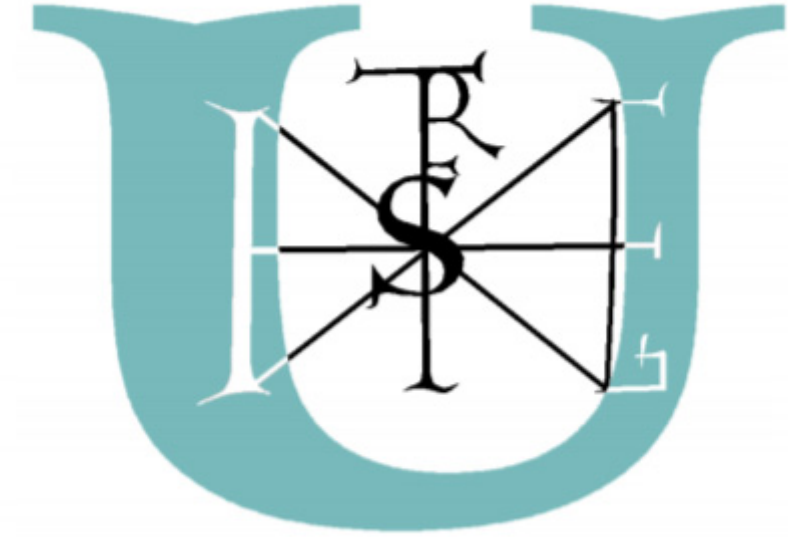

SZENT ISTVÁN UNIVERSITY

DEVELOPMENT OF A METHOD MEASURING THE SUSTAINABILITY OF AGRICULTURE

MÉSZÁROS DÓRA

Gödöllő

2017

PhD school

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…… ……

Approval of Head of Doctorate School Approval of Supervisor

INTRODUCTION, TARGETS

Nowadays there are several international organisations, research institutes and governmental organisations searching for an answer to the question how to lead agriculture with growing ecological footprint to a sustainable path.

When analysing the sustainability of agriculture three areas (environmental, social and economic) have to be considered. Despite of the fact that sustainable agriculture has no globally accepted definition, these pillars are usually mentioned.

To achieve sustainability in agriculture it is crucial to measure its sustainability on both macro and micro levels. The European Union and in Hungary the Central Statistical Office (KSH) worked out already macro level indicators to measure the sustainability of agricultural sector. However no micro level indicator system has been created so far focusing on farm-level sustainability.

Sustainability assessments on micro level are important because they provide the possibility to compare sustainability performance of farms, increase the environmental awareness of farmers and support their farm management decisions. Furthermore these assessments can provide information for political decision makers and contribute to the planning of more efficient result-based agri-envionmental schemes in agriculture.

During my PhD research I participated in the further development and validation of a farm-level sustainability assessment tool which has not been applied in Hungary before but proved to be applicable under Hungarian circumstances as well. I also accessed the sustainability performance of Hungarian farms by applying the improved tool. In my opinion this research was significant because there has been only one research so far measuring the environmental sustainability of farms in Hungary. This analysis was done with the so called Agridiag Green-point System and did not consider the economic and social pillars. Thus I attempted to measure the sustainability performance on farm-level including economic and social sustainability as well.

In my research I used the tool called SMART (Sustainability Monitoring and Assessment RouTine). One of the reasons why it was selected is that I managed to get a scholarship from ÖMKi (Ökológiai Mezőgazdasági Kutatóintézet, Research Institute of Organic Agriculture), the Hungarian partner of FiBL (Forschungsinstitute für biologischen Landbau). Via ÖMKi I joined one of the research teams of FiBL and participated in the further development and Hungarian adaptation of SMART.

Targets

The main target of my research was to apply a farm-level indicator system in practice which allows me to compare the results of different farms and which is applicable in Hungary as well. To reach this goal I defined five targets in my PhD work. My first target (T1) was to review and systemize the development of the notion sustainability and sustainable agriculture in the international and Hungarian special literature.

As a second target (T2) I aimed to summarize the knowledge on public goods, particularly public goods provided by agriculture and to analyse the connection of sustainability and agricultural public goods.

The third target (T3) of my research work was to collect, systemize and evaluate the already available farm-level indicator systems designed to measure sustainability and to select those ones which seem to be suitable for a Hungarian application.

I also aimed to modify and further develop the selected indicator system based on the Hungarian requirements (T4).

Finally, I targeted to evaluate the sustainability of 50 Hungarian farms (T5) – 25 organic and 25 conventional – with the tool called SMART in a way which includes the evaluation of all the three pillars (environmental, economic and social) of sustainability and all the sub-themes of sustainability defined by the FAO guidelines.

MATERIALS AND METHODS

I wanted to make sure that SMART is a good choice for the Hungarian assessments. Thus based on literature review I selected and compared those indicator systems which might be suitable for my assessments. For the comparison I used the SAFA guidelines of FAO.

After collecting the indicator systems available in the special literature I defined those parameters which are a must for my research. I searched for indicator systems which:

- are designed for farm-level assessment,
- evaluate all the three pillars of sustainability,,
- can be applied on any farm (with any production lines) and
- are developed with the aim to guarantee the global applicability (in other words applicable in any country).

After systemizing the available indicator systems based on the above parameters I found seven tools which were theoretically suitable for my research. However, SMART was the only one measuring all the dimensions (pillars) and sub-themes of sustainability defined by FAO. As a result of this I used SMART in my research.

Introduction of SMART

The SMART Farm Tool analyses to what extent a farm meets the sustainability targets defined in SAFA guidelines. The analysis is done by indicators. Each sub-theme is measured with more indicators and the results of the sub-themes are presented on a 0-100% scale, where 0% means the farm did not do any action to reach the given target and 100% refers to the fact that the farm took several steps to reach the given sustainability goal.

Results are also presented on a spider web diagram and detailed explanations are given, including the general description of the farm, the goal of the 58 sustainability targets and the explanations of the final scores reached by the farm.

The system consists of 327 indicators.

Data collection necessary for the farm evaluation is done in the course of an interview conducted with the farm manager. The interview requires 2-3 hours depending on the farmer and the diversity of the farm. The interview consists of two parts. In the first part the auditor ask the farmer to introduce the farm by showing the auditor around. In the second part the auditor asks questions from the farmer based on a pre-defined questionnaire. Answers are recorded on a laptop and the sustainability evaluation is done after the face-to-face interview.

Preparation of SMART for the Hungarian assessments

Preparation of SMART for the Hungarian assessments was done in more steps (see Figure 1.)

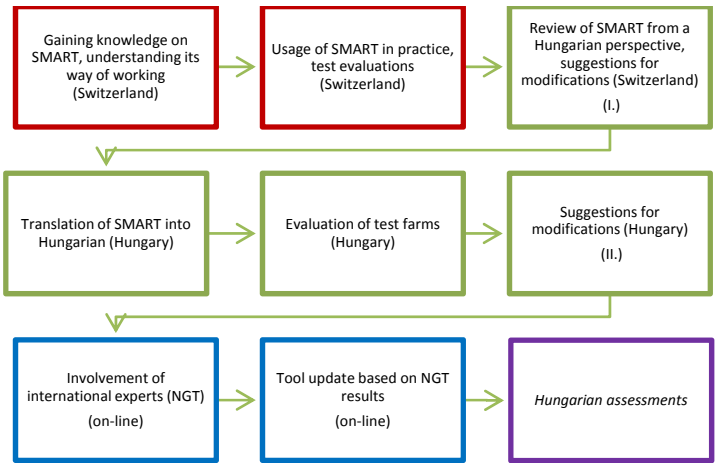

Figure 1: Preparation of SMART for the Hungarian assessments

To get to know the indicator system in details and to understand how it works I spent two months at FiBL with the SMART research team in Switzerland. During this period I also conducted test evaluations on three Swiss farms to get practical knowledge as well.

Following this I reviewed the indicator system from a Hungarian perspective. With this I aimed to filter out those indicators which are not applicable in Hungary or which can be applied only after certain modifications.

After the review of the tool I translated it into Hungarian and tested the translated version on three Hungarian farms. Test evaluations were followed by further amendment suggestions.

To finalize the indicator system international experts were involved to get the tool and the indicators validated.

Opinion of external experts was collected with the so called nominal group technique (NGT). After contacting the relevant experts 112 positive answers were received from 18 different countries. Their opinions were collected in excel and with the help of an online tool (clickmeeting) in three steps.

Feedbacks were analysed and SMART was modified based on them. Thus the final version of the tool was created what I also used in the Hungarian assessments.

Preparation of the Hungarian assessments

In my research plan I defined (among others) to assess 25 organic and 25 conventional farms in Hungary with SMART. Farmers were selected from the database of NéBiH (Nemzeti Élelmiszerlánc-biztonsági Hivatal, National Food Chain Safety Office) with random selection based on the following parameters:

- farm size is 10-300 hectares,
- both plant production and animal husbandry exists on the farm,
- there has to be at least 25 organic and 25 conventional farms in the selection.

Farmers were contacted first by NéBiH in a letter and I called the farmers on the phone to agree on the timing of the interview. The 50 assessments were conducted by me between December 2015 and February 2016.

Evaluation of results with statistical methods

Steps of statistical analysis were the following:

1. Similarity test of the two samples (Mann-Whitney U-test)
2. Comparison of organic and conventional groups
    - Analysis of data distribution (One sample Kolmogorov-Szmirnov test)
    - Independent two sample t-test (in case of normal distribution)
    - U-test (in case of not normal distribution)
3. Correlation analysis between dimensions and sub-themes
    - Pearson correlation (in case of normal distribution)
    - Spearman rank-correlation (in case of not normal distribution)
4. Correlation analysis between farm size and dimensions (Pearson correlation analysis)
5. Comparison of dedicated organic farmers' group and the group of organic because of financial reasons:
    - Independent two sample t-test (in case of normal distribution)
    - U-test (in case of not normal distribution)
6. Comparison of conventional farmers and the group of organic because of financial reasons
    - Independent two sample t-test (in case of normal distribution)
    - U-test (in case of not normal distribution)
7. Creation of farm clusters and dendrogram with multivariate biometrical methods based on multidimensional distance (D^2) of farms measured by sustainability indicators.

RESULTS

Similarity test of the two groups

I compared the two groups (organic, conventional) in my sample based on seven parameters to make sure that farm sampling was done in the right way. Based on this my sample proved to be homogeneous.

Comparison of organic and conventional groups

I presented the summary of the results of assessed farms on twos spider web diagrams. Figure 2 shows the results of organic farms, Figure 3 presents the outcome of conventional farm assessments.

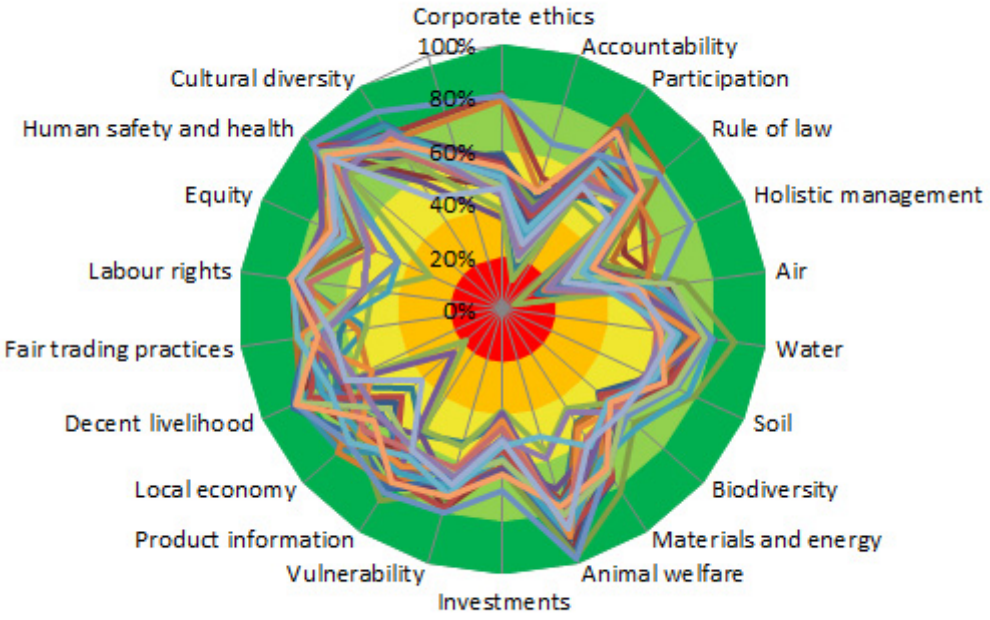

Figure 2: Sustainability assessments of organic farms

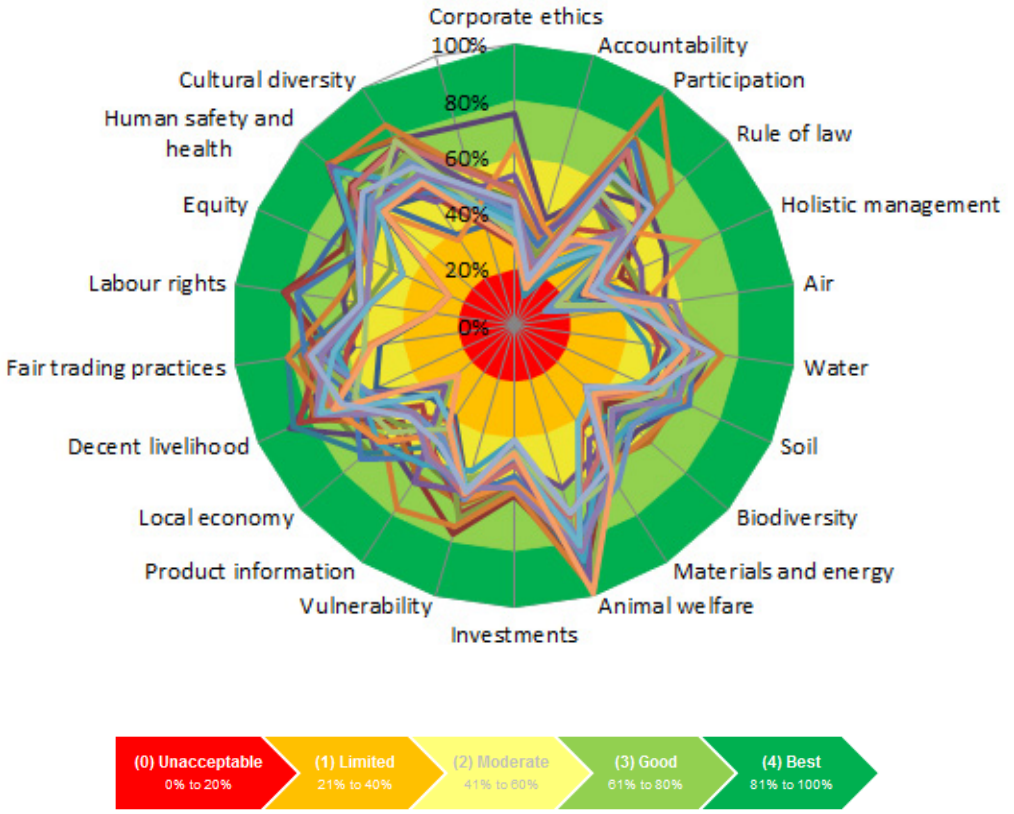

Figure 3: Sustainability assessments of conventional farms

Based on the above figures one can state that most of the problems occurred both in organic and conventional farm groups in Accountability and Holistic management sub-themes. Best results were reached in Animal welfare and Human health and safety sub-themes.

To be able to understand the results of Figure 2 and 3 easier I defined the % of farms in the different scale categories (marked by colours) on theme level. Vast majority of the farms got at least into the "moderate" category. Most of the farms are in the "good" category followed by the "moderate" category. If we separate the organic farms from the conventional ones it becomes visible that **most of the conventional farms are in the "moderate" category whereas most of the organic farms are in the "good" category**. The least amount of farms is in the "unacceptable" category in case of both groups and in the "best" category there are twice as many organic farms (20%) as conventional ones (6%).

I presented the **average results on theme level** for organic and conventional farms on separate spider web diagram (Figure 4). This way it is clearly visible that organic farms performed higher in each theme, except in Animal welfare.

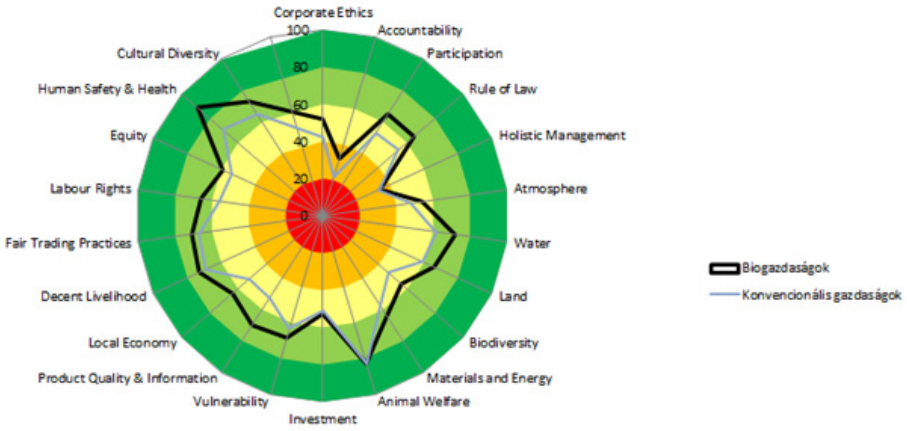

Figure 4: Average sustainability results of organic and conventional farms on theme level

Comparison of results on theme and sub-theme level

I compared the results of organic and conventional farms on sub-theme level and I examined in which sub-theme the results show significant difference between the two groups. **As a summary** we can state that except two environmental (Animal health, Freedom from stress), three economic (Community investments, Profitability, Liquidity) and one good governance (Mission statement) sub-themes organic farms scored higher in environmental, social, economic and good governance dimensions. Consequently, **organic farms perform better in all pillars of sustainability compared to conventional ones.** These results are demonstrated on the following four figures.

In case of **environmental sub-themes** I found significantly better results for organic farms in 11 sub-themes out of 14 (p=0,05) (Figure 5). Significant differences are highlighted with a star on the figures.

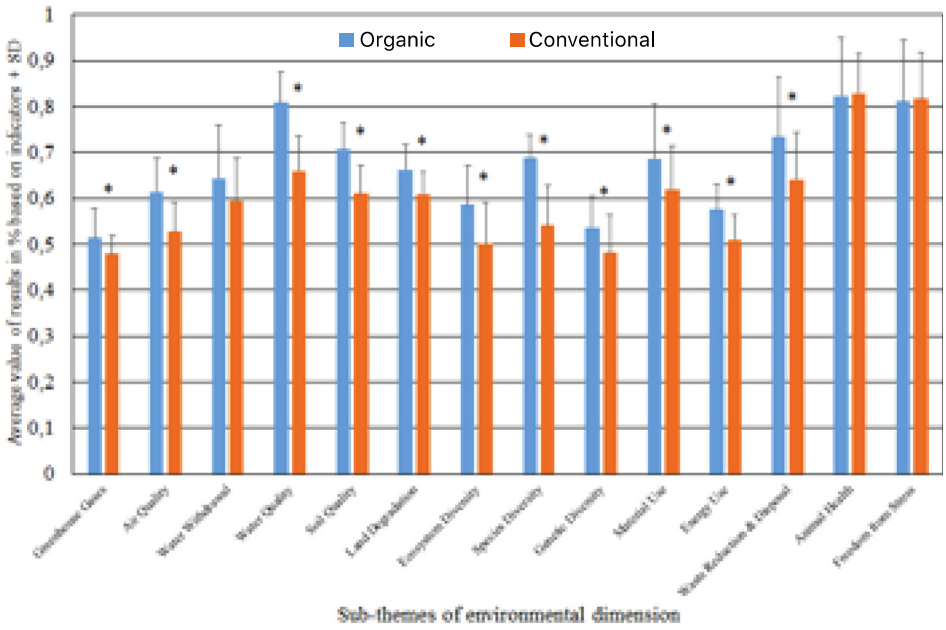

Figure 5: Results of environmental sub-themes for organic and conventional farms (significant differences highlighted with a star)

When analysing the **economic sub-themes** organic farms showed better results in 11 categories, where in 8 sub-themes the difference was significant (p=0,05) (Figure 6).

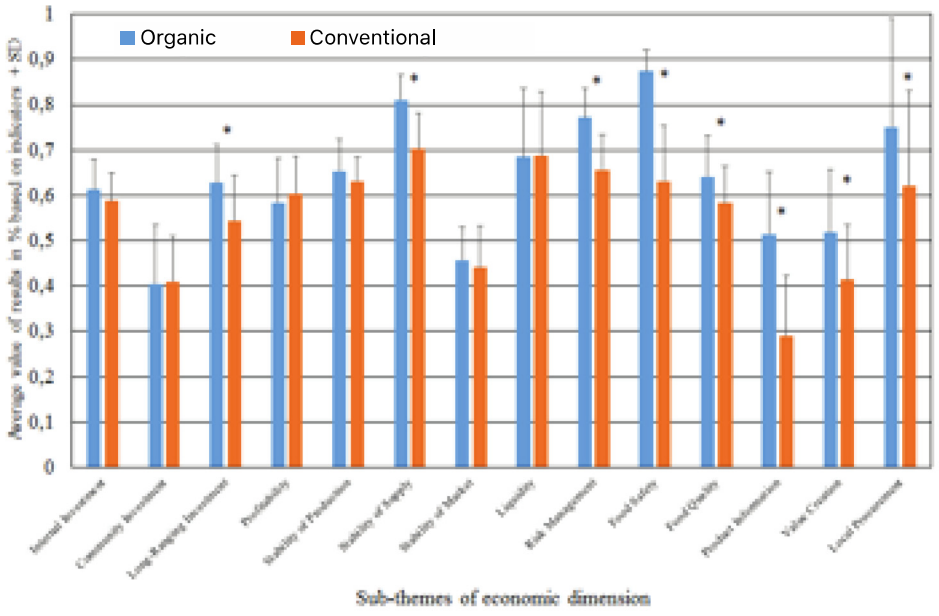

Figure 6: Results of economic sub-themes for organic and conventional farms (significant differences highlighted with a star)

In **social sub-themes** it was the organic farms always overperforming the conventional ones (Figure 7). However here the number of sub-themes with significant differences was lower (7 out of 16 sub-themes).

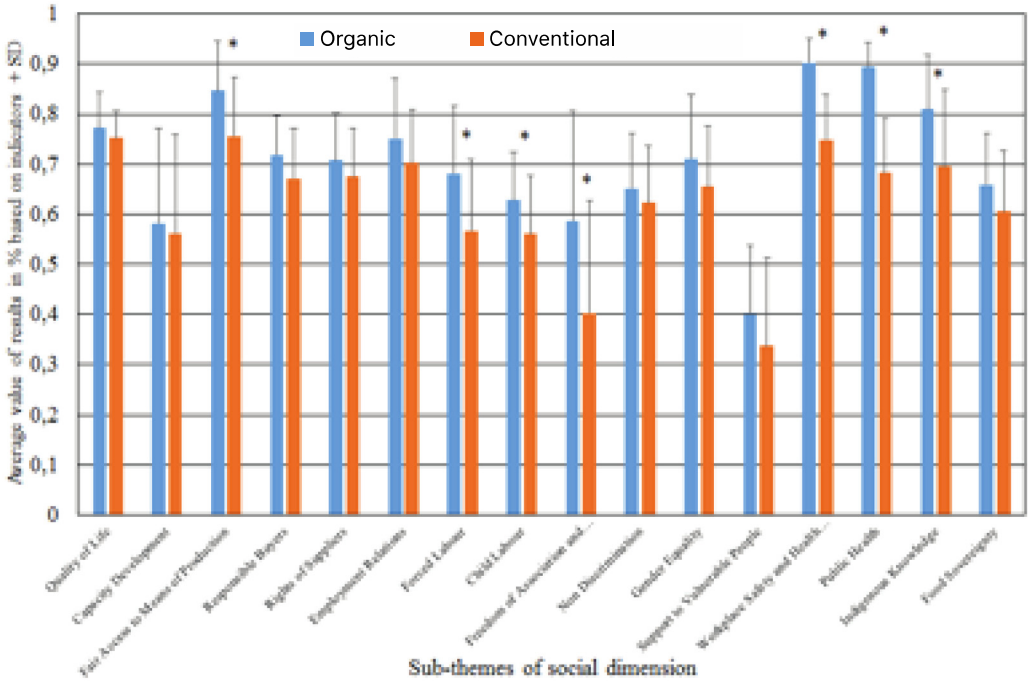

Figure 7: Results of social sub-themes for organic and conventional farms (significant differences highlighted with a star)

Also in **good governance** dimension organic farms proved to be better in all sub-themes, except in Mission statement (Figure 8). 7 out of 14 sub-themes showed significant difference (p=0,05).

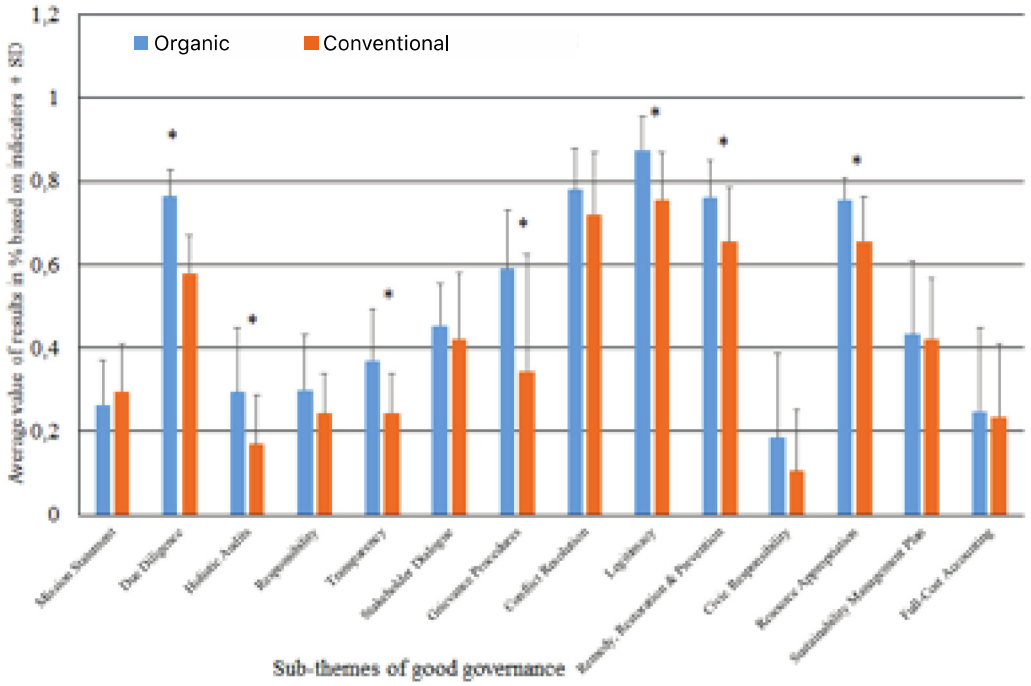

Figure 8: Results of good governance sub-themes for organic and conventional farms (significant differences highlighted with a star)

In sub-themes with significant difference I checked which indicators cause this significant deviation. As one indicator might have an effect on more than one sub-themes, the **indicators responsible for significant difference** in the different sub-themes overlap. Most of the deviations originate from the chemical usage related indicators. Further significant difference could be detected for the benefit of organic farms in the following topics/indicators:

- winter coverage is more frequently used,
- animals spend more time on pasture,
- the distance between the manure storage and the nearest water source is satisfactory,
- land parcels are smaller,
- the share of consumed food produced by the farmer is higher,
- farm infrastructure is in a better condition,
- share of farms where sewage water handling is in line with the regulations is higher.

If we analyse which are the **themes** farmers **performed** the **best** or the **worst** in, it is clearly visible that in environmental, social and good governance

dimensions organic and conventional farms performed the best/worst in the same themes. However there is a difference in the economic dimension. As long as organic farms scored quite well in Product quality and information theme, conventional farms were the worst in it.

Correlation analysis between dimensions and sub-themes

In case of **organic farms** at p=0,01 significance level there is a moderate connection between environmental and economic and economic and social dimensions. This means that **those organic farms which perform better in the environmental dimension, most likely will perform better in the economic dimension as well and this is also valid for the economic and social dimensions**.

In case of **conventional** farms the connection between the economic and social dimensions is a bit stronger compared to the connection between the environmental and economic dimensions. In turn there is a connection - not too strong though - between the environmental and social dimensions. In other words **those conventional farms which perform better in the economic dimension probably will perform higher in the social dimension as well. And those who perform better in the environmental dimension probably will perform better in the economic and social dimensions as well**.

When analysing the **connections between sub-themes within the dimensions** I found several ones where the connection was statistically strong and the difference between the groups was significant (r>0,7; p=0,05).

In the **environmental** dimension the strongest positive connection (r>0,9; p=0,01) was found between the following sub-themes in case of **organic farms**:

Species diversity ⟶ Ecosystem diversity

Material use ⟶ Water withdrawal

Animal health ⟶ Freedom from stress

Strong and moderate positive connection of sub-themes at **conventional farms** almost completely overlap with the connections at organic farms. The only difference is that here the connections are usually weaker by one hundredth. Strong positive connection (r>0,9; p=0,01) appeared in one sub-theme (the same was visible at organic farms as well):

Animal health ⟶ Freedom from stress

In **economic** dimension there was no connection with r>0,9 strength when analysing the **organic farms**. The strongest positive connections (r>0,8; p=0,01) outlined in the following cases:

Profitability → Stability of production

Stability of production → Risk management

Food safety → Product information

In case of **conventional farms** no particularly strong positive connection (r>0,8; p=0,01) was found, strong positive connections (0,8≥r>0,7; p=0,01) are the following:

Long-ranging investment → Risk management, Food safety, Food quality

Profitability → Stability of production

Risk management → Food safety

Food safety → Food quality, Product information

There were also several sub-themes in **social** dimension at **organic farms** where strong positive connections are visible (r>0,8; p=0,01):

Workplace safety and health provisions → Freedom of association and right to bargaining, Child labour, Forced labour

Forced labour → Child labour, Freedom of association and right to bargaining, Support to vulnerable people

Food safety → Product information

Child labour → Freedom of association and right to bargaining

There was almost as many strong positive connections (r>0,8; p=0,01) in case of **conventional farms** as in case of organic:

Responsible buyers	⟶	Rights of suppliers
Forced labour	⟶	Child labour, Freedom of association and right to bargaining
Workplace safety and health provisions	⟶	Support to vulnerable people
Support to vulnerable people	⟶	Freedom of association and right to bargaining

Correlation analysis between the size of the farm and the sustainability dimensions

I found weak correlation between the farm size (in 10-300ha category) and the dimension level (environmental, economic and social) sustainability results which means that **sustainability performance does not depend on the size of the farm.** This is true if we analyse all the 50 farms' data together and also if we separate organic and conventional farms.

Comparison of dedicated organic farms and the group of organic because of financial reasons

Based on the interviews there were 8 dedicated organic farms and 17 which choose to be organic due to financial reasons. I am aware of the fact that statistically this sample size is small therefore results can not be generalized, still I thought it is important to check if sustainability performance differs in case a farm meets only the legal requirements of organic farming (in other words doing „organic business") compared to those farms where holistical views of organic agriculture are fully or at least partly followed.

My analysis show that **there are sub-themes in each dimensions where dedicated organic farms performed significantly better** ($p=0,05$) in comparison to organic due to financial reasons. See Table 1.

Table 1: Sub-themes of dedicated organic farms showing significantly better results

In environmental dimension: • Air quality • Water quality • Material use • Energy use • Waste reduction and disposal	In economic dimension: • Profitability • Food safety • Food quality • Product information
In social dimension: • Public health	In good governance dimension: • Due diligence • Transparency • Sustainability management plan

Comparison of conventional farms and the group of organic because of financial reasons

In my opinion it was important to compare the results of conventional farms with the results of organic due to financial reasons. With this I intended to check if organic farms reach a better result than conventional ones even if they choose to be organic only because of financial reasons. In other words are organic results better than conventional ones in almost all sub-themes just because of dedicated organic farms1 results?

Results show that the **sustainability results of organic farms even without the dedicated organic farms are higher than the results of conventional farms however there are fewer sub-themes with significant difference.**

Creation of farm clusters and dendrogram with multivariate biometrical methods based on multidimensional distance (D^2) of farms measured by sustainability indicators

Based on the dendrogram two farmer groups could be identified. In the first group there were 27 farms, 78% of which are conventional. The second group contained the remaining 23 farms where 83% of the farms were organic. Consequently based on the results of the 21 analysed themes organic and conventional farms are separated – with 77-83% reliability – from each other.

New scientific results

1) I modified the farm-level sustainability assessment tool called SMART to make it applicable under Hungarian circumstances as well.
2) In Hungary I was the first assessing all the three pillars (environmental, social, and economic) of sustainability on farm-level. In my assessments I

analysed sustainability results from each of the 58 sub-themes' point of view defined by FAO.

3) My scientific results based on the empirical analysis of farms (where farms had the parameters: size 10-300 ha, production lines: mixed) are the following:
    - Organic farms reached better results in all three areas of sustainability compared to conventional farms.
    - In case of both groups (organic, conventional) those farms which perform better in the environmental dimension most likely have higher score in economic dimension as well and the same connection is visible between economic and social dimensions.
    - Conventional farms with higher scores in the economic dimension are most likely perform better in the social dimension as well.
    - Sustainability performance (in the range of 10-300 ha) is not dependent on the farm size.

CONCLUSIONS AND RECOMENDATIONS

My analysis clearly highlighted that sustainability performance of organic farms based on the 58 sub-themes are better than the performance of conventional ones. This means that organic farming system can contribute better to the realisation of sustainable agriculture than conventional (industrialized) farming.

The same outcome was visible when analysing the results of sample farms along the dimensions/pillars of sustainability.

As a summary one can state that the results of my research are in line with the results of international researches. In my opinion this is a proof that SMART is suitable for assessing the sustainability performance of Hungarian farms. However the system could be further developed, the possible improvement areas are:

- There are some animal groups where species specific indicators are missing and should be developed (rabbit, horse, bees, duck, goose).
- It would be desired to add forest management related indicators to the system as they are not available currently.
- It is difficult to evaluate some of the social indicators because the answer/score is dependent on the sincerity of the responder.
- The problem is the same in case of the work contract related indicators.
- The evaluation of applied pesticides from hazardousness point of view also does not give reliable results because it turned out in case of several farms that the pesticides in the farm diary are not in line with the applied ones.

- Product quality related indicators mainly assess the processed products which makes it difficult to evaluate them in case of farms where food processing does not exist.
- The indicator set applied during the tour of the farm is detailed enough for animal husbandry but the number of plant production related indicators could be increased.
- It would be useful to walk around the whole farm at the beginning of the interview however this is not possible in case of bigger farms.
- Collected data could be handled easier if the currently excel based tool would be replaced with an online one. This is especially important in case of bigger samples.
- It would be useful to design built-in analysis to create basic statistical analysis with one click. Further methodological development would be also needed with the structured application of simple and multivariate statistical methods.

Some of the above mentioned problems could be avoided if auditors got access to databases (for e.g.: database of registered employees) stored at governmental organisations, thus they should not rely on the farmers.

It would also contribute to the better quality of the evaluation if publication period at KSH shortened and there were a possibility to get data in different breakdown.

In case of national level usage of the tool, it would be advisable to check the data collection possibilities with GIS methods.

Agricultural knowledge and experience of the auditor also influences the reliability of the collected data.

Reliability of the data could be increased if the knowledge of farmers about the environmental effects of farming widened. This way farmers might have a better overview and understanding of regulations and might comply the rules. My experience is that law is ignored in many cases (fertilization, plant protection, manure storage, water usage) because farmers are not aware of the impacts of their activity.

Finally I would like to highlight the importance of farm data availability for research purposes as during my work one of the biggest challenges was to get farm data.

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Book editing, international

Katalin Balázs, Dóra Mészáros, László Podmaniczky, Balázs Sipos (szerk.): Handbook of the "DIALECTE" Agri-Enviromental Evaluation System: The Agridiag project. Gödöllő: SzIE, 2014. 92p. (ISBN:978-963-269-452-8)

Book editing, national

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Awarded foreign or international scientific and R+D projects, research assignments (participant)

AGRIDIAG: az agrár-környezeti teljesítmény értékelő szakképzés hazai feltételeinek megteremtése", mely az Európai Unió „Leonardo da Vinci – az egész életen át tartó tanulás program" keretében valósult meg. A projekt azonosító száma: 2012-1-HU1-LEO05-04850

A fenntartható természetvédelem megalapozása magyarországi Natura 2000 területeken" (Svájci-Magyar Együttműködési Program, Végrehajtási Megállapodás száma: SH/4/8)

Conference participation (with poster):

5th CASEE Conference (25-27 May, 2014): Healthy Food Production and Environmental Preservation – The Role of Agriculture, Forestry and Applied Biology. University of Novi Sad, Serbia. Poster címe: *Measurement of sustainability outputs in agriculture*

Conference participation (as lecturer):

ICOAS Conference (14-16 October, 2015): Bringing innovations to organic farming. Bratislava, Slovakia. Előadás címe: *Conceptual approach to assess farm-level sustainability in the Hungarian organic sector*

AGRIDIAG International Conference: Farm environmental performance evaluation in Europe and in Hungary (2nd October, 2014), Gödöllő. Előadás címe: Hungarian adaptation of the French Dialecte tool