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„THE COMPLEX BREAK POINTS IN THE DEVELOPMENT OF COMPETITIVENESS OF THE AQUACULTURE SECTOR „ – NEW POSSIBILITIES FOR AQUACULTURE SECTOR

The project „Complex break points in the development of competitiveness of the aquaculture sector" (project number: VKSZ_12-1-2013-0078) is implemented in the frame of Program for R&D Excellence and Competitiveness Treaties within a consortium. 1,235 billion HUF is ensured from National Research, Development and Innovation Fund for project accomplishment. The research and development results of the project provide an opportunity for international market entry and penetration of the sector.

AquaFuture, a large-scale research and development project with dominant players of aquaculture sector, successfully completed first work phase of the project. The consortium members have started their research activities and the development of nutrition technology, both in production and fish processing, and research tasks set off against a variety of pathogens.

Main tasks of the project were generated by demands of entrepreneurs, of which competitiveness are set back by national aquaculture technologies and production, furthermore solution of these problems would step forward a serious market progress for the industry as a whole. The consortium has identified the elements which provide the opportunity to improve and develop breakthrough for the industry. The aquaculture field is needed to fully develop from basis of production to processed products so an impact will be achieved, which generates already a measurable result on our country and the EU at sector level.

Project contains From Farm to Table elements of conception and it concentrates on a total production process and it ensures availability of quality and well-controlled products for consumers. The development will be implemented in many parts of the country, through cooperation within project partners covering all areas of the sector. The project strengthens position of participants in the market to diversify their activities through the development of the supply and range of services.

Project partners:
ÖKO 2000 Ltd. (project coordinator)
Bocskai Halászati Ltd.
Czikkhalas Halastavai Ltd.
Hoitsy és Rieger Ltd.
Szabolcsi Halászati Ltd.
PLP Seafood Ltd.
Szent István University
Hungarian Academy of Sciences, Centre for Agricultural Research

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Cover photo: Planting old treasures at Lokod in Transylvania (Dominik Samol)

"THE EARTHWORM IS THE BEST WORKMATE OF THE FARMER" –or the beneficial effects of minimal soil disturbance on soil structure

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ABSTRACT

In recent decades in Germany the soil structure has been greatly improved in a substantial part of the arable land. Soil erosion can be observed less commonly. Since the 1970's in Germany the intensity of soil disturbance has been significantly reduced. The less disturbed soil has more mechanical load, namely the stability of soil structure. The perforated structure with stable biopores ensures ecological functions, such as infiltration, aeration, root permeability, fertility. For this reason, soil compaction and soil erosion occur less frequently, they can be detected only in exceptional cases. But in Hungary the same cannot be stated, therefore it is desirable to explore the cause for differences. Usually the best soil structure can be found on arable lands where ploughing is not applied. In Germany there was an opportunity for us to study the condition of soils in farms which use no-till system. We have analyzed the effect of soil cultivation methods on soil structure.

keywords: soil structure, tillage methods, compaction, earthworm

INTRODUCTION

Since the 1970's in Germany – partly because of rational aims – the intensity of soil disturbance has been greatly reduced; even ploughing tends to be evaded.

Several forms of reduced/adaptive soil cultivation have become widespread, but basically mixed tillage systems dominate, since plant protection strategies to be developed for cultivated crops have a vast impact on tillage systems. Although the majority of farmers still use ploughs, they do not employ them regularly, and they plough the soil less deeply than they used to. Farmers plough for plant protection purposes only – and only before certain crops – while before other plants in the crop rotation they use merely a heavy duty cultivator. An ever increasing number of farmers use cultivators for primary tillage, and do not use ploughs at all.

With the decrease of soil disturbance, the structure of soils significantly improves. Our experiences are promising, and the improvement of soil quality can be verified by field test methods as well. The improvement of soil structure can be linked to an increased biological activity of soils, as tillage without inverting provides favourable conditions for earthworms (***Lumbricus terrestris***). Earthworms get enough food on the surface in the form of organic residues (mulch), and as a result their activity improves the structure of the soil. In order to facilitate/establish sustainable soil use, it is absolutely necessary to study the link between German tillage methods and the quality of soils, as well as share gained experiences in order to contribute to the adaptation of optimised soil disturbance methods in Hungary. Nothing proves this idea better than the words of Heisenberg: "Science has two components: observing phenomena and sharing the results..." (Heisenberg 1978). This was our aim in planning a study tour to Germany.

SOIL COMPACTION: ITS FORMING AND DEFINITION

In accordance with Act CXXIX of 2007 about soil conservation, the sustainment of the yield potential of arable lands is our common task, therefore land users should prevent or terminate the compaction of soil in order to avoid excess water or inland inundation. Soil

is a conditionally renewable natural resource, as well as the basic production means of agriculture and forestry. Thus, soil protection primarily means quality protection: the protection and improvement of quality, but first and foremost the prevention of physical, chemical and biological deterioration.

The German Packungsdichte is a complex concept, but basically it means a simple field method that aims at the assessment of the condition of soil structure. This field method primarily examines the degree of density of the soil, which has a fundamental impact on the most important aspects of soil, such as porosity, water and air permeability, root penetrability and fertility (DIN 19682-10:2007).

Compaction basically reflects the adhesive and cohesive forces between soil particles, which are manifested in the soil's resistance to cultivation. Soil compaction depends on several factors: the morphological, physical and chemical properties of the soil, as well as the vegetation that covers the ground, the way the land is used, and also the method of tillage.

When determining compaction, the moisture content of the soil plays an important role.

Regarding soil compaction, the following categories can be established with field methods: friable soil, loose soil, slightly compacted soil, compacted soil, heavily compacted soil, very heavily compacted soil, and solid soil.

In trying to visually determine soil structure in the field, the simple and universally applicable "Spatendiagnose" ("spade test") method may help, but reliable and practically useful results are obtained through the joint analysis of regular soil sampling, plant studies and crop yield (Tebrügge and Eichhorn 1992). Soil tests carried out in the field are practically the intersections of theoretical research on soil science and soil tillage.

Spade tests actually mean the examination of the place where the plant is grown. During this process the structure and colour of the soil, root distribution, pores in the soil, as well as transition horizons were examined. The name and description of the method comes from Görbing (Görbing 1947). Spade tests can be used to examine the soil down to approximately 25-28 cm below surface, regarding its structure, water content, the location of the solid layer, the condition of the soil, and accordingly, the suitability for cultivation (Birkás 2007; Birkás 2011). In most cases earthworms and wormholes can be found within the depth of shovel blade. In critical situations it is worth digging two spits deep. The great advantage of the method is that it can be gained information about the condition of the soil right in the field. Since there are using a smaller soil profile, it can be excellently observed root distribution or the ratio of macropores. However, if the soil is too wet or too dry, it can be a problem. This is why sampling should take place in spring, when the saturation of the soil is optimal. Spade tests can also supplement the examination of soil compaction.

FIELD EXPERIENCES: A GERMAN STUDY TOUR

In connection with sustainable cultivation and the field study of soil structure, this summer we had the opportunity to visit Justus-Liebig University in Giessen, Germany, which is one of the most significant universities in the area of agriculture, soil studies and soil protection in Germany (Justus-Liebig-Universität, Institut für Bodenkunde und Bodenerhaltung). It is characterised by a high degree of interdisciplinarity. The study tour was made possible by the Campus Hungary Higher Education Staff Long Term Mobility B2/4H/12385. So there was an opportunity to observe and study the educational and research structure of Germany, a country with highly advanced economy. At the Justus-Liebig University, where some thematic research involving practical problem solving is also part of PhD studies, so it seemed like a good chance to learn about educational/research techniques that – due to the significant innovation – are more developed than what Hungarian infrastructural conditions allow. This research is aimed at solving actual problems, and the results are immediately utilized in the agricultural and environmental industries. Within each research unit of the university, PhD students and visiting professors of the same study field but coming from different countries work together, thus create an international scene where it is possible to share research, educational and professional experiences with one another. They carry out theoretical research primarily, relying on an advanced laboratory infrastructure

However, in order to emphasize and widely share the importance of practical knowledge, it was necessary to establish presentation and training centres on German universities and colleges. One perfect example of such a centre is the Hochschule Weihenstephan – University of Applied Sciences in Triesdorf. The significant results had been achieved in the area of agriculture that is highly adjusted to local conditions and circumstances. Furthermore the two institutions of higher education mentioned above have developed very strong bonds with farmers, in the area of applied research, experimental development and education.

They realized that the more complicated problems in the area of practical agricultural research should always be solved with the contribution of farmers, for it is in the intersection of discovery and applied research where the solution to the problems lies. This way the crossing points of education and research (theory and practice) will be highly satisfactory. Innovation and interdisciplinarity are also greatly propagated. The Hochschule in Triesdorf regularly offers agricultural MBA courses (in German), where practical farm activities are combined with the mastering of theoretical knowledge. Those who enrol in the courses will receive an internationally acknowledged degree and understanding, since this training is internationally

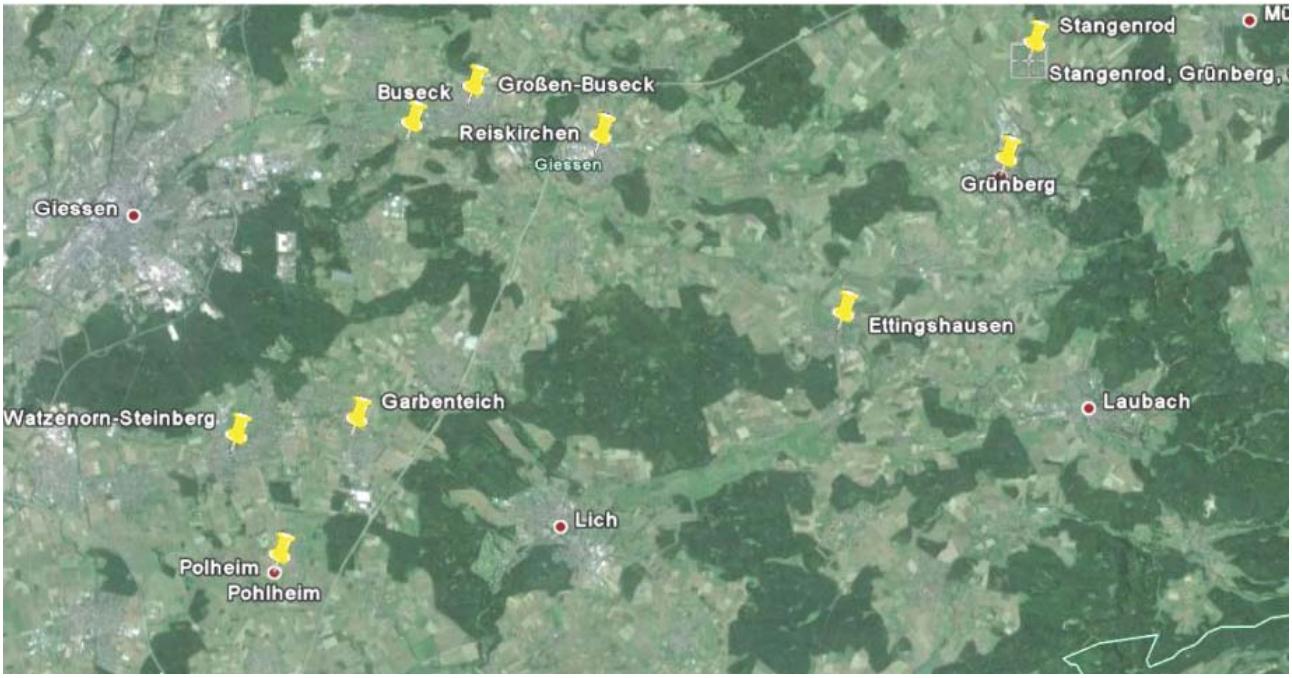

Figure 1: The Giessen basin, Grünbergand its surroundings, Vorderer Vogelsberg
Source: Google Earth map

accredited. Such an educational, research and student base attracts a number of manufacturers and dealers, who provide practical training opportunities for high quality educational / research activities.

THE EFFECTS OF SOIL DISTURBANCE ON SOIL STRUCTURE – OUR EXPERIENCES IN GERMANY

The colleagues of the Institute of Soil Science and Soil Protection at Justus Liebig University feel responsible for the sustainable use of natural resources including soil, and they realised years or decades ago that this requires active cooperation with farmers.

There was a great opportunity to study the condition of German soils in order to explore the effects that tillage methods and tools have on the soil. This study was organised by the scientists of the institute, under the leadership of Professor Dr. Tamás Harrach. It is important that the signs of the interactive relationship between the soil and the tools used on it can and should best be studied in the field, taking into consideration the biological processes of the soil. Since, from the viewpoint of plant production, not only the nutrient content but also the structure of the soil can be a limiting factor (Tebrügge and Eichhorn 1992; Beste 2002).

The different levels of this method indicate how compacted or loose the soil is. This includes a number of very important aspects about the condition of the soil, such as total porosity, the ability of plants to grow roots, or the amount of water that the soil can contain, as well as the soil's permeability. During our first study tour, we visited the German and Bavarian farms as indicated in Figure 1 (basically in the Giessen basin and in the Vorderer Vogelsberg subregion), where we learnt about the tillage methods used, as well as the condition of the soil of cultivated lands. This also provided the opportunity for researchers to share their experiences with local farmers.

With the active contribution of farmers, it could be observed how local farms or family farms work. With the German colleagues, we could also carry out soil field diagnostic tests on the areas belonging to the farms listed in Table 1.

When deciding which farms to visit during this study trip, primarily those farms were chosen which cultivate the soil without using ploughs. One of the reasons behind such tillage methods is that some of these lands have shallow topsoil, since they have been formed on the basalt of the mountain. Because of this these soils contain a large amount of hard basalt and rubble. However, both in the shallower, poorer basalt soils and in the more fertile loess soils, another aspect is considered: besides economy, farmers favour methods which rather increase the fertility of the soil than decrease it. Both reasons are a motivation and challenge for farmers.

Accordingly, tillage methods involving minimal soil disturbance are rather widespread in Germany. The quality of tillage methods are also valued by how much the biological processes in the soil are taken into consideration. The agricultural engineering industry in Germany, including market leading Horsch Company, recognized this, and, through its absolute partnership, has facilitated the

TABLE 1: Main information of farms

farm/ farmer location	landscape, mean annual temperature/ average annual precipitation	area of cultivated land (crops)	main soil types (score on a 100 point scale)	cultivation method
Peter Fay Pohlheim, Watzenorn-Steinberg	Giessen basin 8.9 °C / 600 mm	120 ha (rapeseed, autumn wheat, rye, spring barley in crop rotation)	some shallow gravelly and clay topsoil from basalt (30-35), some excellent loess soils 70-84)	with cultivator for 10 years, no ploughing for 5 years
Agrarservice Bank GmbH Oliver Jung Reiskirchen, Ettingshausen	Vorderer, Vogelsberg 8.0 – 9.0 °C / 600 - 750 mm	700 ha (rapeseed, autumn wheat, spring barley, spring barley in crop rotation)	some shallow gravelly and clay topsoil from basalt (30-35), some leached loess soils (55-68), some excellent loess soils (68-74)	with cultivator–parts of the area has not been ploughed for 20 years
Dr. Dietmar Schmidt Buseck, Großen-Buseck	Giessen basin 8.8 °C / 600 - 650 mm	165 (rapeseed, autumn wheat, autumn or spring wheat, autumn barley in crop rotation)	some shallow gravelly and clay topsoil from basalt (45-65), mostly excellent loess soils (68-75)	with cultivator, no ploughing
Manfred Balser Pohlheim, Garbenteich	Giessen basin 8.8 °C / 600 mm	70 ha (rapeseed, autumn wheat, rye, spring barley, autumn barley)	some shallow gravelly and clay topsoil from basalt (36-55), some Stagnosol loess soils (55-70)	with cultivator, sometimes shallowly with disc harrow – for 10 years partially, for 5 years totally without ploughing
Reinhard Keil Reiskirchen, Ettingshausen	Vorderer, Vogelsberg 8.5 °C / 600 - 650 mm	260 ha (rapeseed, autumn wheat, spring barley)	some shallow gravelly and clay topsoil from basalt (38-55), some leached loess soils (55-68)	traditional tillage with ploughing, but sometimes cultivator without ploughing
Henning Schäfer Grünberg, Stangenrod	Vorderer, Vogelsberg 8.1 °C / 750 mm	190 ha (rapeseed, autumn wheat, autumn barley, spring barley in crop rotation)	some shallow gravelly topsoil from basalt (38-55), some leached loess soils (55-74)	with cultivator–partially without ploughing for 12 years, mostly without ploughing for 4 years

spreading of tillage methods adapting to local needs and conditions (by the continuous development of related machinery). The farms cultivate their lands with joint acquisition and use of machinery, which is based on the ownership share of cultivated land areas.

Due to the minimal disturbance of soil, a large part of farmlands in Germany is in a very good condition, or at least significantly better than 30-40 years ago. The same is not true about Hungary, despite that fact that according to the Programme of National Cooperation published in 2010, soil protection is one of the main aims of the government: "***The aim is to create diverse agriculture, environmental and landscape management which produces valuable, healthy, and safe food in a way that taxes the environment and local energies and raw materials to the least possible extent while preserving our soil, water stock, wildlife, and natural values."*** (PNC 2010) Thus, it is desirable to explore the causes for these differences, since by adapting German good practice, soil structure in Hungary could also be improved (although some farms make soil conservation tillage for 32 years). The basic difference lies in the intensity of soil disturbance. The less the soil is disturbed, the better its structure, since excessive tillage causes the disintegration of soil structure, while optimised disturbance facilitates biological processes in the soil, as well as the proliferation of earthworms, thus having a key role in the development of excellent, stable soil structure.

Optimised soil disturbance methods have provided us with good results, the achievements are well documented. The structure of the soil is especially good in areas where the land has not been ploughed for years or decades. The greatest disadvantage of ploughing – besides its being energy and time consuming – is that it inverts the soil too deep. This way organic remains get into the deeper parts of the soil (down to 20-40 cm), leaving no mulch on the surface, therefore earthworms (***Lumbricus terrestris***), which play a crucial role in improving the porosity and structure of the soil, will not have enough food that is rich in organic material. Without ploughing, however, mulch remains on the surface, which provides the necessary conditions for earthworms. (Note here that an even distribution of mulch does not require any extra effort, since this can be done at the same time as harvesting the

Figure 2: Structure of undisturbed soil

Figure 3: Biopores and roots permeating the pores in undisturbed soil

crops.) So, fewer disturbances and more mulch lead to more earthworms, the activity of which results in a better soil structure. Besides plant remains as food, the lime content of the soil is also important, therefore lime-free soils should regularly be supplemented with lime, or else biological processes will deteriorate, which has an adverse effect on the activity of earthworms.

Of course, the soil cultivation methods have other roles as well. Applying ploughs or deeper disc harrows have plant protection objectives, too. Consequently, those who apply minimal soil disturbance, use chemicals for weed control and plant protection. Therefore, when introducing adaptable cultivation systems, the greatest challenge is to develop an appropriate plant protection strategy. The use of chemicals is an obvious choice, but there are other solutions as well. This is proven by the increasing numbers of organic farms that change over to reduced/optimised tillage and minimal disturbance cultivation methods.

The spade test method was applied to examine soil structure in the field. Nowhere within the farmlands did we experience any "harmful compaction". The part of the once ploughed topsoil that has been tilled with a cultivator 18-25 cm deep was definitely loose and friable, which was not true about the layers beneath. Previously, the soil had been ploughed 32-35 cm deep. The topsoil that has not been disturbed for years is more difficult to dig 25-35 cm below the surface, and at first sight it seems compacted, but at closer inspection it is revealed that this relatively compacted layer also has a lot of biopores, especially former root spaces and wormholes.

Figure 2 illustrates the structure of such soil that has not been ploughed for years, where, close to the surface, the structure is loose and friable, and there is no harmful compaction in the deeper layers either. The large number of vertical biopores ensures infiltration, ventilation and root growth (Figure 3). Thus, ecological functions of the soil are intact, so harmful compaction can be excluded. At the same time, the more compacted matrix has higher stability, and it prevents the subsoil from compaction caused by heavy tillage implements and traffic. So, in the soils, the subsoil below the once ploughed level shows no sign of compaction. Here an especially large number of biopores are visible to the naked eye (Figure 3).This layer should not be disturbed in such condition, because the current, moderate compaction ensures higher load capacity, while the loosening of the layer would annihilate the existing, definitely stable bio pores.

With the simple spade test method described above, it can be seen in the whole section that the optimised amount of disturbance has a positive effect on the structure of the soil. As a result of leaving mulch on the surface, earthworms start to flourish (Harrach 2011), they improve the structure of the soil and its porosity. With this kind of farming, soil compaction and water logging hardly ever occur, there will be no crust formation on the surface, and soil erosion rarely takes place, either. If plant protection strategies work as well, plants will grow successfully, and they will not show any signs of deficiency caused by inappropriate structure of the soil, even where the heaviest traffic occurs at the edge or in the cultivation rows of the plot.

Therefore, poor soil structure and harmful compaction can be identified by the presence of crust formation on the surface, water-logging, signs of soil erosion, and last but not least, the insufficient development of crops. These signs should particularly be monitored in case of extreme weather. With the spade test method, it can be easily identified which layer of the soil is affected by harmful compaction. It should be particularly careful where biopores (former root spaces, wormholes) are missing. Harmfully compacted layers should be loosened, because heavy compaction cannot be improved by biological processes only. Note here, though, that the stability of loosened soil is poor, and the risk of recompaction is high. Thus, intervention should take place only where appropriate, and even in such cases, the soil should not be disturbed any deeper than truly necessary. The soil should be loosened only when its water content is optimal for the operation.

It has been proven by a number of experiments and practical cases that direct sowing without soil disturbance can also give maximal yield, provided that the appropriate sowing strategy and plant protection technique are applied. The soil should be loosened only if its structure has been damaged.

In order to assess the condition of the soil, each year farmers perform 3 or 4 field tests, or have them performed

by professional soil experts, in line with due agricultural work.

To perform these tasks is their primary interest, since their "taxing" system is based on maintaining or improving the soil's condition, (there exists a so called 100 point soil classification system to help the assessment of the soil).

Through the examples of the farms we visited during this study tour in Germany, it became perfectly clear for us that the interdisciplinary nature of adaptive agriculture (involving agriculture, engineering and plant protection) is becoming more and more important. Moreover, in addition to basic research, practical experience is also indispensable, while spectacular results can be achieved through the cooperation of regional agricultural research institutions and farms.

CONCLUSIONS

We were pleased to discover that we share our views with German colleagues and local farmers concerning the potentials and challenges of sustainable and adaptive agriculture, consequently the aims of our research work are the same: to improve the condition of soils. This research, however, should never be an end to itself; it should always help to find answers to actual social challenges, according to the motto: "Science that looks far: responsible answers for the future."

However, we all agree that the natural environment contributes to human well being. The optimal depth of soil cultivation is a highly disputed question in Germany as well, since ploughing and the several operations associated with it, are, among other things, quite energy consuming. This is why there is a growing demand for economically more efficient solutions that require fewer operations. There is, however, no universal solution to the problem; the appropriate soil tillage strategy should always be developed according to local and specific conditions and experience, during which several factors should be taken into account, namely:

- In case of ploughless cultivation earthworms will proliferate and improve the structure of the soil

- Vertical wormholes reaching down to the soil, as well as those leading to the surface are of particular importance. The greater the number of such wormholes per square metre, the better the conditions for infiltration and thus the permeability of the soil.

- Disturbance of the subsoil is appropriate only when compaction of deeper layers need to be loosened.

- In order to achieve optimal soil structure, the straw is shredded at the time of harvest (ideally into pieces smaller than 4 cm), and that it is spread equally. Novel sowing techniques enable leaving mulch on the ground, which is very valuable from the viewpoint of soil biology and soil protection.

- Plant protection strategies should apply a moderate amount of chemicals, and they should prefer the use of ecological methods.

The path to adapt optimal soil disturbance in Hungary and to assessing our potentials in the light of our abilities leads through an all-society awareness raising educational activity, as well as proper educational and research work. The feasibility of such a path has been full confirmed by this study tour.

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