favourable for the performance of the measurements even in the autumn period. There was no extreme drought within the periods with high evapotranspiration values, thus soil moisture deficit, which impedes measurements did not distort the results. In the scope of our examinations, penetration resistance of the soil was measured by means of a PEN-100 M 500 type penetrometer. The device measures soil resistance values by cm, the

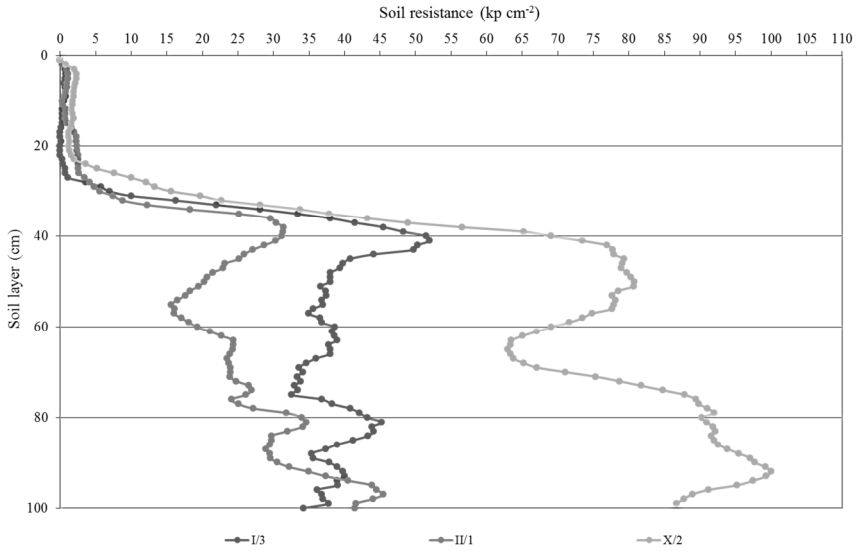
measured soil layer was 0–100 cm and the date of measurement was 17th November 2017. Penetration resistance is represented in units of kp cm^{-2}. Measurements were performed in three repetitions in different crop rotation phases. Present study evaluates and compares the soil resistance results of crop rotations including lupine with fallowed (crop rotation I) and livestock manured (crop rotation X) treatments. Statistical processing of data was performed with the help of Microsoft SPSS Statistics 22 software package, and by means of the application of the Tukey test.

Results and discussion

Lupine directly preceded rye within the crop rotation which included primarily sown lupine green manure (crop rotation II), which was ploughed into the soil at the end of summer. The obtained penetration resistance values did not show any significant difference in the 0–30 cm layer as compared to the fallowed or livestock manured crop rotations. Below the cultivated layer, there was a significant difference in the values of penetration resistance of different crop rotations. The most favourable values were found in the crop rotation including primarily sown lupine, and it was found that soil resistance values were much higher in the fallowed and livestock manured crop rotations in every soil layer (below 0–30 cm). Significant differences were found among the maximum values of penetration resistance results. Maximum penetration resistance values were found in the 35–45 cm soil layer of the fallowed and primarily sown lupine green manure crop rotations (in the case of the lupine green manure crop rotation it was 31.47 kp cm^{-2}, while in the fallowed crop rotation it was 52.00 kp cm^{-2}). In the case of crop rotations including livestock manure, much higher soil resistance values (80.80 kp cm^{-2}) were measured in the 45–50 cm soil layer. The highest absolute value of soil resistance was measured in the 80–100 cm layer, which has a low influence on cultivation thus its effect is less determinant (*Figure 1*).

In the case of the crop rotation sown for primary seed saving (III), lupine was a direct green crop of the rye phase. Examination of penetration resistance values revealed that within the 0–30 cm cultivated soil layer, no significant difference was found amongst the results when compared to fallow and livestock manured crop rotations. Below the 30 cm cultivated layer, significant difference was observed in terms of penetration resistance. The most favourable value was measured in the case of the fallow area, followed by the lupine sown for seed saving and the livestock manure treatment.

Figure 1. *Development of soil penetration resistance in the case of fallowed, livestock manured and primary sown lupine green manure crop rotations (Nyíregyháza, 2017)*

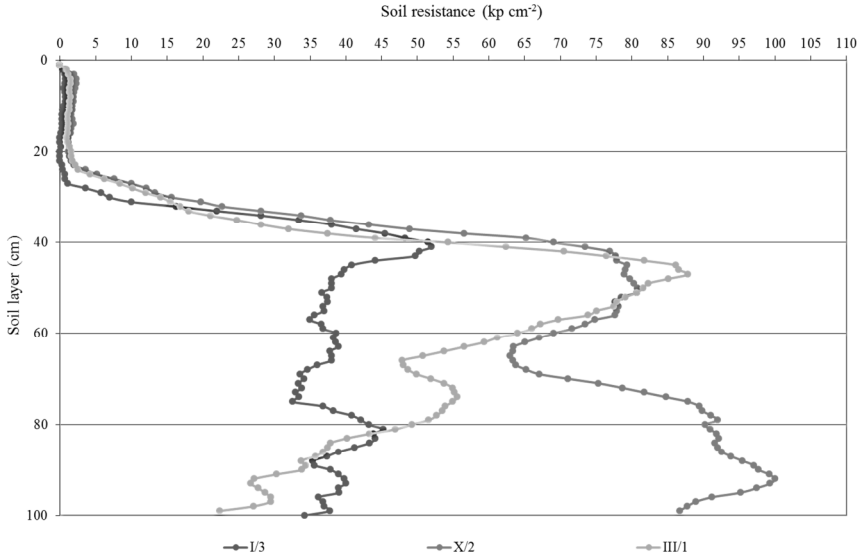


However, the highest penetration resistance value was recorded in the case of the lupine grown for seed saving in spite of the fact that soil penetration resistance was lower in comparison to the livestock manure treatment in the majority of the soil profile. There was also a significant difference between the maximum values of penetration resistance. In the case of fallow-based crop rotations and the ones including lupine for seed saving, the maximum penetration resistance was found in the 40–50 cm soil layer (87.7 kp cm^{-2} in lupine for seed saving and 52.00 kp cm^{-2} in the fallowing crop rotation). In the livestock manure crop rotation, a much higher soil resistance (100.00 kp cm^{-2}) was measured within the 80–100 cm soil layer (*Figure* 2). In this latter case, a soil resistance peak was found in the 45–50 cm layer as well, which appeared in a similar layer as in the case of the two crop rotations analysed above.

In the crop rotation including primary sown lupine for seed saving, lupine besides being primarily sown also appears as a secondarily sown green manure. In the case of crop rotation VIII/1, lupine was the green crop before rye while in the case of VIII/3, the direct green crop was potato. The peculiarity of the crop rotation is that only crop rotation VIII has a 4-year cycle within the long-term experiment. Among the penetration resistances obtained during the study, there was a particular difference in the soil layers under the cultivated layer, with the exception

of the potato green crop, which could be due to the compaction caused by the mechanical harvesting of potato.

Figure 2. *Development of soil penetration resistance in the case of fallow-based crop rotations and crop rotations including primary sown lupine for seed saving (Nyíregyháza, 2017)*

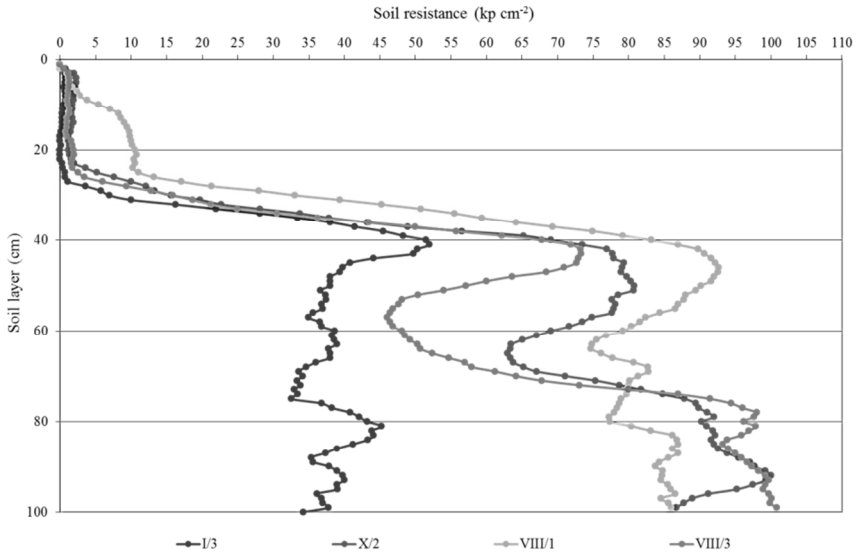


The results show that the largest penetration resistance was observed in the case of the 0–70 cm soil layer of the plot including lupine sown for seed saving. In the case of the lupine green manure (following rye as a secondary sowing) penetration resistance of the 0–70 cm soil layer is between the fallow and the livestock manure treatments, but in the layers below 70 cm the resistance exceeds even the value of the livestock manured plot (*Figure 3*).

Conclusions

Long-term experiments provide an excellent opportunity for the examination of the effect of different green crops and crop rotations on soil resistance parameters. In our examinations, development of soil resistance was observed in crop rotations including lupine within the long-term crop rotation experiment set up by Vilmos Westsik. One of the problems in terms of the measurement of soil resistance is the punctual, static measurement, which has the potential of errors.

Figure 3. *Development of soil penetration resistance on fallow-based and livestock manured crop rotations and crop rotations including primarily sown lupine for seed saving*
(Nyíregyháza, 2017)



However, performing a sufficient number of measurements is suitable for comparison even with static results; this aspect was taken into account upon the determination of the sample size. Based on the results it can be stated that at the time of measurement, different crop rotations had a significant effect on the penetration resistance of the soil in the examined soil layer. The most favourable penetration resistance values were recorded in the crop rotation, which includes primarily sown lupine green manure. The favourable effect is dominant below the cultivated layer, which is statistically verified. Although this effect did not occur in the cultivated layer, production of lupine green manure grass was advantageous for ground water and air management, thus the use of lupine green manure instead of fallowing should be considered in practice due to its favourable impact on soil penetration resistance.

Penetration resistance values of lupine green manure did not differ significantly from the values measured for fallowing and livestock manure crop rotations. In the case of seed production, this beneficial effect appeared less compared to the fallowing crop rotation, which could be due to the higher amount of machinery-induced compaction and the longer growing season compared to green manure. There was no significant change in the effect of lupine seed production even if lupine

was included as a secondarily sown green manure (in the case of the 4-year crop rotation). In the case of potato green crops, the observed compaction in the cultivated layer is obviously the consequence of harvesting, thus machinery operations are decisive for the development of penetration resistance within the cultivated layer.

In addition to the beneficial effect of lupine as green manure on soil condition, its nitrogen-fixing ability is also important; it makes the crop special in terms of soil management

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