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Content

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A HYDROGEOLOGICAL APPROACH OF THE OLD DRAVA RIVERBEDS' REHABILITATION

Dominika Pollermann*, Angéla Anda, Imre Müller

University of Pannonia, Georgikon Faculty, Keszthely, Hungary

*pollermann.dominika@gmail.com

Abstract

In the past decades the water management of the Ormánság used to be based on the drainage of surface waters instead of retaining them in the catchment area. However, the present aim of the new water regulation concept of Ormánság is the rehabilitation of the water management by transforming the straightened streams and drainage canals into the old, meandering, natural beds and in the meantime by increasing the surface water levels. These bed pathways could be completely new or they might remain in the already existing old Drava river beds.

The aim of our research consists of a hydrogeological approach of existing old riverbeds by soil analysis and by geophysical soundings, to determine the thickness and the hydraulic permeability of the sediments. With the help of this information we can conclude whether in the three pilot research sites the thickness and permeability of the river bed sediments would allow the renewal of permanent surface flow systems if artificial alimentary streams will feed them.

Key-words: Drava, Ormánság, water management, hydrogeology, geophysics.

Összefoglalás

Az Ormánság, bár mind néprajzi, mind pedig természeti szempontból jelentős értéket képvisel, jelenleg hazánk egyik legelmaradottabb térsége. Míg e vidéket egykor a Dráva áradásai éltették, a zöldellő legelők, az erdők, a folyó és holtágai jólétet biztosítottak, addig ma a térségnek komoly kihívásokkal kell szembenéznie. Az elmúlt évtizedekben ugyanis az Ormánság vízfolyásainak és belvízcsatornáinak medre beágyazódott, vízszintjük lesüllyedt, mely a táj kiszáradásához, szerkezetének átalakulásához vezetett.

Megszületett azonban az Ormánság vízrendezésének koncepciója, mely szerint a táj kisvízfolyásai és belvízcsatornái bevágódott, kiegyenesített medreikből régi vagy teljesen új, kanyargós medrekbe kerülnének, vízszintjüket megemelnék.

Kutatásunk célkitűzése a régi folyómedrek hidrogeológiai vizsgálata volt. Talajfizikai vizsgálatokat és geoelektromos szondázásokat végeztünk a medrekben lerakott üledék vastagságának, permeabilitásának és térbeli elhelyezkedésének meghatározása érdekében. Ezen adatok ismeretében ugyanis következtethetünk arra, hogy ha az egykori folyómedrekre vízfolyásokat engednek, a régi medrek üledékeinek vastagsága és permeabilitása elegendő lesz-e ahhoz, hogy tartós vízborítás alakulhasson ki.

Introduction

Nowadays the Ormánság, situated in the southern part of Baranya County, is one of the most disadvantaged areas in Hungary (http://baranyakonf2013.pte.hu/en/about-us/old-drava-program/). However the ethnographical and natural values of this region are of paramount importance. The floodplain of the Drava, the oxbow lakes, wetlands and marshes provide habitats for a valuable wildlife. For example there are 56

protected plant species and 49 endangered plant communities in the Ormánság, and ornithological biodiversity the area of the Drava is not only of national but also of international importance (Reményi and Tóth, 2009). Along the river an especially diverse range of habitats can be found, and there are numerous geomorphological phenomena that cannot be detected in the majority of regulated flowing waters (Závoczky, 2005).

The wealth of the area was provided by the floods of the Drava but in the recent times many adverse change occurred (http://www.osdrava.hu/download/tajgazdalkodasi.pdf). In the last centuries the meandering streams of the Ormánság were straightened and drainage canals were constructed. Later the straightened beds became deeper and deeper. The streams and drainage canals started to draw off the water from the area and caused the dehydration of the region (Molnár, 2012).

Currently the water management of the Ormánság is based on the draining of water. In rainy periods precipitation cannot infiltrate and leave the area as surface runoff. In dry periods the catchment area - unlike the small permanent reservoirs - cannot retain the water (Molnár, 2012).

The continuous decrease of the water resources of the land threats the valuable wildlife of the Ormánság by changing the living conditions. The decreasing water and forest surface diminution induce also a reduction in the amount of evaporation, which produces the breakdown of the microregional water circle (Molnár, 2012). In the same time the land use has been changed. Decades ago the land was used as orchard, pasture, meadow, forest or fishpond, which were replaced by industrial agriculture (http://www.osdrava.hu/download/tajgazdalkodasi.pdf). The traditional way of making a living for the inhabitants, such as fishing, fruit growing and the grazing animal husbandry disappeared. As a result, besides the degradation of the natural ecosystem the social and economic impoverishment started as

well (http://baranyakonf2013.pte.hu/en/about-us/old-drava-program/). Nowadays the area is characterised by poor living conditions and low level of education (Jelenszkyné Fábián, 2009). In addition the rate of the job-seekers in the Sellye microregion is four times higher, than the Hungarian average (Tésits, 2007).

Phrase rehabilitation means applied measures for re-establishing an area, rivers are included, close to near-natural condition (Pickett et al. 2001). These authors called the attention that although these measures address ecological issues, other impacts for society may arise as well. Due to complexity of the issue, separate evaluation is essential (Gardiner 1992). Habersack et al. (2008) published that out of 139 river systems of US, Europe and the former Soviet Union, 77% of them has to be classified as negatively impacted by human activity.

There are projects such as Old-Drava Program and Old-Drava ORMÁNSÁG Program in order to develop the Ormánság, which define the modification of water management of the region as an important factor of development. The aim of the new water regulation concept of the Ormánság is to build up a surface flow network and land structure reorganisation, which will be able to retain the water in the area. The reorganisation of the water management would concern all streams and drainage canals in the area. They will be directed back into their former meandering riverbeds from their current, straightened beds and their water level will be artificially raised. This intervention will help to store the water in the area, increase water resources and reconstruct the microregional water circle and landscape structure (Molnár, 2012).

Korcsina Canal, which is one of the most important drainage canals in the Ormánság, is in the centre of our research. A detailed study already exists, which plans the reconstruction of the Korcsina Canal, including a

concrete proposal about the new, meandering and natural fall line following the riverbeds instead of the present pathway. Before we start this project it is important to explore the permeability and the thickness of the sediment fillings at the bottom of these old river beds to estimate their storage capacity by artificial recharge. This is the goal of the present research.

Materials and methods

The field measurements were carried out in October 2012 and July 2013 in the area of Drávafok – Markóc – Drávakeresztúr, which belongs to the floodplain of the Drava River and the catchment area of the Korcsina Canal. In this region three pilot study areas (A, B and C study areas) were appointed crossing old riverbeds. The realization of the water regulation concept of Korcsina means an artificial recharge planned to be led through these study areas.

During the research six manual drillings were carried out, two on every study area, down to 250-300 cm with Eijkelkamp drilling equipment. From every drilling 3-5 soil samples were collected according to the change of the soil type. The mechanical composition of the samples was determined using the pipette method (Buzás, 1993). During the process at first sodium pyrophosphate was given to the dried soil samples. Then the suspensions were shaken in a soil shaker for 6-10 hours in order to disintegrate the probe to smaller particles. Next the suspensions were poured into a measuring cylinder through a sieve with an 0.25 mm hole diameter. The part of the sample which could not flow through the sieve was the biggest fraction. To determine the smaller fractions the measuring cylinder was put aside to settle. After suspension fractions were pipetted at specified time intervals, from the specified depths, they were put in designated weights, in numbered beakers. The samples were dried in a drying cabinet at 105°C to constant weight. In

the next step the weight of the samples was measured after drying. With the help of the Stokes equation the rate of the different fractions and the mechanical composition of the soil sample can be defined. The soil type was determined by the clay and silt content (less than 0.02 mm particle diameter) (Buzás, 1993).

Beside the soil measurements geophysical vertical electrical soundings (VES) were carried out. Geoelectrical methods are based on the ability of rocks to conduct electric current. Saturated rocks have lower resistivity than unsaturated and dry rocks (Müller et al., 2008). The presence of clays reduces the resistivity. The resistivity of rocks can be studied by measuring the electrical potential distribution produced at the Earth's surface by an electric current that is passed through the soil via two electrodes (A and B). The potential difference resulting is measured between a second pair of electrodes (M and N). The current and potential measurements may be used to calculate specific resistivity (Ωm). The well-known Wenner array was used to explore the very shallow depth, down to 4-5 m fast and accurately. The four electrodes A, M, N, and B are placed at the surface of the ground along a straight line so that the distance "a" between all these electrodes will be the same. In electric sounding the electrode spacing "a" is increased at successive logarithmic intervals, and the value of the appropriate apparent resistivity is plotted as function of the electrode spacing on logarithmic coordinate. The successive apparent resistivity values give a sounding curve. Numerical interpretation of the Wenner sounding curves, to obtain trough resistivity and layer thickness, is not yet done because sharp layer boundaries does not exist in these sediments (Müller et al., 2008; http://www.epa.gov/esd/cmb/GeophysicsWebsite/pages/reference/methods/Surface_Geophysical_Methods/Electrical_Methods/Resistivity_Methods.htm).

In the present paper only qualitative interpretation of apparent resistivity data is used.

With the Wenner array five measuring points built up our sounding curves at every sounding location. The spacing between A-M-N-B electrodes which are marked with "a", are: 0.25 m, 0.5 m, 1 m, 2 m and 4 m. The depth of the sounding is estimated with the favourite rule-of-thumb, the electrode spacing is equal to the depth of probing (Müller et al., 2008).

At the "A" pilot- study area 13, at "B" area 8 and at "C" area 12 geophysical soundings were carried out crossing the old riverbeds. The mechanical composition of the soil samples from the drillings and the apparent specific resistivity measured on the same location were compared. In the next step the existing visible correlations between resistivity values and the characteristic of the different soil types were estimated. This relation was used to draw the soil profiles of the pilot-study areas transforming the resistivity values to different soil types.

Results and Discussion

The results of the soil analysis were summarized in Table 1. The upper layer of the first drilling was silt but deeper sand was also found. In the case of the second drilling the upper layers were clay, silt and clay, following by silt and sand in the deeper layers. The top layer of the third segment was silt but deeper clay was the specific sediment. The soil types of the fourth and fifth drillings were similar to the first one; the upper layer was silt, but in deeper layers sand were found. In the case of the sixth segment only sand was defined.

The following diagrams present the results of the geophysical soundings in log-log scale, measured at the drilling points. On the X axis the "a" values were represented, which means the distance between the

electrodes and corresponds approximately to the depth penetration of the sounding. On the Y axis the apparent resistivity can be seen. Also the specific soil types of the sample were represented on the graphs. In the case of the first drilling the resistivity is about 37-51 Ωm down to the depth of about 1 meter. The characteristic soil type of this layer was silt. Deeper sand layer was detected. The changing of the soil type was presented with the increase of the resistivity (Fig. 1).

Table 1 Mechanical compositions and soil types

Segment	Sample number	Clay %	Silt %	Sand %	< 0.002 mm particle diameter (%)	Soil type
Drilling 1	1/1	19.0496	59.8905	21.0600	49.6619	silt
	1/2	21.5352	58.7098	19.7550	47.4064	silt
	1/3	13.6442	51.2468	35.1091	41.3578	silt
	1/4	4.9299	15.6053	79.4648	12.0899	sand
	1/5	2.4372	11.4963	86.0665	9.2516	sand
Drilling 2	2/1	27.1802	59.9584	12.8614	66.2139	clay silt
	2/2	41.0870	56.3289	2.5841	80.0533	clay
	2/3	36.9387	51.7346	11.3267	74.9634	clay
	2/4	8.5219	74.7636	16.7144	30.2374	silt
	2/5	6.4720	74.8624	18.6656	18.1380	sand
Drilling 3	3/1	27.2571	42.3131	30.4298	57.0972	silt
	3/2	16.8456	81.4284	1.7260	83.7748	clay
	3/3	22.3113	68.8513	8.8374	75.1888	clay
Drilling 4	4/1	9.6633	35.1996	55.1371	30.1572	silt
	4/2	13.4560	29.8111	56.7329	29.4424	sandy silt
	4/3	15.7243	22.9629	61.3128	27.8697	sandy silt
	4/4	2.8703	6.4462	90.6834	6.0614	sand
Drilling 5	5/1	11.9808	59.1258	28.8934	40.8060	silt
	5/2	10.2950	58.7754	30.9296	35.2231	silt
	5/3	8.7461	51.6393	39.6146	27.7847	sandy silt
	5/4	7.0208	39.5586	53.4206	24.7907	sand
Drilling 6	6/1	6.4355	41.1773	52.3872	21.6935	sand
	6/2	3.0026	14.5635	82.4339	7.4664	sand
	6/3	3.8938	22.6390	73.4672	11.2310	sand

The geophysical sounding at the second drilling gave lower specific resistivity values as in the case of the first one. Down to the depth of 1 meter the values were situated between 13 and 32 Ωm and the soil type is clay and silty clay. The deeper layers were silt and sand layers. However, the specific resistivity values were not so high, which ought to characterise sand. This can only occur because of the presence of some conductive lenses (Fig. 2).

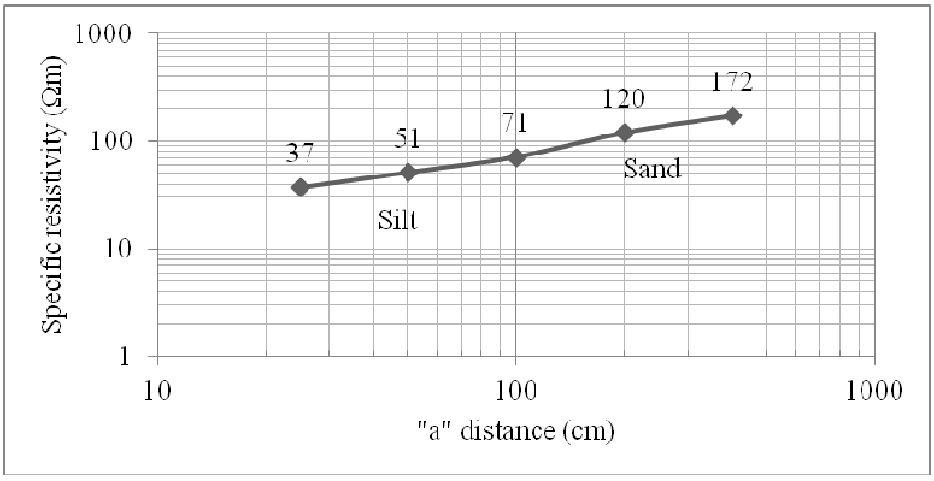

Figure 1. Results of the geophysical sounding at the 1st drilling

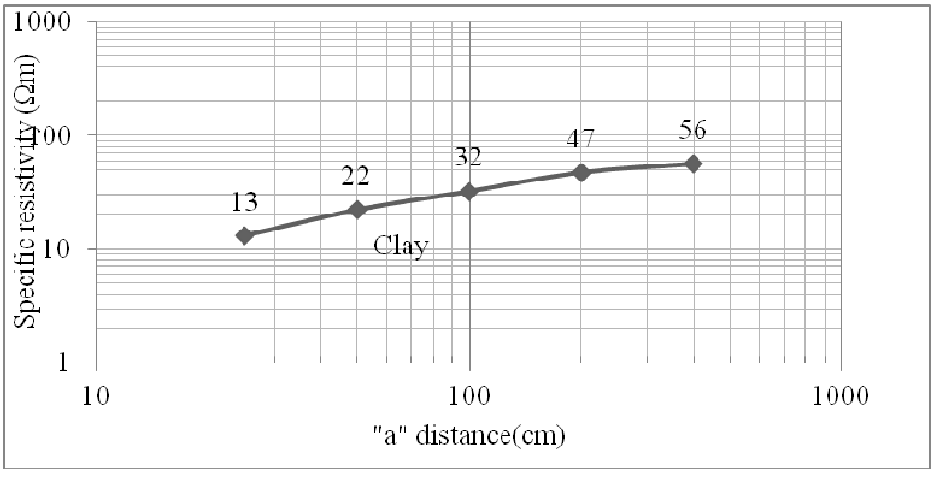

Figure 2. Results of the geophysical sounding at the 2nd drilling

The topsoil of the third segment was silt but the deeper clay was also present. With the change of the soil type the resistivity values varied simultaneously. The values in the case of the topsoil were situated between 63 and 44 Ωm but deeper, in the clay layer lower resistivity values were measured in the range of 20 Ωm (Fig. 3).

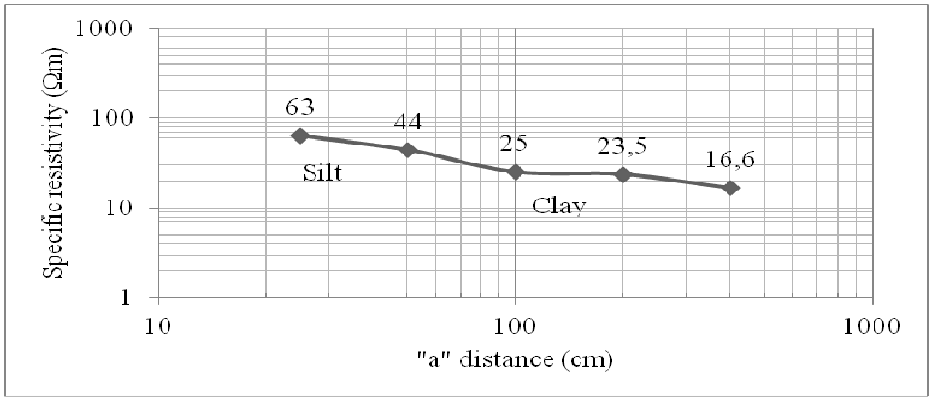

Figure 3. Results of the geophysical sounding at the 3rd drilling

The topsoil of the fourth segment was silt with the specific resistivity of 88 Ωm. Below a thin silt layer, sand and sandy silt were found. The resistivity values are about 110 and 203 Ωm in these layers (Fig. 4).

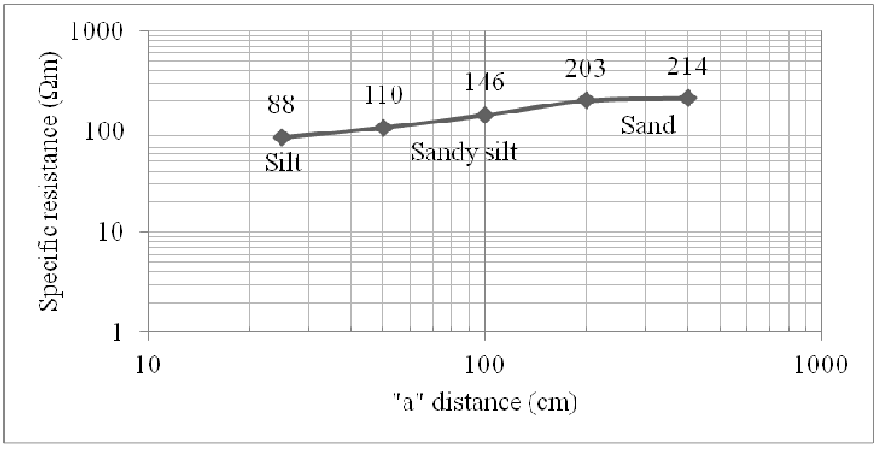

Figure 4. Results of the geophysical sounding at the 4th drilling

The upper layer of the next segment was silt and the resistivity values were 37 and 39 Ωm. Deeper, at 150 cm sandy silt and sand can be found. The resistivity values were similar to the second segment, probably due to the presence of the soil lenses (Fig. 5).

The first measured resistivity value at the sixth profile was 75 Ωm, indicating a thin silt layer but in the lower layers the results of the soil analysis were sand with higher resistivity between 117 and 326 Ωm (Fig. 6).

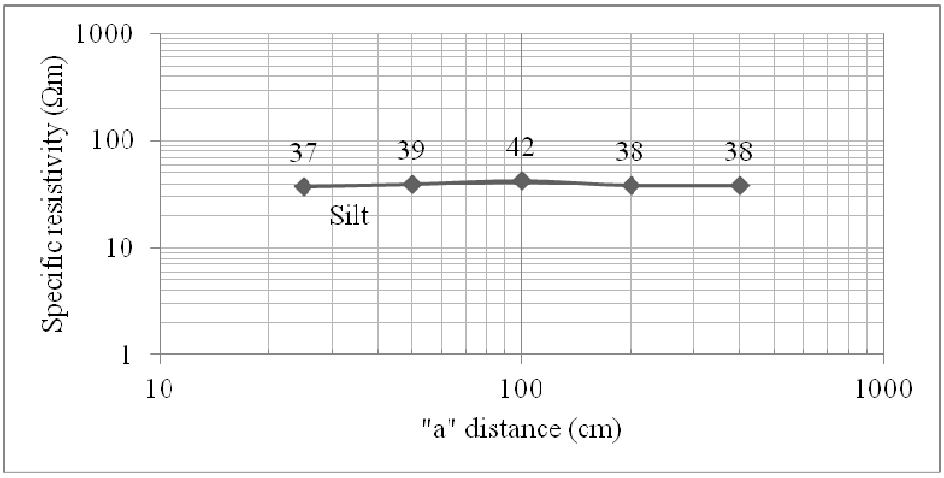

Figure 5 Results of the geophysical sounding at the 5th drilling

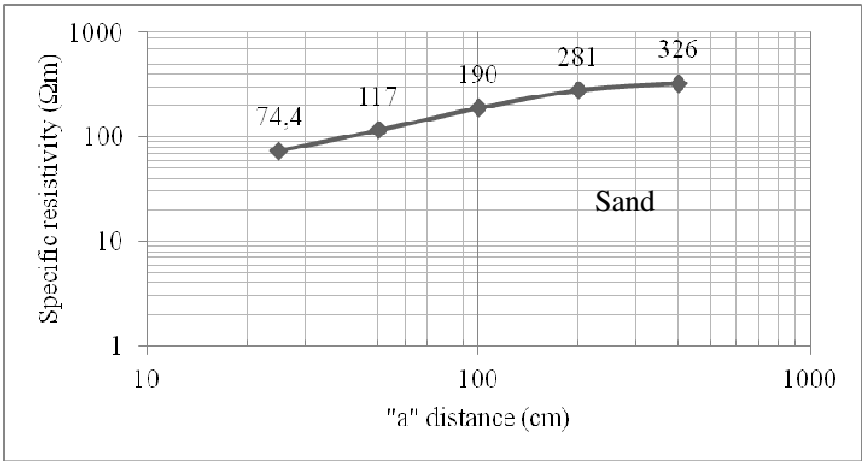

Figure 6. Results of the geophysical sounding at the 6th drilling

Comparing the soil types from drillholes to the resistivity values measured in the same location, we concluded, that the clay sediments give the lowest specific resistivity values, less than 30 Ωm. The specific resistivity values of silt were between 30 and 100 Ωm and the values of sand are more than 100-110 Ωm. These typical values can be explained with the different water holding capacity of different soil types, related to the porosity of the rock and the salinity of the saturating fluid.

Calibrating and correlating the drilling results and the characteristic values of rock resistivity, we attempted to draw the sedimentary soil profile of the three pilot-study area crossing the old riverbeds.

On Fig. 7 the soil profile of the “A” study area was presented. On the northwest side of the profile the resistivity values indicated the presence of silt. Moving to the middle of the old riverbed the specific resistivity values were continuously decreasing.

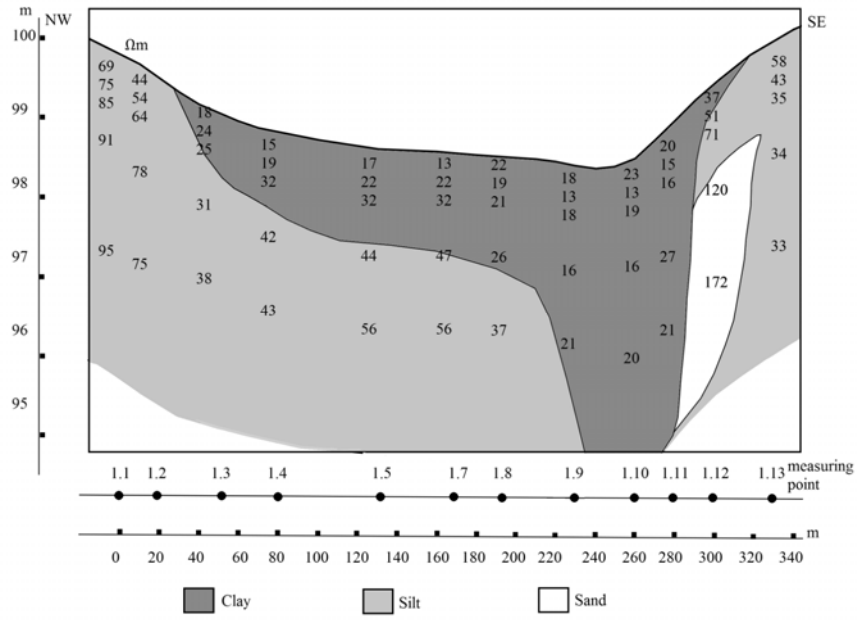

Figure 7. Soil profile of the "A" study area

From the measuring point 1.3 clay in the upper layer is observed. By measuring point 1.9, 1.10 and 1.11 the soundings gave low specific resistivity values, approaching the category of clay. This means that there was a thick clay layer. Moving to the direction of the riverbed edge the resistivity values start the increase, and the clayey soil is changing to silt. At the measuring point 1.12 below the clay and the silt layer sand was detected, which can be presented there as a result of slipping from the steep edge.

In the case of the soil profile of the "B" study area on the western edge, high resistivity values were measured. For example at measuring point 2.5, more than 100 Ωm resistivity values were detected, which indicate the beginning of a sand layer. Moving from the edge of the riverbed to the direction of the centre, the resistivity values decreased. At the measuring point 2.4 and 2.3 silt was the typical sediment, but at 2.2 and 2.1 below a thin silty deposit clay was detected (Fig. 8).

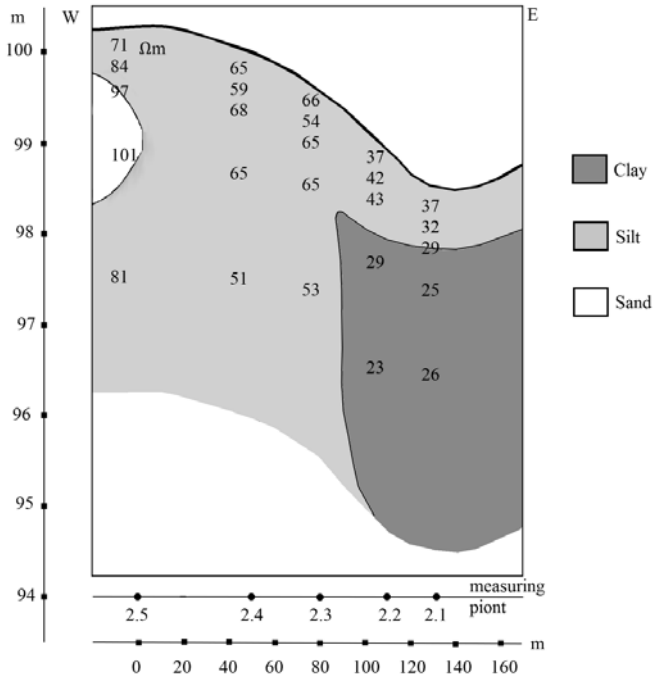

Figure 8. Soil profile of the "B" study area

On Fig. 9 the soil profile of the “C” study area was presented. On the northern edge of the riverbed at first silt sediment was measured but below sand layer can be found with high, 131-200 Ωm specific resistivity. Moving to the centre of the riverbed, the silt appears again. From the measuring point 3.3 a thin clay layer is detected, which seemed to move to the centre of the riverbed. From the measuring point 3.4 to 3.8 only clay was detected with the geophysical sounding. From 3.8 the clay layer was covered by a thin silt deposit. Moving to the southern edge the specific resistivity values increased and the clay was turning to silt, later to sand.

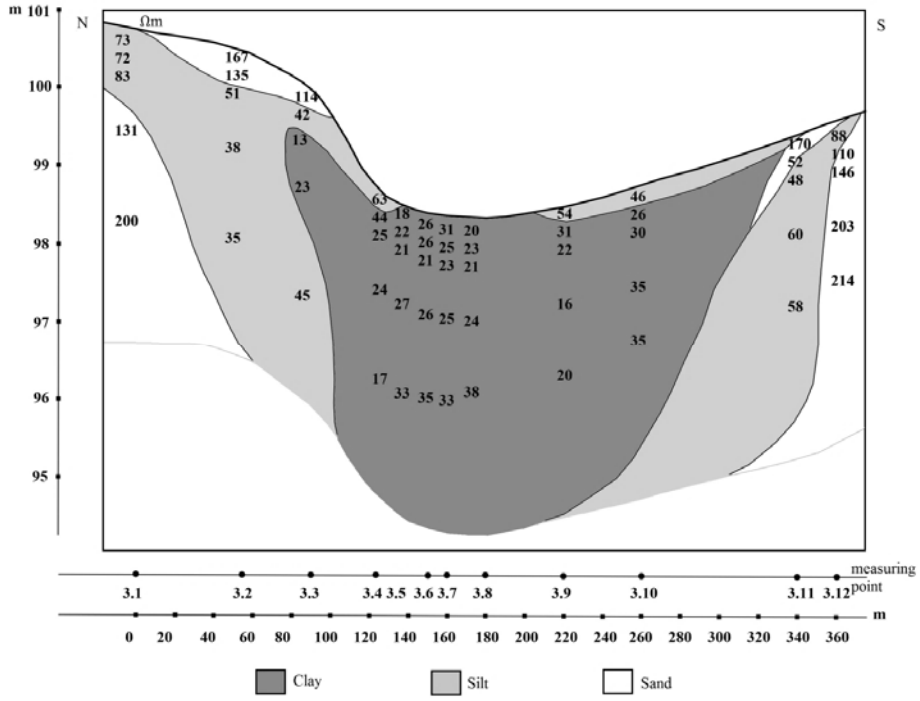

Figure 9. Soil profile of the "C" study area

Conclusion

Comparing the soil types to the specific resistivity values measured in the same location, different soil types in the surveyed area could be characterised by the following resistivity values: clay: < 30 Ωm, silt: 30-100 Ωm, sand: > 100 Ωm.

On the three soil profiles, the central area of the old riverbeds appeared as a few meters thick clay layer with low resistivity values. Moving from the middle to the edges of the river beds the resistivity values increased and the clay was replaced by silt and later by sand.

It is important to know that if artificial streams were led on the old riverbeds, the thickness and the permeability of the sediment would be enough to keep the water in place, on the surface. If we accepted the log-log correlation of Müller et al. (2008) concerning resistivity and hydraulic conductivities in the saturated zone, we could conclude, that the measured resistivity data in the pilot-areas indicate the presence of thick and low permeable sediment. In the central areas of the old river bed the hydraulic conductivity of clay deposits could be estimated about 10^{-7} m/s and outside from the bed, the sand deposits about 10^{-4} m/s.

This sedimentary setting and permeability distribution in the old riverbed indicate that surface water infiltrations into the water table would occur much more laterally, in sands, and less vertically in the clay.

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APPLYING VEGETATION MAPS IN THE CALCULATION OF PLANT COMMUNITIES AREA IN KIS-BALATON

Veronika Kozma-Bognár [1], Péter Szeglet [1], Piroska Pomogyi [2*]

1. University of Pannonia, Georgikon Faculty, Keszthely, Hungary

2. Middle-Transdanubian Water Directorate, Székesfehérvár

kbv@georgikon.hu, szeglet@georgikon.hu, pomogyi@kdtvizig.hu*

Abstract

Vegetation maps of Kis-Balaton were made since 1980 knowing the changes of the marsh vegetation. For the changes of the environmental factors for the stresses the plants reacts, they often react as indicators, so we can make conclusions for the ecological condition, for the environmental stresses, and for the biodiversity of the biotopes. In this paper the results of the vegetation mapping made for the Lake Fenéki in the time-series are shown, in connection with area calculation. Despite of the big heterogeneity characteristic for our sampling area using the times-series aerial photographs the dynamic of the changes can be easy describe, and calculate. Considering spatial spreading the main plant communities, and using the crop coefficient the evaluation of the regional evaporation can be estimated more exactly.

Key-words: Kis-Balaton, aerial photography, vegetation maps, plant communities, macrovegetation changes

Összefoglalás

A Kis-Balaton területére vonatkozóan már az 1980-as évek óta készítenek vegetációtérképeket a magasabb rendű növényzet változásának megismerése céljából. A környezeti feltételekben bekövetkezett változásokra, stresszhatásokra a növények válaszreakciót adnak, gyakran indikátorként viselkednek, így segítségükkel következtetni tudunk az egyes élőhelyek ökológiai állapotára, biodiverzitására, környezeti terheltségére. Jelen publikációban a Kis-Balaton Fenéki-tó területére elkészített idősoros vegetációtérképek területszámítást érintő eredményeit mutatjuk be. A mintaterületünkre nagyfokú heterogenitás jellemző, ennek ellenére a vegetációban bekövetkezett változások idősoros felvételek alkalmazásával kitűnően leírható és számszerűsíthető azok dinamikája. A főbb növénytársulások területi elterjedésének figyelembevételével valamint a növénykonstansok felhasználásával a későbbiekben pontosabban becsülhetővé válik majd a területi párolgás.

Kulcsszavak: Kis-Balaton, légifelvételek, vegetációtérképezés, növénytársulások

Introduction

Data supplied by remote sensing and Geographic Information System (GIS) have of the utmost importance for getting information about our environment. The plant research methods based on remote sensing, supplemented with surface data collecting techniques, significantly support the exact and reliable data collection in the course of defining land cover categories. They can be used in situations, in case of protected, or hardly accessible territories, or if the land cover is rather heterogenic (Goetz et al., 2007). For these reasons in many researches in the course of investigation of vegetation pattern the use of

remote sensing data happens (Dronova et al., 2012, Berke, 2010, Klenoid et al., 2005). If the aim of the research is to detect changes in the plant communities, vegetation maps based on aerial -, or satellite images give essential information (Kelly, 2011, Zlinszky 2012). The key objective of the vegetation mapping is to follow the changes in the structure of the vegetation caused by changes of environmental factors and by identifying the principles the possible impacts of further changes can be forecasted. Analysing time-scale structure of vegetation maps hydrobiological, ecological, botanical changes can be detected. space structure can be detected. With the help of this information the ecological state, biodiversity, and the environmental load can be concluded.

Connecting diverse data sets in GIS database all information regarding the vegetation changes can be handled together (Dömötörfy, 2003). Time-series monitoring of GIS databases can provide useful information for identifying and understanding problems of other phenomenonspecialites, e.g. climate change.

From 2012 at the University of Pannonia Georgikon Faculty Department of Meteorology and Water Management evaporation researches have been carried out that aim is to estimate the evaporation of Kis-Balaton area considering crop coefficients (Anda et al., 2014), and their spatial spreading. The basic pillar of these researches are spatial data sets based on the vegetation maps, that insure a comparison base for further evaluation of the results of aerial- and spatial measurements.

Materials and Methods

Research area

The Kis-Balaton together with the Lake Balaton composes a special ecological system and designated for the ”List of Wetlands of International Importance” in 1979 and 1989, respectively (Website of the Ramsar Convention on Wetlands) The need of building the Kis-Balaton Water Protection System (KBWPS) raised in 1970s, when the water quality of the Lake Balaton deteriorated. The main goal of constructing KBWPS was to moderate nutrient pollution of the Lake Balaton (mainly diffuse contamination) originated from the water reservoir of the River Zala. The KBWPS was built in two stages and consist of two lakes: KBWPS Stage I. - Lake Hidvégi and KBWPS Stage II. - Lake Fenéki (Figure 1.). In order to mitigate water quality of the Lake Balaton construction works began in 1984 with the building dams around Lake Fenéki. In 1992 the 16 km^2 area of Grove Ingói was temporarily flooded. Since that time beside the water protection goals the protecting of natural and ecological values came to the view, and this resulted the beginning of the investment of the biological monitoring of the 75 km^2 area KBWPS II. Stage in 2012 (homepage of the West-Transdanubian Water Directorate).

We choose as sampling area for our investigations the Lake Fenéki in KBWPS II. , extending 54 km^2 between Balatonhídvég and the firth of the river Zala. There are 15 water bodies distinguished in the area of Lake Fenéki. The borders of the water bodies are mainly line shape establishments from 1992 like dams, dykes, channels, and ways, paths, because it was assumed, that they can be identified in the future, too. After 2007 an extra water body (nr. 16) was connected to the system, the Zalavár inland water bay.

Figure 1. Map of the Kis-Balaton Water Protection System (Pomogyi, 1996)

Taking into account the heterogeneous plant stands and the main plant communities the following categories were identified: reed stands, other herbaceous marsh plants, trees, terrestrial grass, terrestrial forest, open water, seaweed.

Vegetation mapping

Survey of the vegetation and its classification was made with the traditional method of digital vegetation mapping. The applied method is suitable for making well detailed and precise vegetation maps of the Kis-Balaton that meets our expectation and aims. The process of vegetation mapping basically consists of tree subfields: othophotos, field measurements, and data processing based on the given information. Aerial photography and vegetation mapping were managed until 2006 in the frame of the investment program with the organisation and contribution of West-transdanubian Water

Directorate , in 2007-2008 in the frame of the preparing program finishing the KBWPS II., with the organisation of the Aquaprofit Ltd.

Orthophotos

The vegetation mapping of the Kis-Balaton begun in the early stage of the building works in 1982 before flooding the KBWPS I. Stage (Lake Hidvégi) (at that time with field methods) (Pomogyi, 1985). With these research works the regularly hydro biological-, ecological investigation of Kis-Balaton has began and since than monitoring extended to the territory of the Lake Fenéki (KBWPS II. Stage), too (Szeglet et al., 1998). Since 1985 the vegetation maps are made on the basis of colour infrared (CIR) aerial images with surface interpretation. From the year of 2000 quality change happened, the vegetation maps were made on the basis of digital orthophotos with high resolution. In 1999-2000, due to the developed technical methods, it became feasible to convert the original CIR negatives of Lake Fenéki 1988 aerial images into substantially better quality images, so called "quasi-digital orthophoto (Pomogyi és Dömötörfy, 2002). The elaboration of the aerial images changed radically in course of time, the image processing was initially in an analogue way, and from 1999 making othophotos became general.

Field measurements

The basic aim of the field interpretation is identification of the vegetation units, and other mapping units, the identification in the othophoto visually recognisable spots, the survey, and documentation of the sampling areas. The terrain photo documentation measured with GPS, and fitted in HD72 Oblique Conformal Cylindric proves the vegetation characteristic of the given time and place. This documentation method has been applied since 2003 in Kis-Balaton. Because the vegetation mapping can only be made in the vegetation period, when the plants can be recognised and identified in all developed

living conditions. The field measurements and the observation of vegetation from boat began at the beginning of springtime. In territories covered by marsh plants – reed, bulrush, sedges – being under water, where boating is impossible, the field measurements could be made using SEIGA reed harvesting machines. This should be carried out in late autumn, at the end of the vegetation season, when the wheels of the machine does not cause damage in the emerging shoot, and the tread damage could be minimised.

Data processing

For data processing, vegetation map preparations and territorial data visualization ArcInfo/ArcView GIS system was used. Applying digital orthophoto CIR the spots of the plant were marked on the screen, they were measured earlier by GPS. On the territory of KBWRS II. Stage the applied digital othophotos having 0,5x0,5 m high resolution give opportunity to mark spots in 100-200 m^2 with acceptable accuracy, if there is need because of a plant stand with particular interest. In the course of data elaboration we solved the coupling between the data collected on the surface (field notes, photos, etc.) and the maps. After with the help of aerial images, field notes and photos the plant spots were identified, and was given a cönotaxonomical code. To the main taxonomical groups colour code was given, the groups in lower rank were signed by graphical signs used in maps. All this gave the signal code. After the controlling process had finished the editing of the database, making the selection, the layouts, the vegetation maps for demand, editing the printing forms, and the evaluations were prepared.

Results

In the course of our research the changes in the spatial expansion of plant communities and in the tendencies were calculated for the whole region of the Lake Fenéki, and for its two parts: the Grove Ingói, and the water

reservoir Zalavár. Based on the results we stated, that before flooding the Grove Ingói (1988 and 1992), and its first stage the cover of reed stands, and herbaceous marsh plants were mostly the same. it can be seen from the data in Figure 1. the cover of the reed stands (reed and bulrush) did not changed: with minimum variation coefficient: CV= 3%. The linear trend line is slightly rising. In a similar way, the tendency of terrestrial forest (because of plantation), and open water/water weed (because of the flooding of Grove Ingói) also slightly increased. The territory of herbaceous marsh plants decreased after 1995, althoug in the last years it was a moderate declining tendency. The territorial changes of the terrestrial grasses, and other herbaceous plants is also slightly decreasing (Figure 2.).

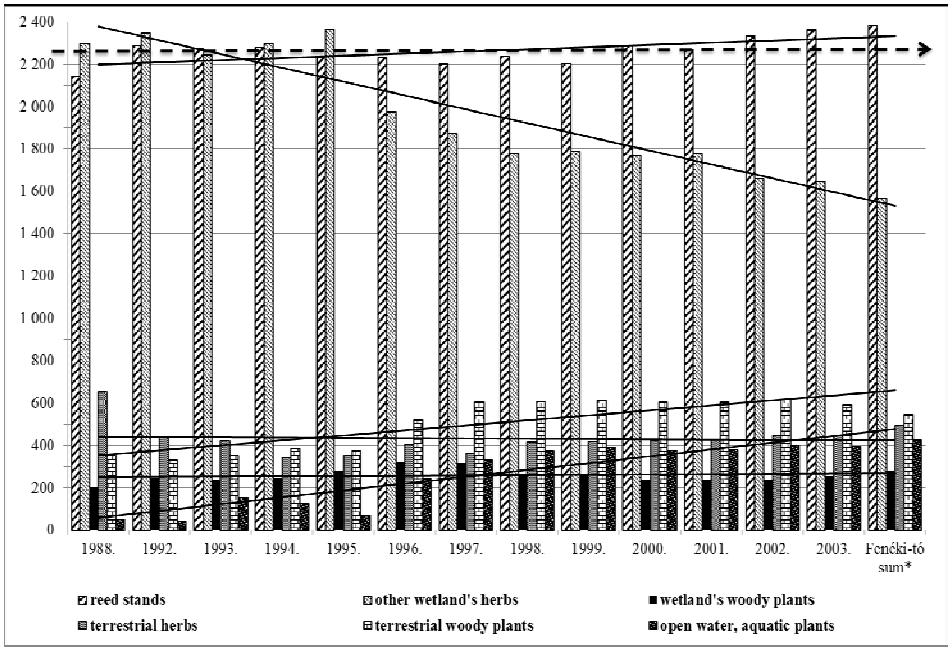

Figure 2. Changes of different plant-groups areas at the KBWPS's Lake Fenéki (ha), between 1988 and 2008, with the lines of trends

This tendency can be concluded to the forestation of the edge territories. Comparing with the main tendency of the changes of Outer-part (Figure 3.), it can be stated that the result is very similar except the open water, and water weed surfaces.

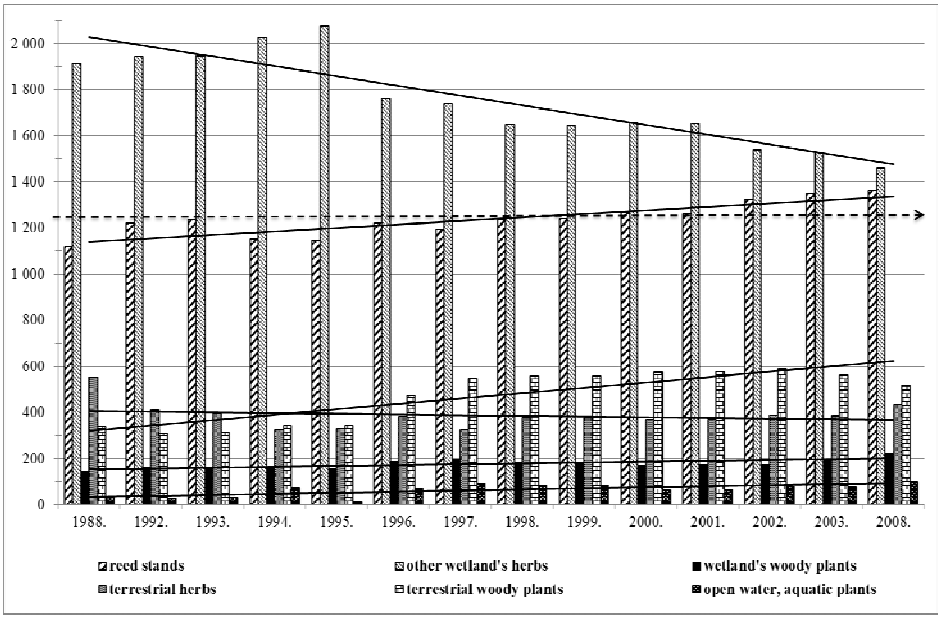

Figure 3. Changes of different plant-groups areas at the Outer-part of the KBWPS's Lake Fenéki (ha), between 1988 and 2008, with the lines of trends

Compared with the Grove Ingói (Figure 4.), it can be seen, that the territory of reed has a slightly declining tendency (average: 1027 ± 4%), but between 1988 (1025 ha), and 2008 (1019 ha) the territorial difference is not significant. After 7-8 years of installation there was a minor fluctuation in the territory of reed, but after 2000 it seems to be stabilizing in about 1000 ha. The proportion of the other herbaceous plant is reducing in the territory of Grove Ingói, the open water, and water weed surfaces are growing at the same time. The other mapping groups are less changeable.

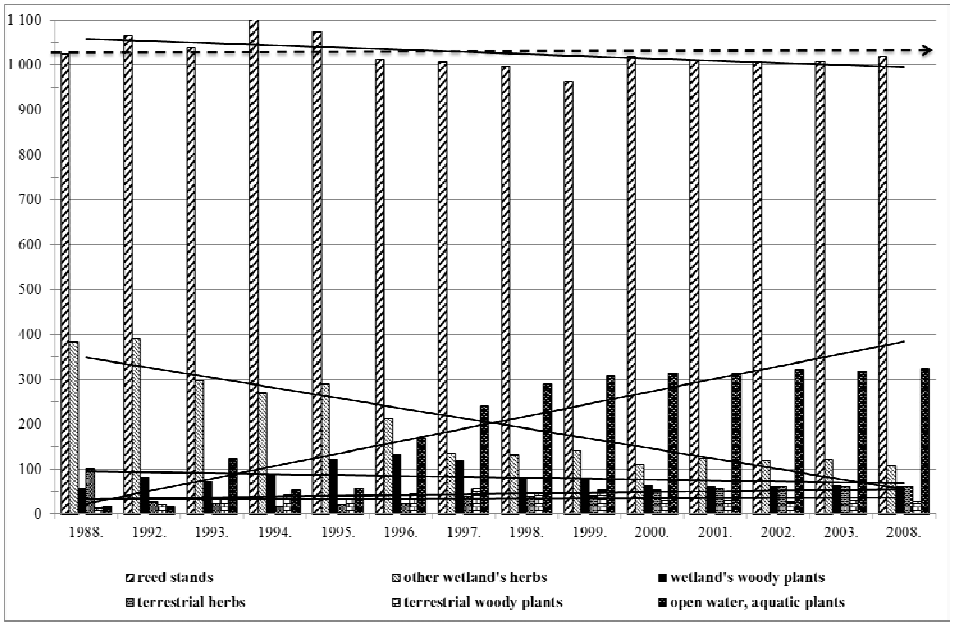

Figure 4. Changes of different plant-groups areas at the Grove Ingói of the KBWPS's Lake Fenéki (ha), between 1988 and 2008, with the lines of trends

The main cause of the changes is, that the Grove Ingói is a 16 km^2 subfield surrounded by dams, where there is no natural area for forest plantation and for natural shrub vegetation, except for the lover part of the dams, and the connecting highlands (e.g. Island Diás).

The water- and/or marsh vegetation can only occupy the habitat at the expense of each other. This happened after a short period of installation of Kis-Balaton Water Protection System. The changes and its trends differ significantly from each other in the four water bodies of the Grove Ingói:

I. On the water body 1 the territory of marsh herbs from 200 ha dropped down fast, with nearly one order of magnitude to the 1/10, in parallel the surface of open water, and water weed grew rapidly. This surface was periodically covered by water and now with 70-100 cm streaming, or standing water, where the place of high sedge vegetation occupied the water

weeds alternately with open water. This water body is the upper part of Lake Fenéki, which gets the water from KBWPS I. Stage (Lake Hidvégi)determining the water quality, too. The stress reaction of the vegetation in the first period is clearly seen. The territorial changes of other plants took place in the first 5-6 years with high extremities, but after 1998 remain unchanged. The tendencies can be characterised by polinoms.

II. On the next water body 2 in the flow direction the tendencies of changes are similar to the water body 1 so far, that the reed territories were slightly diminished, but the standard deviation of the 20 years average was only 4% (345 ha ± 4%), and can be described with 2nd grade polinom.

On this water body as well, the place of other marsh herbaceous plants were occupied by the open water/water weeds in 100%. The participation of other groups can be neglected.

III. The water body 3 can be found East to the deflector dam. The water arriving to this water body comes from Lake Hidvégi and had already gone through the reed and bog of water body 2, with a different water quality from the upper part. In this territory are characteristic bog, and the ecological circumstances determined by reed vegetation staying in water since more hundred years. In the mean time Gyöngyös-Páhok channel was lead to the water body, which water reservoir is about 225 km^2, but its effect on the macrovegetation cannot be detected according to the reults of the vegetation mapping. On the about 560 ha territory the plant groups beside the reed does not reach 50 ha. To illustrate the territorial distribution the best way was to use logarithmic scale. The whole territorial change of reed within 20 years showed 2 ha CV% (average 522 ha ± 2%), in such a way there is no importance to put trend on this water body.

IV. The trend of the plant territorial change on the water body 4 differ from the other ones mentioned above. Beside the territory of the marsh

herbaceous plants, apart from reed after 2000 became about 15-20% less, then before the installation (1988, 1992), and the trend can be characterised with a linear diminishing curve (R2=0,5), the change seems to be more complicated. A 2nd grade polinom can be better fitted (R2=0,7), and shows more accurately the concrete changes, too. The territorial changes of reed is nonlinear, the growing and decreasing segments clearly differentiate. The long-term average of changes varies between wider extremes (141 ha ± 13%). In the first period after installation the territory of both plant groups showed growing tendency, while the territorial participation of the terrestrial herbaceous plant and trees growing in marsh diminished. After 2000 the territory of reed was growing, the territory of other marsh herbaceous plants was diminishing, while the territory of terrestrial herbaceous plants, and trees was slightly growing, and the surface of open water/water weed was detected.

Conclusion

On the changes of space-time structure of the macrovegetation of Lake Fenéki beyond the natural, or almost natural so called "classical" ecological circumstances the direct human impact - carrying out the investment program - act drastically. For these impacts the living organism, the vegetation gave a fast answer, which we can consider as a stress reaction. During our research work the analysis of the macrovegetation changes were achieved. According to the results of our investigation we decided to take vegetation maps of 1992 as basis. The main reason for our decision was that the earlier survey in 1988 was less detailed, the mapping methods were not so developed. The state in 1988 posteriorly elaborated digitally and can be used to supplemental analysis, in doubtful cases for corrections, or to state assessment of technical impacts. We propose the consideration as background documentation, too. Using the area calculation data based on the time-series vegetation maps of

Lake Fenéki, and the crop coefficient measured in situ the evaporation can be calculated. In future investigation we plan to calculate the changes of the climate with weather generator to which the dynamic of vegetation change will be adjusted. At the end of our investigation a prognosis will be given from the evaporation of Lake Fenéki.

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THE EFFECT OF LIVE PREY FISH FEEDING ON ACCEPTANCE OF DRY FEED OF PIKEPERCH *(SANDER LUCIOPERCA* L.*)*

Zoltán Horváth Jr[1*], Gabriella Morvai [2], Sándor Németh [1], Gábor Beliczky [1], Szabolcs Nagy [1], Zoltán Horváth [2], Miklós Bercsényi[1]

[1]*University of Pannonia, Georgikon Faculty, Keszthely, Hungary*

[2]*H & H Carpio Fishfarming Ltd., Szentlőrinc, Hungary*

*hhori2@gmail.com

Abstract

The aim of the experiment was to find out whether pikeperch *(Sander lucioperca* L.*)* trained on pellet feed would accept artificial pellets again, after consuming prey fish. Yearlings of pikeperch previously accustomed to pellet feeding were subjected to the following four treatments during a 23 day long experiment:

- Control (C): fish were fed with pelleted feed during the whole experiment
- Two days (2D): fish were fed with topmouth gudgeon (*Pseudorasbora parva)* for two days and after one day of starvation, with pelleted feed until the end of the experiment

- Eight days (8D): fish were fed with topmouth gudgeon for eight days and after one starvation day with pelleted feed until the end of the experiment.
- Fifteen days (15D): fish were fed with topmouth gudgeon for 15 days and after one starvation day with pelleted feed until the end of the experiment.

The fish accepted dry pellets after two as well as eight days of predation, but refused to do so after 15 days of predation. Growth loss was observed in the 15D groups, although in the other treatments the growth rate also dropped. Even then, the difference was still significant between the 15D treatment and the others. According to the results, a few days of prey fish feeding does not affect the acceptance of dry feed in pikeperch.

Key-words: pikeperch, dry-feed, prey fish

Összefoglalás

Vizsgálatunkban arra kerestük a választ, hogy a táp elfogadására megtanított süllő *(Sander lucioperca* L.*)* folytatja-e a tápevést zsákmányhal fogyasztás után. Négy kezelést alkalmaztunk a 23 napos kísérlet során:

- Kontroll: a halakat kereskedelmi táppal etettük végig a kísérlet ideje alatt.
- 2 napos kezelés: A halakat 2 napon keresztül etettük kínai razbórával (*Pseudorasbora parva),* majd egy nap kihagyás után, ismét táppal kaptak.
- 8 napos kezelés: 8 napon keresztül etettünk zsákmányhalat, majd egy nap kihagyás után kezdtük meg ismét táp etetését ezekben a csoportokban.
- 15 napos kezelés: 15 napos razbóra fogyasztás, és egy nap szünet után kaptak ismét tápot a süllők.

A halak a 2, és 8 napos ragadozás után is folytatták a tápevést, míg a 15 napos ragadozás után már nem tudtak visszaszokni a tápfogyasztásra. A 15 napos kezelés esetében tapasztaltunk tömeg csökkenést, de ezzel együtt a többi kezelésnél is visszaesett a tömeggyarapodás. mértéke. Ennek ellenére még mindig szignifikáns különbségeket találtunk a 15 napos kezelés és a többi között. Az eredményeink alapján megállapíthatjuk, hogy tápra szoktatott süllő néhány napos zsákmányhal fogyasztás után még könnyen visszatér a tápfogyasztáshoz, két hét ragadozás után azonban nagy valószínűséggel elveszíti ezt a képességét.

Introduction

The intensive farming of European percid fishes started in the last 15-25 years (Kestemont & Mélard, 2000). The biggest interest on the European markets is in pikeperch, due to its good meat quality (Policar et al. 2012). The markets are undersupplied. In Eastern Europe, pond production is unstable, and it is unlikely to increase in quantity due to the limited availability of prey fish (Hilge & Steffens, 1996). The only way to increase the production is by using intensive systems, which is now done mainly in Western Europe (Policar et al. 2012). Now a lot is already known about the weaning of pikeperch fry (Ostaszewska, 2005; Zienert & Heidrich, 2005; Kestmenont, 2007; Szkudlarek & Zakęś, 2007; Szczepkowski, 2011; FAO, 2012), and fingerlings (Zakes & Demska, 1998; Ljunggren et al., 2003; Zienert & Heidrich, 2005; Bódis et al. 2007; Policar et al. 2012; FAO, 2012) to artificial diet.

The intensive systems used for grow out phase are mainly indoor recirculating systems (Philipsen & de Braak, 2008; Rónyai & Csengeri, 2008). There were also experiments (Bódis & Bercsényi, 2009; Schlumpberger & Zeitbarth, 1981) carried out in cage systems. Jokelainen et

al. (2009) suggest this type of production system for grow out phase in Finland, but also mention RAS (recirculating aquaculture system).

In Eastern Europe in the last five years, a few newly adapted combined technologies are becoming more and more popular. In Hungary, due to the increase in production costs (Gyalog et al., 2011), some farmers started to use pond-in-pond and pond RAS technologies (Juchniewicz, 2009; Borbély, 2008; Gál et al., 2009; Gál et al., 2010; Gál et al., 2011). Pond-in-pond technology is a system, where floating fish tanks are stocked intensively in an extensive pond. The clean water filtered by the pond is pumped through the tanks. The pond RAS is a production system, where few intensively stocked small ponds are connected to a bigger extensive pond. The water is pumped from the bigger pond to the small ponds, and then it flows back. With these systems the farmers can use their existing infrastructure more intensively with lower investment costs, than in the case of indoor RAS.

Pikeperch can be a possible candidate species for these combined systems, due to its high value. Currently it is not known what happens, when a pikeperch trained to accept artificial feed eats live prey fish for shorter or longer periods as in such systems the encounter between them is highly possible. The aim of our experiment was to find out whether the trained pikeperch will continue to feed on pellets if live forage fish was provided for a given period.

Materials and Methods

Technological parameters

The experiment was carried out in a pilot scale recirculation system. The whole system volume was 9.5 m^3, with nine fish tanks (tank volume was 635 l). The water was treated with a lamellar sedimentation tank (approximately 900 l, cleaned every three days), a moving bed biofilter (1.5 m^3) and two UV lamps (18 watt each). Twenty-five percent of the system volume was changed daily with tap water. The salt concentration of the system was maintained between 2.5-3.0 g/l (Németh et al., 2013).

The experiment took place in three fish tanks of the whole system. Each fish tank had four cages (67 l each) in it. This way we had 12 experimental groups. Each cage was aerated individually by air, with an air stone from the main air supply. In the experimental tanks oxygen supply was added for emergency purposes. Under the cages we used 10 Siberian sturgeon (*Acipenser baerii*) (average weight 400 grams) for cleaning the fish tank of faeces, and uneaten feed originating from the cages. In the other fish tanks of the system pikeperch (*Sander lucioperca*) and Siberian sturgeon were reared in a density of 12 kg/m^3 (30 % Siberian sturgeon; 70 % pikeperch).

Feeding protocol and treatments

Seven days prior to the experiment 10 individuals were randomly stocked into each cage and fed the same pelleted feed as before. After seven days the fish were measured and weighed (10.94 $\pm$ 0.47 cm; 10.43 $\pm$ 1.64 g).

During the experiment, a 3 mm pellet sized commercial feed with 49 % protein and 10 % fat content was applied. As prey fish, topmouth gudgeon (*Pseudorasbora parva)* was used. This fish is an introduced, invasive species in Europe, considered as an ideal forage fish for pikeperch. The weight of the

prey fish was 0.45-0.50 grams. Fish were fed three times a day (8:00; 13:00; 21:00) by hand in the case of artificial feed, and once a day by prey fish in the morning. In the case of pelleted feed 6 % of the body weight per day was given in order to be sure that each fish would have access to it. The prey fish was fed according to the appetite of the pikeperch in the morning. The experiment lasted for 23 days.

The trial had four treatments in three replicates:

- Control: fish were fed with commercial feed during the whole experiment (C).
- Two days: pikeperch was fed with topmouth gudgeon (*Pseudorasbora parva)* for two days and after one day of starvation, we switched to artificial feed (2D).
- Eight days: The fish were fed with topmouth gudgeon for eight days and after one starvation day, they were fed with commercial feed (8D).
- Fifteen days: We fed the fish with prey fish for 15 days and after one starvation day they were fed with artificial feed (15D).

Collected data

Total length and weight were measured in each group in the beginning, on day 16, and on the last day of the experiment (day 23). During the trial, the following parameters were recorded:

- daily: the temperature (^{o}C), the oxygen saturation (%) and concentration (mg/l) in each tank of the experiment (Hach Lange HQ-LDO),
- every two and three days: the salinity (ppt – based on conductivity) and pH (Hanna instruments, HI 98130),

- every three days: the NH_3/NH_4^+, NO_2^-, NO_3^- concentration (mg/l) (sera NH_4/NH_3; NO_2; NO_3 -Test),
- weekly: the approximate average weight/growth of fish in the other fish tank

We calculated specific growth rate (SGR) too, with the following equation:

Specific growth rate (SGR) = (lnWt - lnW0)/t x 100 (in % bw/d);

Wt: weight at time t; W0: initial weight

Data handling and analysis

The data management and descriptive statistical analysis were done by Microsoft Excel. Further statistical tests were done by SPSS 20.0. We used one-way analysis of variance (ANOVA) with a post-hoc Tukey test to test the difference between the treatment means in case of the growth data.

The length-weight relationships were evaluated by ANCOVA (analysis of covariance). We wanted to see if there is any difference between the data measured on the 15th and 23rd day of the experiment the case of each treatment separately. The idea behind the methodology is, that if there is no difference between the length-weight relationships (L-WRC) measured on the 23rd day compared to the (L-WRC) measured on 15th day in a treatment separately, it means that most of the fish were feeding. If there is a difference – the condition of the fish decreased. The minimum levels of significance were set at $P<0.05$ for one-way ANOVA, mean comparisons, and ANCOVA.

Results

Environment

With the used equipment, we could not hold the oxygen saturation above 70 % in the system with the amount of fish we were keeping in it (Table 1). The lowest oxygen saturation was 51 %. There were only 7 days, when the

saturation went below 60 % during the trial. These oxygen saturation levels result in decreased growth rate, but do not inhibit the feed intake according to Stejskal et al. (2012). The average oxygen concentration was 5.5 (± 0.6) mg/l, 6.0 (± 0.8) mg/l and 5.8 (± 0.8) mg/l in the three experimental fish tanks.

The temperature (22.3 ± 1.1 ^{o}C), pH (7 ± 0.1), nitrate concentration (34.6 ± 11.8 NO_3^- mg/l) and salt concentration (2.7 ± 0.2 ppt) showed acceptable levels and were stable during the experiment. The ammonia concentration was sufficiently low, too (0.1 ± 0.1 NH_4/NH_3 mg/l). We had problems with nitrite in the last 10 days. The average concentration in the first 13 days rose from 0.66 ± 0.2 mg/l to 2.1 ± 0.2 mg/l. Unfortunately, there is no data available on the nitrite tolerance of pike-perch. According to Krupova et al. (2005) we calculated and found that we had a high $Cl^-/N\text{-}NO_2^-$ ratio (>3000). This should be enough to inhibit the toxic effect of nitrite.

Table 1. Different water quality parameters

	0-15 days	**15-23 days**	**0-23 days**	**S.E.M of 0-23 days**
Temperature (^{o}C)	22.7	21.4	22.3	1.1
Oxygen (%;mg/l)				
Tank2	64 ; 5.3	66 ; 5.7	64.7 ; 5.5	6.9 ; 0.6
Tank3	69 ; 5.8	70 ; 6.3	69.9 ; 6	7.8 ; 0.8
Tank4	65 ; 5.5	71 ; 6.2	76.6 ; 5.8	8.1; 0.8
pH	7.05	6.99	7	0.1
Salt (ppt)	2.68	2.84	2.7	0.2
NH_4^+/NH3 (mg/l)	0.13	0.00	0.1	0.1
NO_2^- (mg/l)	1.3	2	1.5	0.8
NO_3^- (mg/l)	30	45	34.6	11.8

Even with that, in the last two weeks the growth of the fish in the other fish tanks stopped and then decreased. This can be seen in Figure 1, which shows the average bodyweight and SGR of all non-experimental fish tanks together. Please note that the experiment was between 23rd August and 14th September. The growth did not increase between 6th and 13th September, and decreased between 13th and 20th September. Even though there was still growth with a 2.49 % specific growth rate (SGR).

According to the measured parameters of the environment, we can conclude that it was not ideal, but fish production was still possible in the experimental fish tanks.

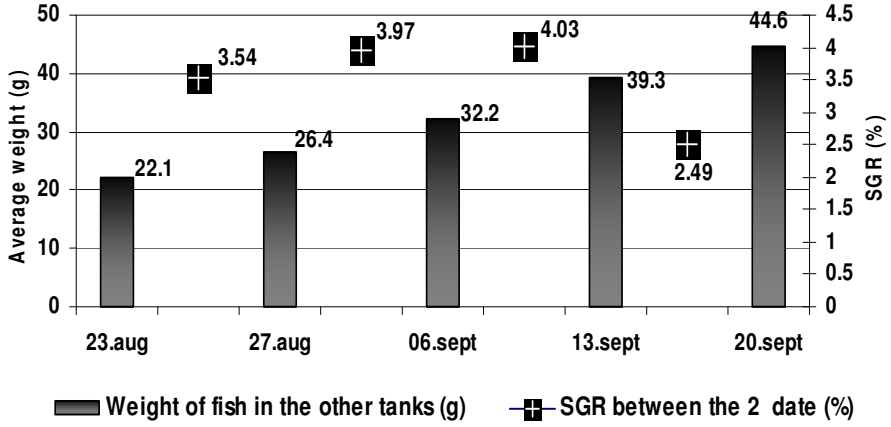

Figure 1. The average bodyweight and SGR of fish in all non-experimental tanks

** The SGR data shown describe the growth rate between the two dates.*

***The experiment was led between 23rd of August and 14th of September*

Growth results

In Figure 2 weight data on days 0, 15 and 23 are shown. At the start of the experiment there were no differences among the treatments in terms of weight. On day 15 we found significant ($p < 0.0001$) differences between the C treatment (15.2 ± 2.06 g) and the 15D treatment (18.1 ± 2.95 g). The other

two treatments (2D - 13.8 ± 2.50 g, 8D - 15.2 ± 2.19 g) significantly differed from the 15D groups in weight, but did not from the C treatment. In each treatment we experienced growth, so the fish were feeding during the experiment.

On day 23 the 2D (14.9 ± 3.21g) treatment significantly ($p < 0.0001$) differed from the 15D (17.9 ± 2.64 g) group, but not from the C (16.2 ± 2.46 g) and 8D (16.3 ± 3.34 g) groups. The 15D treatment, after its higher growth during the prey fish feeding period, lost weight (0.2 g on average) in the last week of the experiment.

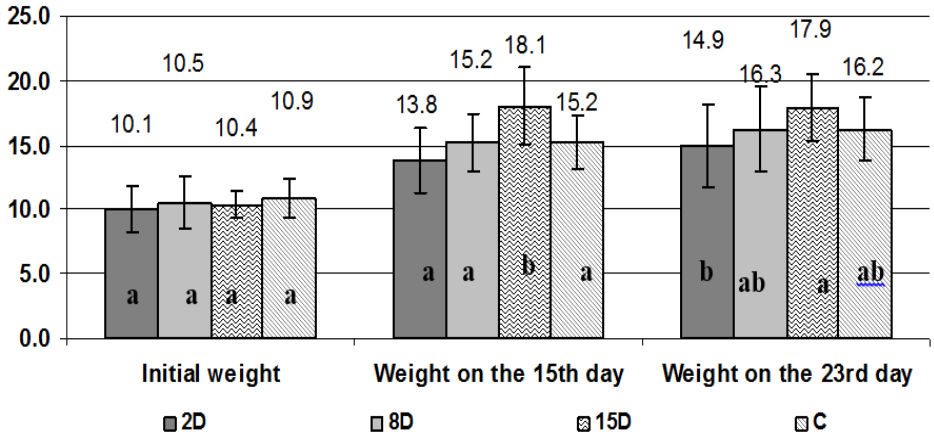

Figure 2 Average weight in each treatment on days 0, 15 and 23 of the experiment. Mean and +/- SD values are presented

Table 2 shows the calculated SGR data. In the first two weeks of the experiment the SGR was much better than in the third week of every treatment. The growth rate was significantly better in the first 15 days in the 15D treatment. In the last week of the experiment in these groups the average SGR had a negative value. In other treatments the SGR was still positive, but the growth rate dropped nearly 4 - 7-fold. The difference from 15D treatment

was still significant. This shows that in the 15D treatment the drop in growth was slightly larger than in the other treatments.

Table 2. Calculated SGR data (mean+SEM) between 0-15 days and between 15- 23 days. Different superscripts indicate significant difference at p<0.01.

	C	2D	8D	15D
SGR 0-15 d	2.4 (0.25)[a]	2.2 (0.19)[a]	2.7 (0.59)[a]	3.9 (0.2)[b]
SGR 15-23 d	0.47 (0.13)[a]	0.53 (0.26)[a]	0.47 (0.25)[a]	-0.05 (0.13)[b]

Length-weight relationship results

In Figure 3 we show the length-weight relationships of the 2D treatment. The data show that after two days of prey fish feeding all fish continued feeding on dry pellets. There was no significant difference by ANCOVA between the measured data on days 15 and 23. So the fish were still feeding after 2 days of prey fish feeding.

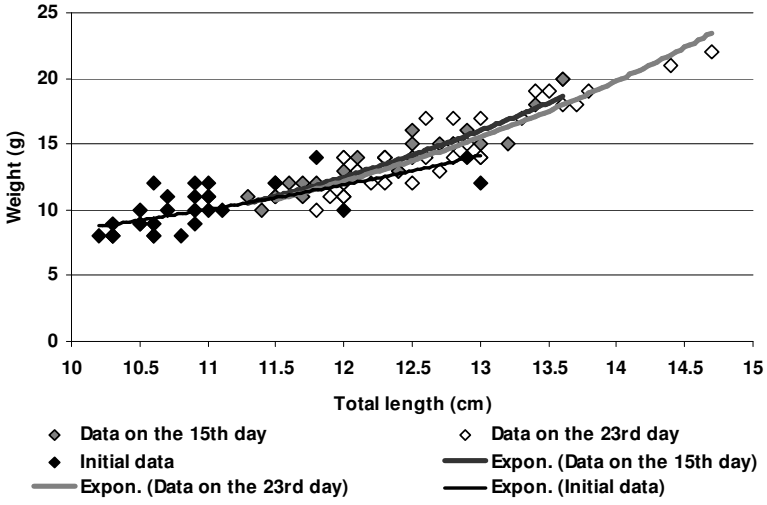

Figure 3. Length-weight relationships during the experiment in the 2D treatment

Figure 4 shows the data of the 8D treatment during the experiment. In this case too, after eight days of feeding on prey fish there was no significant difference between the data collected on days 15 and 23 by ANCOVA. The condition was weaker on the 15th day of the experiment compared to initial data. This phenomenon is the result of switching back to dry feed after 8 days. We detected the growth of the first 8 days of prey fish feeding, but then they did not start to feed on dry feed immediately. During the last week in these groups we experienced depressed growth (Table 2), just like in the control groups, and there was no significant difference between them. So the fish were still feeding after 8 days of prey fish feeding.

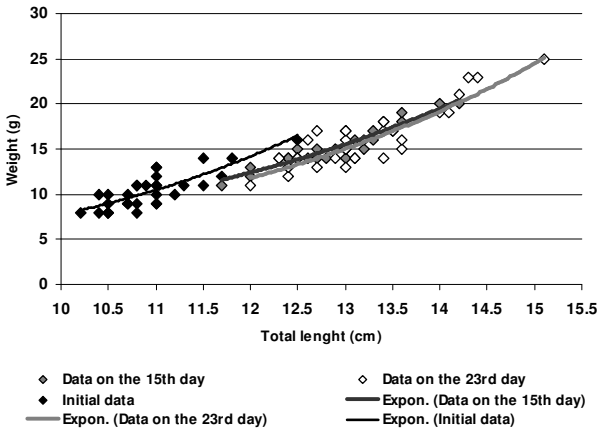

Figure 4. Length-weight relationships during the experiment in the 8D treatment

Figure 5 shows the same results in the case of 15D treatment similarly to the previous figures. The results of this treatment showed significant differences ($p < 0.000$?) between days 15 and 23 by ANCOVA. This means that the condition decreased significantly in the last week of the experiment. According to this statement the fish were not feeding on pellets after 2 weeks of prey fish feeding.

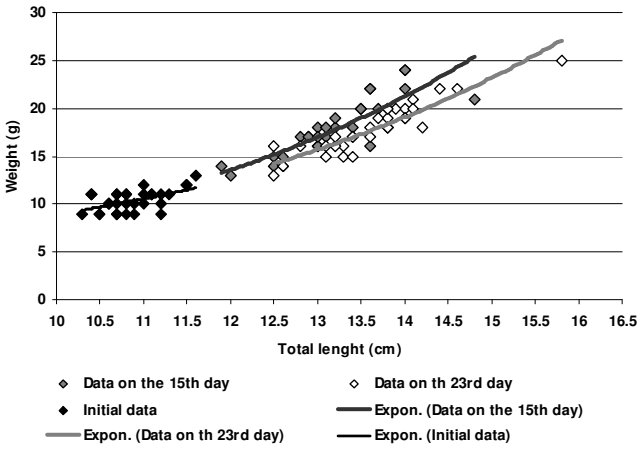

Figure 5. Length-weight relationships during the experiment in the 15D treatment

Figure 6 shows the length-weight relationships of the control group. In this case, like in the 2D and 8D treatments there was no significant difference between the last two measured data sets.

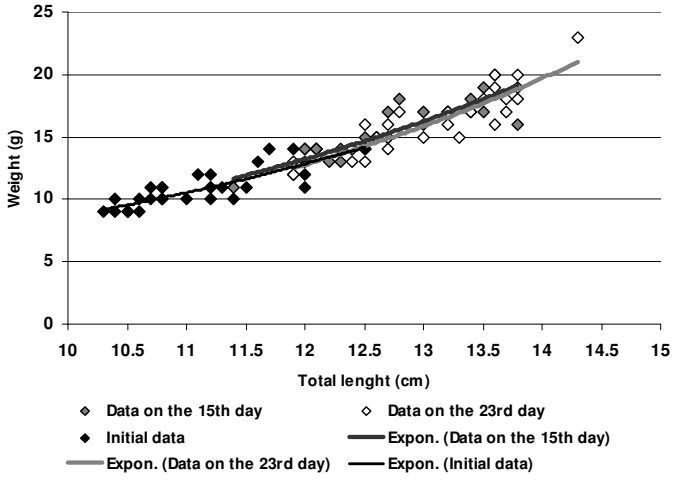

Figure 6. Length-weight relationships during the experiment in the control (C) groups

Conclusions

The decreased growth rates mask the results of the 3rd week of the experiment, but it is still detectable that after eight days of predation the acceptance of pellets still exists. We think that the decrease in condition (Fig. 4) in the 8D treatment is due to the fact that following the eight days of live fish feeding the fish did not start to feed immediately. It is probable that they were not hungry enough until they started to feed on dry feed again. Unfortunately we were not able to test this hypothesis, because we did not measure them when we stopped the prey fish supply of these cages. However, we will keep this phenomenon in mind when designing future experiments. The feeding did not start in the 15D group after 15 days of predation. The control groups do not approve this statement, because of the decreased growth in the last week. We do not know the reason for this immense drop in growth not just in the control groups but in each treatment. The growth data from the other fish tanks also do not approve this drop in the experimental tanks, because there was not such a huge drop in growth. The higher nitrite values are not the cause, as there is a high salt concentration of the water. The handling stress caused by the measuring and weighing cannot be the cause either, since the fish were feeding properly when the experiment started with the same handling stress. It seems to us pikeperch may forget the learned skill of dry feed acceptance after 15 days of predation, but this statement should be tested further to be approved.

According to our results, a few days of prey fish feeding will not affect the acceptance of dry feed by pikeperch. The results suggest that pikeperch can be reared in a pond-in-pond or pond RAS systems, even when the chance of encounters between trained pikeperch, and prey fish is high.

This amount of prey fish feeding in intensive culture conditions also has some advantages. We can boost the growth of pikeperch with the prey fish,

since we received significantly better growth results in the first two weeks of the experiment. The nutritional value of live fish supplements the dry feed.
With uncertainty caused by the phenomenon of the last week of the experiment, the investigation should be repeated with longer prey fish feeding intervals to see when the pikeperch will actually forget the acceptance of dry feed. The next step of this study is to see if the fish will continue feeding in a semi-natural environment.

Acknowledgement

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ASSESSING THE CHANGES OF SOIL HUMUS CONTENT IN ZALA COUNTY

Gizella Martin[1*], Mihály Kocsis[2], László Menyhárt[3]

[1]*Department of Meteorology and Water Management*
[2]*Department of Plant Production and Soil Science*
[3]*Department of Economic Methodology*
Georgikon Faculty, University of Pannonia
H-8360 Keszthely, Deák Ferenc utca 16. Hungary
[*]gizela.martin@gmail.com

Abstract

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

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

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

Összefoglalás

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

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

Introduction

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

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

Agri-environmental programmes have been operating in Hungary since 2002 requiring environmental agricultural management practices from farmers, e.g. soil protection. Well before the first agri-environmental programme was launched, a soil quality monitoring system was set up in 1991 and sampling started at 1992. One of the functions of the Soil Information and Monitoring System (TIM - acronym of the Hungarian name of the database) is to follow agri-environmental processes. Soil organic matter (SOM) plays a significant role in soil quality. Monitor the effects of agri-environmental programmes on soil, soil quality indicators have been introduced (Bindraban et al., 2000; McRae et al., 2000). Among these indices organic matter (OM), SOM or humus has the most generally recognised influence on soil quality, affecting physical, chemical and biological indicators (Doran and Parkin, 1996). Its presence in soils, in a satisfactory level, can positively influence various physical and biological processes

beneficial for agricultural production (e.g. yields). Balanced humus content improves cation exchange capacity, buffering function, lessens surface compaction and changes in soil temperature, contributes to better soil water balance (Wolf and Snyder, 2003; Hülsbergen, 2003). If allowing SOM concentrations decrease too much, the productivity of agriculture will be at risk (Loveland and Webb, 2003).

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

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

Materials and methods

Soil Information Monitoring System of Hungary

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

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

TIM sites of Zala County in agricultural areas

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

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

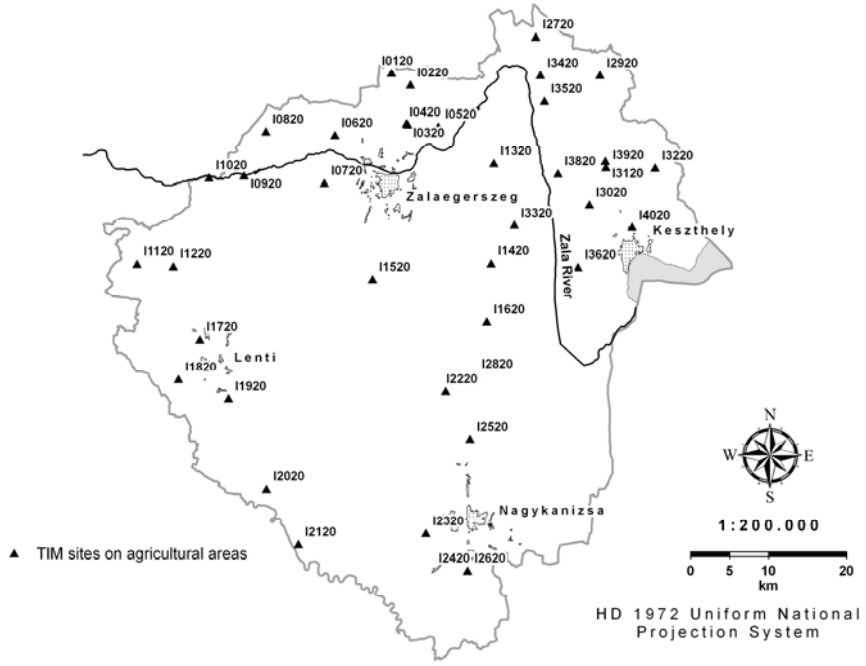

Figure 1. TIM points on agricultural lands in Zala County

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

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

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

Between 1992 and 2010 humus content sampling and analysing was carried out six times from three different soil depths at each point. Qualitative determination of soil organic matter was performed according to Tyurin

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

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

Results and Discussion

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

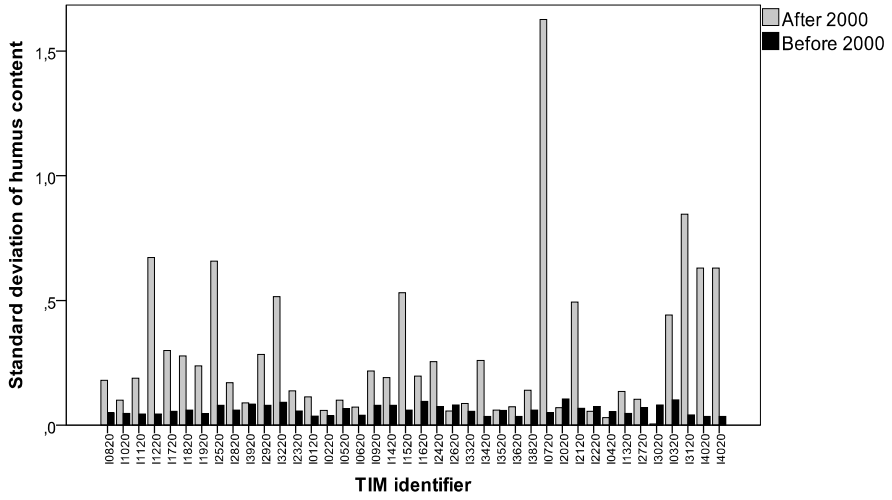

Figure 2. SD of humus content with the new and the old sampling method

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

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

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

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

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

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

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

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

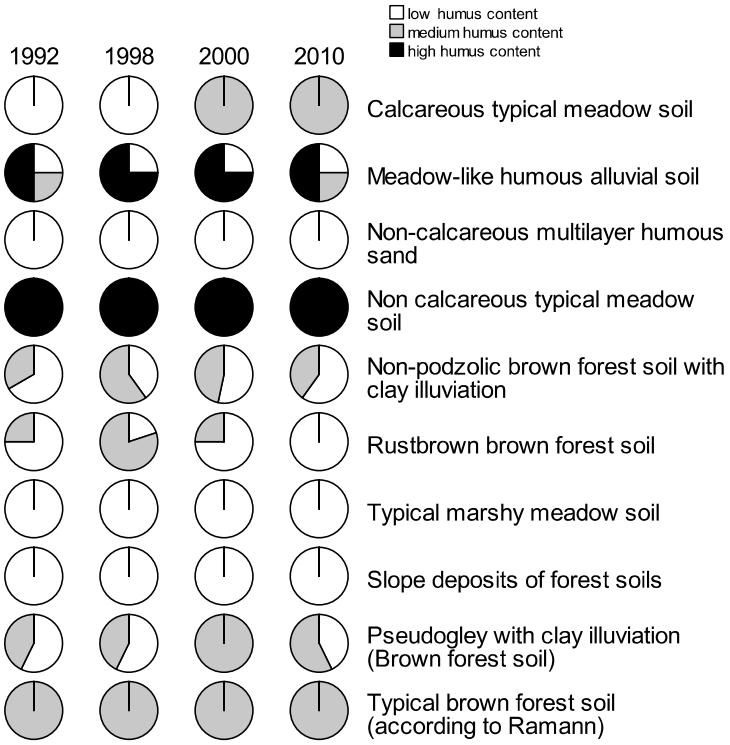

Figure 3. Humus content changes within soil subtypes by humus content categories

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

In the case of soils with minimum of four or more TIM sampling sites paired sample t-test was used in order to assess whether detected changes in humus contents in different years were significant. (Data of measured humus content show normal distribution thus paired sample t-test can be used.) Between the years 1992 and 1998 the growth of humus content was 7,6% ($p \leq 0{,}001$) at TIM sites of non-podzolic brown forest soil with clay illuviation, 6,2 % ($p \leq 0{,}001$) of pseudogley with clay illuviation (Brown forest

soil) and 10% ($p \leq 0{,}004$) of rustbrown brown forest soil. No significant changes were detected at sampling points of meadow-like humous alluvial soil. During the sampling period II., between 2000 and 2010 significant 5,5% ($p \leq 0{,}007$) decline of humus content change was identified at TIM points of pseudogley with clay illuviation (Brown forest soil). The 3,2% ($p \leq 0{,}023$) decline was also significant at meadow-like humous alluvial soil sampling sites. Due to the low number of sampling sites (≤ 3) of other soil subtypes the significancy of humus content changes was not analysed.

Conclusion

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

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

with clay illuviation (Brown forest soil) and meadow-like humous alluvial soil.

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

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A METHODOLOGICAL STUDY ON LOCAL APPLICATION OF THE FAO-56 PENMAN-MONTEITH REFERENCE EVAPOTRANSPIRATION EQUATION

Gábor Soós*, Angéla Anda

Pannon University, Georgikon Faculty, Keszthely, Hungary

*sgkert@gmail.com

Abstract

In our study we discuss the theory and application of the FAO-56 Penman-Monteith equation to count reference evapotranspiration (ET_0). Establishing ET_0 derived from meteorological variables, together with crop coefficient (K_c), the actual ET could be estimated easily for a desired time-period (from hours to seasons). Daily evapotranspiration of common reed (*Pragmites australis*) was measured in evapotranspirometers. The measured ET was used to calculate K_c locally. Our study confirmed the earlier investigations that reed stand transpired more water than open water bodies in hot season.

Key-words: actual evapotranspiration, reference evapotranspiration, crop coefficient

Összefoglalás

Megfigyelésünkben a FAO-56 módszer néven ismert Penman-Monteith egyenletet és annak egy lehetséges gyakorlati alkalmazását mutatjuk be hazai példán. A dolgozat célja a FAO-56 módszer helybeli alkalmazhatóságának áttekintése, valamint egy gyakorlati példa alapján történő felhasználása volt. A referencia evapotranspiráció és a növénykonstans segítségével meghatározhatjuk egy adott növény faj tényleges párolgását különböző időintervallumokra. A napi nád párolgását evapotranszspirométerben mértük, melyből a nád növénykonstansait származtattuk. Bár megfigyelésünkben a cél nem a konkrét ETc meghatározás volt, a mintapéldánk alapján 2007-ben a nád párolgása mintegy 30%-kal meghaladta a szabad vízfelület evaporációját, mely összhangban van a korábbi irodalmi adatokkal.

Introduction

Evaporation and transpiration are important components of water balance because approximately 60% of precipitation is returned to the atmosphere by evaporation and transpiration in Europe (Baumgarter and Reichel, 1975). These two compounds take also dominant part in determination of the soil moisture; and both of them are major factors in crop water supply analysis and irrigation design.

Actual evapotranspiration (ET_c) is the combination of soil evaporation and crop transpiration under actual meteorological (environmental) conditions. The key components of evapotranspiration processes are: meteorological components (radiation, temperatures, vapour pressure, wind speed), soil-moisture components (available soil water), and plant factors (species, stage of growth, plant density, plant height, leaf area index - LAI etc.).

In water balance, the size of actual evapotranspiration (ET_c) over the long term is more difficult to estimate than either precipitation or streamflow, so we have to find the empirical solution to estimate ET_c.

Allen et al. (1998) gave the basic definition of ET_0 as follows:

"The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_0. The
reference surface is a hypothetical grass reference crop with specific characteristics". The only factors affecting ET_0 are climatic parameters. Penman model is widely used in ET estimation because of its sound analytical basis (Sun and Song, 2008).

Knowing ET_o, ET_c can be determined easily using a specific coefficient named crop coefficient (K_c). Great number of studies had been dealing with estimating wetland evapotranspiration by K_c application where reed was included (Headley et al. 2012, Borin et al. 2011, Herbst and Kappen 1999, Hargreaves 1994). Published results differed greatly irrespective to climatic conditions and used methodology.

The purpose of the study was to examine the applicability of the Penman-Monteith Method with locally measured data. As an example we estimated local ET_c from crop coefficients and reference crop evapotranspiration at a daily timestep using standard meteorological data only. According to one seasons sample data for reed evapotranspiration or crop coefficients, the analysis of reed ET_c or K_c were excluded from this work.

Material and Methods

Theory of the Applied Method: Evaluation of Reference Crop Evapotranspiration, ET_0 (FAO-56 Method)

Many empirical methods have been developed over the last five decades estimating evapotranspiration from climatic variables. Some of them derived from the original Penman equation (Penman, 1948) to determine evaporation from open water, bare soil and grass based on a combination of an energy balance and an aerodynamic formula:

$$\lambda E = \frac{[\Delta(R_n - G)] + (\gamma \lambda E_a)}{(\Delta + \lambda)} \qquad (1)$$

where λE is the evaporative latent heat flux [MJ m^{-2} d^{-1}], Δ is the slope of the saturated vapour pressure curve [kPa] R_n is the net radiation flux [MJ m^{-2} d^{-1}], G is the sensible heat flux into the soil [MJ m^{-2} d^{-1}], γ is the psychrometric constant [kPa°C^{-1}], and E_a is the vapour transport of flux [mm d^{-1}].

After various derivation of the original Penman equation the so called Penman-Monteith equation was developed including a bulk surface resistance term by Monteith (1965) :

$$\lambda ET = \frac{\Delta(R_n - G) + \dfrac{\rho_a C_p (e_s - e_a)}{r_a}}{\Delta + \gamma(1 + \dfrac{r_s}{r_a})} \qquad (2)$$

where ρ_a is air density [kg m^{-3}], C_p is specific heat of dry air, e_s is mean saturated vapour pressure [kPa], e_a is mean daily ambient vapour pressure [kPa], r_s and r_a are the bulk surface and aerodynamic resistances [s m^{-1}].

The aerodynamic resistance (r_a) determines the transfer of heat and water vapour from the evaporating surface into the air above the canopy (Allen et al. 1998):

$$r_a = \frac{\ln\left[\frac{z_m - d}{z_{om}}\right]\ln\left[\frac{z_h - d}{z_{oh}}\right]}{k^2 u_z} \quad (3)$$

where z_m is the height of wind measurements [m], z_h is height of humidity measurements [m], d is the zero plane displacement height [m], z_{om} is roughness length governing momentum transfer [m], z_{oh} is the roughness length governing transfer of heat and vapour [m], k is the von Karman's constant: 0.41, u_z is the wind speed at height z [m s^{-1}]

The bulk surface resistance (r_s) describes the resistance of vapour flow through the transpiring crop and evaporating soil surface (Allen et al., 1998):

$$r_s = \frac{r_l}{LAI_{active}} \quad (4)$$

where r_l is the bulk stomatal resistance of the well-illuminated leaf [s m^{-1}], LAI_{active} is the active sunlit leaf area index [$m^2 m^{-2}$], and LAI_{active}=0.5LAI.

An updated and simplified equation of the Penman-Monteith equation was recommended by FAO Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements (Allen et al., 1998) with the FAO-56 Penman-Monteith Equation. This equation utilizes some assumed constant parameters for a reference crop (alfalfa or short cut grass). The adopting characteristics for the reference crop was a hypothetical reference crop with a height of 0.12 m, a surface resistance of 70 s m^{-1} and an albedo value of 0.23 (Allen et al., 1998).

ET_0 parameters measured at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface, so the only factors affecting ET_0 are climatic parameters.

The basic form of FAO-56 Penman-Monteith ET_0 [mm day^{-1}] Equation (Allen et al., 1998) is as follows:

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma\,\Delta\,(1 + 0.34\,u_2)} \quad (5)$$

where R_n is net radiation at the crop surface [MJ m^{-2} day^{-1}], G is soil heat flux density [MJ m^{-2} day^{-1}], T is mean daily air temperature at 2 m height [°C], u_2 is wind speed at 2 m height [m s^{-1}], e_s is saturation vapour pressure [kPa], e_a is actual vapour pressure [kPa], (e_s-e_a) is saturation vapour pressure deficit [kPa], Δ is slope vapour pressure curve [kPa°C^{-1}], γ is psychrometric constant [kPa°C^{-1}], 0.408 is a conversion factor from MJ m^{-2} day^{-1} to equivalent evaporation in mm/day.

As soil heat flux is relatively small compared to R_n beneath the grass reference surface, and hourly or longer calculation time is used, the G is assumed to be zero.

The slope of the relationship between saturation vapour pressure and temperature**,** Δ [kPa°C^{-1}], is counted by:

$$\Delta = \frac{4098\left[0.6108\,\exp\left(\frac{17.27\,T}{T + 237.3}\right)\right]}{(T + 237.3)^2} \quad (6)$$

The psychrometric constant**,** γ [kPa °C^{-1}], is given by:

$$\gamma = \frac{c_p P}{\varepsilon \lambda} = 0.664742 * 10^{-3} P \quad (7)$$

where P is atmospheric pressure [kPa], λ is latent heat of vaporization, 2.45 [MJ kg^{-1}], c_p is specific heat at constant pressure, $1.013*10^{-3}$ [MJ kg^{-1}°C^{-1}], ε is ratio molecular weight of water vapour/dry air = 0.622.

The atmospheric pressure, P [kPa], is also needed to calculate for Eq. 7:

$$P = 101.3\left(\frac{293 - 0.0065\,z}{293}\right)^{5.26} \quad (8)$$

where z is elevation above sea level [m], it is 124 m at Keszthely.

The wind speed has to be adjusted to standard height, u_2, [m s^{-1}] of 2 m:

$$u_2 = u_z \frac{4.87}{\ln(67.8\, z_m - 5.42)} \qquad (9)$$

where u_z is measured wind speed at 10.5 m above ground surface [m s^{-1}], z_m is height of measurement above ground surface (10.5 m).

The net radiation (R_n) is the difference between the incoming net shortwave (R_{ns}) and the outgoing net longwave radiation (R_{nl}):

$$R_n = R_{ns} - R_{nl} \qquad (10)$$

The R_{ns} net solar or shortwave radiation [MJ m^{-2} day^{-1}] is given by:

$$R_{ns} = (1 - \alpha) R_S \qquad (11)$$

where α is albedo for the reference crop. The R_s incoming solar radiation [MJ m^{-2} day^{-1}] was measured locally by CM-3 pyranometer. The fixed value of 0.23 was used for the albedo.

Net longwave (outgoing) radiation, R_{nl} [MJ m^{-2} day^{-1}] was calculated as follows:

$$R_{nl} = \sigma \left[T_{mean,K}{}^4\right](0.34 - 0.14\sqrt{e_a})\,(1.35\frac{R_S}{R_{SO}} - 0.35) \qquad (12)$$

where σ is Stefan-Boltzmann constant [$4.903\ 10^{-9}$ MJ K^{-4} m^{-2} day^{-1}], $T_{mean,K}$ is mean temperature during the 24-hour period [K], e_a is actual vapour pressure [kPa], R_s/R_{so} is relative shortwave radiation (limited to ≤ 1.0), R_s is measured solar radiation [MJ m^{-2} day-1], R_{so} is calculated clear-sky radiation [MJ m^{-2} day^{-1}], see Eq. 13.

To get clear-sky solar radiation R_{so} [MJ m^{-2} day^{-1}] the station elevation is required:

$$R_{SO} = (0.75 + 2 * 10^{-5} z) R_a \qquad (13)$$

where R_a is extraterrestrial radiation [MJ m^{-2} day^{-1}]. See Eq. 14.

The extraterrestrial radiation R_a, [MJ m^{-2} day^{-1}] was calculated by:

$$R_a = \frac{24\,(60)}{\pi} G_{SC}\, d_r \left[\omega_S \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_S)\right] \quad (14)$$

where G_{sc} is solar constant = 0.0820 MJ m^{-2} min^{-1}, d_r is inverse relative distance Earth-Sun (Equation 11), δ is solar declination (Equation 12) [rad], ω_s is sunset hour angle (Equation 17) [rad], φ is latitude [rad]; at Keszthely=0.81.

The lacking Eq. of 11-13 are as follows:

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right) \quad (15)$$

$$\delta = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \quad (16)$$

where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31
December).

The sunset hour angle**,** ωs, is given by:

$$\omega_s = \arccos\left[-\tan(\varphi)\tan(\delta)\right] \quad (17)$$

The vapour pressure deficit, e_s-e_a [kPa] is the difference between the saturation (e_s) and actual vapour pressure (e_a). The saturation vapour pressure, e_s [kPa] is:

$$e_s = 0.6108 \exp\left[\frac{17.27\,T}{T + 237.3}\right] \quad (18)$$

The actual vapour pressure, e_a [kPa] is**:**

$$e_a = e_s \frac{RH_{mean}}{100} \quad (19)$$

where RH is relative humidity [%].

The calculation of the crop coefficient as a dimensionless indicator using reference evapotranspiration (Eq. 5) and the measured actual evapotranspiration:

$$K_c = \frac{ET_c}{ET_o} \qquad (20)$$

The site of observation was reed dominated Kis-Balaton wetland. In 2004 reed rhizomes were collected from the Kis-Balaton area and were transplanted into metal containers of Thornthwaite-Matter-type compensation evapotranspirometers of the Meteorological Research Station at Keszthely. The volume of tanks were 4 m^3 (2 × 2 m surface area and 1 m depth) with four replications and were provided unlimited water supply. Measured and reference evapotranspiration (ET_m and ET_o) of common reed was detected between 2005 and 2011, except of 2006.

Meteorological variables were observed at Keszthely Meteorological Research Station (latitude: 46°44′, altitude: 17°14′, elevation: 124 meters above sea level) by a QLC-50 (Vaisala, Helsinki, Finland) automatic climatic station equipped with a CM-3 pyranometer (Kipp & Zonen Corp., Delft, The Netherlands). The combined sensors of air temperature and humidity were placed at standard height 2 meters above the soil surface. Signals from air temperature, humidity, wind speed and radiation were collected every 2 sec, and 10-min means were logged by the QLC-50 station. The height of the anemometer was 10.5 meters.

Practical sample for the applicability of FAO-56 equation (Discussion)

Common reed (*Phragmites australis*) is the most widely distributed wetland crop species in Hungarian areas. Reed covered areas on lakeshore of Balaton

exceed 1000 ha (Virág, 1998), and on the Kis-Balaton Water Protection System there are more than 2000 ha (Pomogyi, 2001).

Our ET results will be presented by using 2007 as a sample season because in most months, the seasonal air temperatures and rainfall sums were close to climatic norms. There were two exceptional hot months, the June and July, where monthly air temperatures were about 1°C higher than that of the long-term averages. This hot summer months increased the reed ET significantly.

Figure 1 shows the daily pattern of measured and reference ETs of 2007. These two types of ET were close to each other at the beginning and in the end of the season. In the middle of the season, values of daily ET_m increased on higher extent in reed stand grown in lysimeters than calculated reference ET data. This is in accordance to measurements of earlier investigations for wetland crops at unlimited water supply (Irmak et al., 2013). During 2007, reference and measured seasonal ET totalled 639.8 and 785.5 mm, respectively.

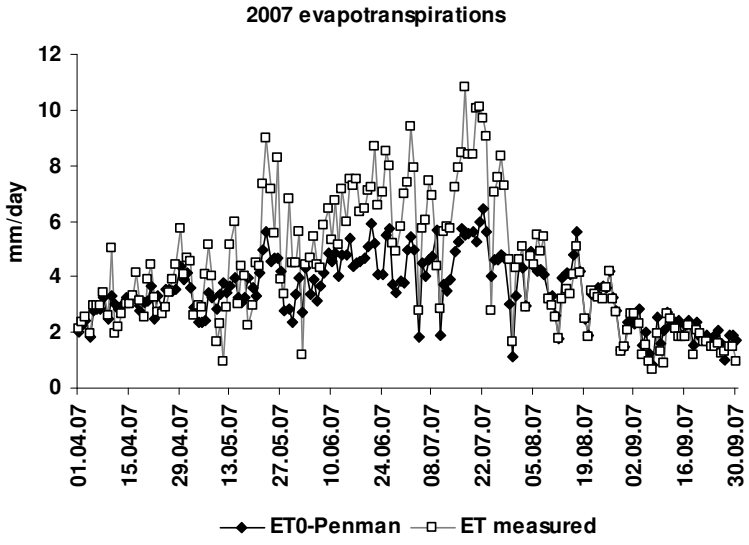

Figure 1. Daily measured and reference evapotranspiration at Keszthely, in 2007

Close relationship was found between measured and ET_o calculated based on meteorological data (Table 1, Fig. 2). Correlation of ET_m and ET_0 was good (R^2= 0.76) and the slope of forcing line through the origin was also close to 1. The values of daily ET_m were on average 27.5% higher than calculated ET_0 for common reed for the whole season of 2007. Relative divergence between the two ETs varied; greatest differences occurred during hot days, while better accordance between ET_m and ET_0 was observed on cooler periods. The RMSD was 1.277 mm/day. This error exceeded with 0.29 mm/day the RMDS for reed ET determined earlier between 2005 and 2011 time-period (Anda et al., 2014). Penman-Monteith equation underestimated reed ET in the Kis-Balaton wetland that could be improved using locally measured K_c values.

Table 1. Table of regression analysis

Regression statistics	
r	0.873
R^2	0.763
corr. R^2	0.762
SE	1.130
n	183

ANOVA

	df	***SS***	***MS***	***F***	***F sig.***
Treatments	1	744.303	744.303	582.477	0.000
Error	181	231.286	1.277		
Total	182	975.589			

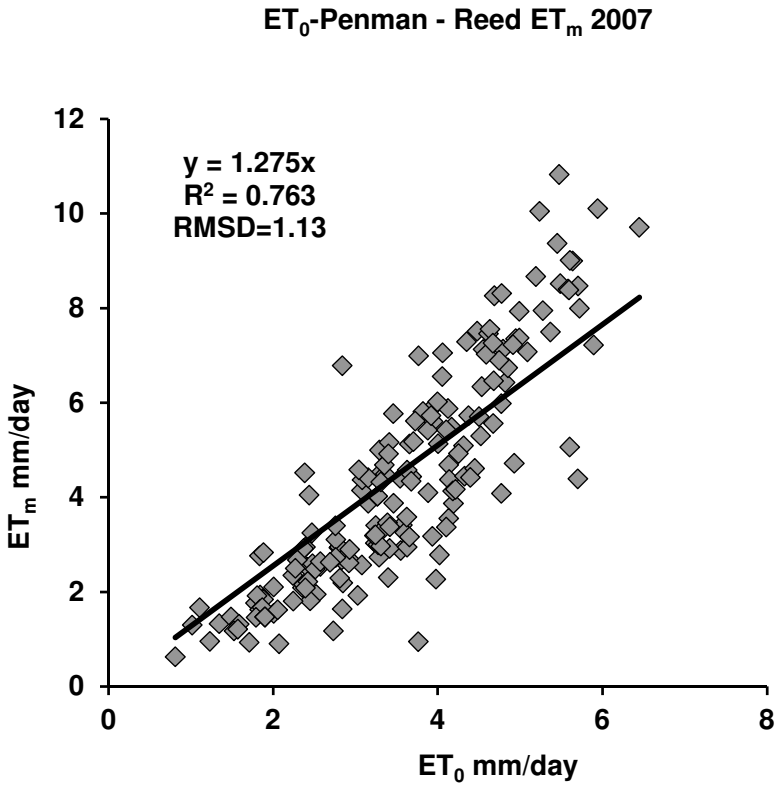

Figure 2. Comparison of measured and reference evapotranspiration in common reed during the growing season of 2007. Reference evapotranspiration was calculated using the Penman-Monteith equation (FAO-56 method).

Ratio of the two ET values provides K_c. This coefficient may be used later to calculate actual reed ET based on meteorological parameters only. The monthly mean K_c for 2007 ranged from 0.77 (September) to 1.51 (July) with an average of 1.16. Monthly K_c exhibited an increasing trend until July then K_c means dropped until the end of September. K_c above 1 means that reed stand ET exceeds evaporation of open water bodies (Table 2).

Table 2. Average monthly values of reed K_c

Kc	April	May	June	July	Aug.	Sept.	Seasonal Avg.
Monthly Avg.	1.03	1.23	1.4	1.51	0.99	0.77	1.16

Conclusion

The Penman-Monteith equation is widely applied to calculate ET_0 as an international standard introduced by FAO. In our experimental sample, daily evapotranspiration for common reed (*Phragmites australis*) was measured and calculated during the "average" season of 2007. Our study confirmed the earlier investigations that reed stand transpired more water than open water bodies. Later on, locally established reed K_c allows estimation of reed ET based on meteorological parameters only. The Penman-Monteith method suited well in our sample calculation of reed ET_c at Kis-Balaton wetland.

Acknowledgement

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THE ANALYSIS OF PHYSICAL PERFORMANCE CHANGE IN THE CASE OF STUDENTS FROM THE UNIVERSITY OF PANNONIA, GEORGIKON FACULTY

Ákos Pintér, István Sárközi

University of Pannonia, Georgikon Faculty, Keszthely, Hungary
pa@georgikon.hu, sarkozi.istvan@georgikon.hu

Abstract

The beneficial impact of sport was formerly justified by numerous national and international literatures, highlighting the correlation between exercise training and psychological condition, as well as that between physical and mental health. Nevertheless – as far as the authors know – the effects of a once-a-week, vigorous exercise training has not been examined yet; therefore, the area being a "terra incognita", the results of the locally conducted survey can even have interesting scientific aspects. The discussed research primarily focussed on the following: the students of the University of Pannonia/Georgikon Faculty, originating from different settlements and schools have diverse physical fitness, and are either active or inactive concerning doing sports. The authors wanted to figure out, whether the weekly physical activity could possibly bring positive results in their performance; and in which kind of numerical data could it be recorded.

Key-words: physical fitness, exercise training, students, moderate to vigorous physical activity

Összefoglalás

A sport jótékony hatásait korábban számos hazai és nemzetközi szakirodalom igazolta, melyek összefüggéseket mutattak ki a fizikai aktivitás és a pszichés állapot, illetve a testi és lelki egészség kapcsolatrendszerében. Tudomásunk szerint azonban a heti egy alkalommal végzett komoly terheléssel járó fizikai aktivitás hatásait még nem kutatták le szakemberek – a terület ezáltal meglehetősen „ismeretlen föld" – így lokálisan végzett felmérésünk eredménye érdekességgel szolgálhat tudományos szempontból is. Jelen kutatásunk elsősorban arra irányult, hogy a különböző településekről, iskolákból a Pannon Egyetem Georgikon Karára érkező, s eltérő fizikai felkészültséggel bíró, a sportolást tekintve aktív és inaktív életet élő hallgatók heti rendszerességgel végzett mozgatása során érhető-e el teljesítményükben pozitív változás, s ha igen, milyen számszerűsíthető érték mutatható ki.

Introduction

The competences of a qualitative professional lifestyle do not evolve till the end of secondary education. Although the National Curriculum defines the requirements of prevention, living standards and health improvement, they need to be continuously developed parallel with the personal aspect. The initiation of higher education studies – including those of the students enrolled at the University of Pannonia/Georgikon Faculty – introduces an important change in lifestyle. Most of the students have to establish their way of living far from their residence, in a foreign environment, and the daily-weekly routine has to be adjusted to their studies.

They not only have to accommodate themselves to the new circumstances, but also have to independently solve essential activities like recreation, eating, physical activities, entertainment etc. within the limits of free time. The authors of this article conducted a three-year-long data collection and analysis (with 184 students), focussing on exercise training – particularly on compulsory PE lessons – and aim at the summary of general conclusions in connection with the effects of once-a-week sporting activities.

Materials and Methods

The research basically dealt with the following: the students originating from different settlements and schools have diverse physical fitness, and are inhomogeneous in terms of sporting activities. The authors wanted to figure out, whether the weekly physical activity could possibly bring positive results in their performance; and in which kind of numerical data could this be recorded. We consider it is very important to analyse the relationship of the university students to physical activities since in 2011 Ács, Borsos and Rétsági refers that 77% of the Hungarian population live a physically inactive life. According to the hypothesis, even a once-a-week MVPA (moderate to vigorous physical activity) can result in a quantitative performance increase in the human body.

At the University of Pannonia/Georgikon Faculty, Keszthely every student is required to attend compulsory PE lessons, within a period of 2-4 semesters. In the first semester, every full-time student participates in a general cognitive improvement lesson once a week, lasting 90 minutes, conducted and structured by an expert. During the forthcoming semesters, the students have to choose at least one out of the offered, optional branches of sport.

In the last couple of autumn semesters, full-time first-year students participating in BSc or Higher Education Trainings (Hungarian abbr. FSZ) were examined with various performance tests. During the 14 weeks of the semester, the body changes resulting from exercises were observed, i.e. the data of the same applied performance tests were collected and analysed at the beginning and at the end of the semester. The students were divided into smaller, co-educated groups, which actively participated in a 90-minute-long cognitive improvement lesson once a week. The occasions incorporated a warm-up, strengthening exercises, stretching and some games at the end of the lesson.

The physical performance tests applied at the beginning and at the end of the semester were chosen from the „HUNGAROFIT" measurements (http://www.bdf.hu).

The measurements included the following physical tests:

1. The aerobe fitness was measured with the "Cooper-test", i.e. a 12-minute-long flat-race, on the university athletic field's 400-metre-long running track. The accomplished distance was recorded in metres.
2. The measurement of the general physical strength/fitness was realized with 3 different tests.

   The fitness of the shoulder girdle and arm muscles, as well as the static strength of the trunk muscle was defined with arm bending and stretching done during push-ups; the fitness of back muscles was shown through trunk raise from arse upwards; while the performance of the abdominal muscles was examined via sitting up from supination. In each case, the exercises lasted 30 seconds, and the number of the accomplished pieces was recorded. The measurements were carried out in the gym of the Faculty.

Results

The beneficial somatic effect of physical activity was proven by several national and international literatures (Ács, Borsos and Rétsági 2011, Bellocco, Jia, Ye and Lagerros 2010, Lee et ass. 2011, Stephens 1988), though the quantitative limits prevents the authors from further elaborating on their details. Nevertheless, among its impact mechanism on health, we should draw special attention to the components of health education and health behaviour. The attitude towards health is continuously changing through life, which is reflected in the applied tests and physical parameters adjusted to the personality change. A given condition can be interpreted only within the given environment and interaction, and requires a persistent activity aiming at the prevention and improvement of that given condition.

In connection with the topic, two closely related issues should be discussed. According to Csányi T. (2010), exercise training involves "every activity that is produced by the skeletal muscles, and is accompanied by energy consumption". Therefore, he assumes energy use as the basis of exercise training. The formula of Caspersen, Powell and Christenson (1985) shows: „kcal sleep + kcal occupation + kcal conditioning + kcal household +kcal other – kcal total daily physical activity. Exercise training is a complex behaviour". One can claim that the related scientific fields evolved a holistic approach regarding movement activities. It is impossible to extract the whole sporting activities from everyday activities and the complex lifestyle standards. This study deals with the exercise training and the related habits of a given generation. The higher education institutions also have to face the challenges originating from the characteristics of the generation "Z".

The determinant foundation stones of generation research were laid down by Strauss and Howe (1991) in their work "Generations". Based on this, their 1997 publication claims that each generation has a different

attitude. This deviation can also be detected in the movement activities, i.e. in terms of exercise training. The generation's main features can be best highlighted through their attitude towards the internet. As in the case of any other activity, exercise training is determined by the motivation structure. The action is defined by the external-internal control attitude. In case of the generation "Z", the values related to fatalism increase (Pais, 2013). Thus – during the acquirement of lifestyle competencies – this generation can be less effectively motivated by the traditional 'reward-penalty' method. The expression of self-efficiency as well as the increased desire to experience success becomes highlighted. Considering the above listed components, the Georgikon Faculty provides for its students appropriate PE lessons: it is a good opportunity to establish an effective self-definition, and to realise an anxiety-minimizing way of self-expression.

Several research results have already elaborated on the relation between exercise training and cognitive performance.

It is generally accepted and scientifically proven that exercise training causes noteworthy cognitive performance increase. The California Fitness Research 2002 (Grissom, 2005) examined approximately 900.000 students, and showed a significant correlation between physical fitness and reading, as well as mathematical performance.

In connection with strength improvement, numerous recent publications were released. Compared to the beginning of the '80s, it is already justified that a 9-13-week-long period can bring an average development of 30-40% in strength improvement (Payne et ass., 1997) – though there were no examinations related to the minimal number of trainings. Further to this, Faigenbaum and associates even showed a 74% increase in 2009. According to these, the authors' hypothesis should reveal a

measureable performance increase during a 14-week-long period, involving a once-a-week physical training/sporting activity.

The concrete examination involved three subsequent autumn semesters, during which data from a total number of 184 students were collected (69 people in 2011; 72 people in 2012; 83 people in 2013) at the beginning and at the end of the semester. The results of the three years were evaluated according to sexes, while the changes and improvement tendencies were also examined in the form of total values (%) *(Table 1).* In order to interpret the gained data, the average calculation was chosen. According to Ozsváth and Ács, out of the three index-numbers (median, modus, mean) mean is the most important, therefore it was being used in our research.

When considering the results of the performance tests separately, the data analysis reveals positive change, i.e. performance increase in the majority of the groups – out of the 104 group data, only 9 included a lower value in the second measurement. When the four tests were evaluated as a summarized group, all the 26 data show a detectable performance improvement. The distribution of increase varies between 1% and 22% extreme.

The distinct analysis of the test results shows a basically positive change in each of the four cases; these tendencies prove the efficiency of competence improvement.

The students' most significant performance development was registered in the case of *arm bending-stretching*. This exercise always preceded the other three, and showed a total increase of nearly 20% (19,9%). It is interesting to note that women reached a development outnumbering that of men by 4%.

The least development of the students' results was discovered in the case of the *Cooper-test* (12-minute-long flat-race): the total increase of a

modest 6% (5,9%) is accompanied with a much higher distribution; some group showed a 30% increase, while others suffered a 10% decrease. The development rate of men outnumbered that of women all the time, with a total value of 3%. The performance average values of the different women groups varied between 1700 and 2100 meters, while men accomplished 2100 to 2500 meters during the 12 minute-test (only a single group showed a value below 2000 meters).

Regarding the other two tests, there are no unambiguous correlations between sexes and the measured performance development values. On the whole, each test reveals a more than 10% increase in the data. Women reached a 3% higher development rate in *sitting up from supination*, while men performed better in *trunk raise from arse upwards* in the same extent.

Table 1. The physical performance change (%) of the students from the University of Pannonia/Georgikon Faculty, recorded on the PE lessons (2011-2013; first measurement=100%)

Groups	Performance tests				
	Cooper-test (running)	Arm bending-stretching	Sitting up from supination	Trunk raise from arse upwards	Total result
2011.					
Women 1.	105,7	148,52	106,5	106	116,4
Women 2.	120,3	125	102,61	113,22	114,63
Women 3.	90	122,1	112	106,27	107,6
Women 4.	101,8	140,23	111,7	114,89	117,15
Women 5.	96,42	102,94	114,84	91,7	101,48
Total average of women (24 people)	**102,84**	**127,76**	**109,53**	**106,4**	**111,45**
Men 1.	104,7	117,05	107,04	105,7	108,4
Men 2.	100	107,98	103,2	92,31	100,86
Men 3.	113,72	140,15	101,75	127,8	121,01

Men 4.	110,94	106,2	118	123,3	115,4
Men 5.	96,63	107,4	100,44	112,9	104,35
Total average of men (45 people)	**105,2**	**115,75**	**106,1**	**112,4**	**110**
Total average of students (69 people)	**104**	**121,75**	**107,8**	**109,4**	**110,7**
2012.					
Women 1.	104,13	127,63	107,76	111,25	112,89
Women 2.	111,5	123,15	117,14	110,57	115,59
Women 3.	91,18	119,51	103,92	109,58	106,05
Women 4.	100,37	90,41	117,6	151,39	115,25
Total average of women (35 people)	**101,8**	**115,2**	**111,6**	**120,7**	**112,44**
Men 1.	103,63	127,02	111,92	134,89	119,37
Men 2.	105,14	141,23	102,94	113,89	114,35
Men 3.	103,08	132,71	97,29	108,47	110,17
Men 4.	101,82	107,55	103,53	105,63	104,68
Total average of men (37 people)	**103,42**	**127,1**	**103,9**	**115,7**	**112,14**
Total average of students (72 people)	**102,6**	**121,15**	**107,75**	**118,2**	**112,3**
2013.					
Women 1.	108,42	114,11	108,1	100,95	107,9
Women 2.	112	118,67	118,17	112,45	115,32
Women 3.	108,44	122,9	116,71	108,8	114,21
Women 4.	107,23	137,15	120,8	114,7	117,53
Total average of women (49 people)	**109,02**	**123,21**	**115,94**	**109,22**	**113,74**
Men 1.	129,51	113,18	104,37	117,35	116,1
Men 2.	120,7	104,2	116,77	103,58	111,31
Men 3.	97,05	117,87	124,33	112,2	113,31
Men 4.	106,2	105,75	124,1	137,84	122,07
Total average of men (34 people)	**113,36**	**110,25**	**117,4**	**117,74**	**115,7**
Total average of students (83 people)	**111,2**	**116,73**	**116,67**	**113,48**	**114,72**

Regarding the total results of the three years, the average of the summarized data of all students shows a 12,5% improvement, confirming the above mentioned hypothesis, i.e. the once-a-week, more vigorous exercise training can cause a measurable performance improvement in the human body. Neither the total averages, nor the distribution values reveal important differences between the sexes (in the case of men, the study defined a 10-15,7% increase, while the same value was 11,4-13,7% with women) (*Table 2.*).

Table 2. The summarized physical performance change (%) of the students from the University of Pannonia/Georgikon Faculty, recorded on the PE lessons (2011-2013; first measurement=100%)

Year	Sex	Performance tests				
		Cooper-test (running)	Arm bending-stretching	Sitting up from supination	Trunk raise from arse upwards	Total result
2011	Women	102,84	127,76	109,53	106,4	111,45
2012	Women	101,8	115,2	111,6	120,7	112,44
2013	Women	109,02	123,21	115,94	109,22	113,74
2011-2013	**Total for women**	**104,5**	**122,05**	**112,35**	**112,1**	**112,5**
2011	Men	105,2	115,75	106,1	112,4	110
2012	Men	103,42	127,1	103,9	115,7	112,14
2013	Men	113,36	110,25	117,4	117,74	115,7
2011-2013	**Total for men**	**107,3**	**117,7**	**109,13**	**115,28**	**112,6**
2011-2013	**Total for students**	**105,9**	**119,9**	**110,74**	**113,69**	**112,55**

Fortunately, the total values of the subsequent three years highlight a constant rise in performance development (*Figure 1.*). Nevertheless, the direction of this tendency, as well as the clarification of the uncertainty, whether this is due to the poorer and poorer physical condition of the Faculty's fresh-year students or not, is still to be dealt with during the forthcoming researches and detailed data evaluation.

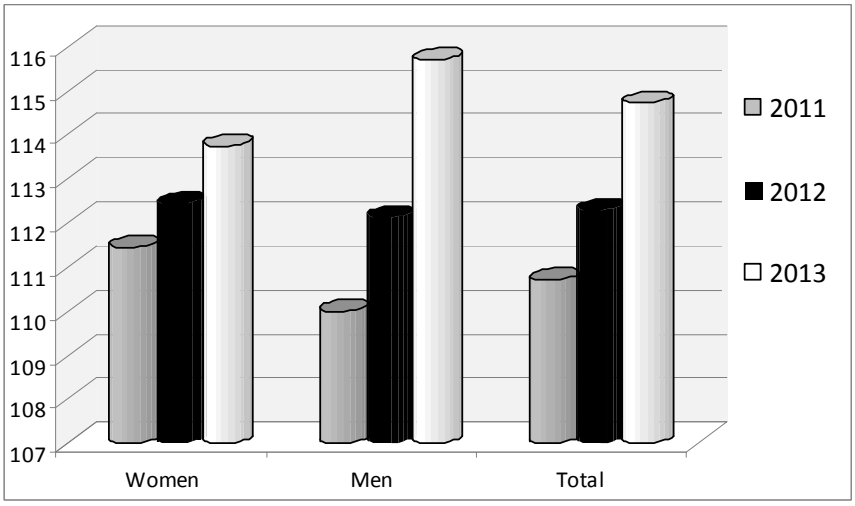

Figure 1. The physical performance change (%) of the students from the University of Pannonia/Georgikon Faculty (2011-2013; first measurement= 100%)

Conclusions

The beneficial impacts of sport on physical and mental health were justified by several national and international literatures. This study focussed on members of a target group called generation 'Z', characterized by a considerably low level of physical activity: after secondary education, they arrive in higher education, and try to meet the expectations and new challenges. The aim of the study was to define the possible degree of physical

performance increase, as a result of a once-a-week competence improvement occasion, lasting throughout a whole semester. The students' conditional training of this kind brought interesting, novel results. Indeed, the authors assumed performance development, which was proven and justified by the total positive change in the form of an improvement rate above 12%.

Acknowledgement

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RESURGENCE OF *TOMATO SPOTTED WILT VIRUS* ON PEPPER (*CAPSICUM ANNUUM* L.) PLANTS IN SZENTES REGION

István Tóbiás [1]*, Gábor Csilléry [2], Asztéria Almási [1], Katalin Salánki [1], Zsófia Csömör [1, 3], László Palkovics [3]

[1]*MTA ATK Növényvédelmi Intézet, Budapest*

[2] *Budakert Kft., Budapest*

[3]*Budapesti Corvinus Egyetem, Kertészettudományi Kar, Budapest*

*tobias.istvan@agrar.mta.hu

Abstract

In Hungary *Tomato spotted wilt virus* was considered as an important pathogen since the mid-nineties. The introduction and spread of western flower thrips (*Frankliniella occidentalis*), an efficient TSWV vector, in that time certainly played an important role in TSWV emergence. Management of TSWV control was first directed against the thrips and weeds. Later on *Tsw* resistant gene was introduced into different types of pepper. In 2012 heavy crop losses were observed on TSWV resistant pepper varieties in Szentes region. Systemic virus symptoms on leaves and fruits and decline were observed in TSWV resistant cultivars, caused by resistance breaking strain of *Tomato spotted wilt virus.*

Key-words: *Tomato spotted wilt virus*, pepper, resistance, resistance breaking strain

Összefoglalás

Hazánkban a paradicsom foltos hervadás vírus (*Tomato spotted wilt virus*, TSWV) az 1990-es évek közepén vált jelentős kórokozóvá. Ebben döntő szerepet játszott a vírus hatékony vektorának, a nyugati virág tripsznek (Frankliniella occidentalis) a Magyarországra történő behurcolása. A betegség elleni védekezés eleinte a vektor ellen irányult, majd később a nemesítő intézetek TSWV rezisztens fajtákat állítottak elő szinte minden fajtatípusból, a Tsw rezisztenciagén sikeres beépítésével. 2012-ben Szentes környékén nagymértékű fertőzést figyeltünk meg a TSWV rezisztens paprikafajtákon. A jellegzetes levél és bogyó tünetek mellett nagyarányú növénypusztulást is észleltünk. A fertőzést a paradicsom foltos hervadás vírus rezisztencia áttörő törzse okozta.

Kulcsszavak: paradicsom foltos hervadás vírus, paprika, rezisztencia, rezisztencia áttörő törzs

Introduction

Tomato spotted wilt virus (TSWV) is the type member of the genus *Tospovirus* (family *Bunyaviridae*), causes an important disease of horticultural and agronomic crops. The virus distributed worldwide is having extremly broad host range and is now considered as one of
the ten most economically destructive plant viruses (Adkins 2000, Moyer 1999, Tomlinson 1987). TSWV is transmitted by thrips in a persistant manner, only the larvae can acquire the virus, which multiplicates in the vector and the adults can trasmit (Ullmann et al 1992). The virion varies in size from 80 to 120 nm and has spherical enveloped character (Prins and Goldbach 1998). The genome of TSWV consists of three ssRNA segments:

small (S) and medium (M) RNAs have ambisense coding strategies, whereas the large (L) RNA is of negative polarity (Fig. 1.).

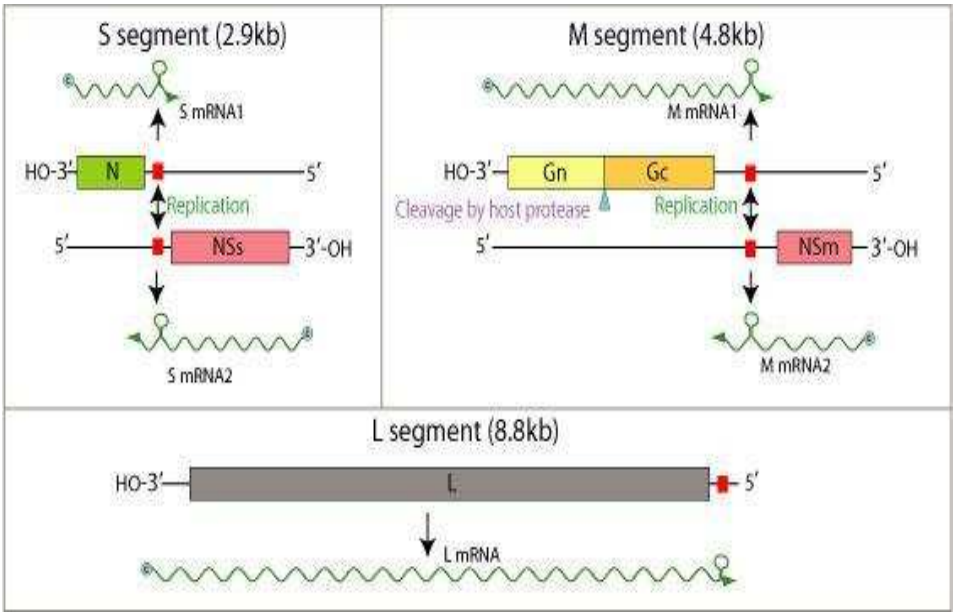

Figure 1. Tomato spotted wilt virus genome

In Hungary TSWV was described in 1972 (Ligeti and Nagy 1972), but the virus was not considered as an important pathogen. In 1995 very severe damage of TSWV infection was observed in tomato and pepper production in the Szentes vegetable growing region. The introduction and spread of western flower thrips (*Frankliniella occidentalis*), an efficient TSWV vector, in that time certainly played an important role in TSWV emergence (Csilléry et al 1995, Gáborjányi et al 1995, Jenser and Tusnádi 1989, Jenser 1995).

Management of TSWV control was first directed against the thrips using different insecticides or plastic traps, and against weeds as host plants of the virus and the thrips. Later on *Tsw* resistant gene from *Capsicum chinense* PI-

152225 és PI-159236 (Black et al 1996) was introduced into different types of pepper (conical white, long pale green hot and sweet, tomato shape, spice pepper and blocky types) (Csilléry unpublished). Pepper cultivars carrying *Tsw* resistance gene upon TSWV inoculation show necrotic local lesions on the leaves or other parts of the plant without systemic infection.

It was demonstated that TSWV can adapt very rapidly to plant resistance, and the *Tsw* resistance gene was broken down only a few years after its deployment in pepper crops (Roggero et al 2002, Thomas-Caroll and Jones 2003, Margaria et al 2004, Sharman and Persey 2006).

In 2010 and 2011 sporadically, but in 2012 and 2013 more frequently systemic virus symptoms were observed on resistant pepper cultivars in Szentes region (Bese et al. 2012, Csilléry et al 2012, Salamon et al 2010). The presence of new resistance breaking strain of TSWV was proved by virological (test-plant, serological and RT-PCR) methods.

Materials and Methods

Virus isolates. TSWV isolates originated from pepper cultivars susceptible and resistant

against TSWV from Szentes region. Fruit samples were collected from plants exhibiting typical symptoms of virus infection such as stunting, mosaic, chlorotic and/or necrotic spots, rings and distortion on the leaves and fruits (Fig. 2). The isolates were investigated on test plants, ELISA serological tests, RT-PCR and maintained by mechanical inoculation on *Nicotiana tabacum* cv. *Xanthi-nc* plants. The original samples were kept at – 70 C^{o}.

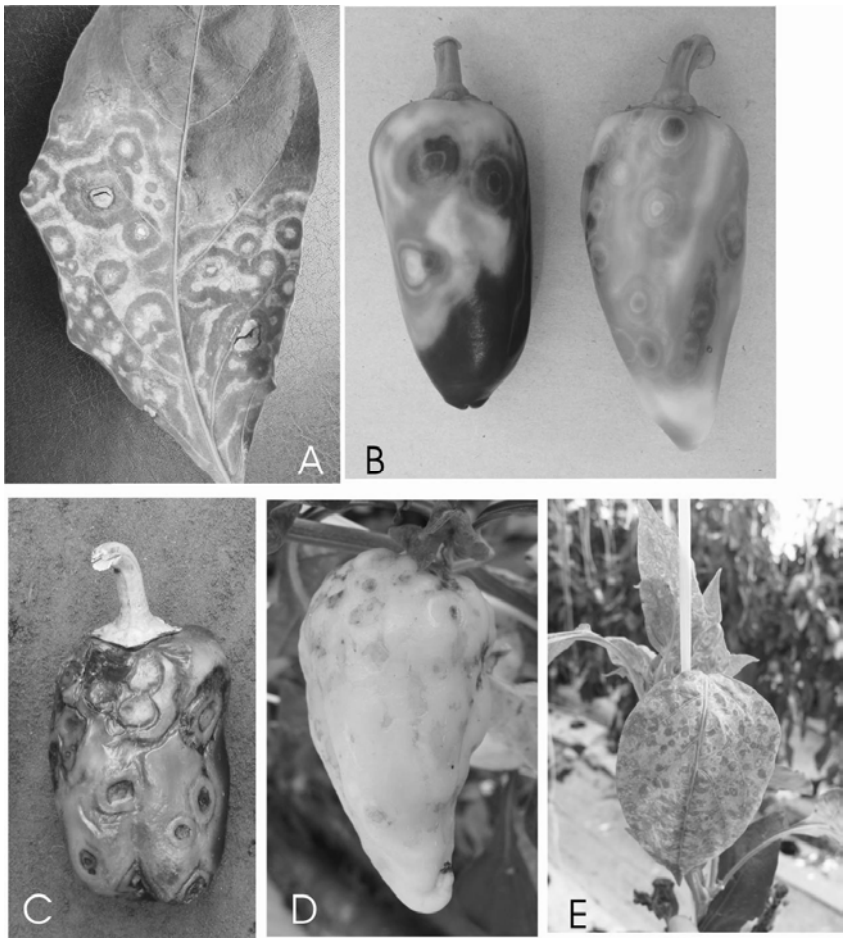

Figure 2. Symptoms of TSWV infection on leaves (A) and fruits (B) on susceptable cultivars, and on fruits of resistant cultivar (C). Systemic symptoms of resistance breaking TSWV isolate on resistant cultivars (D and E)

Results

The collected samples showed typical symptoms of *Tomato spotted wilt virus* infection. The virus was transmitted by mechanical inoculation onto test

plants. On *Nicotiana tabacum* cv. *Xanthi*-nc plants chlorotic and necrotic spots and rings on inoculated leaves and systemic
mosaic or necrotic rings or necrosis were observed (Fig. 3). Slight differences on symptoms were observed among different isolates independently whether originated from TSWV susceptible or resistant pepper cultivars

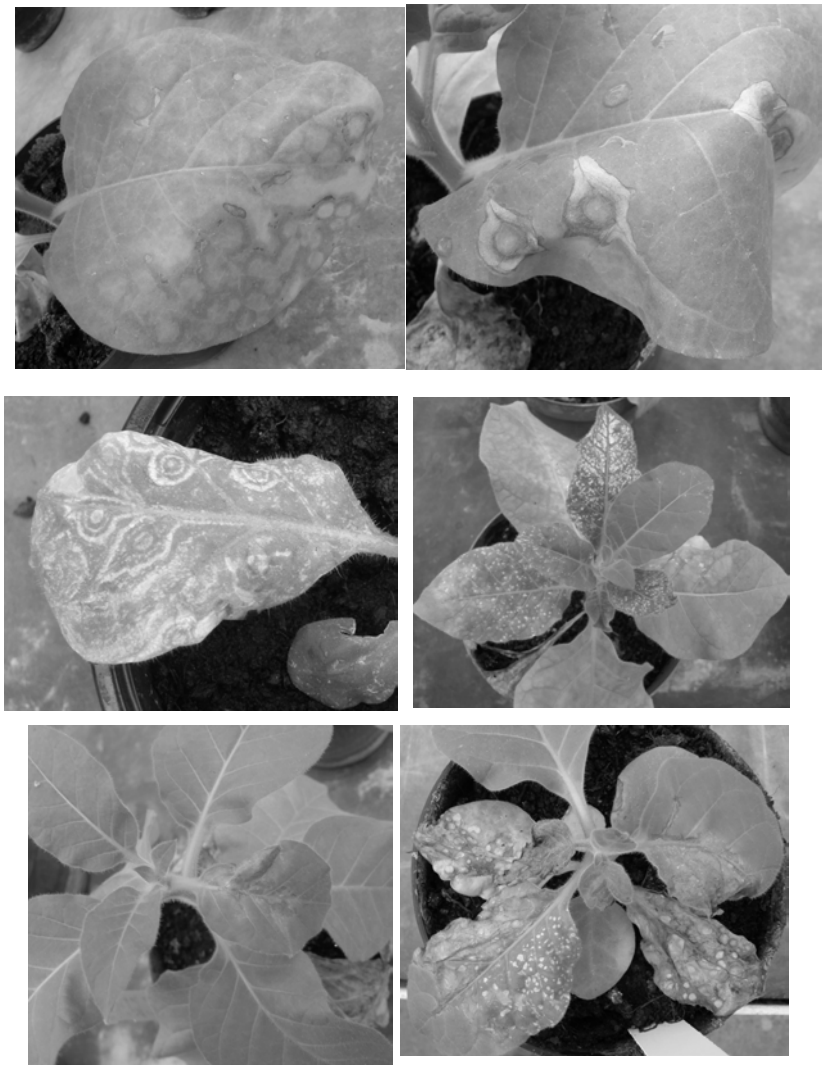

Figure 3. Different type of local and systemic symptoms on Nicotiana tabacum cv. Xanthi-nc plant caused by different TSWV isolates

Some TSWV isoltes were inoculated onto *Emilia sonchifolia* (this plants are systamically infected by TSWV and generally used to maintained the TSWV isolates) and only local necrotic symptoms were observed in contrast with other TSWV isolates (Fig. 4).

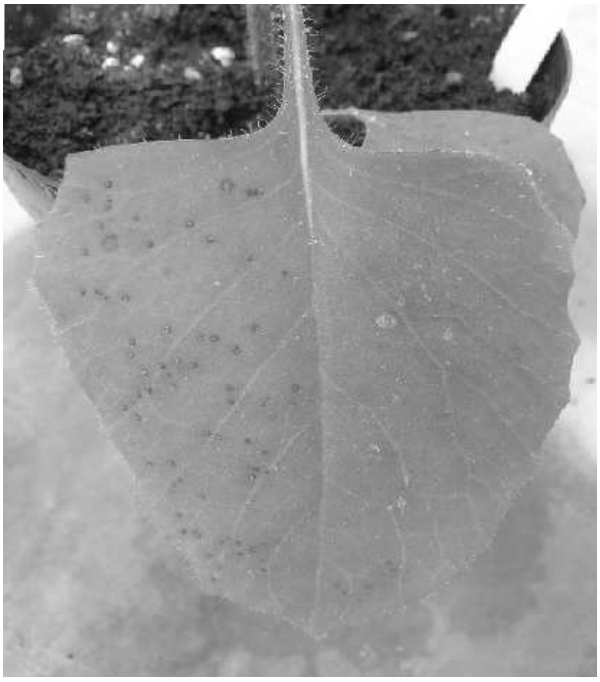

Figure 4. Local symptoms of Emilia sonchifolia after inoculation of Tomato spotted wilt virus isolated in Hungary.

TSWV specific PCR-product was amplifyed by RT-PCR method (Fig. 5). Our results confirmed the presence of *Tomato spotted wilt virus* both in TSWV susceptible and resistance cultivars in Hungary. Our results confirmed the presence of the resistance breaking isolate of
Tomato spotted wilt virus in Hungary. Further investigations needed to characterize the resistance breaking TSWV isolates from Hungary.

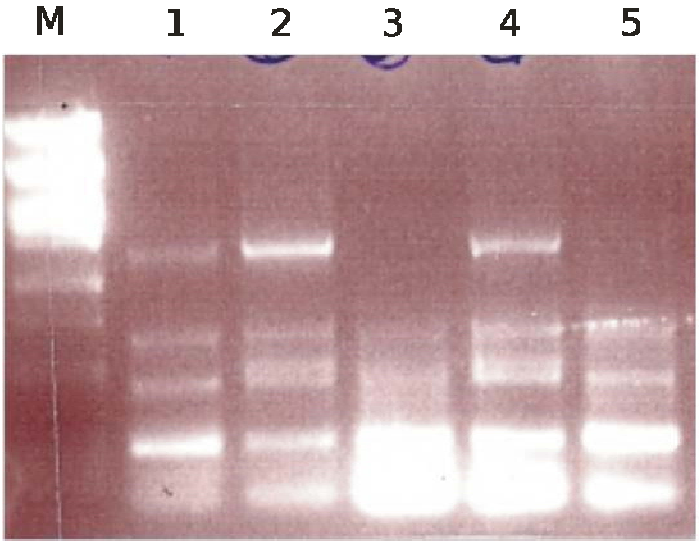

Figure 5. Separation of amplified RT-PCR products of TSWV infected pepper plants on 1 % agarose gel stained with ethidium bromide.
M– DNA lenght marker Pst I digested λDNA, Lane 1, 2 and 4 TSWV infected pepper, Lane 3 uninfected and Lane 5 healthy pepper plants.

Summarizing our investigations on TSWV resurgence in Hungary we can conclude that the first TSWV epidemic in mid 1990 years was connected with the introduction and spread of western flower thrips (*Frankliniella occidentalis*), an efficient TSWV vector, while the second emergence in 2010 and later was due to the appearence of resistance breaking isolates of TSWV.

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