INVESTMENTS IN EDUCATION DEVELOPMENT

Current Trends in Agronomy for Sustainable Agriculture

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Dear participants,

You have in your hands the Proceedings of the Summer School 2013 focused on the issues of sustainable development in agrosystems. This is organized in the framework of the project number CZ.1.07/2.3.00/20.0005 for PhD students and teachers of agricultural faculties of universities from the Central and Eastern Europe.

The target topics of the Summer School are different comprehensive and systematic approaches to field production and problems that have to be solved in the arable farming as well as the possibilities and methods for sustainability assessment of agrosystems and their optimization.

How to achieve sustainability in agriculture has become an important issue, but not an easily achievable goal. Farming activities are influenced by a number of different factors (from climate change, through the input and output prices, cultivation practices and work habits, rules set by CAP, Cross compliance, GAEC and SMR, crop rotation, and a possible commercialization of outputs, etc.). In addition to agronomic problems, it is necessary to take into account the aspects of economic, social and farm management levels.

Each farm is a unique and complex system which includes many components, effects and interactions, and therefore this is a challenging topic. A farm is a hierarchical system in which each organizational level is interlinked with the upper and below levels. Problems often occur at higher organizational levels, such as population, community and ecosystem. It is necessary to deal with these problems at the appropriate level, or at least with regard to the hierarchical relations in the agricultural system.

Our intention was to organize meetings of PhD students, researchers and tutors, who are involved in different aspects of crop production sustainability, the procedures for the systematic improvement, and the possibilities and methods of its assessment and further use of the results of such evaluations for optimization of the farming systems. We would like to create conditions for fruitful mutual exchange of knowledge, experiences and methodologies used in different countries.

I believe that your contributions and active participation will help to the success of the Summer School. The biggest reward for the organizers will be your satisfaction with creation of new personal contacts and drawing inspiration for further investigation of sustainable farming.

On behalf of the organizers

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CONTENT

THE CZECH AGRICULTURE AND ITS ISSUES

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Introduction

The Czech Republic ranks amongst the smaller countries of the European Union. With regard to some of its growth-limiting factors, development in the next decade can only be achieved by intensive but sustainable and environmentally friendly agricultural production, concentrated on branches of animal husbandry with high nutrient conversion and enhanced soil quality, the basic element of production.

With its food safety strategy in mind, it is appropriate to focus on a long-term goal of economically tenable production levels of major temperate zone agricultural commodities such as cereals, dairy products and meat, etc., and to ensure an adequate market share of agricultural and processed food products, especially those which compete well under Czech economic conditions.

From a production viewpoint, basic restructuring of the sector occurred as early as the 1990's (that is prior to entry into the EU on 1.5.2004). It was accompanied by a significant decrease in production, higher unemployment and a deepening imbalance of agrarian foreign trade.

With regard to the countryside together with its environment, landscape and recreational potential, the Czech Republic supports long-term orientation of the Common Agricultural Policy in the development of rural areas. This includes the non-production function of agricultural, diversification of activities and incomes, and the improvement of rural life quality. Therefore, during the future development of Czech agriculture, it is also necessary to address the expectations of inhabitants concerning agriculture, e.g. qualitative amelioration of the environment, improvements to recreational facilities and flood relief undertakings.

Because of Czech geographic, economic and historical considerations, these activities cannot be separated from agricultural production - not even in less favoured areas (LFA) which will always play an important role owing to their extensive acreages.

It has been proven that the farming community's contributions to the nation, and the increase of agricultural subsidies distributed to them, is directly proportionate to their know-how. Therefore, the question of support for the transfer of knowledge and technology is one of the key challenges for the sector, e.g. in the form of support for functional technological platforms or certification of sustainable farming.

This contribution has made use of data quoted in a conceptual document produced by the Czech Ministry of Agriculture, bearing the title: "Strategy for growth – Czech agriculture and food industry within the framework of the Common Agricultural Policy of the EU after 2013”, Prague 12. 12. 2012, http://eagri.cz/public/web/mze/ministerstvo-zemedelstvi/koncepce-a-strategie/strategie-pro-rust.html

The Status of Agriculture in the Czech Republic

Agriculture belongs to strategic branches of national economy of the Czech Republic as summarized by its production and off-production functions. Agricultural land resources occupy 54 % of the country’s acreage.

The importance of agriculture in the national economy, measured by its proportion of gross added value and employment, is gradually increasing (similarly to other EU member states). In the Czech Republic, labour productivity in agriculture is gradually approaching the mean of the national economy due to more rapid decrease of the number of employees compared to the rate of production decrease (from about 65 % proportion in 2004 to nearly 70 % proportion in 2011). Production potential of the Czech agriculture represents the area of 4.25 mil. ha of farm land with more than 70 % of its plough-up. The level of arable land is higher compared to EU states with similar soil-climatic conditions. Approximately 50 % of farm land is located in less favoured areas (LFA) because of lower soil quality and adverse climatic conditions. The relationship between the production level of the Czech agriculture and local demand in the crucial commodities is shown in Figures 1 and 2.

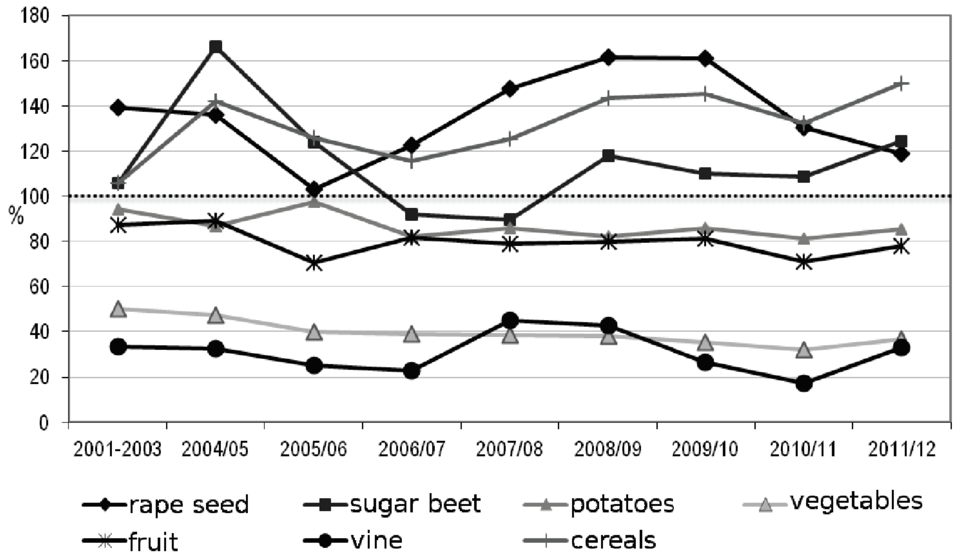

Figure 1: The evolution of self-sufficiency in major crop commodities in the CR (%), (Source: Report on the state of the agriculture of the CR, Ministry of agriculture, UZEI)

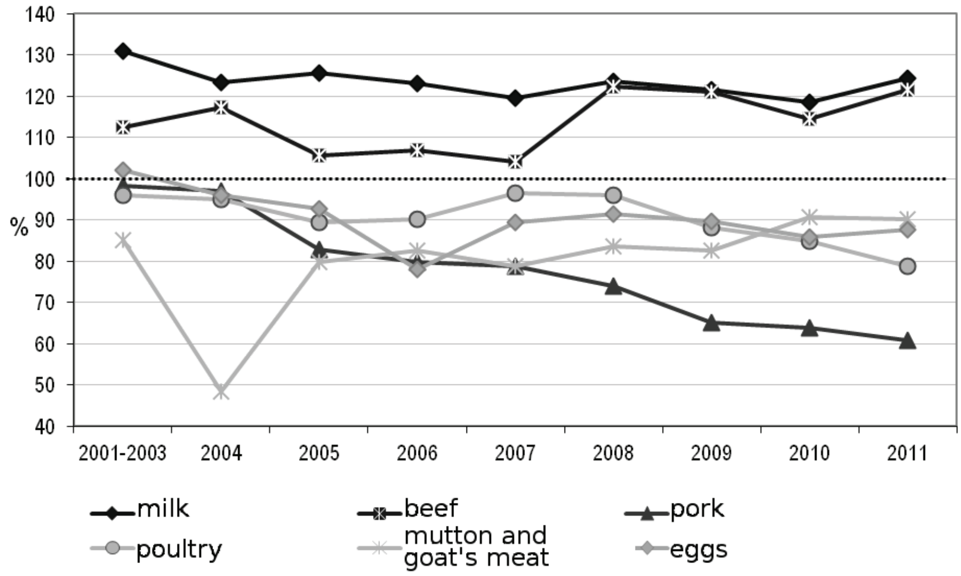

Figure 2: The evolution of self-sufficiency in major animal commodities in the CR (%), (Source: Report on the state of the agriculture of the CR, Ministry of agriculture, UZEI)

Since entry into the EU and during gradual integration of the Czech Republic to common market and implementation of the Common Agricultural Policy, deepening of structural disequilibrium has occurred. In spite of generally favourable impact on income situation of the Czech agrarian enterprises, guaranteed especially by permanently growing EU subsidies, serious and in many cases negative changes occur within this development.

These are predominantly apparent in the production structure and in relation of agriculture to natural resources. A negative phenomenon is the decreasing added value and efficiency of the Czech agriculture as compared with EU-15 and even EU-27 Member States. Proportion of intermediate-consumption in the production increased from 70 % in 2001-2003 to 75 % in 2007-2010 (compared to 60 % average in the EU). Productivity of utilization of resources measured by value amount of production in current prices per ha of farm land increased during the same period from 28 000 Czech crowns to 31 000 crowns, but it by far does not reach the average of EU-15 Member States (63 000 crowns), nor of the EU-27 Member States (54 000 crowns).

Frequent tendency of ascribing the cause of this state to uneven amount of direct payments compared to the original EU-15 is not very apt because when we take the proportion of subsidies to form gross agricultural production, the Czech Republic is not beyond the subsidy level in the region. Besides relatively high proportion of the less favoured areas (LFA), one of the major causes of such development are significantly higher subsidies to agriculture after joining the EU (2009-2011), averaging about 35 billion of Czech crowns, i.e. nominally about 3 times more compared to the period before entry into the EU (Figure 3). Then the consequence of the existing implementation of common agricultural policy is extremely high proportion of operational subsidies (especially income subsidies, i.e. direct payments and LFA payments) in revenues or in net added value of agricultural enterprises (increase from 29 % in the period 2001-2003 to 75 % in 2007-20010, compared to 41 % of the EU average).

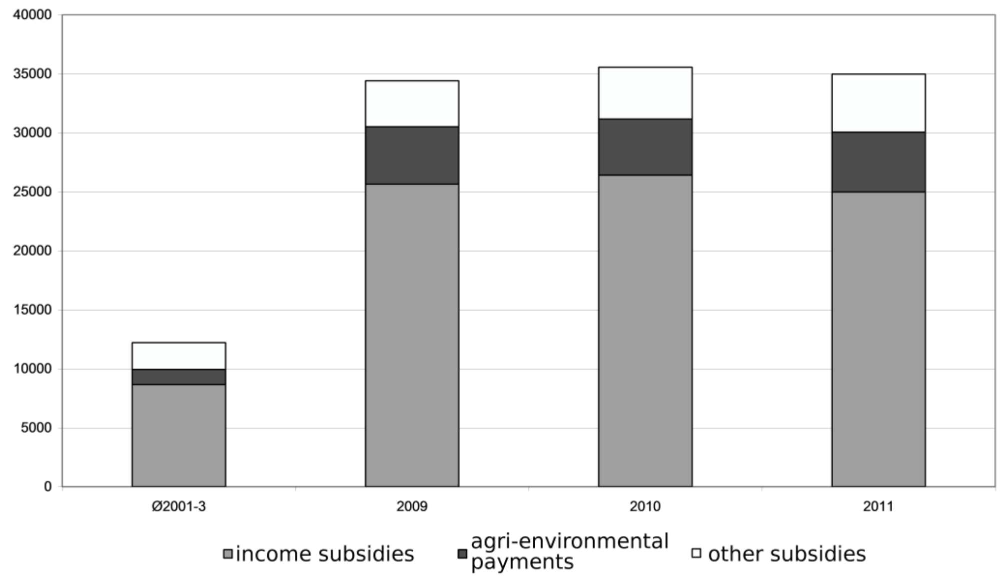

Figure 3: Development of agricultural subsidies and their structure (million CZK)

The efforts of enterprises are, more than to market, oriented to the subsidy obtaining which results in the following:

- changes in production structure (Table 1), i.e. total decrease of animal breeding, especially of monogastric animals, decrease of acreage of plants which are too demanding on quality labour including management and marketing (fruits and vegetables), and also acreage of forage crops on arable land with significant positive impacts on the environment. These structural changes cause at the same time the decrease of total agricultural production.
- less pressure on increased efficiency of production, grouping of enterprises and their innovative behaviour etc. which is manifested by decreased interest of enterprises in education and training, transfer of research results into practice and consultancy.

The total subsidies are unevenly allocated from the viewpoint of regions, enterprise size and production structure. This is reflected in considerable differences in the level of Net Added Value (NAV)/Annual Working Unit (AWU) among individual enterprise categories and also in differences among summarized profitability of major commodities (Figure 4). In a synergic acting of supports of both pillars of the Common Agricultural Policy (CAP) and market conditions concerning inputs and outputs, two highly profitable areas of the Czech agriculture has been formed, in which predominantly large enterprises implement extremely high level of NAV/AWU, thus generating an extraordinary rent. These areas where technologically simple production with minimum human inputs and maximum subsidies prevail are more and more frequently the aim of non-agricultural and partly foreign capital. This includes especially the following cases:

- less favoured areas (LFA) with very extensive breeding of ruminants (predominantly cows without market milk production) which obtain additional rents from global subsidies provided for the acreage of permanent grass land (PGL), which in large enterprises usually highly exceeds the nutritional need of the kept animals;
- large-area “two-crops” plant production in lower and partly in some central locations (cereals, oilseed rape) which, besides subsidies, profits from relatively high prices of agricultural producers.

Table 1: Changes in the structure of production after the accession to EU

Crops, Category of animals	Units	Ø 2001-3	Ø 2008-10	Index
Sum of cereals	Thous. ha.	1547,1	1521,0	-1,7
- wheat	Thous. ha.	808,1	822,4	1,8
- barley	Thous. ha.	512,0	442,0	-13,7
- corn	Thous. ha.	67,6	107,5	58,9
Pulses	Thous. ha.	34,7	27,5	-20,6
Potato	Thous. ha.	48,2	36,5	-24,3
Sugar beet	Thous. ha.	77,5	46,6	-39,9
Fodder crops on arable land	Thous. ha.	571,3	396,4	-30,6
Oil crops	Thous. ha.	422,5	486,9	15,2
Flax	Thous. ha.	6,2	0,1	-97,8
Vegetables	Thous. ha.	20,4	14,2	-30,3
Permanent crops	Thous. ha.	46,9	51,0	8,7
Permanent grasslands	Thous. ha.	895,0	915,7	2,3
Dairy cows	Thous. units	497,0	396,7	-20,2
Meat cows	Thous. units	102,0	163,7	60,5
Pigs	Thous. units	3424,7	2104,3	38,6
Sheep	Thous. units	95,7	188,0	96,5
Poultry	Thous. units	28561,7	26215,3	-8,2

Although the Czech agriculture is in the average still less efficient compared with more developed EU Member States, approximately one third of the Czech enterprises reach good profitability. It is partly due to the present relative low cost of labour and land. In contrast to these, about one third of agricultural enterprises survive only thanks to economic subsidies. The current level of management plays also an important role, and generation change appears necessary.

The market of agricultural commodities is considerably affected by relationships with their customers, predominantly food processors. Of these, the primary processors such as the slaughterhouses, dairies etc. play an important role as they are logistically bind to local sources, the efficiency and productivity of which is considerably lower and reflects in lower prices of the bought material by agricultural producers compared with more developed EU Member States. At non-functional linkages, the farmers logically try to find other ways of marketing their products including raw material exportations, formation of other market segments e.g. “short chains” or verticals in the newly developing enterprises of holding type.

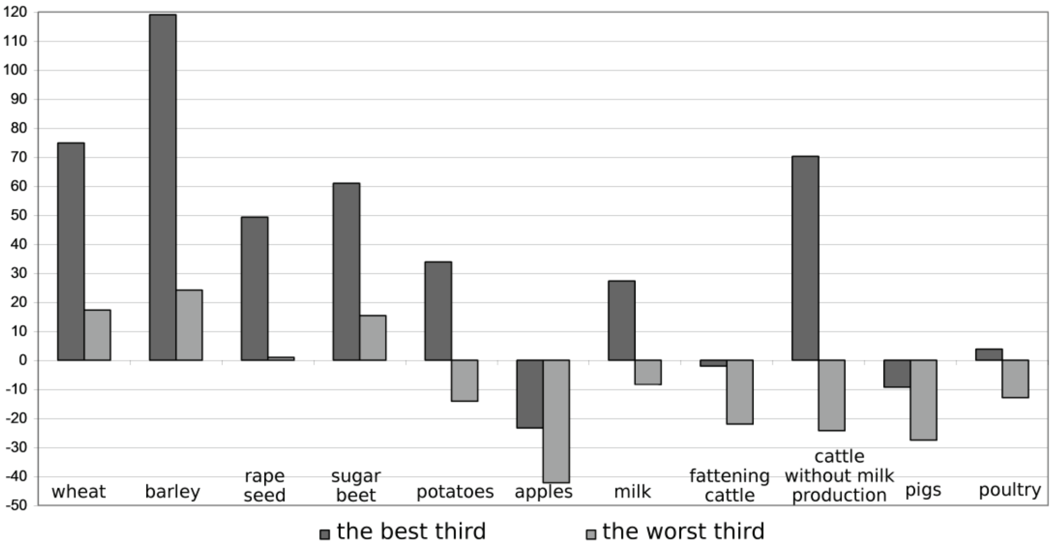

Figure 4: Summarized profitability of major commodities (%) 2008-2010: differences between the best and the worst enterprises

In spite of the subsidies granted, the market based on the Czech organic agriculture and following organic food market have been developing slowly, with high proportion of imports, because most of the Czech organic agriculture has been implemented with very extensive use of the permanent grass land, and at the same time part of the organic production has been sold without the “organic” marking for economic reasons.

Although the current regulatory measures (cross compliance) and stimulation agro-environmental measures within the rural area development strive for better relationships between agriculture and the environment, further soil quality degradation, water regime deterioration and biodiversity loss continuously occur. Soil quality and water regime are predominantly affected by inappropriate large-area utilization of farm land together with reduction or even giving-up of animal husbandry accompanied with shortage of organic fertilizers. Reduction of desirable diversity of soil use e.g. by growing forage crops is also one the courses. In addition, recent support of construction and operation of biogas stations also affected the above mentioned status. Inappropriate use of predominantly rented farm land contributes to the increase of internal and external negative impacts of climatic changes on soil quality, water regime and risk to conduct a business in agriculture under more and more frequent periods of drought and floods. Climate changes cause the transformation of some regions into new ones, often with adverse climatic conditions (e.g. constant increase of temperature and water shortage in the South Moravian region) together with higher importance of agriculture in less favoured areas (LFA).

On the other hand, the permanent growth of agricultural land under an organic management is positive (at present more than 11 % of farm land). However, in most cases extensive agriculture in the permanent grassland is applied with relatively small volume of organic production.

The system of consultancy and education, supported by the government, is less flexible and is predominantly oriented to adaptation of the private sphere to payment and regulatory conditions of the Common Agricultural Policy. Transfer and distribution of knowledge through the suppliers of inputs are limited by the copyright laws and are connected with the risk of advancement of one’s own interest versus social interests. Extremely high economic supplies effected to agricultural enterprises result in their low motivation to implement scientific and research results. This would require improvement of research, consultancy and information activities and better links between national research and its transfer into the practice.

Structural indicators of the Czech agriculture differ considerably from those in most EU Member States (Table 2). The proportion of agriculture which is decisive for the Czech economy has a large-scale production character where rented land prevails (averaging 78 %), as well as hired labour (about 76 % according to EUROSTAT 2009 compared to 13 % in EU 27) and relatively low level of activity diversification. These characteristics on one hand create a potential for the use of size advantages but on the other hand reduce the space where to control the risk, especially at the control of money flow, and increase requirements and cost for labour management. They also include impaired relations to land use and do not contribute to employment and sustainable development of rural areas.

Table 2: Indicators corporate structure of agriculture in selected EU countries

Country	The share of farms owned by private persons	The share of own land at agricultural companies	The share of family workers in total FTE[1)]	Agricultural land per company (ha)	
				All companies	Only over 100 ha
Czech Republic	93,0	16,2[2)]	26,7	89,3	727,4
Denmark	97,9	70,7	61,2	59,7	199
Germany	93,5	36,7	68,7	45,7	276,8
Netherlands	93,0	58,6	60,8	24,9	154,3
Austria	94,9	66,4	87,9	13,3	232,9

1) FTE staff with annual working time 1800 hours

2) The share of own land increased from 16.2% to 22.1% in 2011. The basic merit is on the privatization of state-owned land.

Source: Eurostat - Farm Structure Survey 2007

Table 3 shows individual branches of Czech agriculture listed according to their current importance from the viewpoint of economic value formation (gross agricultural production expressed in money) in combination with their labour demand and contribution to the employment.

Table 3: Estimate the importance of commodities in terms of volume of production and labor intensity

Commodity	Share of total agricultural production [1)]	Rank by the share in production	Working intensity % of labor costs in the 100 CZK of production [2)]	Rank by labor intensity
Cereals total	24,6	1	[3)] 16,38	9
Oil crops total	10,6	3	[4)] 13,07	11
Sugar beet	2,5	8	15,36	10
Potatoes	2,3	9	23,26	6
Hops	1,1	10-11	35,94	4
Fruits	1,1	10-11	[5)] 50,28	1
Vegetables	4,9	7	[6)] 47,40	2
Grapes	0,8	12	43,28	3
Milk cow	18,3	2	23,09	7
Cattle for slauther	6,7	5	31,58	5
Sheep and goats	0,1	13	n.a.	n.a.
Pigs	9,2	4	17,58	8
Poultry	5,4	6	6,28	12

[1)] According to the economic accounts for agriculture, the average 2009 - 2011.
[2)] According to data from a sample survey costs 2009 – 2011. By commodities of animal production is not considered labor intensity of feed production.
[3)] Wheat, [4)] Rape seed, [5)] Apple, [6)] Onion.

The use of agricultural production in power engineering

The Czech agriculture has a free market in biomass production for energetic utilization. For this purpose, up to 900-1 100 thousand ha (about 25 % of farm land) can potentially be used while maintaining food self-sufficiency. The volume of energy produced from biomass occupies within the renewable energy sources (RES) increasingly important position in the Czech mixture of energy sources. Future development in the use of RES will be formed according to the obligations of the Czech Republic which delimitate the national goal of RES proportion of gross energetic consumption to 13.5 % till 2020 or 10 % proportion of biofuels in transportation. Currently, this goal is being re-evaluated at the EU level. A considerable decrease of subsidies or more strict conditions of their granting can be expected in the field of RES. Goal fulfillments will be connected with orientation to energetic utilization of agricultural commodities (including energy crops and fast-growing species) and agro-wastes and crop residues for heat production or a combine production of power and heat.

The most common energy crops grown on arable land are maize (43.4 %), oilseed rape (44.2 %), sugar beet (16.7 %) and cereals, as well as other herbs and grasses with high biomass production. Non-food crops for energy use on arable land form 10.9 % of its area. It was assumed, that extension of growing crops for biomass production can improve diversity of the landscape and contribute to better protection against erosion and floods. Anyway, current situation when the main crop for energy production is maize means the opposite situation.

For agriculture, the most important by-product of energy production from biomass is digestate from biogas production. It is the only way to partly return the nutrients to the soil but this fertilizer is rather similar to the mineral than organic fertilizers. According to experiments on oilseed rape and wheat it has good nutrient content and a slightly alkali reaction (Ciganek, 2011; Roháček, 2013). Anyway, a lot of organic substance is lost and does not return to the soil.

With declining numbers of animals, biogas power plants could be an interesting alternative how to use part of the crop production. Unfortunately, the structure of crops for biogas plants differs from the structure for feed crops; clover crops are lacking and other crops have been introduced.

In 2010 the biogas produced 9.7 % of electricity and 2.7 % of heat from renewable sources. However, number of biogas plants is rapidly growing. In 2010, there were 174 biogas plants and at the end of 2012 there were already 481 of them producing 15.9 % of energy from renewable resources. The vast majority of them are agricultural biogas plants, opposite to situation in other EU Member States. Thus, the Czech agriculture has large reserves in energy utilization and its own production of renewable energy sources and raw materials for industries.

The Czech agriculture fails in creation of economic value

Since entry of the Czech Republic into the EU and during gradual integration into the Common Agricultural Policy, deepening of structural disequilibrium has occurred. In spite of generally favourable impact of constantly growing EU subsidies to agricultural enterprises, serious and in many cases negative changes have been observed, especially in the production structure and in the relationship of agriculture to natural resources.

A more detailed view on the structure of the sector is not satisfying, there are trends showing increased orientation to the production of commodities with low added value. This is not a good presentation of a country with long agricultural tradition, possessing all human and technological facilities for sophisticated agricultural and food production. These trends start to show some features of a developing country, e.g. an simple massive production of plant commodities without added value and processing.

Especially alarming has been in recent years the development of some branches of animal husbandry which significantly loose their positions (pigs, poultry, eggs) and food products with higher level of processing even though preconditions for a competitive production exist in the Czech Republic.

Structural imbalance is a great problem

Soil degradation causes annual damages estimated to be 4 to 10 billion of Czech crowns (loss of arable land and soil quality, decreased yields, clogging of watercourses, property damage etc.) and poses a significant threat for long-term competitive strength of the branch. A considerable part of waters is constantly contaminated; 82 % do not reach a suitable ecological status, and 25 % of waters do not comply with a good chemical status even though nearly no watercourses flow into the Czech Republic. On the contrary, our country is an important European water divide and the status of ground- and surface-waters is entirely dependent on precipitations and the landscape status. Water flows very fast from the Czech area due to degradable changes in agricultural land, and thus the landscape losses its retention capacity. Great part of the present cultural landscape lost its natural characters owing to unsuitable farming. This results in lower ability of the landscape to cope with fluctuations in climate changes.

Due to the loss or insufficient renewal of landscape elements, agricultural land does not fulfil its role in protection and maintenance of biodiversity. There are more than 300 000 ha of valuable grassland of which 80 % are in insufficient status. The numbers of invertebrate animals on grassland decrease sharply, as well as the numbers of birds associated with farmland.

Emissions of greenhouse gasses are relatively high compared to the EU Member States. CO_2 fixation by far did not reach its potential even though the volume of CO_2 stored in soil and wood substance is great. The Czech agriculture is not enough adapted even to the expected manifestations of climate changes. All these trends, when not detected, present in the context of the expected development the threat for its long-term competitiveness.

Growing dependence on subsidies is strengthened by wrong redistribution at the national level

The Czech agricultural enterprises and the food industry show increasing dependence of the sector on subsidies and their inappropriate targeting which started to be applied especially after joining the EU. Major cause of imbalanced development of individual branches is the way of means redistribution within the Czech Republic which on one hand over-compensates some simple forms of highly profitable production and on the other hand does not motivate to more sophisticated and technologically demanding productions with higher added value. Analyses of agricultural status and profitability prospects of major commodities after 2013 confirmed that a mere continuation of the current redistribution of agrarian subsidies would mean inefficient investments of public means into branches that will be viable in market by their owns but the means will not be used to benefit the branches which need fundamental incentives (e.g. animal husbandry with linkage to employment).

Together with necessary increase of efficiency, there has to be the positive impact of agro- and food industry on employment in rural areas, and on development of its human and social capital and improvements to recreation facilities.

Conclusions

In general, the Czech agriculture reached cost-ineffective type of farming with decreasing intensity, which in addition does not contribute to amelioration of the environment and countryside development.

Major strategic goal of further development of the Czech agriculture should therefore be a long-term and sustainable ensuring of food safety at both national and European levels and contribution to energetic self-sufficiency of the Czech Republic within the determined energetic mix at considerable increase of its efficiency and competitive strength and relationships to the used natural resources.

It concerns at least the restoration of a balanced structure of crops and proportions of individual agricultural branches with corresponding proportion of ruminants in relation to farmland. There should be an effective dimension of animal husbandry which participates fundamentally in the improvement of relationships between agriculture and the environment, and in creation of higher added value and employment.

It is clear that if the government and businessmen will not address the above mentioned problems, then the future of several branches of agriculture is actually threatened even though they have, under the Czech conditions and the expected form of the EU Common Agricultural Policy, all preconditions of competitive production.

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REVIEW OF METHODS FOR SUSTAINABILITY ASSESSMENT IN AGRICULTURE

Dušková Soňa, Křen Jan

Introduction

As this event is focused on comprehensive approach to arable agricultural systems sustainability, I would like to introduce the review of methods for its assessment.

From about the seventies of the 20th century it has become obvious that economic development is dependent and limited by natural resources which have been recognised to be exhaustible and damageable, therefore beyond the commonly used economic indicators of well-being, environmental and social indicators have to be taken into account as well.

Environmental effects of agriculture originate on the level of single farms, therefore tools for optimisation on this level are needed. The development started in the 1990s and there are about 150 methods for farm level sustainability assessment documented today (Rosnoblet et al. 2006). One of the first activities in this issue was done within the Research Network on Integrated and Ecological Arable Farming Systems for EU and associated countries, where 25 research teams from 15 European countries participated (Vereijken 1994). The aim of this project was to provide farmers and advisors in agriculture with tools for continuous improvement of farm performance regarding its environmental effects, resources consumption and sustaining its productivity. In the recent years there are attempts to finalise the assessment process by granting farms a certificate (label), (e.g. DLG) to provide them with an advantage for communication with business partners and the public.

Principle of sustainability assessment in agriculture

The idea is that particular characteristics of resources and agrosystem management are monitored and recorded, with the intention that this information serves as an aid for decision-making by farmers and/or policy- makers on local, regional, national or international level.

To assess sustainability of agriculture on the farm level, indicators dealing with fundamental features of the agricultural system (agrosystem) have to be emploied. The agrosystem is a production system absolutely dependent on basic biological processes which distinguishes it from other sectors of economic activities. Its main feature, soil fertility, is defined as the ability of the soil to provide, through synergy of physical, chemical and biological factors, conditions for growth and development of plants. It is the main task for the farmer to maintain the fertility of his soil as the basic means of production in agriculture.

In the agriculture sector, the environmental aspect of sustainability is often considered in its bio-physical or agronomical aspects. Thus, this concerns both the impact of the agrosystem on the environment and the system management. Indicators such as nutrients balances, organic matter balance, (bio)diversity, soil cover, soil erosion and compaction affect the soil fertility and functioning of the whole agrosystem. At the same time, they also indicate interaction with the environment and a possible negative impact on it (e.g., nitrogen leaching into ground water, conditions for wildlife, water contamination and other threats caused by eroded soil, etc.). Other indicators, such as energy balance and pesticide use, indicate an interaction with the surrounding environment and resources intensity.

Earlier research of sustainability indicators for farm level was focused mainly on problems of a physical, chemical and biological nature. The most common principle of agri-environmental indicators calculation is to compare inputs and outputs of the agrosystem and calculate the balance as it is assumed that all substances which are removed from the system in the harvested biomass have to be returned to the system in appropriate form and amount to prevent exploitation of soil fertility or loses of nutrients or other substances into the environment. This approach should enable assessment of environmental impact of agro-business management and changes in the management. Goodlas et al. (2003) and Halberg et al. (2005) identified in Europe 55 so called Input-Output Accounting systems (IOAs). The basic and most frequently used indicators are balance of nutrients (N, P) and organic matter, and energy balance (Halberg et al., 2005; van der Werf, Petit, 2002; Payraudeau, van der Werf, 2005; Goodlas et al., 2003; Tellarini, Caporali, 2000). The assessment of pesticide use and agrosystem biodiversity is also included (Bockstaller et al., 1997; Eckert et al., 2000; Häni et al., 2003).

However, the sustainability concept involves environmental, as well as economic and social pillars and an institutional (governance) dimension. Therefore indicators for these issues (which are much more complex regarding type of farm activity) were gradually involved into the sustainability assessment methods and are also used today (Rosnoblet et al., 2006).

The implementation of a comprehensive analysis of farming systems sustainability requires the processing of large amounts of information of a different nature and the use of indicators of different types. These procedures have recently included:

- Indicator selection and data gathering. A selection of relevant indicators based on strict quality criteria and accurate data gathering to calculate empirical values of these indicators are an essential element of this kind of study. In order to manage the huge amount of possible indicators and data required, it is recommended that a solid theoretical framework be utilised.
- Normalization of indicators. Transforming base indicators into a-dimensional variables (normalization) is required before any aggregation (i.e., to make indicators mathematically operational) is performed. For this purpose, the use of a multiple-

attribute utility theory and reference values (sustainability levels that determine the minimum/maximum values of the indicator values) are suggested.

- Weighing indicators. Since sustainability is a "social construction", in order to determine the overall sustainability function, it is convenient to take into account society's preferences in order to assign different importance to each dimension/indicator included in the composite indicator. A sensitivity analysis is also advised, with the aim of determining the extent to which weights influence results.
- Aggregation of indicators. Although there is a wide variety of functional forms that permits indicators to be aggregated, it is worth taking into account the possible incommensurability of different indicators or dimensions of sustainability.

Methods for Sustainability Assessment on farm level

Farmers, practitioners, managers of the farms and agricultural enterprises, have direct impact on the performance of the farms and manage their interaction with the environment. They need relatively simple methods able to provide fairly detailed results, which can be used here for identifying risky points in environmental performance and sustainability of the farm management.

From the indicator methods for farming sustainability assessment we can mention here, for example, the German KUL/USL (Eckert et al. 2000), the KSNL (Breitschuh et al. 2008), REPRO (Hülsbergen 2003) and German Agricultural Society (DLG - Deutsche Landwirtschafts-Gesellschaft) sustainability standards (Schaffner and Hövelmann 2009), the French Indigo method (Girardin et al. 2000) and the Swiss SALCA (Nemecek et al. 2011a, 2011b) and RISE (Grenz et al. 2009) methods.

All these methods are based on the same principle, which utilises indicators. However, each method contains its own set of indicators regarding their number, focus, calculation process, normalization, weighing and aggregation. The important difference means also the organisational level on which the input data are collected and on which the results are evaluated and compared.

Although all the methods should assess the sustainability of farm performance, most of them do not cover all the three sustainability aspects. With some generalization it can be stated that the formerly developed methods focus on environmental effects (Indigo, KUL/USL, SALCA) or include some economical assessment (REPRO). The social issues have been included since about the year 2000 (KSNL, DLG sustainability standards, RISE).

What also makes important difference, from the users' point of view, is whether the method is primarily a certification procedure (DLG sustainability standards, KSNL) or advisory tool (RISE). According to this, farmer receives just the confirmation of the fulfilment of certain criteria (certificate) or also an analysis of weaknesses of his farm management, suggestions for improvement, or he has the possibility to test these proposals on a computer model of the farm.

Table 1: List and short description of selected methods for assessment of agricultural management

Methodology	Area of agriculture	Organisational level	Dimension of sustainability	Short description
Indigo	arable land, vegetable production, grassland, vineyards	field (plot), farm	environmental	8 indicators; evaluation 0 (best) – 10 (worst) points; threshold 7 points; final value for farm is calculated as weighted mean of single fields; graphical final evaluation – net diagram
KUL/USL	arable land, grassland, animal keeping	farm	environmental	18 criteria; evaluation by marks 1 (best) – 12 (worst); threshold mark 6; final evaluation by table with bar graph
KSNL	arable land, grassland, animal keeping	farm	environmental, economic, social	34 criteria; evaluation by marks 1 (best) – 12 (worst); threshold mark 6; graphical final evaluation – net diagram
REPRO	arable land, grassland, animal keeping	field (plot), crop, crop rotation, stable house, farm	environmental, economic	ca 200 indicators; a) normalised results 0 (worst) – 1 (best) b) relative numbers (%) 0 – 200 depicted in net diagram
DLG sustainability standards	market crops	field (plot), crop, crop rotation, farm	environmental, economic, social	23 indicators aggregated in 3 indexes for single sust. dimensions and to one complex index; evaluation 0 (worst) – 1 (best); threshold 0,75; graphical final evaluation – net diagram
SALCA	arable land, grassland, animal keeping	field (plot), organisational unit of the enterprise, farm	environmental	Life Cycle Assessment method
RISE	all kinds of agricultural production	farm	environmental, economic, social	10 aggregated indicators; evaluation 0 (worst) – 100 (best); threshold 66; graphical final evaluation – net diagram (polygon)

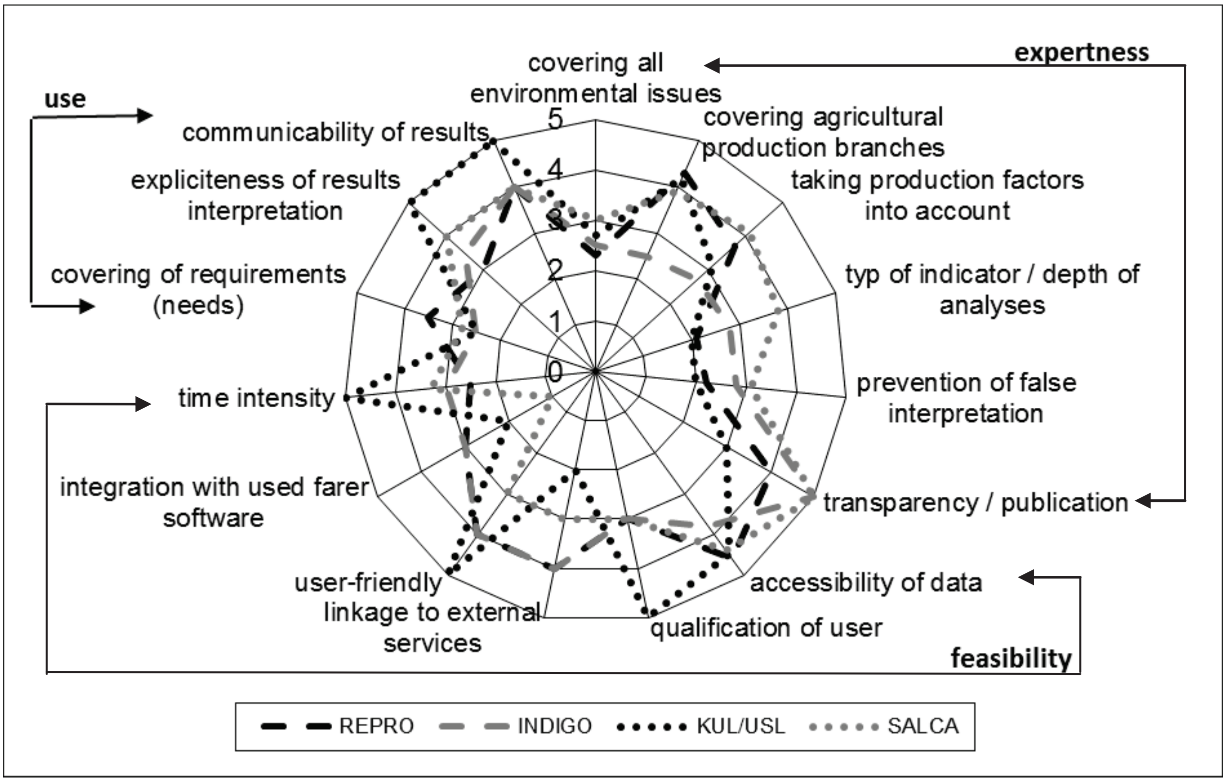

Figure 1: Evaluation of four methods according to Bockstaller et al. (2006)

In case these methods should be utilised in wider practice, they are more suitable to be used by advisors, who can cover higher need of time to work with them, especially to analyse and interpret the results and to search for suitable optimisation measures. Therefore it could be very useful when the method is the tool for keeping agronomic records of farm in the same time and it enables to compile obligatory table forms for official use or it enables data import from such softwares.

Overview of agri-environmental indicators used in the Europe on farm level

Most of the complex methods use relatively simple procedures of indicator calculation in order to reach better feasibility of a method. It appears, generally, that the risk of errors in using a method increases with its complexity. Equally, the demand for input data is increasing (Bockstaller et al. 2009).

The other reason is that, due to a practical feasibility of assessment, input data should only include current agronomical records and eventually basic characteristics of the locality including information about the soil, the character of terrain relief, climate etc.

The analysis of **nutrients management** is most frequently oriented on the nitrogen (N), and less frequently to the phosphorus (P), though agriculture can significantly contribute to the eutrophication of water ecosystems. The potassium (K) is mostly ignored. It is not generally a limiting element for water quality but K is important for a long-term soil fertility and production quality (Öborn et al. 2005). Moreover, the interest in optimization of P and K balance is substantiated by the fact that these nutrients originate from limited, non-renewable resources (Bassanino et al. 2011).

The balance is the basis of indicators which deal with nutrients. In all three nutrients (N, P, K), it is based on the same principle of difference between inputs and outputs (Bassanino et al. 2011; OECD 1997). However, in the case of the nitrogen, more possible inputs into the agrosystem can be considered, as well as more ways of its changes and losses compared to the phosphorus and potassium.

The **balance of organic matter** is based on the differences between inputs and loss of soil organic matter by mineralization. The level of mineralization depends on the grown crop, intensity of soil tillage, soil quality and weather, which are taken into account to a different extent. The established equivalents with defined contents of the carbon and the nitrogen are often used in German methods for the expression of organic matter level (Humuseinheiten – HE (Hülsbergen 2003) or t Reproduktionsfähige organische Substanz – t ROS (Eckert et al. 2000)). Other frequent equivalents are the dry matter of organic substance or the amount of oxidisable carbon (C_{ox}).

The **energy assessment** is a significant objective indicator of the efficiency of agricultural production (Neudert 1998). The advantage of this approach is that different forms of inputs can be conveyed to the same units (Christen and O’Halloran-Wietholz 2002) and different kinds of products and greatly different ways of production can objectively be compared (Halberg 1999; Refsgaard et al. 1998; Tellarini and Caporali 2000). Different methods can be used for the calculation of plant production energy balance depending on the objective of the analysis performed. The methods mentioned in the literature differ in the spatial and time definition of agrosystem boundaries, in flows of substances and energy, which are taken into account, and in energetic equivalents established for these flows (Kalk and Hülsbergen 1997). The most common indicators are energy balance per unit of area or unit of production and energy efficiency.

The indicator assessing the **use of pesticides** can be included into the complex methods but frequently, because of its complexity, builds an independent method. In this case, there is the most expressed variance from simple indicators (of the type of average applied dose of active substance per hectare) to complex models, which also include the persistence period in the environment, the toxicity of substances for particular components of the environment and groups of animals. All indicators for this area use some form of score (Reus et al. 2002). A relatively great number of indicators also includes the component assessing the system of plant protection or non-chemical ways of protection. Indicators also exist which only assess this aspect.

Diversity of an agricultural system can be considered from several points of view. This can be the diversity of groups or plant species grown in a given year, plot size diversity (Eckert et al. 2000) or the proportion of ecologically valuable area within the farm acreage (Eckert et al. 2000; Grenz et al. 2009). However, the term can also be comprehended differently as the diversity of a farming system concerning the frequency and date of work operations, diversity in soil cultivation, ways of harvest etc. (Schaffner Hövelmann 2009). Leteinturier et al. (2006) and Thenail et al. (2009) also assess crop rotation, which affects both the stability of the agrosystem, enabling the reduction of inputs of plant protection preparations, and landscape diversity.

Quite often, this area is comprehended from the point of view of the diversity of non-production free living organisms. Actually, it is the original point of view. For example Manhoudt et al. (2005) differentiate biodiversity in crop stand, in field margin stripes, and in stands of line landscape elements.

The information value of indicators assessing spatial and species diversity of the grown crops and the proportion of ecologically valuable areas is influenced by the compactness of the land tenure of the enterprises.

The most frequent field of **soil protection** assessment is its erosion and compaction. Some authors are also interested in chemical changes characterized by soil reaction changes (Eckert et al. 2000). However, this requires soil analysis; therefore it is indirectly assessed through soil liming (Lewis and Tzilivakis 1998). For the estimate of the soil erosion risk, several procedures have been developed, independently to the sustainability assessment, which are widely used and included in the methodologies for a complex assessment of agricultural enterprises. This is for example the ABAG method (Germany) or USLE (USA). These methods have been adjusted so that they require a relatively large amount of input data, these are nevertheless easily available. The methods assessing the risk of soil compaction require quite detailed information about the mechanization used in each plot (Lebert et al. 2007; Rücknagel et al. 2007).

Discussion and conclusions

In the Czech conditions we try to use sources of data for the calculations defined according to records obligatory for the Czech farmers and within the public available statistics and information. This is important for the practical feasibility of the assessment and it influences reliability of the results as farmers are not forced to create additional records and analysis only for the purpose of the sustainability assessment. In the Czech conditions are for the environmental part of analysis usualy available: records of fertilisers and manures application; plan of sowings; yield records or estimations; records of working operations on each field; records of plant protection preparations application; results of the agrichemical soil analysis; map of the farm’s fields.

Reference values of the indicators are set according to the legislation and production conditions in the country and in some cases are distinguished regarding the production regions or other conditions. Therefore it is always necessary to reconsider reference values when using the methodology in new region.

The sources of data and information used as indicators or for their determination should meet the following requirements:

- high quality statistics, regular monitoring and on a reasonable relationship between costs and predicative ability;
- determination of methodology should be sufficiently exact and reflect the current state of scientific knowledge of the issues described;
- fulfillment of international standards and their usability in modeling or forecasting;
- user-friendliness, which means to be used successfully if parameters of indicators may be logically understood and interpreted;
- contain exact thresholds (reference values) allowing comparison and determination of their evidence.

However, these comprehensive analyses have not yet found a wider introduction in practice. The reasons can be simply summarized in a question “Why in the existing bureaucratic conditions with plenty of legal requirements should further evaluation system be established?” Actually, many working operations on farm must be documented. Usually they are accurate records of the product or the production processes. Gathering the necessary data creates, for the benefit of farm managers a large number of options and supporting documents for practical decision-making. Results of analyses can also be used for the certification of the farm and improvement of its public relations, or to assess the future prospects of the farm.

There are some attempts to incorporate such assessment in agricultural policy and to use it to condition payments to farms. On the other hand, this would probably cause manipulation with data entering the calculations and disable objective results.

All of these are challenges for serious and objective research in this area ensuring the sustainable development of agriculture.

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SUSTAINABILITY MANAGEMENT AT FARM SCALE – CONCEPT, OPERATIONALIZATION AND APPLICATION

Siebrecht Norman, Wolfrum Sebastian, Hülsbergen Kurt-Jürgen

Introduction

Almost each sector strives for sustainability or sustainable development. Likewise a sustainable agriculture is requested since years. At the moment this is seen as the answer for future challenges[1] but today's agriculture is not sustainable (Jordan et al. 2007, McIntyre & Beverly 2009). Without distinct changes we will not be able to initiate sustainable development and will probably fail to cope with future challenges. What are the reasons? Agriculture sustainability is well defined and relevant components are known and described (Zhen & Routray 2003). Transferring the theoretical concept into the agricultural praxis was rarely successful (cf. Lütke Entrup 1999). Responsible for this are missing implementations of sustainable agriculture concepts comprising of comprehensible methods and indicators. Additionally sustainability is often not seen as a holistic approach, methods used are not adapted to the problems and impact categories are missing (Siebrecht 2010). To achieve sustainable development a process comprising the following steps is required: defining the overall targets; conduct target-performance comparisons, develop optimizing strategies based on deficits, implement measures and reevaluate the system. However, such a "sustainability management" can only overcome the status of theoretical thoughts and initiate sustainable development if it is applied to the farm level. On this scale optimization measures can be realized. Also this level provides the links between management, side conditions and sustainability effects. Finally, the farm is the economic unit witch needs to be considered in the economic pillar of sustainability.

In this article an approach for "sustainability management" on farm scale in agricultural systems is presented. The development of the theoretical principles and methods will be shown with a new methodical framework and the application of the process is demonstrated. Especially the integration of previously disregarded impact categories like biodiversity and soil erosion is described. The application of the approach on different farms allows comparing and discussing results, possibilities and limitations.

Material and methods

Several definitions for sustainable agriculture exist (Zhen & Routray 2003). This is caused by varying goals, objectives and scopes, different spatial resolutions or levels of

[1] The population growth and the increasing demand for food and fiber require higher productivity. The competition for land leads to a decrease of available agricultural areas. The climate change will raise the need of adaptive and more flexible production systems. Resources like water, soil or biodiversity are supposed to be protected and the management has to comply with the relevant laws and regulations.

concretion. Thus the overall concept „sustainable agriculture“ is well specified but the embodiment and the operationalization is still difficult. Because sustainability cannot be analyzed and evaluated with one single parameter, different indicators are required. Indicators allow describing and analyzing complex relationships or circumstances. To improve sustainable management and to make the selection and combination of indicators comprehensible, the application of a generic framework is recommended (Fig. 1). The basis of the framework is, that based on the overall concept and understanding of "sustainability" principles, criteria, indicators etc. need to be derived. To ensure a high level of traceability the system boarders and the intended purpose have to be defined. "System" characterizes the object of investigation with its' specific spatial scale or unit.

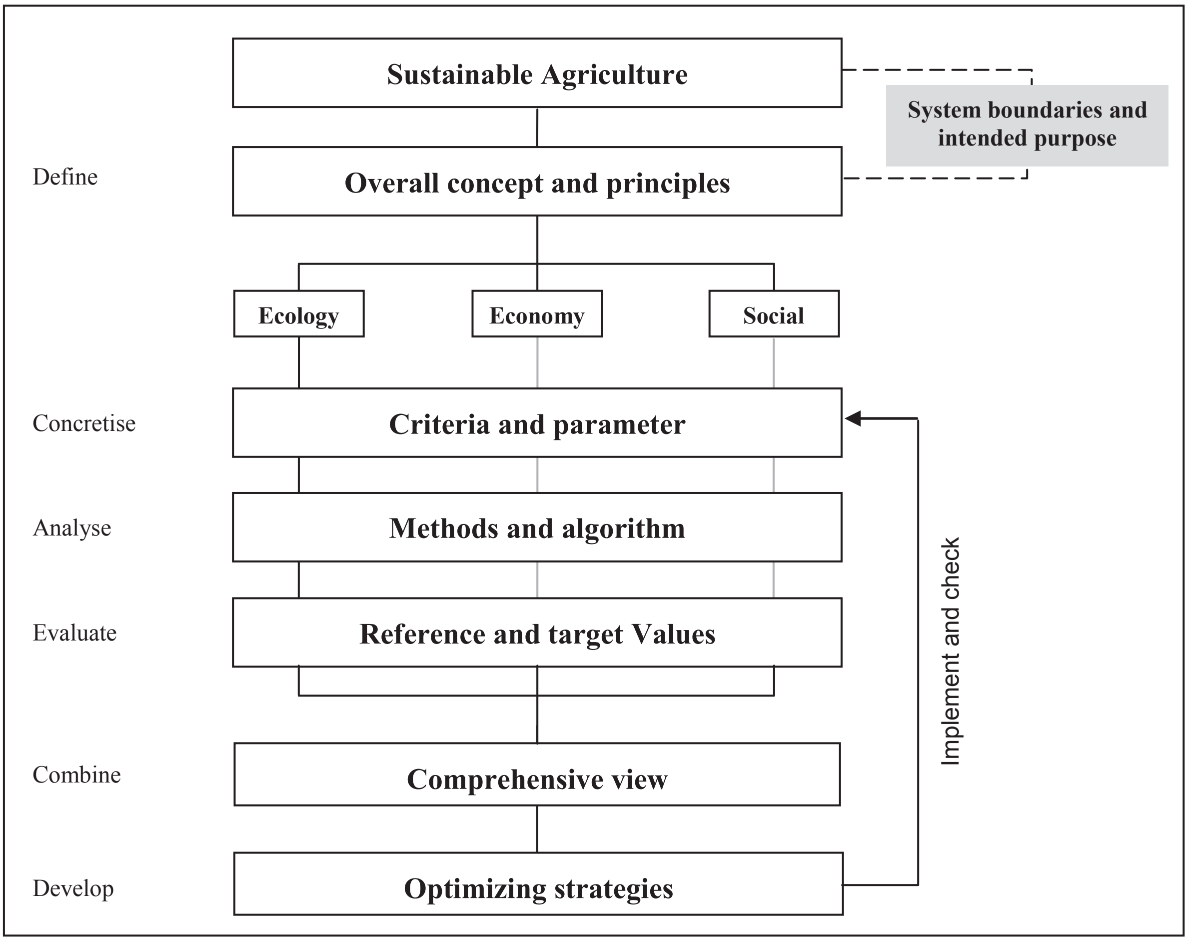


Figure 1: Framenwork „sustainability management“ (Siebrecht 2010, modified from van Cauwenbergh et al. 2007)

Purpose of our approach was supporting sustainability management of farms to enable a sustainable development of agricultural cropping systems. For the development of the approach several specification should be considered: the approach supports an overall and holistic view of sustainability, interactions between impact categories (e.g. fertilizer intensity and energy consumption) were covered by the model (system approach), and to use or develop methods of high sensitivity for agricultural measures. As a result recommendations for management changes to improve sustainability should be easily deducible and previously insufficient or not integrated impact categories like “biodiversity” or “soil erosion” should be integrated. Furthermore the methods have been chosen to integrate them into the agricultural management software REPRO (Hülsbergen 2009). A high applicability and suitability for the use in agricultural praxis is ensured by using input data which are available on almost every farm and to avoid input data based on field surveys (e.g. state indicators for biodiversity). By this the methods can be applied to most farms in Germany. Next the application of the outlined approach is demonstrated for the impact categories biodiversity and soil erosion.

Considering the ecological part of sustainability the overall concept implies the following principles: the cropping system and farm management is oriented to maximum production (food, fiber or biomass), simultaneously resources and basics for production need to be conserved, biodiversity should be protected, negative influences on adjacent ecosystems need to be minimized, ecosystem functions should be protected or restored. With focus on the soil destructive (negative) soil modifications by management have to be avoided. Causes for negative soil modifications based on the system boundaries[2] are soil erosion or soil compaction (BMVEL 2001). From the overall concept it was derived that biodiversity has to be protected and that the management should support conservation. This is of high relevance because agriculture still remains one of the major reasons for the loss of biodiversity. At the same time we have to consider that agro-ecosystems are manmade ecosystems which are developed and managed by humans (e.g. like farmer). In principle, agriculture is a land use type pursuing a special “biodiversity management”. All agricultural measures are directed to optimize the production towards the grown crops. Influencing biodiversity is thus a typical and unavoidable process related to agriculture; the question is if it is possible to limit negative impacts to a defined level. Because no available approach was able to indicate such aspects a method was developed which allows modeling potential effects on biodiversity based on management (decisions) effects like high fertilizer intensity, narrow crop rotations, high pesticide intensity etc..

Implementation of the soil erosion indicator: For the approach existing methods and erosion models could be used as reference. The model of the German version of the Universal Soil Loss Equation (USLE, Schwertmann et al. 1987) was chosen and developed into a GIS[3]-based version coupled to REPRO. In the GIS as a first dimension the landscape related erosion potential is modeled. As a second dimension REPRO calculates for each single field the management caused erosion potential. The combination of both dimensions

[2] Other „system boarders“ like e.g. agriculture under arid climate conditions could have other. For these systems more important degradation types are salinity or desertification.

[3] GIS = Geographic Information Systems.

presents the potential soil losses (t ha^{-1} a^{-1}). Results can be analyzed and presented in different units or scales (farm, field, single plots). Beside the analyses of the magnitude of soil erosion an evaluation is required. Relevant questions are whether there is too much erosion and reduction measures are needed or if there is few soil erosion and there is no sustainability problem? For the step of evaluation and normalization so called “evaluation functions” are used. The basic principle is a Cartesian coordinate system. The abscissa describes the indicators or analysis value (e.g. the soil losses in t ha^{-1} a^{-1}), the ordinate the “level of sustainability” (range from 0 to 1; 0 = worst situation, unsustainable and 1 = best situation, sustainable) [4].

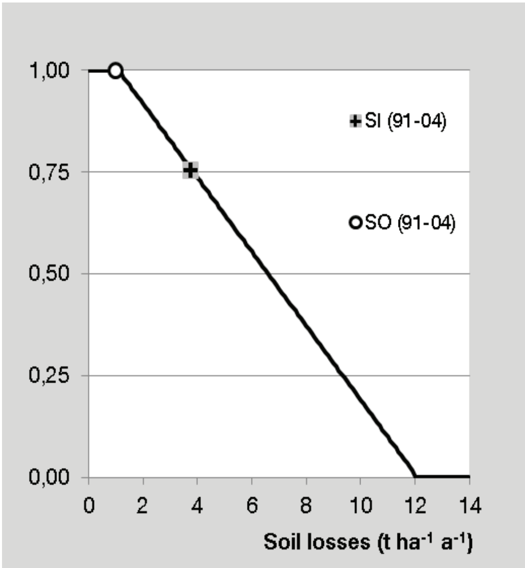


Figure 2: Evaluation function – impact category soil erosion

Implementation of the biodiversity indicator: For biodiversity less preliminary work was available. Because of that as a first step all impacts of agriculture on biodiversity were compiled from literature. Based on this collection impacts were structured and systematized. Effects of agriculture on biodiversity arise from complex relationships. Farms or cropping systems influence biodiversity by management measures, farm structures and management intensity. Different sub-indicators aggregate these impacts to the complex indicators “Biodiversity Development Potential” (BDP). The Analysis and evaluation of the indicator integrates the structural components (cropping and field structures), components for the intensity of the fertilization and pesticide system and sub-indicators for the field operations and measures. The latter covers impacts which influence biodiversity by physical-mechanical, chemical effects or by disturbances of the cropping system. All sub-indicators are aggregated according to a fixed scheme (Fig. 3).

[4] This procedure was devloped for all indicators (Tab. 1) which allows combined analyses of differnet impact categories.

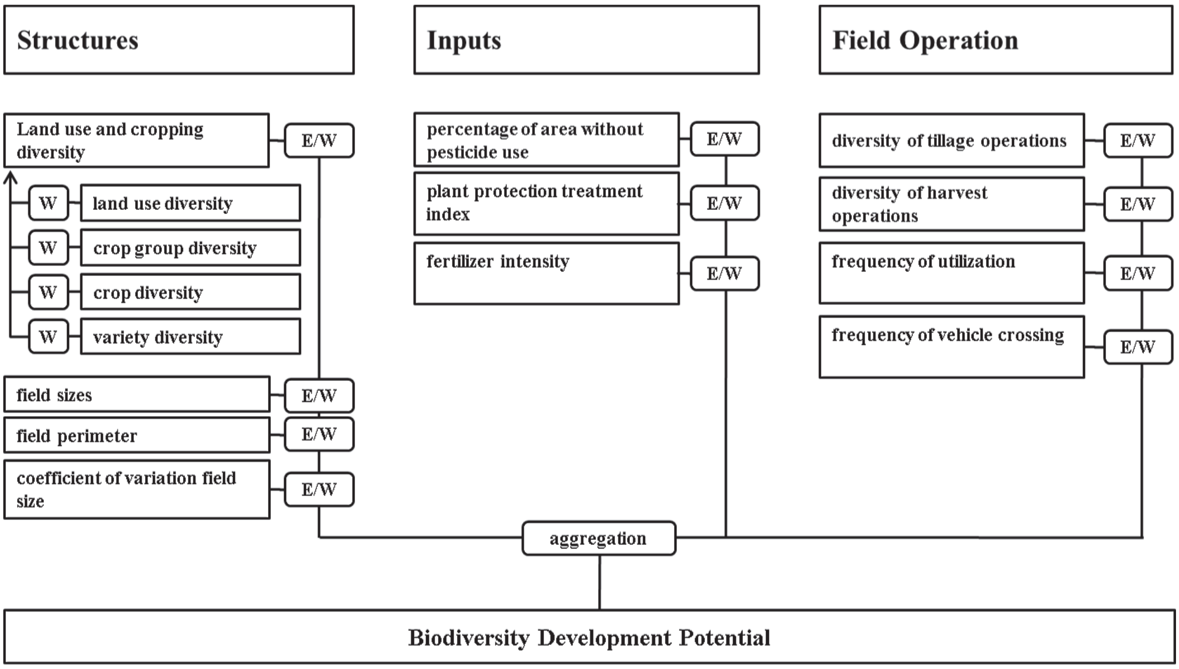


Figure 3: Scheme of partial indicators and aggregation to the BDP; E/W = evaluation and weighting

To illustrate and model interactions between different impact categories (e.g. soil erosion, greenhouse gas emissions, humus balances, profit rate etc.) also indicators for the social and economic aspect of sustainability were developed (Tab. 1). In total this supports a holistic approach in the sense of strong sustainability, where all pillars are equal (Konrad & Döring 2008).

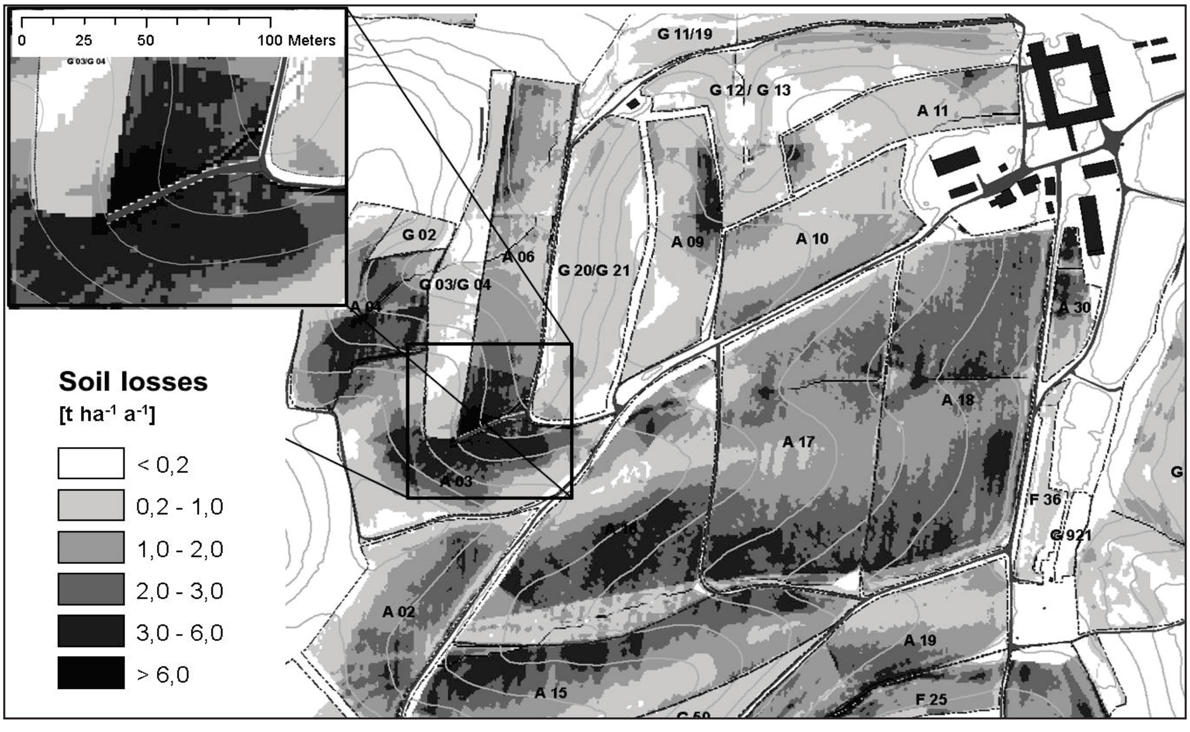
Table 1: Sustainability Indicators

Ecological indicators	Economic indicators	Social indicators
Nitrogen balance	Income	Wage and salary
Phosphor balance	Relative payment	Labor time
Humus balance	Debt service limit	Vacation
Energy intensity	Stockholder's equity change	Education and training
Greenhouse gas emissions	Net investment	Protection of labor and health
Pest management intensity	Profit rate	Protection consideration and
Soil compaction		Support employees interests
Soil erosion		Social activity
Biodiversity potential		
Landscape conserv. measures		

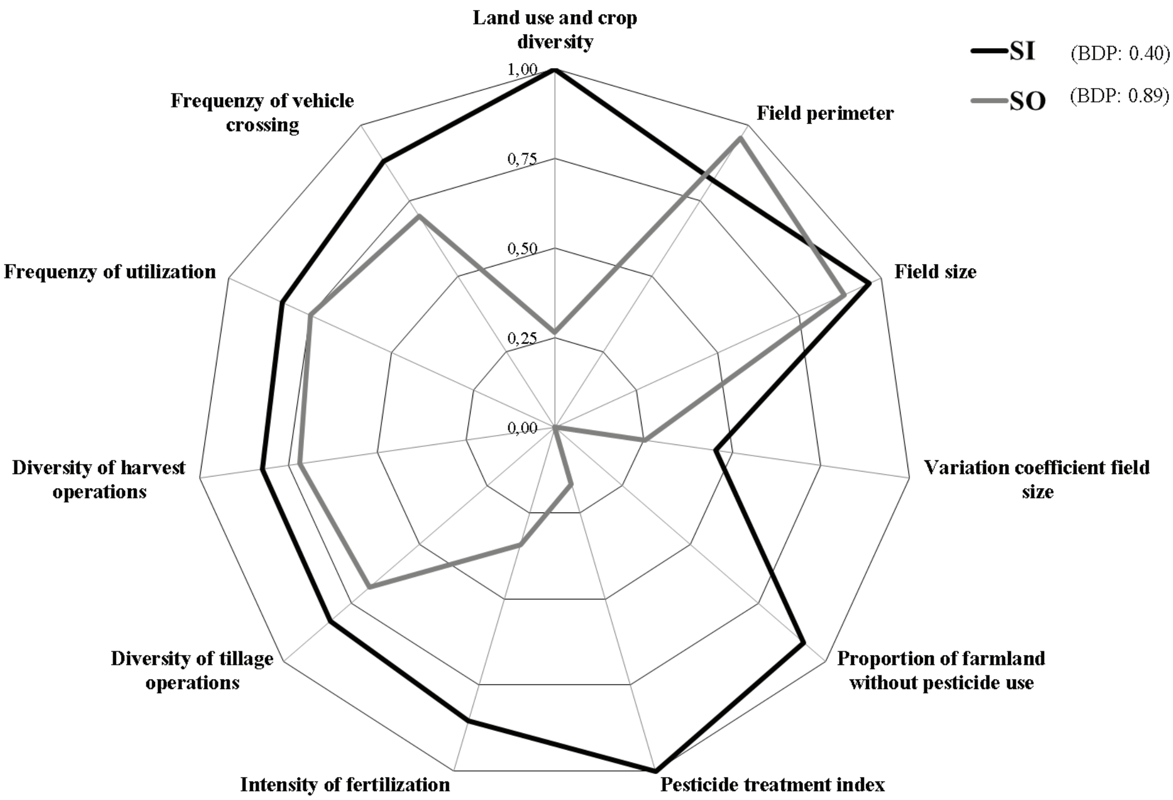
Application and Results

The introduced approach is exemplified on the experimental farm Scheyern (cropping season 1992 – 2004). Scheyern was rent by the Technische Universität München for the long term research project "Forschungsverbund Agrarökosysteme München" between 1991 and 2005. The projects main aim was the development of a sustainable land use concept for an agriculture compatible with environmental protection. The impacts of two cropping systems, which were established in 1992 in the same landscape context, were analyzed. The farm was divided into an integrated managed farm system (conventional) (SI) with simulated steer fattening and an ecological managed farm system with mother cow husbandry (SO). The crop rotations of both systems are: SI (68 ha): potatoes, winter wheat (mustard), silage maize, winter wheat (mustard); SO (42 ha): alfalfa clover gras (Mustard), potatoes, winter wheat, sunflowers, alfalfa clover gras, winter wheat, winter rye. The farm is located about 40 km north of Munich in the “Bavarian Tertiary hill land”. Average elevation is 460 m NN. The fields are characterized by medium to high slope steepness. The average precipitation is 803 mm, and the average temperature is 7.4 °C. Although the site conditions in both farm systems are almost equal, there are differences in the erosion potential with higher potential for the integrated system (SI) when combining all erosion relevant factors.

Results soil erosion: The higher potential of SI is validated by modeling the soil losses in the GIS. On average (1992 – 2004) soil losses of 3.8 t ha^{-1} a^{-1} were calculated for SI and for SO only 1.0 t ha^{-1} a^{-1}. This values vary between the different years subjected to the grown crops between 3.3 – 4.6 t ha^{-1} a^{-1} (SI). The soil losses of the farm systems correspond to evaluation values of 0.75 for SI and 1.0 for SO (Fig. 2). To specify the risk potential and to identify the best erosion protection measures the approach maps the soil losses with high spatial resolution can be created (Fig. 4).



Results biodiversity potential: Because the “Biodiversity Development Potential” is a dimensionless value its interpretation compared to other indicators is not easy. Rising values indicate that the negative impact of the system is declining and thus the influence of agriculture on biodiversity also declines. For this reason the results of the sub-indicators can support the understanding of the overall result of the indicator. In general the indicator approach allows differentiating between the two farm systems. Considering the BDP overall index, SO was evaluated with a value of 0.89, SI with 0.40. Based on this values it is assumed, that SI is influencing the natural potential for biodiversity much more negative than SO does. This differentiation can be explained by the sub-indicators. The land use and cropping diversity of SI is quite low (narrow or short crop rotation). The integrated farm system has only fields with pesticide use (proportion of farm land without pesticide use = 0), a high average fertilizer (ca. 250 kg N^{-1} ha^{-1}) and plant protection intensity. The sub-indicators “Diversity of harvest operations” and “Frequency of utilization” have almost equal values and thus show almost no differences between the two systems.



The result reflects the influence of higher land use and crop diversity and the omission of mineral fertilizers and plant protection agents in the ecological managed farm system. With regard to the sub-indicators field size and field circumference, which are used to estimate the spatial structure and complexity of the fields, SO ranks slightly behind SI. This can be explained by the fact that SO fields are smaller (1.3 ha on average) and of compact shape (nearly square). So far it can be concluded that diverse structured low-input systems, which are often under organic management, achieve better results regarding biodiversity than specialized high-input systems. Due to its sensitivity to management measures, the BDP indicator provides a good differentiation between farm types.

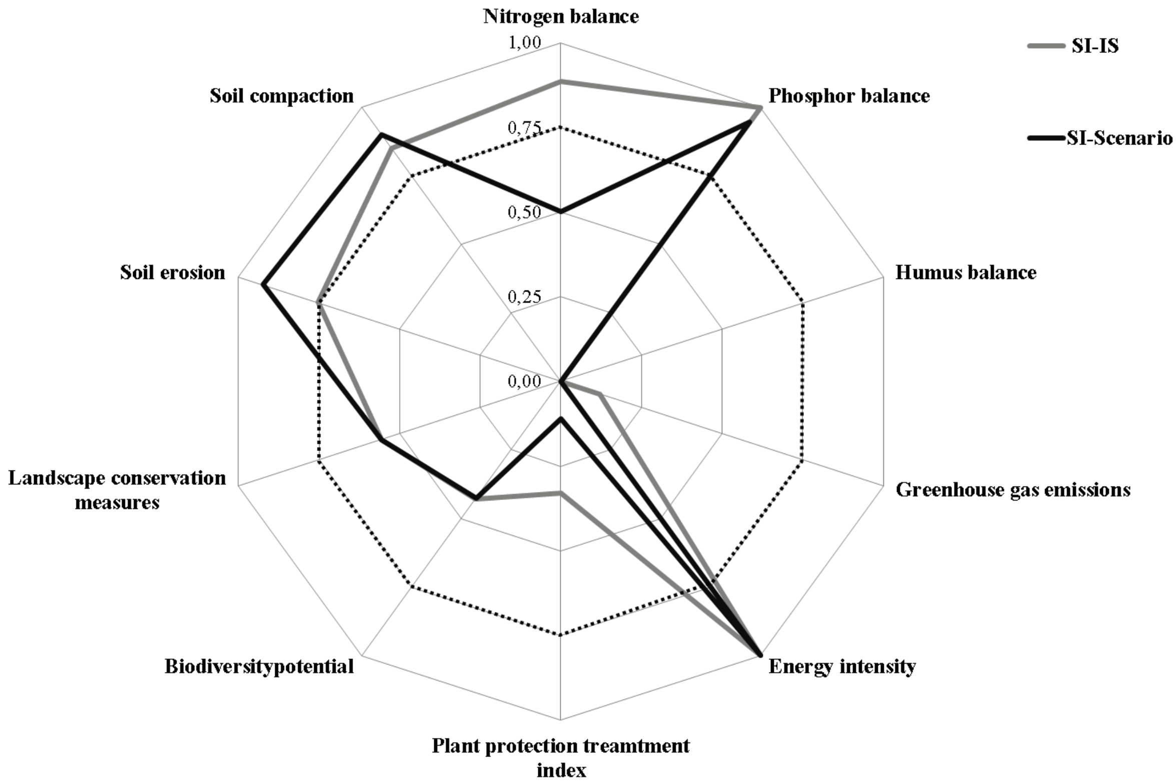
Discussion

For the further optimization of the farm management the question was raised, which effects could be expected due to a modification of the crop rotation? Because of changes in the management system[5] and a growing concern to reduce the erosion potential, different scenarios fore the crop rotations were developed and analyzed with the farmer. Based on the initial rotation (potatoes, winter wheat, silage maize, winter wheat) a scenario, where rapeseed replaces the maize in the rotation (potatoes, winter wheat, rapeseed, winter wheat) was chosen as the most realistic one.

The GIS-based erosion analyses provide evidence that with the new rotation a reduction in soil erosion of about 50 % is possible (1.9 t ha^{-1} a^{-1} to 3.8 t ha^{-1} a^{-1}). Regarding the sustainability evaluation, this would improve the value from 0.75 to 0.93. However, in light of the claim of a holistic understanding and analyses, other effects of the scenario should be tested, too. Optimizing one impact category should not deteriorate others or only to a defined level. The introduced approach provides different possibilities to extend the analyses to other sustainability indicators.

For a fast and easy interpretation of the results net diagrams can be used. Here all evaluation results were combined in one figure (Fig. 5). While positive effects for soil erosion are obvious, indicators like the nitrogen balance and the plant protection treatment index show a negative development. The higher fertilizer intensity for rapeseed would increase the N-balance (SI-IS 62 kg N ha^{-1}, SI-Scenario 100 kg N ha^{-1}) and the higher plant protection intensity for rapeseed is also visible (maize 3 plant protection measures, only herbicides; rapeseed 7 measures, combined). While the evaluated values of the other indicators do not present differences between the initial rotation and the scenario, the indicator values illustrate further effects (Tab. 2). Because of the evaluation process it is sometimes not possible to indicate the positive development of indicators e.g. “hums balance” (SI-IS -394 kg C ha^{-1}, SI-Scenario -226 kg C ha^{-1}). The evaluation value still remains on 0, but the indicator value presents an improvement of the situation. Another example is the indicator „Energy intensity“. The intensity is in both cases evaluated with 1 while the intensity varies between both systems by 18 MJ GE^{-1}. For interpretation of the results and the evaluation of scenarios it is thus recommended to use evaluation and indicator values. Only then all information are available to make holistic and comprehensive decisions.

[5] Aabolishment of steer fattening and the use of silage maize.



the sustainability level 0.75

Besides the described results Fig. 5 shows, that the farming system has "sustainability hot spots" – in terms of deficits in sustainability – for the impact categories "Greenhouse gas emissions", "Humus balance" and "Plant protection treatment". Aim at improving sustainability of the system, these bottlenecks should be improved first.

Table 2: Initial and the scenario crop rotation with ecological sustainability indicators

Indicator	Unit	SI-IS	SI-Scenario
Nitrogen balance	kg N ha^{-1}	61,40	99,96
Phosphor balance	kg P ha^{-1}	-14,47	-20,32
Humus balance	kg C ha^{-1}	-394,40	-226,20
Greenhouse gas emissions	kg CO_{2eq} GJ^{-1}	23,50	28,50
Energy intensity	MJ GE^{-1}	143,21	161,20
Plant protection treamtment index	Index*	0,33	0,11
Biodiversitypotential	Index*	0,43	0,43
Landscape conservation measures	Index*	0,56	0,56
Soil erosion	t ha^{-1} a^{-1}	3,80	1,9
Soil compaction	Index*	0,85	0,90

Conclusions

The new approach proofed to be applicable to implement a "sustainability management" at the level of farms. It provides several starting points for validation and improvement. Particularly with regard to the Biodiversity Development Potential the method is innovative. The methods for analysis and evaluation of soil erosion are also an improvement due to their high sensitivity and the possible integration of the special heterogeneity. In addition to this the possibility of combining different impact categories needs be pointed out. _This allows a comprehensive conceptualization and a holistic sustainability assessment. Only when this is consequently realized, a sustainable progress is possible.

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EFFICIENT BIODIVERSITY INDICATORS IN THE CONTEXT OF SUSTAINABLE AGRICULTURE – BACKGROUND, DEVELOPMENT AND APPLICATION

Wolfrum Sebastian, Siebrecht Norman, Hülsbergen Kurt-Jürgen

Introduction

Within the last years the awareness for the loss of biodiversity has increased. Consequently biodiversity has become a prominent topic within different scientific disciplines, too. Especially agriculture is said to exert a high pressure on biodiversity. The challenge for agriculture is to find solutions to minimize its' impact on biodiversity and to develop production systems which conserve and utilize benefits from biodiversity related ecosystem services. Knowledge about the quantity of biodiversity present on farmland and the relation to management activities is thus crucial to achieve different targets of sustainable agriculture. Examples in this context are natural pest control, the conservation of habitats or the enhancement of environmental quality.

Measuring biodiversity directly is, however, a complex and laborious issue. One solution to solve this problem is the use of indicators. Nevertheless, efficient biodiversity indicators for the level of the individual farm, which is the actual instance where most biodiversity relevant decisions are made, are scarce. This may be due to the complex notions of the buzzword "biodiversity", which make it hard to find a single definition and corresponding indicators. Therefore, the conceptual origin and scope of "biodiversity" has to be clarified. Only then comprehensible and applicable indicators can be developed.

To avoid pitfalls in the indicator development process, challenges in defining, measuring and valuing biological diversity are discussed. Problematic issues are then related to the different steps in a generic indicator model for the assessment of "biodiversity". Based on this analysis a solution for the complex of problems is drafted. Regarding the development of indicators, links to concepts like "agrodiversity", "ecoagriculture" or the "agroecological matrix" and "nature conservation" are presented.

Finally the applications of the previous theoretical analysis are illustrated with examples from current projects like the EU project BioBio and other efforts to assess biodiversity in agroecosystems.

Starting from scratch: the development of "biodiversity"

The concept of "biodiversity" is not easy to grasp. Answering scientific questions related to sustainable agriculture – like how to optimize nitrogen fertilization or how to reduce greenhouse gas emissions – is already hard work due to the complex nature of agricultural systems. However, working on biodiversity issues is worse. Contrary to rather clear defined and measurable problems, e. g. how the amount of mineral nitrogen input affects the yield of a crop, "biodiversity" is an amorphous catchword, which is neither consistently defined nor unambiguously to measure. In fact there is a “diversity of diversity” (Takacs 1996; Beierkuhnlein 2001; Hoffmann & Richter 2003). Nevertheless, “biodiversity” is a popular and widely used term e. g. in conservation biology (Haila & Kouki 1994). Likewise the divers nature of the term has fostered its’ popularity, it has also raised critics (Hurlbert 1971; Haber 2008) and produced a considerable amount of literature trying to define and clarify what is actually the scope of the “biodiversity” term (Sarkar 2002; Beierkuhnlein 2003; Norton 2004; Ricotta 2005; Jurasinski *et al.* 2009; Tuomisto 2010) and what are adequate measures (Hawksworth 1996; Purvis & Hector 2000; Magurran 2004). Despite of these efforts the notion of ambiguity, which is expressed in titles like “What does 'biodiversity' mean - Scientific problem or convenient myth?” (Ghilarov 1996) and “Biodiversity: from Babel to biosphere management” (van der Maarel 1997) or by connotations like “fata-morgana word” (Magurran 1988), keeps sticking to the term. One solution proposed is to accept this lack of clarity and to adopt a constructivist perspective for a case specific definition of “biodiversity” (Meinard *et al.* 2013). By that the importance of context (van Weelie & Wals 2002), worldviews (Mayer 2006) and values (Meinard *et al.* 2013) to the idea of “biodiversity” is acknowledged. However, the key to fully understand why this is necessary to improve the operationalization of the “biodiversity” concept is to analyse the historical development of the term.

A very basic and rather undoubted aspect of “biodiversity” is the notion of difference and similarity. The concept of difference and thus of “diversity” in biological entities was important to humans since the beginning of mankind (Oksanen 2004). Already in prehistoric times it was necessary to distinguish edible from toxic plants or a deer, that could be prayed on, from a sabre-toothed tiger to whom you would fall pray to yourself. Much later the first scientific thoughts about “diversity” stem from the Greek philosophers Aristoteles (384 - 322 v. Chr.), seen as the founder of biology as scientific discipline, an his mentor Platon (427 - 347 v. Chr.) (Oksanen 2004). Their ideas about systematic differences and similarities in nature, the “scala naturae”, lead to Linnaeus's “Systema Naturæ”. Published in 1737, Linnaeus's work initiated taxonomy by introducing a binary nomenclature applicable to all organisms. Until now the modern taxonomy concepts have constantly improved the abilities to detect and classify differences in nature, culminating in genetic analysis like DNA barcoding of organisms.

Another important aspect, shaping conflictive notions of “biodiversity”, becomes apparent by comparing the theories of Wilhelm von Ockham (1285-1347 n. Chr.) and Gottfried Wilhelm Leibniz (1646-1716 n. Chr.). Kirchhoff & Haider (2009) use this comparison to show contrasting ideas of “biodiversity”, which for example manifest in the ecological discussion on positive or negative impacts of invasive species on biodiversity. For their analysis Kirchhoff & Haider (2009) use the dichotomy of liberalism and conservatism described by Kirchhoff & Trepl (2001) as an analytic tool.

According to Kirchhoff & Haider (2009) Ockham argues for a liberal perspective in which god has an absolute free will and is thus totally independent. In Ockham’s cosmology god has created a world full of unique individual elements, which are simply aggregated. Constructing a systematic classification of these elements, e. g. based on their usefulness, is only a matter of the human mind. Ockham’s theory is thus the basis for scientific empiricism and liberal or individualistic theories. To describe the liberal position words like “multiplicity”, “elements”, “traits” or “usefulness” could be used.

Contrary to that, Kirchhoff & Haider (2009) describe Leibniz monadology as a conservative perspective. Leibniz claims that god’s free will is bound to reason and thus creation has to be based on an universal ordering principle. Although each creature is created as individual, individuality stems from the creatures’ unique relationship to others. The world is not an arbitrary aggregate of elements, but a harmonic system, which was selected by god as the best of all possible variations. Leibniz theory is the basis for the idea of the “organism” in biology and holistic or oganismic theories. To describe a conservative position words like “variety”, “places”, “phenomenons” or “quality” could be used.

The important conclusion from the distinction sketched in the last two paragraphs is, that the dichotomy of liberal and conservative worldviews can be identified throughout the discussion on different meanings of “biodiversity”. Besides this, it may be the reason for a considerable number of conflicts regarding the conservation of biodiversity. A good example are the conflicts between farmers an conservationists summarized by Henle *et al.* (2008). While nature conservationists, who are in favour of an unique ”quality of place”, would e. g. spend money for the protection of the last common hamsters (*Cricetus cricetus*) to protect biodiversity, a farmer or agronomist would prefer to introduce a new modified variety of rye (*Secale cereale*) to increase diversity. Nevertheless it seems clear that a consistent and comprehensible operationalization of biodiversity needs to address the issue of different ideas that can be at the bottom of the concept.

To conclude the historic overview, the impressive development of “biodiversity” from a neologism to a global buzzword has to be sketched. Since the beginning of modern biology the analysis and assessment of “biological diversity”, either as pure natural history or connected to more sophisticated questions, like the relation with stability or productivity of ecosystems, was a major item on the scientific agenda. During the 80ies scientists realized a growing loss of biological diversity. Concerned about this development the problem was made public and brought to the political agenda. For that reason in 1986 Walter G. Rosen, crafted the term “biodiversity” as title for a conference through the connection and shortening of the term “biological diversity” (Oksanen 2004). The proceedings of the “Forum on BioDiversity” titled “Biodiversity” (Wilson 1988) mark the start of the terms steep career. However, not before the “United Nations Conference on Environment and Development” in 1992 led to the “Convention on Biological Diversity” (CBD) the “biodiversity crisis” reached greater public and scientific awareness. Figure 1 gives an idea of the rapid adoption of the term by science and politics. Within the last years biodiversity was recognized as a major global issue. Consequently the term is frequently used in various contexts and by different stakeholders. Lately biodiversity has even attracted the attention of the economic sector like e. g. food producers (Christen *et al.* 2009) or even large companies (Schaltegger & Beständig 2010).

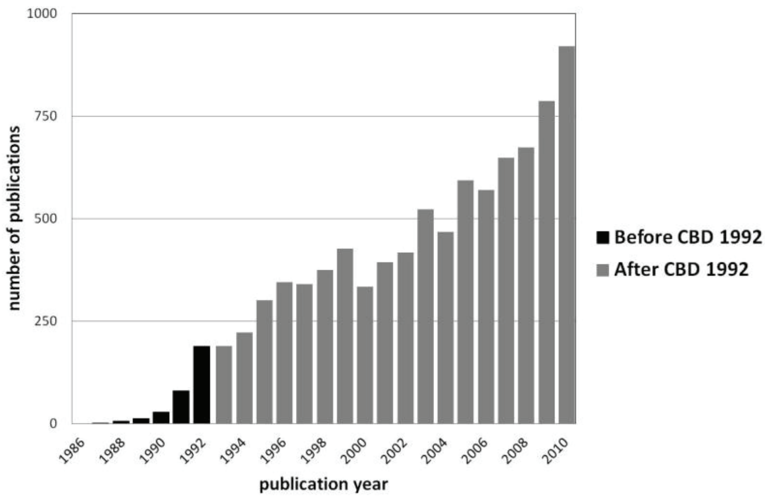

Figure 1: Number of papers between 1986 and 2010 with “biodiversity” explicitly mentioned in the title (retrieved from Web of Science)

To sum up, “biodiversity” is a popular but ambiguous buzzword. Basically the concept is connected to some notion of difference in biological entities, but in detail it is burdened with diverse ideas from conflicting world views. The next chapter will illustrate why and where this may cause problems.

“Biodiversity” – a problematic concept?

If biodiversity was a pure scientific concept, like e. g. temperature, life would be easy. Unfortunately the term’s history has created a hybrid concept that is located somewhere between sciences and politics (Norton 2004; Turnhout *et al.* 2007; Norton 2008). As a consequence Eser (2003) characterizes “biodiversity” as a “boundary object”, which is able to integrate different stakeholders and allows for cooperation without consensus. While this may be an advantage for the acceptance of political declarations of intent, it is problematic for actual operationalization and scientific analysis. Hoffmann *et al.* (2005) have identified three major problems, which need to be sketched briefly:

The definition problem:

The first issue with „biodiversity“ identified by Hoffmann *et al.* (2005) is the lack of a general and unambiguous definition. Although this can be an advantage because the term is quite inclusive and thus widely acceptable, this vagueness has up till now hampered the development of rigorous regulations concerning the topic. The problem can neither be solved by an explicit nor by an implicit definition of “biodiversity”. Hoffmann *et al.* (2005) suggest that there is not one single solution and that a concrete definition is dependent on a discourse about context an values. However they see “biodiversity” always connected to a biological background and the notion of social welfare.

The measurement problem:

Assuming a solution for the definition problem, a second issue identified by Hoffmann *et al.* (2005) is the problem of measuring “biodiversity”. The basic question behind this problem is how to correctly measure the quantity of biodiversity present at a given place and time. Basically two different classes of measures can be distinguished (Baumgärtner 2003). On the one hand there are measures for the “Richness-Eveness-Diversity” (RED) incorporating information on the quantity and the frequency distribution of organisms. Examples are species richness, Shannon-Index or Simpson-Index. On the other hand there are so called “Attribute-Diversity” (AD) measures accounting for differences in traits of organisms. Hoffmann *et al.* (2005) discuss advantages and disadvantages of both approaches. They conclude depending on the kind of diversity to measure the right indices have to be used or developed. But most importantly they stress the need for a consistent and comprehensible selection process.

The valuation problem:

Finally Hoffmann *et al.* (2005) notice that biodiversity is generally perceived as valuable, but in detail it is rather difficult to determine to whom exactly what kind of diversity has how much value. However, measurement and assessment of “biodiversity” are not independent from valuation issues (Baumgärtner 2003). Selecting specific aspects of “biodiversity” for analysis is therefore dependant on values. Additionally weighting and aggregation of information (e. g. sub indicators) is an act of expressing values.

All three problems together seem to induce a fourth problem – the action problem. Although, since the CBD was signed, programs, strategies and action plans to halt the loss of biodiversity have been issued, little of these efforts were successful (Mace *et al.* 2010). This rises the question, whether not enough was done to meet the targets or if there wasn’t enough information to do the right things. For the latter the use of indicators poses a solution, allowing to gain information on biodiversity and to implement suitable actions.

Indicators as tools to measure “biodiversity”

Indicators are useful tools to gain information on latent variables, that can not be measured directly but are necessary to describe the state of a system (Siebrecht 2010). Figure 2 shows a model for a generic indication process. First of all the “object” under investigation needs to be represented by a simplified “model”, from which an interesting feature (“indicandum”) is selected. The “indicator” is another object with a measurable property, the “indicans”. Because the indicans is causally related to the indicandum, changes in the indicans allow conclusion on the state of the indicandum and thus provides information on the object. (Zehlius-Eckert 2001)

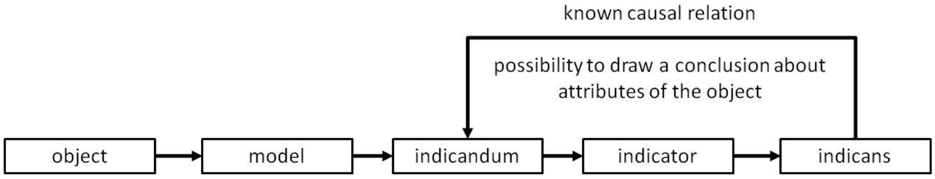

Figure 2: Schematic representation of a generic indication process (Zehlius-Eckert 2001)

As described above "biodiversity" can hardly be measured directly. Applying the indication process to the concept of "biodiversity" and make use of indicators is a popular way to cope with this problem (Büchs *et al.* 2003; Herzog *et al.* 2012). However, biodiversity indicators are subject to the problems discussed in the previous section, too.

Facing the interaction of conceptual issues and the indication process

Figure 3 gives an idea about the indication process for the concept of "biodiversity". It reveals, that the discrete steps in the process are connected to the different problems identified. Figure 3 also shows the connections between the problems.

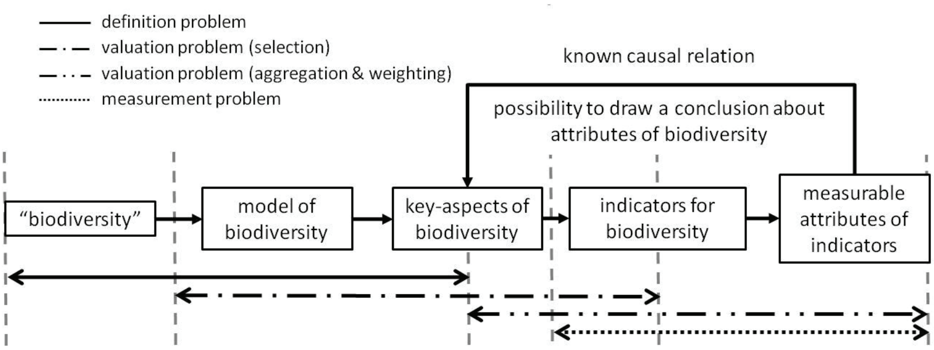

Figure 3: "Biodiversity" indication schema showing relations to problem fields described

For the indication process the definition problem is closely related to the valuation problem, specifically the question on what are the relevant key aspects of "biodiversity". Contrary to that, the measurement problem is more related to the weighting and aggregating issues of the valuing problem and only little to the measure selection issue (RED or AD). Nevertheless for the development of efficient indicators these interactions have to be known and addressed with adequate solutions.

Bearing the challenges – sketching solutions for the future

"Biodiversity" embraces different values and worldviews. The work of Meinard *et al.* (2013) provides a good conceptual starting point for a new understanding of the term. Qualitative methods like interviews or focus groups could then be used to account for changing values and different notions of "biodiversity" in various contexts. As a first step four aspects of "biodiversity", similar to the three proposed by Duelli & Obrist (2003), are identified. To cover the full scope of biodiversity related worldviews these aspects should be represented by indicators. Indicators could e. g. be labeled as "agrodiversity performance", "ecoagriculture efficiency", "high natural value matrix quality" and "nature conservation performance”. Figure 4 shows relevant concepts in relation to the each other and the values covered. Additionally the relation to sustainable agriculture is illustrated.

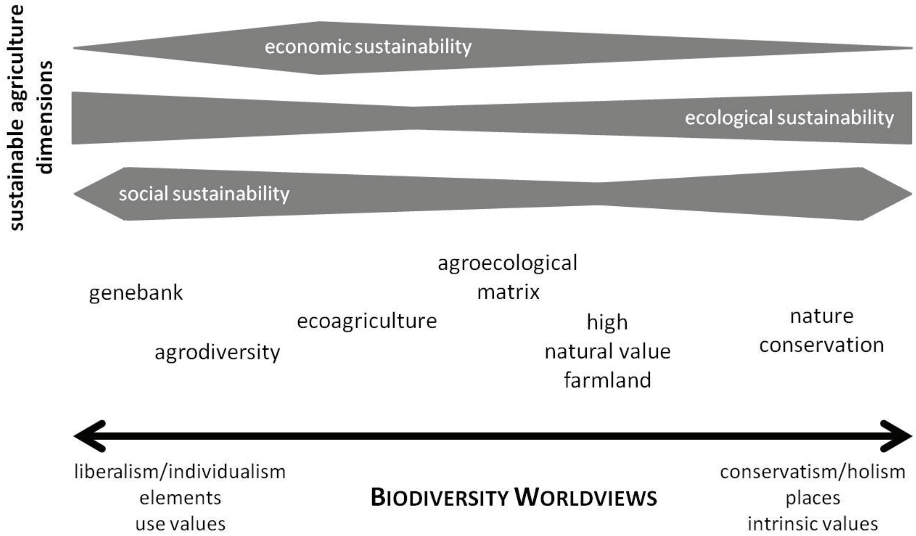

Figure 4: Worldviews on “biodiversity”, sustainable agriculture and related concepts

Regarding the measurement problem RED or AD measures should be chosen according to the results of an analysis of possibly relevant values. Which measure can be used in detail should also be dependant on context and purpose of the analysis. However, especially for the RED sector new methods (Colwell *et al.* 2012; De'ath 2012; Pallmann *et al.* 2012; Wang *et al.* 2012) have been recently developed, which will significantly improve the scope and quality of biodiversity analysis.

Transferring theory into praxis – examples from past an ongoing projects

The presented ideas were applied in several past and ongoing projects of the authors. One of these was the EU project BIOBIO (www.biobio-indicator.org), which aimed at developing a broadly applicable indicator set and providing standardized methods for the assessment of the benefits of biodiversity for organic and low-input farming. Four species indicators, relevant for functional aspects of biodiversity in agriculture were selected (Herzog *et al.* 2012). For the German case study special emphasis was placed on the development and analysis of a functional soil biodiversity indicator with earthworm data. Also for the BIOBIO project focus groups were used to assess the values and worldviews of farmers to improve indicator development (Kelemen *et al.* 2013). The focus group method will also be used in a recently launched project aiming at further development of functional biodiversity indicators for the farm level and the transfer of information between actors along the value chain. In contrary the ELKE project (www.landnutzungsstrategie.de) aimed at improving and assessing biodiversity benefits of agroforestry systems. For that reason the focus was on the nature conservation aspect and thus species like birds, bats and beetles were assessed. Future research will emphasize the conceptual development of indicators covering the different facets of “biodiversity”.

Conclusions

Applying the approach exemplified in this article can foster the development of objective and comprehensible indicator frameworks to assess biodiversity in the context of sustainable agriculture. Future implementations might help to tackle issues like monitoring the impacts of agricultural practices on biodiversity or improving the utilization of ecosystem services for agricultural production.

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MAINSTREAMING BIODIVERSITY CONSERVATION INTO THE COCOA GROWING LANDSCAPE IN SOUTHWESTERN GHANA.

Awotwe-Pratt Vincent

Abstract

The overall goal of the project is to mainstream biodiversity conservation into cocoa production landscape around the Bia Conservation Area in Southwest Ghana. Cocoa production is a major economic activity and land use in the Guinean Forests of the West Africa hotspot, one of the world’s 25 biologically richest and most endangered terrestrial regions. Forest ecosystems here harbour more than half of all mammal species found in Africa. Cocoa farms constitute a threat to the region’s globally significant biodiversity but also offer an opportunity to conserve it. The scale of the cocoa production sector and the global importance of the biodiversity in cocoa production landscapes justify the project intervention.

The Government of Ghana has recognized the threats to the cocoa industry and the present focus of the national cocoa policy is to increase production in existing plantations by introducing better agronomic practices and rehabilitating old farms. The commitment is also consistent with Ghana’s National Biodiversity Strategy, which places a strong emphasis on conserving the remaining forest cover. With an average yield of only 250-300 kg/hectare in Ghanaian cocoa farms, there is a sizeable potential for increased per-area yields and reduce the need for cocoa expansion.

This project addressed barriers to wide-scale sustainable cocoa production at three levels: the market level, the national level, and the local level. At the market level, it will work with cocoa traders to support farmer’s efforts to adopt sustainable practices and increase their understanding of the relationship between biodiversity conservation and productivity. At the national level, the project will promote certification models that provide incentives for biodiversity-conserving and productive agroforestry farm systems. At the local level, it will collaborate with and support farmers to adopt best practices that enhance the ecological integrity of farms and connect forest fragment in the landscape while at the same time improving farm productivity.

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SIZE STRUCTURE OF FIELDS IN PRODUCTION AND LESS FAVORED AREAS OF THE CZECH REPUBLIC

Novák Jaroslav, Lukas Vojtěch, Dušková Soňa, Křen Jan

Introduction

Farmers in the Czech Republic manage approximately half (53.6%) of the total area of the country.

According to Bukovsky et al. (2012) the total area of the Czech republic is 7,887 thousand ha. Total agricultural land area on January 1st 2012 was 4,230 thousand ha. Agricultural land represents 53.6% of the total land area of the Czech Republic. Arable land represents 37% of the total area of the country. The rest of the agricultural land is made of forests, grasslands, orchards, vineyards, hop fields and vegetable gardens. Exact numbers differ in various years. At the data validity moment (beginning of 2012 year) area considered in this article was about 3,686,558 hectares.

From another point of view, agricultural land in the CR can be distinguished to production areas (PAs) with arable land prevailing and less favored areas (LFAs) that contain grasslands for agriculture production mostly.

If it is possible to divide the land in the Czech Republic this way according to the law, then the less favored areas are defined by methodology for implementation the regulation No. 75/2007 Coll. as follows:

- **Mountain area of type HA** – municipalities and the cadastral areas with an altitude of 600 m above sea level or 500-600 meters above sea level while the slope is greater than 15% on 50% of the territory of the village or the cadastral area.
- **Mountain area of type HB** – municipalities and the cadastral areas not fitting criteria for the type of HA which were included into the area to preserve its integrity.
- **Other less favored of area type OA** - municipalities or the cadastral areas with the productivity of agricultural land lower than 34 points located in the region, fitting average demographic criteria - population density of less than 75 people/km^2 and share of agricultural workers in the total working population more than 8%.
- **Other less favored area of type OB** - municipalities with the productivity of agricultural land between 34 and 38 points located in the region fitting average demographic criteria - population density of less than 75 people/km^2 and share of agricultural workers in the total working population more than 8%. These municipalities and cadastral areas were included into Other less favored area in order to preserve its integrity.
- **Specific area of type S** – municipalities or cadastral areas with productivity of agricultural land less than 34 points or between 34 and 38 points with slope steepness more than 7^o on 50% of agricultural land of municipality or cadastral area, with

grassland share higher or equal to 50% of agricultural land of areas (within these territories only cadastral areas where the approximations of calculating land productivity based on real grassing return was less than or equal to 34 points are included to this area type) – these municipalities and cadastral areas do not belong to regions fitting average demographic criteria for Other less favored areas.

According to this definition all other land is included into the category of production areas, although they are not defined by law. Localization of production and less favored areas is shown in Figure 1:

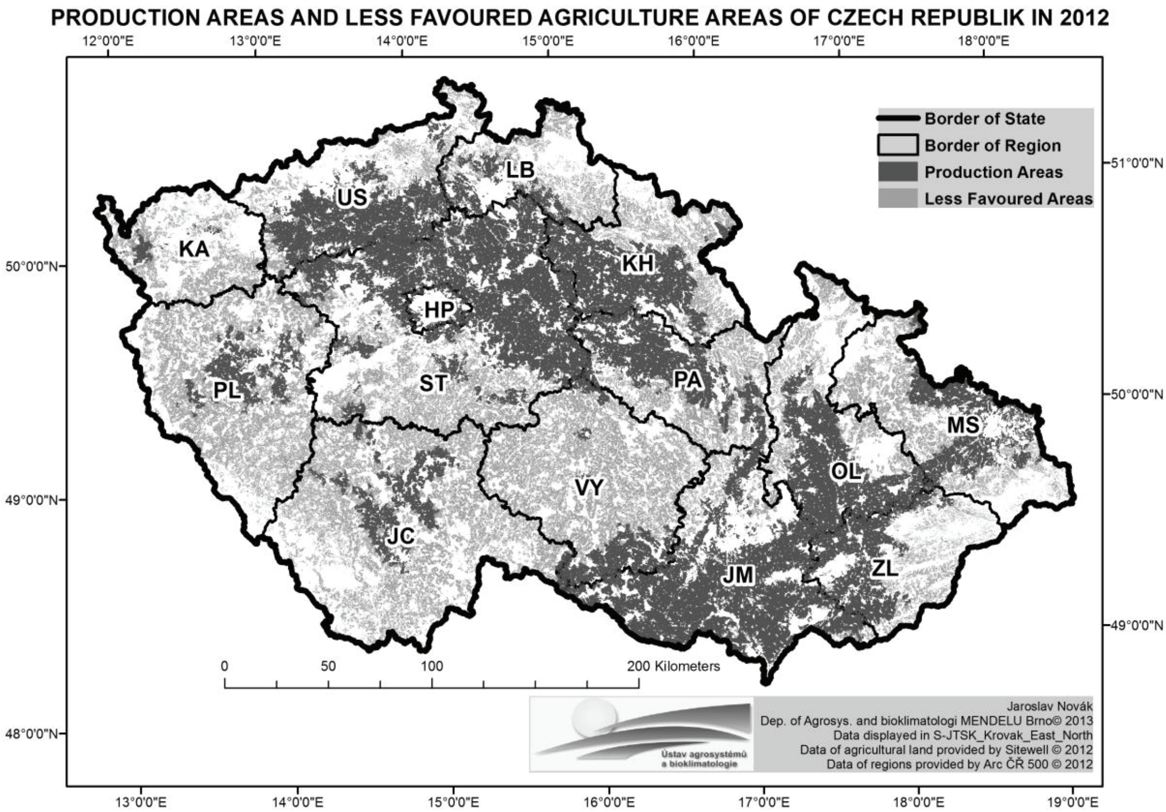

Figure 1: Distribution of PAs and LFAs in the CR

This paper aims to compare two categories of agricultural land using selected statistical indicators, especially average block size and the percentages of summary representation of each block group. The basic hypothesis of this paper is that production areas are made up of blocks of arable land with larger acreage than average blocks in less favored areas.

Material and methods

Production areas and less favored areas data for this article were provided by Ministry of Agriculture (MoA). Data were provided in form of spatial and descriptive representation of blocks of arable land in SHP format.

Land Parcel Information System (LPIS) provides information about the agricultural land used in the Czech Republic especially for Czech Ministry of Agriculture. Its main objective is to provide information about farms applying for subsidies (single area payment, compensatory allowance for farming in LFA and others). It verifies information in aid applications and helps administration of subsidies under conditions of the Common agricultural policy. The system was required to be provided access to EU funds. In 1999 the Czech Republic made a commitment to create new parcel identification system based on user relations (LPIS) before its accession to EU as there had been no such system in the Czech Republic before. In 2000-2002, Ekotoxa Opava Inc. created the first off-line solution of Czech LPIS. However, the off-line LPIS solution turned out to be inadequate and having operational problems with the management of parcel identification as required by the Agriculture Act. Consequently, the Ministry of Agriculture decided in early 2004 to hire a new contractor and change the philosophy of the LPIS solution (Sitewell, 2004).

Basic principles of LPIS:

- LPIS is based on a unique central database
- The elementary identification unit in LPIS is a farmer's block, which represents a continuous area of agricultural land with one type of crop used by one farmer.
- The database is updated on-line in real time over a VPN from the 63 regional offices of MoA – liability for the correctness of data is held by the Ministry of Agriculture
- There may always be only 1 effective version of data at a moment for 1 area
- Classification of blocks against geographic data layers must be performed automatically as soon as a new version is approved, without manual intervention
- A history of changes must be kept for each block – at any time in future, it must be possible to recall the status of the database on any day in the past quickly
- The data of blocks used by a farmer may never be changed without the farmer's knowledge

Other function of LPIS is to be an independent reference register that serves farmers as a quick source of information about the land they use. Based on the information, they can complete their aid applications correctly they also may find out which limitations apply to their farming. Web map application allows to show the map sources as ortophotos, topographical maps, soil erosion risks and other. One very useful function is implementation of the cadastre maps and calculation of the area of each parcel within the farmer’s block, which can be used for preparation of parcel lease contract by farmers.

Borders of the region and the entire state were taken from geographic databases Arc CR 500. Vector digital geographic database Czech Republic ArcCR ® 500 is designed in detail scale 1:500 000. Its contents are clear geographical information about the Czech Republic. Data created in collaboration ARCDATA PRAGUE, Inc., Geodetic Office and the Czech Statistical Office.

The first step in evaluating categories of production and less favored areas was the creation of Exploratory Data Analysis (EDA) and the representation of certain characteristics in the Box Plot.

For comparison of the average size of the fields in two main categories, position characteristics (mean, median, main percentiles) and a measure of variability (variance, standard deviation, coefficient of variation) have been calculated. These data determine the variability around its position (Briš et al., 2004). Furthermore, of total number of blocks of arable land, total areas of arable land, minimum and maximum block size were determined.

For both surveyed categories of land, a uniform classification consisting of seven size categories was chosen. They are shown in Figures 4, 5 and 6. These categories were based on the detected frequency. All acreages and summed acreages are given in hectares. Calculations of statistical characteristics were done in MS Excel 2010.

Results and discussion

In Table 1 the results of exploratory data analysis for the category Production Areas and Less Favored Areas are shown:

Table 1: Result of Exploratory Data Analysis

Measurement	PA	LFA
Count	199,430	340,905
Sum	1710570 ha	1975988.22 ha
Average	8.57	5.8
Q_{25}	0.93	0.74
Median	2.82	2.03
Q_{75}	8.92	5.83
Min	0.01	0.01
Max	398	296
Variance	246.77	122,76
Standard deviation	15.71	11.08
Coefficient of variation	183.31%	191.16 %
Skewness	4.56	5.54
Kurtosis	34.14	53.69

Less favored areas outnumber production areas in both numbers of blocks and total land size. LFAs lead, though slightly, also in degree of dispersion of blocks siye. The variance in PAs is slightly higher, but as neither of variables have normal distribution, it will be better to focus on coefficient of variation here. It better describes comparing of different variables. In both cases, it is extremely sparse file as the coefficient of variation is greater than 100%. The rate of skewness is higher than zero. Therefore, data for both categories of land are the left-distributed with the presence of small values. It is also confirmed by comparing the average and the median - average is greater than the median.

The coefficient of kurtosis is greater than zero. Sharper division and left-sided distribution histograms are also evident in Figure 4.

The histograms and position quartiles shows also apparently that most of the values are between 0.01 and 5.83 for LFAs and between 0.01 and 8.92 in the category of PAs. This is also confirmed by the value of skewness. Interquartile range and standard deviation are higher in the category of PAs. The standard deviation may be influenced by outliers.

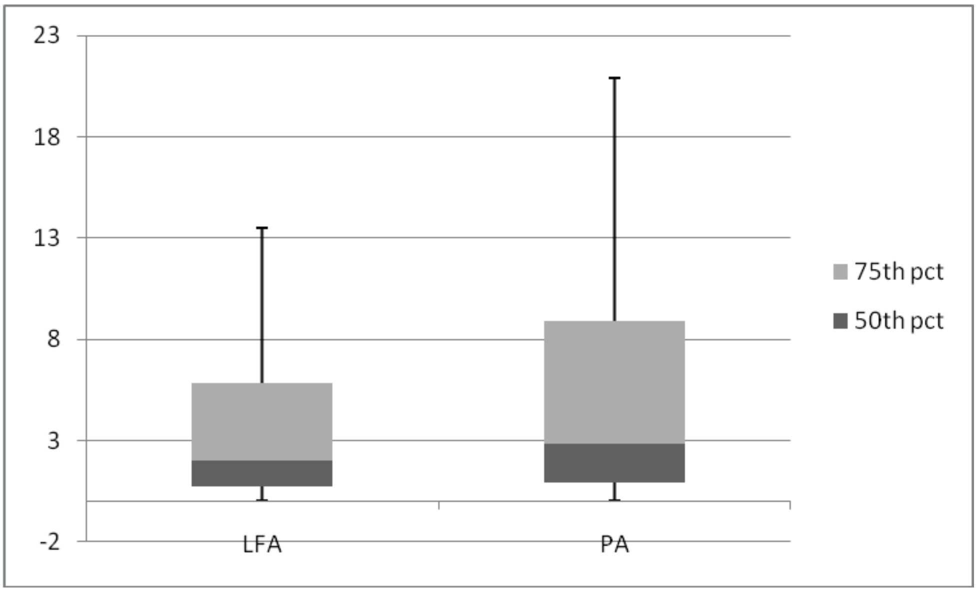

Figure 2: Box plot

The box plot shows the asymmetry of the two variables. The median is closer to the bottom. This confirms the positive a slant of both variables.

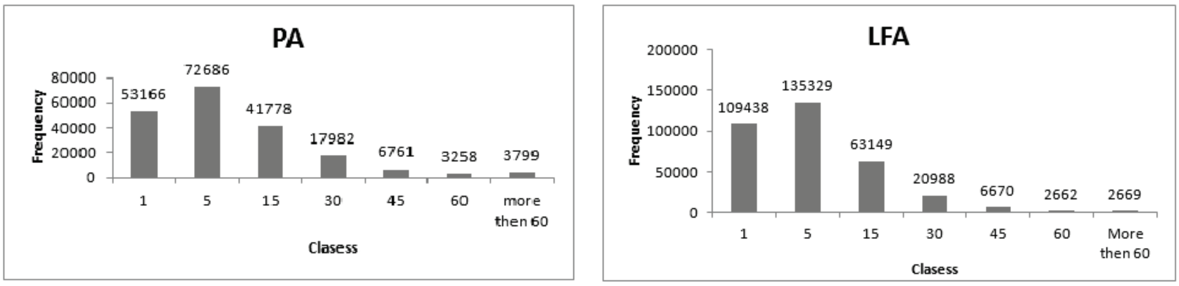

Figure 3: Histograms

Percentage of area sums in LFAs

Graph of percentage representation of block shows that in all regions the largest group of blocks is of 1.01 - 5 hectares. In most regions, this category comprises almost 30% of the area of the region. As well as in the histogram, the largest area is contained in the first three categories. Representation of all categories is relatively balanced. The only exception is the Karlovy Vary (KA) region, in which the category 0.01 - 1 ha is the smallest from all regions. The biggest is a group of 60 ha or more. The capital city, where there is only one land block in the category of 1.01 - 5 ha, is abnormal too.

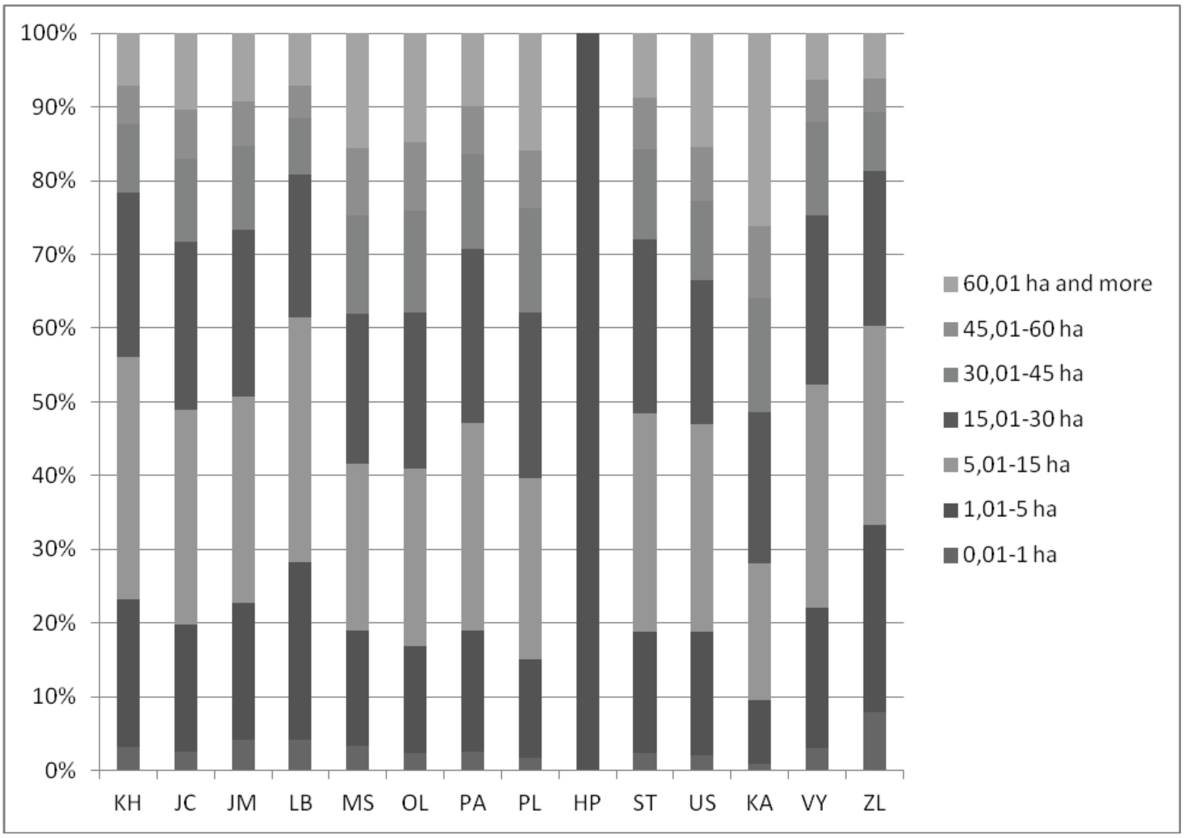

Figure 4: The percentage representation sum of areas in less-favored areas

Percentage of area sums in PAs

In the production areas the largest acreage belongs to blocks in group of 5.01 - 15 ha. The largest area is contained in the first four categories. There was also decrease in the sum acreage in the smallest category. In all regions, on the other hand, the sum of largest area increased. The values of the traditionally agricultural areas Olomouc (OL), Central Bohemia (ST) and Ústí (US) are practically in a straight line. The sum of the first four categories does not exceed 60% of the arable land area. Pilsen region, which is not primarily considered for a production area, is the only curiosity. The sum of the first four categories of the South Moravian Region is even lower than 50%. This is probably caused by the smallest proportion of LFAs in the region from the Czech Republic. This group also includes the Karlovy Vary region, which has, same as in the LFAs, the largest representation in the 60 ha and over. Based on the displayed values we can generally conclude that the regions, whose sum in the first four categories does not exceed 60% of the total, are, without the Pilsen Region, the main producing areas of the Czech Republic.

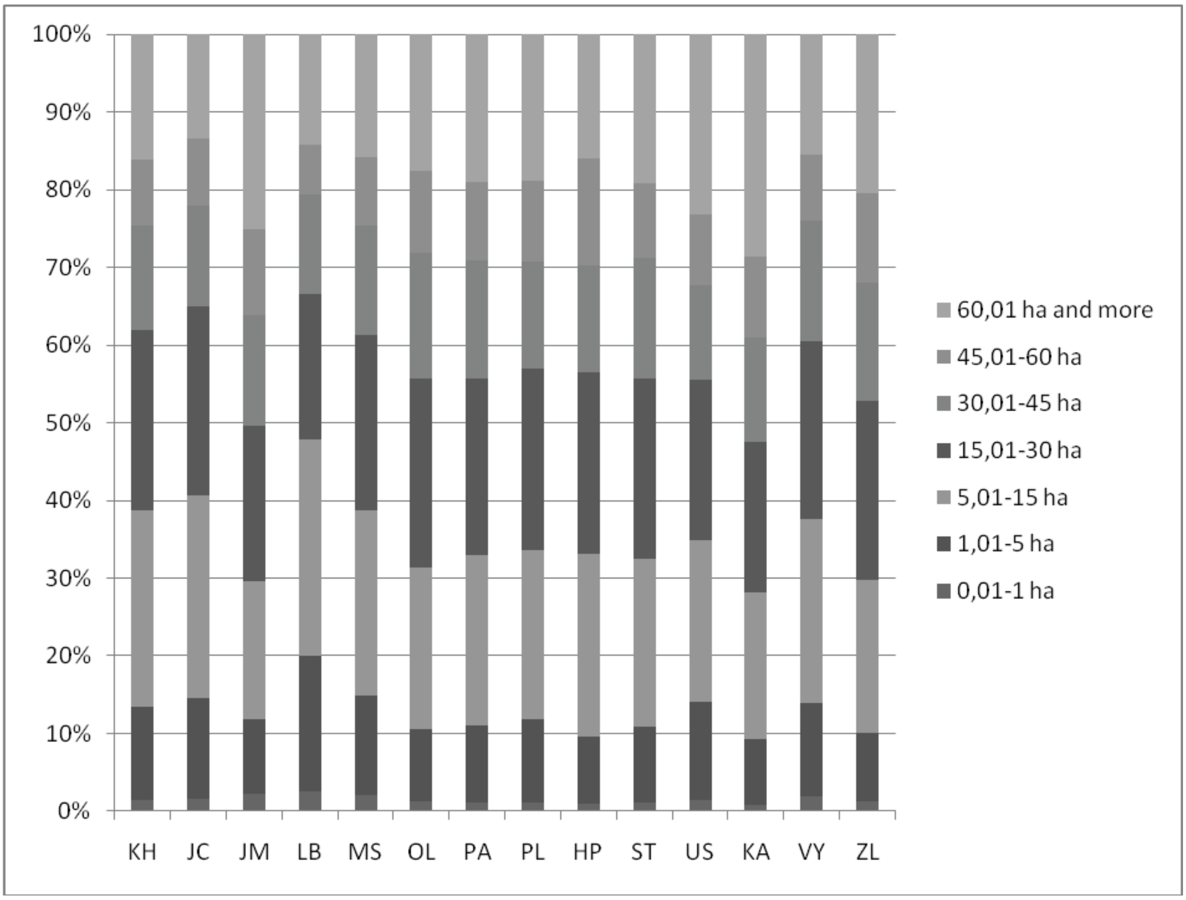

Figure 5: The percentage representation sum of areas in production areas

Conclusions

Less favored areas for agricultural production in the Czech Republic dominate the production areas as the number of blocks and acreage. For users of land falling into the category of less favored areas, certain rights, but also obligations appear. The farmer who decides to apply for payment under the LFA must ensure the land is mowed twice or grazed once per year. In the case of grazing must also comply the condition of intensity of livestock keeping. Another requirement is to limit the supply of nitrogen. These conditions and some others, based on the general rules of good agricultural practice, must be respected by farmer applying for payment for areas under permanent grassland. For arable land the LFA scheme does not provide any subsidies. For cropland the general principles of non-wide-sowing crops and some method of tillage are valid.

Regarding the identified statistical characteristics, there are following conclusions. The mean value of block size is higher in the production areas. This, however, can be affected by outliers. Median of block size in Production areas is higher too. As median has low sensitivity to outliers it can be considered for a good indicator of the average block size in both categories. As neither of the categories has a normal distribution, the coefficient of variation can be the best indicator of variability, which is higher in the less favored areas. From the point of view of the number of blocks the most common category in both categories of land is range between 1.01 and 5 ha. More than 50% of the blocks belong to first two categories. Different situation occurs in the percentage of sum areas. In the case of less favored areas has the largest representation the category 5.01 – 15 ha. In some regions it reaches the level of 30% and more. In production areas has this category already less than 30% and has almost the same representation as class 15,01 - 30 ha. On the other hand, class 60.01 ha and more has in production areas grown twice the representation compared to less favored areas.

Special features of the less favored areas as well as production areas is the Karlovy Vary region, the detailed analysis of which would surely reveal more facts.

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CLIMATE CHANGE AND CROP PRODUCTION ADAPTATION

Jolánkai Márton

Introduction

The world's climate has not been constant. We know it has gone through dramatic past changes, but there is increasing evidence that human activities are altering our climate at an unprecedented rate.

When assessing climate change, natural variability must also be considered. Conditions can vary from one year to the next, and cyclic phenomena like El Nino and the La Nina exert important influences over the climate in far regions.

The global climate change processes

It is well known that the Earth does warm and cool on a long time scale. The ice ages and intervening warm periods have been examples. These changes are caused by a number of natural factors which include solar output, changes in the Earth’s orbit around the sun, and changes in the reflective properties of the atmosphere and the earth's surface that return some of the incoming sunlight back to space. Naturally occurring gases in the atmosphere also form an insulating blanket around the earth. In what is referred to as a “greenhouse effect”, this blanket of greenhouse gases (GHG’s) - primarily water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) - traps outgoing energy of the Earth that would otherwise be radiated back into space. Without the effect of these naturally occurring gases, the temperature on Earth would be too cold to support life as we know it.

In addition to the natural global factors noted above, there are also changes within the climate system itself, such as El Nino, that can cause large regional changes in climate. But these changes alone seem insufficient to explain the steadily accelerated warming occurring since the mid 1970’s. In fact, throughout the globe, mean surface temperatures have generally been rising for the last 100 years. The global average surface temperature has increased over the 20th century by about 0.6^{o}C. Average global temperatures continue to set records. Nine of the 10 warmest years globally have occurred since 1990 and 1998 was the warmest since 1861, and 2001 ranks as the second warmest year globally.

Most scientists agree that the build up of energy - trapping gases from human activities is contributing to the global warming observed over the last 100 years. Since pre-industrial times (1700s), global atmospheric concentrations of greenhouse gases have grown significantly. Carbon dioxide concentrations have increased by 30%, methane by 145% and nitrous oxide by 15%. Based on Antarctic ice core data, current levels of these gases appear to be unprecedented in at least the last 400,000 years (Intergovernmental Panel on Climate Change - IPCC).

There is now abundant evidence to indicate that the above trends are caused by human activities of a rapidly burgeoning global population. In particular, widespread burning of fossil fuels, deforestation and agriculture are enhancing the greenhouse effect. The IPCC concluded that "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities".

Impacts and consequences

Some researchers have reported that the frequency and intensity of extreme weather events has increased over the last 10 - 15 years. Although information about extreme weather events continues to be compiled, scientists agree that there is not yet enough scientific evidence to show they are directly linked to a changing climate.

UNDP produced an elaboration concerning agriculture and food security. In the following we would like to summarize the main topics of that.

Some agricultural regions will be threatened by climate change, while others may benefit. The impact on crop yields and productivity will vary considerably. Added heat stress, shifting monsoons, and drier soils may reduce yields in the tropics and subtropics, whereas longer growing seasons may boost yields in northern Canada and Europe. Projections of regional climate change and the resulting agricultural impacts, however, are still full of uncertainties.

Climate and agricultural zones are likely to shift towards the poles. Because average temperatures are expected to rise more near the north and south poles than near the equator, the shift in climate zones will be more pronounced at higher latitudes. In the mid-latitude regions (45^o to 60^o), present temperature zones could shift by 150 - 550 km. Since each of today's latitudinal climate belts is optimal for particular crops, such shifts could strongly affect agricultural and livestock production. Efforts to shift crops poleward in response could be limited by the inability of soil types in the new climate zones to support intensive agriculture as practiced today in the main producer countries.

Soil moisture will be affected by changing precipitation patterns. Based on a global warming of 1 - 3.5^{o}C over the next 100 years, climate models project that both evaporation and precipitation will increase, as will the frequency of intense rainfalls. While some regions may become wetter, in others the net effect of an intensified hydrological cycle will be a loss of soil moisture. Some regions that are already drought-prone may suffer longer and more severe dry spells. The models also project seasonal shifts in precipitation patterns: soil moisture will decline in some mid-latitude continental regions during the summer, while rain and snow will probably increase at high latitudes during the winter.

Higher temperatures will influence production patterns. Plant growth and health may benefit from fewer freezes and chills, but some crops may be damaged by higher temperatures, particularly if combined with water shortages. Certain weeds may expand their range into higher-latitude habitats. There is also some evidence that the poleward expansion of insects and plant diseases will add to the risk of crop loss.

More carbon dioxide in the atmosphere could boost productivity. In principle, higher levels of CO_2 should stimulate photosynthesis in certain plants. This is particularly true for most C3 plants because increased carbon dioxide tends to suppress their photo-respiration, making them more water efficient. C3 plants make up the majority of species globally, especially in cooler and wetter habitats, and include most crop species, such as wheat, rice, barley, cassava and potato. The response of C4 plants would not be as dramatic. C4 plants include such tropical crops as maize, sugar cane, sorghum and millet, which are important for the food security of many developing countries, as well as pasturage and forage grasses. Experiments based on a doubling of CO_2 concentrations have confirmed that "CO_2 fertilization" can increase mean yields of C3 crops by 30%. This effect could be enhanced or reduced, however, by accompanying changes in temperature, precipitation, pests, and the availability of nutrients.

The productivity of rangelands and pastures would also be affected. For example, livestock would become costlier if agricultural disruption leads to higher grain prices. In general, it seems that intensively managed livestock systems will more easily adapt to climate change than will crop systems. This may not be the case for pastoral systems, however, where communities tend to adopt new methods and technologies more slowly.

Food security risks are primarily local and national. Studies suggest that global agricultural production could be maintained relative to the expected baseline levels over the next 100 years. However, regional effects would vary widely, and some countries may experience reduced output even if they take measures to adapt. This conclusion takes into account the beneficial effects of CO_2 fertilization but not other possible effects of climate change, including changes in agricultural pests and soils.

The most vulnerable people are the landless, poor, and isolated. Poor terms of trade, weak infrastructure, lack of access to technology and information, and armed conflict will make it more difficult for these people to cope with the agricultural consequences of climate change. Many of the world's poorest areas, dependent on isolated agricultural systems in semi-arid and arid regions, face the greatest risk. Many of these at-risk populations live in sub-Saharan Africa; South, East and Southeast Asia; tropical areas of Latin America; and some Pacific island nations.

Effective policies can help to improve food security. The negative effects of climate change can be limited by changes in crops and crop varieties, improved water-management and irrigation systems, adapted planting schedules and tillage practices, and better watershed management and land-use planning. In addition to addressing the physiological response of plants and animals, policies can seek to improve how production and distribution systems cope with fluctuations in yields.

Climate change impacts in agriculture (a Hungarian case study)

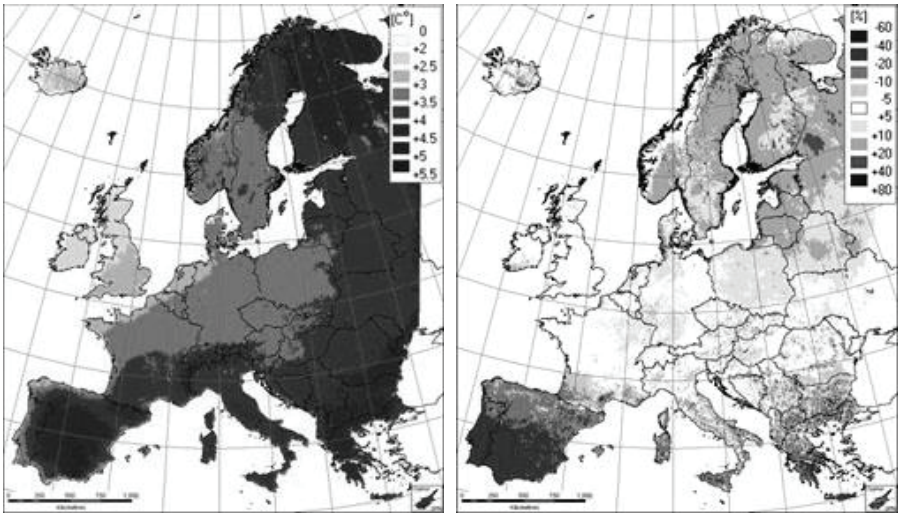
Agriculture in general and crop production in particular are highly affected by climate change impacts. Results of recent climate change researches have highlighted, that climate change impacts may influence production efficiency, quantitative and qualitative deterioration of crop yields produced for alimentary purposes, and determine post harvest manifestation of agricultural products inducing hazard in the field of food safety, transport, storage and distribution.

The problems of any of these fields are manyfold.

- High variability of yield performance in accordance with weather extremities.
- Economic losses in agricultural and food production.
- Quantitative and qualitative deterioration of food and feed products.
- Lack of sustainable long term vertical and horizontal technology structures.
- Limited chances for forecast and prevention, as well as for technological implementation.
- Environmental hazards affecting agro-ecology as a whole.

The main tasks of science, practice and policies regarding adaptation to climate change impacts are as follows:

- to develop agrotechnology and apply to novel biological bases in favour of higher economic turnover in agricultural food production,
- to maintain ecological equilibrum of production sites regarding organic matter, soil fertility and biodiversity,
- to secure food production while establishing energy cropping structures,
- to create new job possibilities and challenges in the rural sector,
- to establish sustainable cropping and landscape preserving systems in favour of environmental protection and nature conservation,
- to provide a quality management system to cover all technological aspects in the food production chain from soil tillage to post harvest stage,
- to provide a technological basis that may serve future assurance and hazard management systems.



„Green book” statements and directives are based on the IPCC A2 scenario. 3-3,5 °C temperature rise and -5 - +5 % rainfall change compared to 1961-1990 years mean is scheduled for Hungary by the end of the century .

Figure 1. IPCC A2 scenarios for temperature and precipitation
Source: EU DG Environment „Green book” 2007

In case of Hungary two facts can be observed in the Carpathian basin. In first place the ascending levels of temperature rise, with a magnitude of 1 °C. The other is the decreasing trend-line of annual precipitation according to what, during one century 83 mm rainfall has disappeared. Hungary is a country in the centre of Europe with a most peculiar geographic location regarding the possible impacts of any sort of climatic changes. The climate of the region has always been highly variable.

Table 1. Main climatic characteristics

Annual precipitation	580 mm
Annual mean temperature	11 °C
Altitude	78-1014 m
Heat amount in vegetation period	1280-1465 °C
Dry matter production	8.3-17.6 t/ha/year
Photosynthetic active radiation	1518-1612 MJ/m^2
Annual snow coverage	41 days/year

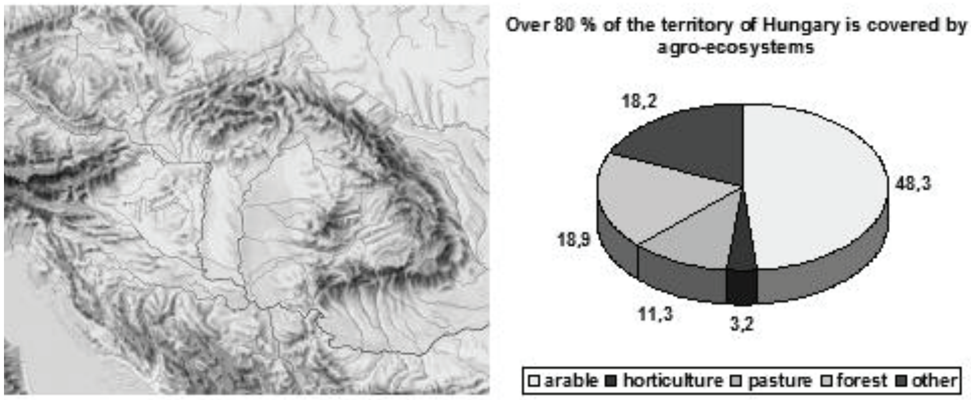


Figure 2. Geographic location and land use distribution of Hungary

Expert teams of various fields of agriculture have been working within the framework of the national VAHAVA project. The main task of this work was to study climate change impacts and possible responses in the respective fields. The working hypotheses of the project were as follows:

- The warming of the climate will be stronger in the Carpathian Basin;
- We may expect the decreasing of annual average precipitation;
- The number and intensity of extreme weather events will be increasing.

The report of the project was edited in English in 2010. The results of expert teams were summarized in that. The following passages present a digest of the report’s crop production postulates.

- Climate change impacts in crop production can be prevented or reduced by the following measures. Water preserving soil tillage that may contribute to storage of higher amounts of annual precipitation. Increment of irrigation. Novel crop production technologies, breeding and use of drought tolerant crop varieties. Establishment of appropriate cropping structures and crop rotations.
- Water supply of crop production involves three major sources; annual precipitation in rainfed cropping depending on the amount and distribution as well as the preservation and storage of that; irrigated cropping where rainfall is considered as additional or modifying means of water supply only; and flood irrigation systems that are mainly independent from precipitation impacts. In favour of preventing harmful climate change impacts the two latter cropping systems should be given priority in the future.
- Climate change impacts may have an influence on the trends of temperature as well as on the vegetation period of various field crops. Ascending levels of temperature induce alterations in the physiological requirements of heat amount. This may result

in a change of duration of crop variety vegetation periods, and also, there is a chance for alterations in yielding ability, winter hardiness, phenological phases etc.

- Warming and drying may have an effect on plant nutrition. In general there is a scientific evidence that high levels of mineral fertilization may counteract the harmful effects of drought. In particular there are several crop species that may respond with yield declines in case of permanent drought. Abundant nutrient supply may result in higher concentrations that may be less beneficial to crop performance. Optimal soil conditions are required for better crop plant development.
- Abiotic stress resistance of wheat varieties is a major issue in Hungary. The major task of plant breeding is to provide high yielding wheat varieties of marketable quality, that are less susceptible to climate change impacts. Any variety has to meet a threefold demand: grain quality, quantity and yield stability.
- Seed production is a field where climate change impacts may have both positive and negative effects. Arid conditions and weather extremities may risk the results of seed production and processing. On the other hand climate change may contribute to favourable conditions, that is essential for producing seed of new species and varieties.
- Agricultural mechanization is also facing new challenges induced by climate change. Such are: Technology improvements (water preserving tillage technologies); combined or reduced number of field operations (to prevent or lessen unfavourable soil conditions); more quick, flexible and efficient machinery; security equipments (installation of special machinery for emergency uses only); propagation of tram line production systems; use of adapted machinery.
- Agricultural mechanization may have a major role in mitigation processes, like CO_2 emission control and carbon sequestration. Specific tillage technologies, mulching and appropriate stubble operations may contribute to a better soil water budget.
- Plant protection is highly affected by climate change. There is an invasion of new plant diseases, insect pests and weed species. To counteract the harmful effects improved methods of prevention, defence and remediation are needed. The major fields of that are as follows: comprehensive and efficient forecasting systems, extension services, integrated pest management, application of high tech implements, site specific precision methods. Genetic resistance and/or tolerance of crop plants has to be improved by breeding. Means of biological control has to be studied and applied.
- A most peculiar field of agriculture is the grassland and pasture management. In Hungary over 1.1 million hectares of grasslands are exposed to climate change impacts, but on the other hand provide new adaptation chances for agriculture and for the country as a whole.

Water availability impacts on wheat crop

Annual amounts of precipitation and winter wheat yields have been examined in a 15 years time range at the Nagygombos experimental field of the Szent István University, Gödöllő. Table 2 shows the annual changes of yield, quality and precipitation mean values. Yields have been correlated with water availability.

Table 2. Annual precipitation, yield and quality figures of a winter wheat trial Nagygombos, 1996-2010

Year	Precipitation, mm	Yield, tha^{-1}	Protein, %	Farinographic value	Wet gluten, %	Hagberg Falling No
1996	544	4,08	15,8	89,7	37,8	339
1997	407	2,88	13,2	50,4	30,5	213
1998	725	6,21	11,5	70,7	27,4	278
1999	837	2,87	14,3	47,4	32,2	-
2000	344	3,32	11,6	44,4	28,3	188
2001	706	5,28	12,0	51,6	27,5	295
2002	426	4,34	17,2	62,4	38,4	362
2003	442	3,47	17,6	63,3	36,8	370
2004	463	6,06	15,3	58,8	29,9	296
2005	705	5,72	14,3	50,9	30,1	282
2006	593	7,11	15,4	54,8	33,7	346
2007	545	5,21	18,1	62,6	38,8	420
2008	612	7,82	13,2	54,1	28,8	349
2009	623	6,55	12,2	58,3	32,7	293
2010	847	3,87	14,5	-	32,3	-

Yield figures were in accordance with annual precipitation patterns with an exception of some years when the distribution was irregular eg. in 1999 year, when 837 mm rainfall, one of the highests in the period examined was recorded, however a sever drought spring was followed by an extreme moist summer obstructing yield formation and ripening as well as harvest. Also, the year 2010 with the ever highest annual precipitation, 847 mm measured at the experimetal site resulted in poor yield performance for both wheat and maize crops due long periods of water logging. Apart from these two years annual precipitation was in accordance with the water consumption physiological patterns.

Table 3. Correlation figures of winter wheat trial Nagygombos, 1996-2010

r	year	Precipitation, mm	Yield, tha^{-1}	Protein, %	Farinographic value	Wet gluten, %	Falling No
year	1	0,25403	0,52618	0,16788	-0,26794	0,08438	0,44935
Precipitation, mm	0,25403	1	0,17985	- 0,24437	-0,04391	- 0,24893	0,17773
Yield, tha^{-1}	0,52618	0,179846	1	- 0,16549	0,058089	-0,2456	0,30831
Protein, %	0,16788	-0,24437	- 0,16549	1	0,358824	0,87452	0,77754
Farinographic value	- 0,26794	-0,04391	0,05809	0,35883	1	0,51347	0,45342
Wet gluten, %	0,08438	-0,24893	-0,2456	0,87452	0,513467	1	0,7164
Hagberg Falling No	0,44935	0,177725	0,30832	0,77754	0,453416	0,7164	1

regr	year	Precipitation, mm	Yield, tha^{-1}	Protein, %	Farinographic value	Wet gluten, %	Falling No
year	1	0,007327	1,492835	0,347641	-0,09792	0,094938	0,029755
Precipitation, mm	8,80714	1	17,69	-17,5442	-0,54727	-9,71012	0,34815
Yield, tha^{-1}	0,18546	0,001828	1	-0,12079	0,00814	-0,0974	0,00741
Protein, %	0,08107	-0,0034	-0,22673	1	0,070247	0,47514	0,02842
Farinographic value	-0,73319	-0,00352	0,41453	1,83288	1	1,42494	0,08127
Wet gluten, %	0,075	-0,00638	-0,61933	1,60957	0,185024	1	0,04819
Hagberg Falling No	6,78571	0,090725	12,8216	21,2753	2,529662	10,6494	1

Quality manifestation of winter wheat yields have been impacted by annual precipitation in general. Apart from grain yields, protein, farinographic value, wet gluten and Hagberg falling number records have also been evaluated all along the experiment. Yield figures were in accordance with annual amounts of precipitation with two exceptions regarding the 1999 and 2010 crop years.

Wet gluten content of grain samples proved to be a most stable quality characteristic. Annual changes of protein figures were significant. Farninographic values and Hagberg falling number figures were affected by precipitation. In some dry years like 2002 and 2003 baking quality was far better than in moist years, however it was escorted by low yield figures as well. The manifestation of the Hagberg falling number was due to the rain conditions of the harvest and post-harvest periods. Re-moistening of ripen dry grain may result in alterations of the α-amylase activity, and so that may have an impact on rheological characteristics of dough.

Water availability can be considered as a basic factor related to yield quality and quantity performance of grain crops. In an agronomic long term trial run at the Szent István

University's Nagygombos experimental site impact of water availability on wheat and maize crop has been evaluated. Regression and correlation tables are presented in Table 3. Various crop years have had different impacts on crop yield quantity. Yield figures were not in correlation with annual precipitation in general. However with an exception of two years of extremely high precipitation yield figures they were in accordance with that. Moisture availability had diverse influence on quality manifestation. High precipitation has often resulted in poorer quality, especially gluten and Hagberg values have been affected by that. Protein and gluten values proved to be a most stable quality characteristics in this study. Drought stress reducing the amount of yield has induced quality improvement in a few cases.

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A WATER STRESS ASSESSMENT SURVEY BASED ON THE EVAPOTRANSPIRATION BALANCE OF MAJOR FIELD CROP SPECIES

Fekete Ágnes

Introduction

Water deficiencies of live systems trend from scarcity to drought. Drought is a physiological water stress causing irreversible changes in live structures (Várallyay, 2006; Jolánkai et al., 2011). Drought is the result of an extended period of months or years when a region notes a deficiency in its water supply. Generally, this occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.

Definition of droughts can be assessed in three main ways:

(1) Meteorological drought is brought about when there is a prolonged period with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.

(2) Agricultural droughts are droughts that affect crop production or the ecology of the area. This condition can also arise independently from any change in precipitation levels when soil conditions and erosion triggered by poorly planned agricultural endeavours cause a shortfall in water available to the crops. Drought is a phenomenon when a plant suffers irreversible physiological damages.

(3) Hydrological drought is brought about when the water reserves available in sources such as aquifers, lakes, and reservoirs fall below the statistical average. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished. Like an agricultural drought, this can be triggered by more than just a loss of rainfall.

Drought can only be handled by appropriate management techniques; by reliable land use and crop species suitable for the climatic conditions (Jolánkai-Birkás, 2009; Vermes, 2011; Tarnawa et al., 2012). The identification of drought is rather complicated since water availability of any live systems can be assessed only by polifactorial methods. The present study focuses on drought processes and evapotranspiration trends regarding the major field crop species of Hungary.

Material and methods

An assessment study has been conducted at the Szent István University, Gödöllő to evaluate and identify the main factors of drought regarding field crop species. In the survey databases of the Hungarian Meteorological Service (OMSZ) and the Ministry of Rural

Development (FVM and recently VM) have been used (VM 2012, OMSZ 2011). The use of drought indices was based on the research results of the European ADAM project (Hulme et al., 2009), while the evapotranspiration patterns of crop species have been determined in accordance with the crop production evaluations of the VAHAVA project (Láng et al., 2007). In the study twelve crop species (Sugar beet Beta vulgaris, spring and winter barley Hordeum vulgare, winter wheat Triticum aestivum, maize Zea mays, sunflower Helianthus annuus, field peas Pisum sativum, potato Solanum tuberosum, alfalfa Medicago sativa, oil seed rape Brassica napus, rye Secale cereale and oats Avena sativa) were involved. Evapotranspiration monthly water consumption data were compared to precipitation means, and monthly water availability budgets were identified. The water availability budget modelling has been done at the SZIU Crop Production Institute.

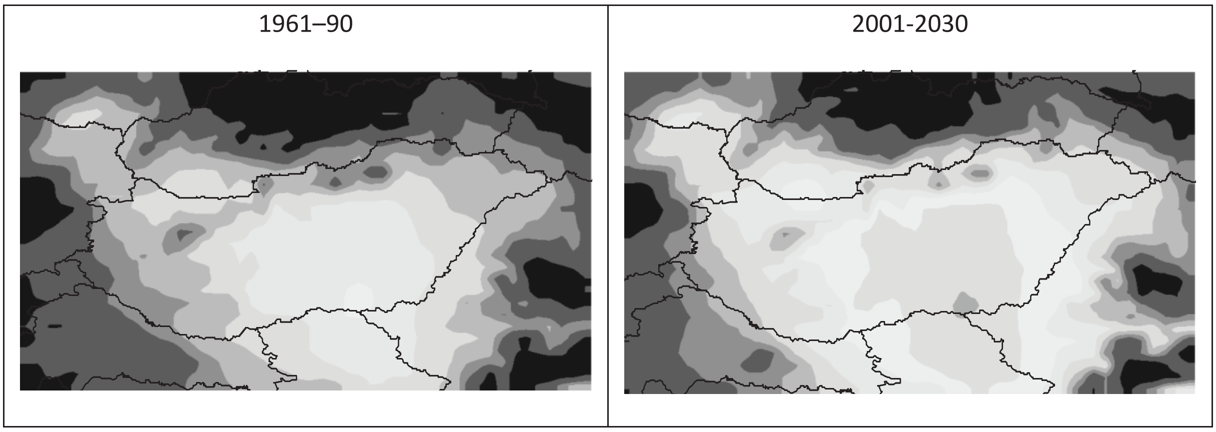


Figure 1. Drought index projection for Hungary (1961-2030) based on IPCC A2 scenario (Hulme et al. 2009)

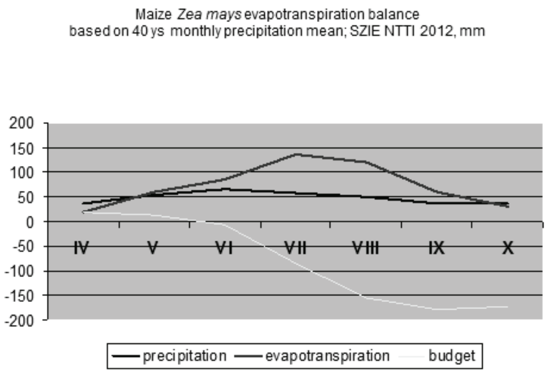
Results and discussion

The results of the survey suggest, that drought is a multifactorial phenomenon that can be assessed by complex evaluations only. However drought is induced basically by the deficiencies of water input within an ecosystem, rainfall, temperature, soil water management characteristics highly influence physiological drought processes. Table 1 presents precipitation and evapotranspiration patterns as well as water availability budget estimates of twelve field crop species. Figure 2 gives an example for maize and wheat crops.

Field crop species respond to water availability in accordance with their life cycle and fenophases. The results obtained suggest, that field crop species respond in a diverse way to drought phenomena. Winter crops tend to have a positive water budget during most of their life cycle, however spring crops rely on precipitation prior to the vegetation period, or they would need additional water supply in form of irrigation. Increasing drought due to climate change may induce alterations in the cropping structure.

Table 1. Monthly evapotranspiration patterns and water availability budget of field crop species (SZIU NTTI, 2012)

	evapotranspiration		Water availability		Critical water supply	
	min	max	min	max	best	worst
Alfalfa						
Barley S	16	106	-37	28	April	June
Barley W	8	112	29	168	March	May
Field peas	6	112	-8	119	March	July
Maize	18	135	-178	19	April	August
Oats	12	110	-26	39	April	June
Potato	14	128	-183	29	May	August
Rape	6	102	25	163	March	June
Rye	6	110	29	177	March	June
Sugar beet	12	122	-148	44	May	August
Sunflower	14	122	-47	100	May	August
Wheat	6	118	7	149	March	June



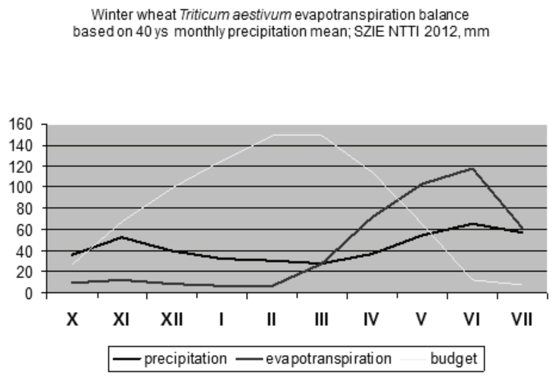


Figure 2. Evapotranspiration patterns and water availability budget of maize and wheat crop (SZIU NTTI, 2012)

According to the drought index projection for Hungary (1961-2090) based on the IPCC A2 scenario, the ADAM project has outlined a probable increment of the drought areas in the Carpathian basin, especially in the centre of the Hungarian Great Plain. Such a trend in climate change processes may lead to an uncertain change in the evapotranspiration patterns of the major field crop species. Since climate change studies deal with scenarios that are calculating with no major changes in the precipitation patterns, however they suggest an evidence of radiation and temperature increment of an unprecedented rate for the region, the interaction of the two phenomena may lead to the reduction of water availability.

Conclusions

Evaluating water availability for field crops in relation with their evapotranspiration patterns, it can be stated, that field crop species respond in a diverse way to drought phenomena. Winter crops tend to have a positive water budget during most of their life cycle, however spring crops rely on precipitation prior to the vegetation period. In accordance with climate change scenario A2 increasing drought due to that may induce alterations in the cropping structure.

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LAND SUITABILITY ASSESSMENT MODELS FOR CROPS

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Abstract:

Awareness towards environmental protection and food quality grows with intensification of agricultural production. Because of this the way of managing natural resources and the impact of management on soil quality becomes essential element of scientific research. The conventional systems for land capability evaluation takes only the agro-ecological indicators of soil fertility into account, unlike multidisciplinary approach which requires a series of accurate data to quantify the processes that occur in soil during crop production. By using such approach it is possible to assess the capacity of food producing area, the justification for renovating agricultural land, zonation in terms of determination suitable and less suitable areas for plant production and planning and analyzing plant production. Therefore, when evaluating soil quality it is important to take ecological, biological, sociological, economical, technical and technological attributes into account. These attributes present a base for identifying indicators of soil quality, understanding of all the properties of soil and climate, collecting and storing all relevant data in a computer database and their computer interpretation and visualization using geostatistics. Approximately 25.000 soil samples (more than one million information) were analyzed in the eastern part of Croatia (Osijek-Baranja County). Using Microsoft Office Excel program, a database was formed. This database contains all necessary information about the land and also chemical analysis of the soil. The base also contains tabular values of certain soil suitability indicators and mathematical formulas for calculating soil suitability. Computer models for suitability assessment of soil for crops, supported by GIS, are fast and efficient, but the greatest value lies in their adaptability for different agro systems. Using geostatistics and GIS applications we can visualize agricultural area and predict different soil properties for the purposes of analysis, planning and rationalization of agricultural production. With more precise data about the soil, the models could be widely used, not only to evaluate the suitability of soil for crops but also for choosing and using farm machines, the need for soil conditioning (liming, input of organic matter etc.) and economic analysis.

Key words: soil suitability, GIS, model, geostatistics, soil quality

Introduction

The main task of any agricultural production is to achieve better quality of plants with higher yields. Soil has an important role in how to achieve this, because it supplies the plant with water, air and nutrients needed for growth and development. Yield and the quality of crops in the complex and dynamic system of soil-plant-atmosphere are defined by the numerous biological, climatic and soil factors. Because of this soil quality, as the most important feature of the soil, cannot be absolutely determined and the potential soil quality is significantly different from the effective soil quality (Vukadinović and Vukadnović, 2011). The main problem of good soil suitability assessment is how to express soil suitability while taking into account its limitations. Therefore, the soil quality and the requirements for its use must be measurable, which is not always easy or possible to completely determine. For all these reasons it is important to develop a model that would connect all the relevant factors of crop production and thus facilitate making important decisions related to the agricultural practices like fertilization, soil conditioning, and planning levels of investment for the highest possible profit.

Multidisciplinary approach

The understanding of factors of plant production and adapting the agrotechnics and the level of investment in specific agroecological conditions, require collection and processing of large amount of data about the soil, plant and climate. These data, which define each agroecosystem, are efficiently used only when stored in corresponding data bases. If stored in data bases, they may be used for interpretation and quantification of soil suitability. In fact, the progress of modern society is increasingly based on a vast amount of information whose significance already surpasses known natural and material resources because the information has no natural origin and, unlike other resources, is inexhaustible. Its contents cannot be destroyed by usage. It is multivalued because it can be used simultaneously in a variety of activities, to suit different needs of multiple users, and by its extensive use it is becoming more important. Information that is not used does not have any value and in the end, people and their knowledge and capability are the only restrictions in its creation and usage (Vukadinović et al, 2005; Đurđević et al. 2010).

Method (model) for quantifying the processes that occur in the soil during crop production requires a series of accurate data and a multidisciplinary approach as opposed to traditional systems of evaluation that are currently used in Republic Croatia and which consider only the agro-environmental indicators of soil quality. The interpretation and classification of data and information about the soil with soil suitability concept (is the soil appropriate or inappropriate for a particular purpose) is old as the civilization itself (Carter et al., 1997).

Therefore, evaluation of soil quality has to respect ecological and biological, socio-economic, technical and technological attributes based on:

a) Determining indicators of quality (fertility) that have to be susceptible, reliable, reproducible and can detect physical, chemical and biological changes in character, processes, and other interactions,
b) Knowledge of the properties of the soil and climate, and other anthropogenic influences,
c) Collecting and storing all relevant data in a computer database,
d) Their computer interpretation with a help of a set of rules (from the group of agrotechnic, plant, climate, soil, environmental, experiential (e.g. best practice) and other).

Land suitability assessment models

Approximately 25.000 (more than one million information) soil samples were analyzed till 2012. in the eastern part of Croatia (Osijek-Baranja County). This paper will present some results from years 2003 to 2009 (17.405 soil samples).

Using Microsoft Office Excel program, a database was formed that contains all the necessary information about the land and the soil chemical analysis. The base also contains tabular values of certain soil suitability indicators (tabular model) and mathematical formulas (score function model). Both models are used separately for calculating soil suitability.

The first model (Tabular model) estimates relative soil suitability for crops on basis of tabular values of soil quality indicators:

a) pH-KCl (3 to 15 points)
b) Organic matter (%) (2 to 25 points)
c) AL-P2O5 mg·100g-1 (2 to 10 points)
d) AL-K2O mg·100g-1 (2 to 10 points)
e) CEC cmol(+) kg-1 (3 to 10 points)
f) Altitude (2 to 10 points)
g) Soil bulk density g·cm-3 (8 to 20 points).

(a total of 100 points)

The model includes only indicators that can be repaired to the required level with anthropogenic activities like soil conditioning, regular mineral and organic fertilization, etc. This way of modeling has not been applied in Croatia yet and represents a completely new way of solving soil suitability assessment problem. The functionality of this model is evident in his adaptability, because the model can easily adapt to different environmental conditions or crop production changing the number of indicators that affect the suitability of land for crops (Đurđević, 2010).

The second model (score function model) is actually a subroutine of ALRxp calculator, a program that is used to determine fertilizer requirements for crops. The model calculates relative soil suitability for crops using score function which describe seven indicators of fertility (pH–KCl, organic matter, AL-P_2O_5, AL-K_2O, soil bulk density, CEC and hydrolytic acidity). Score function values for specific indicators of soil are ranged from 0 or (0%) for non-suitable soils to 1 or (100%) for the soil without any production limitations (Vukadinović, 2001).

Classification of soil suitability for both models was performed according to the FAO classification in three suitable class (S1, S2, and S3) and two non-suitable (N1 and N2). Minimum estimated relative suitability for crops calculated with tabular model was 8%, and the maximum 97.14%. Of the total of 17,405 soil samples, 4.327 (24.86%) had relative soil suitability for crops from 0 to 20%, and belonged in permanently non-suitable soil class, 1.678 samples (9.64%) were in the class of temporarily unsuitable soils. Limited suitability soil class contained 37 samples (0.21%), suitable soil class contained 6396 samples (57.86%), and 4,967 samples (28.53%) were in suitability class with no restrictions for crop production (Figure 1).

The relative suitability of land calculated with a score function model showed that 1.445 soil samples (8.30%) belong in the class of permanently non-suitable soils for crop production and that 2.098 soil samples (12.05%) are in the class of temporarily non-suitable soils. Limited suitability class contains 3.232 samples (18.57%), suitable class contains 10.070 samples (57.86%), and only 260 samples (1.49%) are in a suitable class without restrictions for crop production (S1-class) (Figure 2).

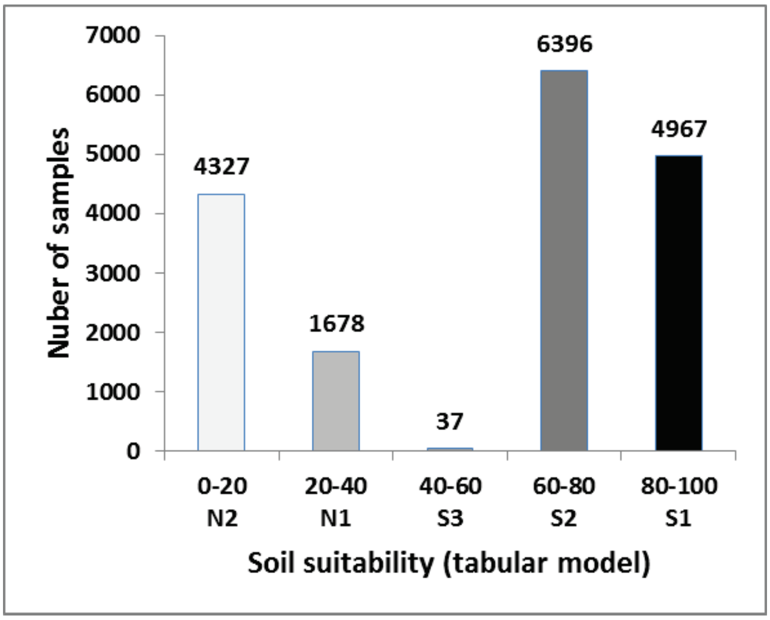

Figure 1: Soil suitability calculated with tabular model

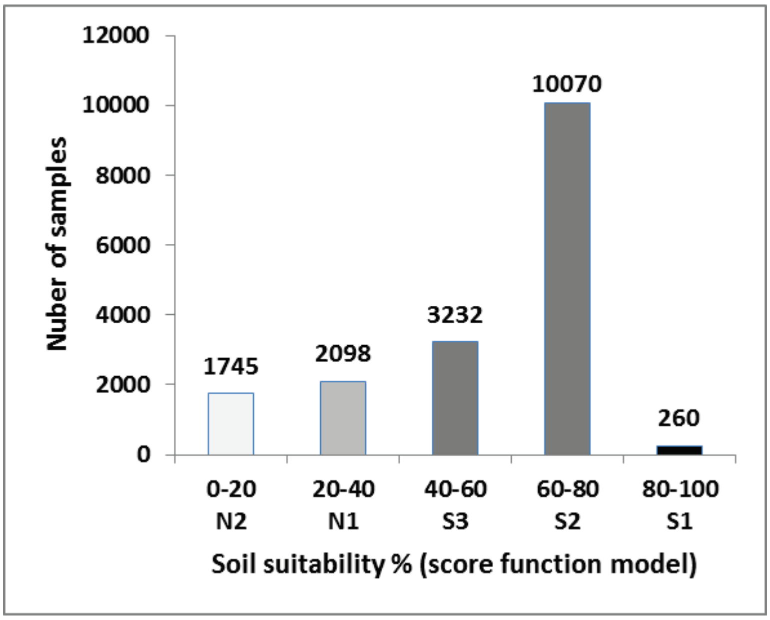

Figure 2: Soil suitability calculated with score function model

GIS (Geographic Information System) application

Regarding the more and more complex models that describe plant production, GIS systems is imposing itself as an excellent tool for visualization and statistical analysis of a large amount of data obtained by modeling. However, most GIS applications are developed to visualize spatial data, and only a small part of them can be used for prediction modeling. To handle all the output data about soil calculated with the model (interpretive base) we used the program ArcMap v9,3 which contains a number of geostatistical tools. Visualization and spatial prediction of agricultural land suitability for Osijek-Baranja

County is calculated with geostatistical method Kriging, which represents an advanced interpolation geostatistical method that can estimate the value of regionalized variables at points of selected network (Malvić, 2005). Kriging assessment is considered reliable and impartial, because the variance between actual and estimated values at selected points is within the acceptable error (Miloš, 2000).

Maps of land suitability for crops created with aforementioned models can show agricultural production capacity and soil quality of agricultural land in Osijek Baranja County (Figures 3 and 4). The maps show a clear division between eastern suitable area for crops production and the western and southwestern, mostly mountain part of county (forest zone), where the conditions for agricultural production are non-suitable, with a large number of limiting factors (usually extremely low pH value) (Vukadinović et al., 2009; Đurđević 2010; Đurđević 2011).

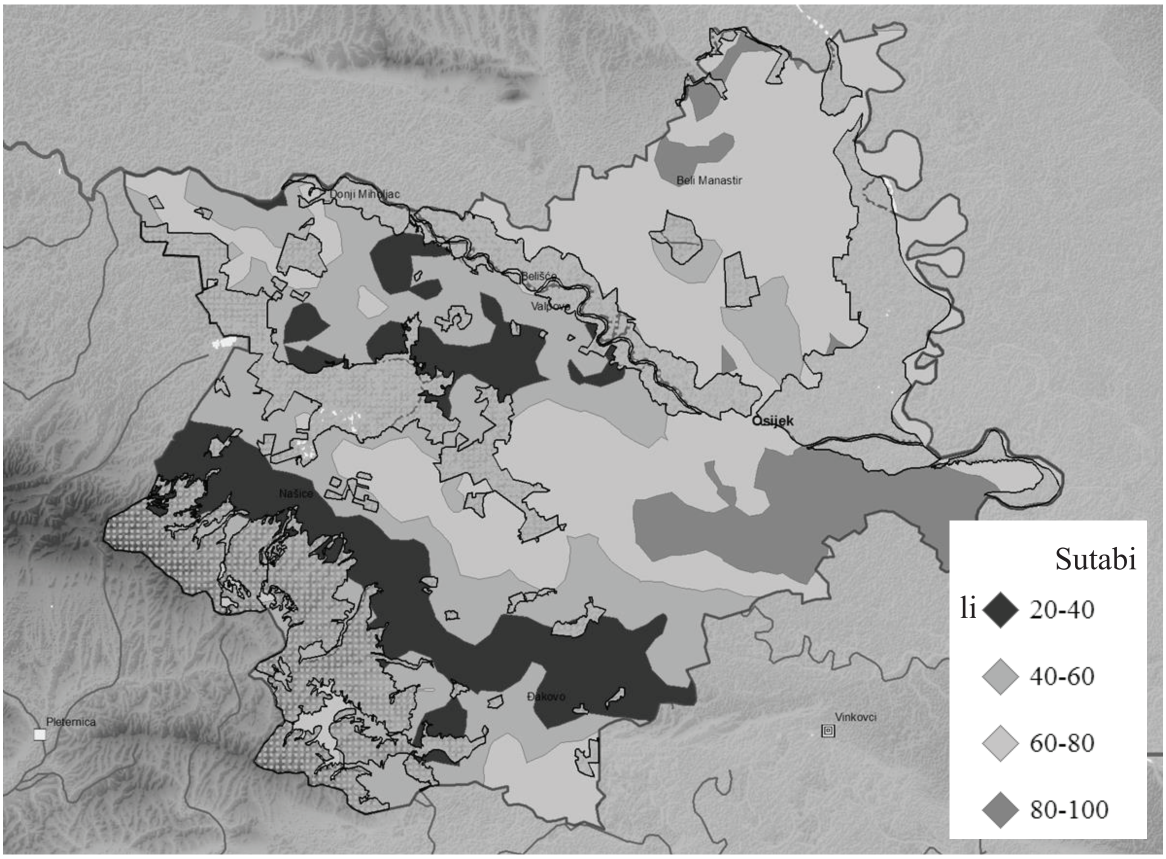

Figure 3: Relative land suitability for crops in Osijek-Baranja County (tabular model)

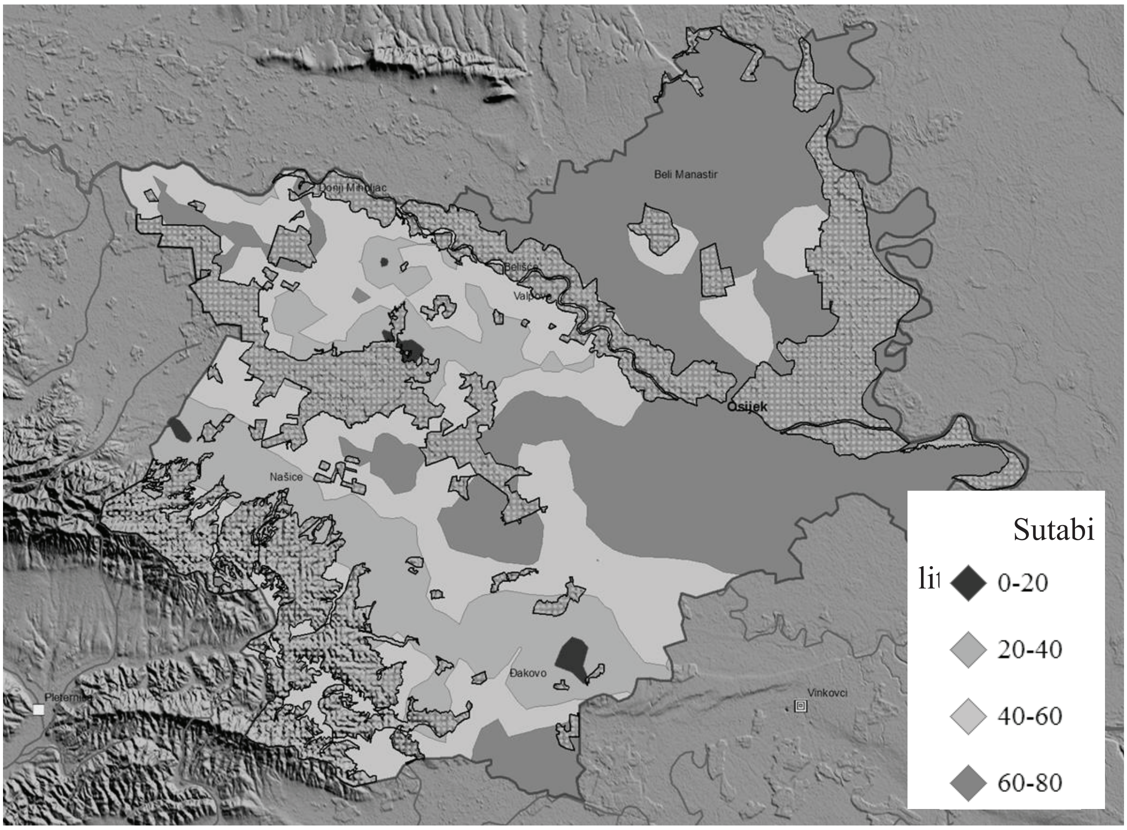

Figure 4: Relative land suitability for crops in Osijek-Baranja County (score function model)

Conclusions

Computer models for land suitability assessment for crops, supported by GIS, are fast, efficient and sufficiently reliable. Models allow the visualization of the agricultural area and prediction of its production properties for the purposes of analysis, planning and rationalization of agricultural production.

The functionality of this model is evident in his adaptability, because the model can easily adapt to different environmental conditions or crop production changing the number of indicators that affect the suitability of land for crops.

With more precise data about the soil (soil and climate as well as reliable Digital Soil Map of Croatia), the model could be an acceptable, not only to evaluate the suitability for producing different crops but also their need for fertilizer, the necessary machinery, the need for soil conditioning like liming, input of organic matter, etc.

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PHENOMENA OF THE CLIMATE EXTREMES ON AGRICULTURAL SOIL – MITIGATION STEPS

Birkás Márta

Introduction

In the last decade, various consequences of climate change have been observed in the Central European region. Agricultural activities have contributed to climate change and that at the same time agriculture is one of the sectors adversely affected by climate threat. Cropping is affected by extreme weather events, such as long dry periods alternating with short rainy periods, abundant rains, extreme hot days in the summer, windy, mild winters, early or late frosts, water-logging, drought, even within a single growing season.

In this paper the climate and tillage induced damages are listed and the main steps of the sustainable tillage are discussed.

Experimental background

The problem of this paper was studied in the long term *Soil quality – climate* experiment that has been underway since 2002 at Hatvan-Józsefmajor (47^{o}68' N, 19^{o}60' E, 130 m a.s.l) on chernozem soil (WRB 2006), on 13 m x 180 m plots with four replicates in a split-plot design (Sváb 1981). Soil assessment was extended to the surrounding area of an approx. 10 km radius with also chernozem type soils having degraded structure. The research site is flat and the soil is of a type that is moderately vulnerable to compaction (Birkás 2010, Csorba et al. 2011). The soil's humus content in the top 40 cm layer is 2.96 (2011), its clay content is 34-36 %, with adequate nutrient supply. The field water capacity at the at 0.15-0.20 m and at 0.45-0.50 m was found to be 0.36-0.38 m^3m^{-3}, and 0.34-0.35 m^3m^{-3}, respectively (Várallyay and Farkas 2010). Six treatments were applied: direct drilling, shallow disking (15 cm), shallow and medium deep tillage with cultivator (15 cm, 22 cm, ploughing (32 cm, with surface forming) and loosening (40 cm). The crop sequence was designed to increase the soil OM content and to protect the soil surface. The main crops provided different rates of soil coverage: densely sown winter wheat (2003, 2005, 2006, 2009, 2012), rye (2004), oat (2011), and wide-row maize (2007, 2010) and sunflower (2008). Mustard (2002, 2005 and 2009), pea (2004) and phacelia (2006) were sown as secondary crops to enhance soil surface protection. The average annual total precipitation is 580 mm (in the growing season: 323 mm). Total annual precipitation figures during the years of the experiment: average (2002, 2006), dry (2003: -138 mm, 2004: -101 mm, 2011: -283 mm, 2012: -286 mm), rainy (2005: + 125 mm, 2008: +152 mm, 2010 +371 mm). 2007 and 2009 were dry during the growing season.

To evaluate the layers of the soil the attributes assessed by a leading author (Dexter 2004), such as the looseness of the root zone, the depth of the loosened layer, the duration of looseness, the occurrence of compaction, the extension of the compact layer, structure, surface cover, the balance of water absorption and loss, the workable soil moisture range, the OM balance and earthworm activity were assessed.

Soil reactions on climate extremes

The rain stress causes water stagnation on the soil surface and on the pan layer, deteriorates the crumbs, silts the dust in the surface, and removes the dusts to the nearest compact layer and contributes to the extension of pan layer. The heat and drought stress causes over drying, greater water deficit and/or limited water transport, serious water loss, soil desiccation, cracking, crumb degradation and crusting. Most of these phenomena are originated from the coupled tillage and climate induced damages (Szász 1997, Birkás 2011, Birkás et al. 2012). The tillage induced defects are well-known, namely traffics' loading, pan-compaction, soil smearing and kneading, dust formation, crumb reduction, remaining bare surface and crust formation. Moreover, the over-settled state, the disk pan, the plough pan, the large, cloddy surface, the cavities in the tilled layer, the dust formation, and the bare surface are found as climate stress increasing factors (Birkás and Kisic et al. 2011).

Basic requirements of the sustainable soil tillage

Soil tillage in a sustainable land management harmonises the soil protection with demands of the crop to be grown on the given land and aims soil conservation, without increasing the production risks even in the long term (Birkás et al. 2002). It can be stressed, that the demand of the crops is independent of the tillage methods. The sustainability in a soil tillage viewpoint can evolve toward greater efficiency of resource use, and can develop and maintain a harmony between crop production technologies and soil environment. For the basic interpretation of the *sustainability* we may revert to the Latin author Cato. The agriculture, in his language means *agri cultura*. Exercise of the *culture* may result a cultural state. The word *cultivation* can be interpreted widely, e.g. exercise, perform constantly, or continuation, improvement and/or maintain of any process. In this way, the *cultivation* is suitable to create and sustain a better soil quality. The *sustainability* (development, farming etc.) as an attainable goal has not been lost its original value in the last decades. A deplorable fact, that this term has often been used in the literature or in the practice, to accept any goals or attitudes, which are not appropriate to the sustainability requirements. In the first part soil quality factors that can be improved or deteriorated by tillage are listed.

The role of soil quality in sustainable soil tillage

The soil quality factors that can be affected by tillage directly or indirectly are listed in Table 1. Soil protection is the key objective, since the demands of any crop can be met in a well-preserved soil. The factors and parameters can be ranked into categories, e.g. favourable, adequate, adequate in a favourable season, unfavourable in any season.

Loosened state of soil presents its physical condition and refers to the absence or presence of the compaction. Important aspect is whether there are tillage-induced *compaction defects* in the root zone. If there is none, the root zone is in an optimum state in terms of water intake and root growth alike, to a depth of 36-45 cm for most crops. One important requirement for this is the lack of a compact layer below the tillage depth. A 25-36 cm *root zone depth* is adequate, while 16-25 cm may be adequate only in a favourable season while a root zone of a depth of less than 15 cm may qualify as unsuitable (Birkás and Kisic et al. 2009).

Table 1: Soil quality factors that can be affected by tillage

Tillage's direct impacts on soil state	Measurable parameter/state	Tillage's indirect impacts on soil state
Soil looseness	bulk density (t m^{-3}), total porosity %, penetration resistance (MPa)	CO_2 release (flux), C/OM deposit or loss, aerobic/anaerobic biological processes, stubble residues decomposition
Compaction in root zone		
Extension of compacted layer	thickness (mm)	
Depth of loosen layer	rooting depth (mm), root formation/deformation	water infiltration and storing capacity
Soil moisture content	w/w %, v/v %, g g^{-1}	Ratio of conservation and loss)
Agronomical structure	ratio of crumb (0.25-10 mm), dust (<0.25 mm), and clod (>10 mm)	soil mellowing
Shape of surface	plane, rough, rolling etc. (differ from a determined unit ±)	water conserving/loss ability
Surface coverage	area (%), mass (t ha^{-1})	earthworm number, activity

The *extension of the compact layer* blocking water transports is indicative of the likely extent of the damage. If there is no compact layer in the root zone, there is no risk. Birkás and Kisic et al. (2009) found that if the thickness of the compact layer is between 1 and 10 mm, the risk is low, while in the case of a compact layer of 10-30 mm, in the case of an 30-50 mm or in the case of a 50-100 mm compact layer medium, high or very high risk should be expected to have to be faced, when severe environmental and farming losses should be taken into account. It should be noted that over 30 mm thick compact layers are frequently found in soils under conventional tillage in our region.

The *depth of the loosened layer* is equal to the depth that is suitable for storing water and for crops to take up water. Our field measurements and trials have proven that the closer the detrimental tillage pan to the surface, the shallower the rooting depth of the crops.

The *soil moisture content* can be expressed in terms of weight fraction (w/w % or m/m %) volume fraction (v/v%) or in millimetres. A soil workable moisture range is determined by the quality of its clay fraction, organic matter content, structure and compactness. Soil moisture content keeps changing dynamically. Input comes from precipitation, irrigation as well as surface and subsurface inflows while output is the sum of evaporation (including plant transpiration), surface outflows and subsurface seepage off the site (csorba et al. 2011). The output is affected by land use and by the soil state shaped by tillage (water wasting or water conserving).

The *soil's agronomic structure* (with the exception of soils not prone to crumb forming) is indicative of the processes affecting the soil structure. The preservation of the crumby structure is closely related to the protection of other soil quality attributes. For about two centuries now farmers have been aiming to create a fine crumbly seedbed year in, year out, to ensure good germination, because of sowing machines' imperfections. The size of 'small crumbs' (0.25-2.5 mm) is closest to that of the dust fraction (<0.25 mm). According to Birkás, Kisic and Jug (2010) there is a high (>30) dust and clod ratio in soils sensitive to climate damage, while in the case of soils not so sensitive there is a >75-80 % crumb ratio. As they found, in the case of soil conserving tillage crumb forming is proven to increase, but the production of wide-row crops has a somewhat negative impact on this trend. Close correlation can be found between crumb formation and earthworm number (Figure 1).

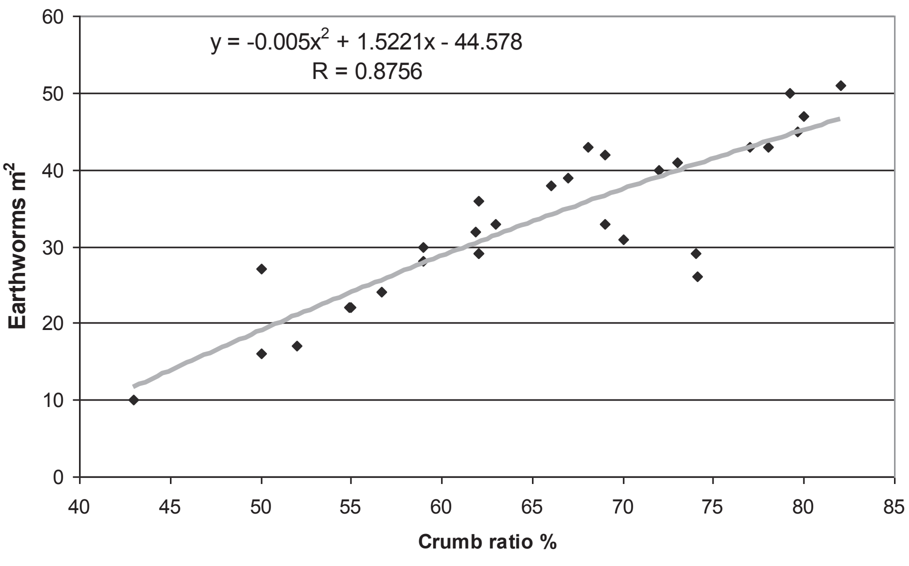

Figure 1: Relations between crumb ratio and earthworm count at moist soil (2002-2012)

The *form of the tilled surface* is characterised in terms of the difference in comparison to what qualifies as 'even' or to a certain expected shape. The shape formed by tillage is largely dependent on the given soil moisture content and the tools applied. The surface of soil remaining after harvest, not broken up by wheel ruts, was found to be the smallest surface per unit of area therefore it is taken as 100 %. The surface of shallow stubble stripping pressed by rolling is 105-110 % (>110 % may lead to losing water during the summer). The surface of the soil after ploughless tillage was found to be some 111-115 %, while after ploughing and surface forming it was 115-122 %. Favourable water retention was found in both cases. By contrast, in the case of ploughing without surface levelling the surface of wet soil was found to be up to 116-126 %, while in dry soil it was as large as 118-138 %. This latter variant results in great water loss in the summer, medium water loss in a mild and windy winter and favourable in a rainy or snowy winter (Kalmár et al, 2013).

Covering and protecting *the soil surface* during the growing season is either good or poor, depending on the crop being grown (densely grown crops provide better protection). The soil is in need of protection during the critical periods, particularly in the summer (Table 2).

Table 2: Cover ratio of tilled/undisturbed fields after harvest in different seasons

Season	Optimal	Adequate	Poor	Positive impacts of optimum surface cover
Rainy	40 – 55	35 – 40	< 20	Less soil structure deterioration and settling, improved straw decomposition, earthworm activity
Average	35 – 45	25 – 30	< 15	Maintaining soil workability and earthworm activity
Dry	45 – 60	35 – 40	< 30	Good moisture retention, crumbling, earthworm activity and straw decomposition

Shading removed by harvest in the summer needs to be replaced by a new protective layer, for which properly chopped and well spread field residues are highly suitable. A new coverage has to be created during the process of stubble stripping, from a mixture of straw and soil to provide protection against heat and rain stress (Birkás and Kisic et al. 2010). The advantages of cover outside the growing season include retaining soil moisture and enabling crumb forming, along with that of useful biological activity in the soil (Table 2).

CO_2 respiration is affected by tillage through the resulting soil state (Farkas et al. 2011). Reports on experiments have been growing increasingly important during recent year, as a consequence of the unfolding climate change. Data reported so far prove that deep tillage, leaving large soil surface behind, leads to increased soil respiration and thereby to higher carbon losses. The soil state causing increased soil respiration is the same as the state causing increased water loss in terms of time, temperature etc. At the same time, preserving tillage causes moderate CO_2 flux, entailing a reliably lower rate of C loss (Figure 2).

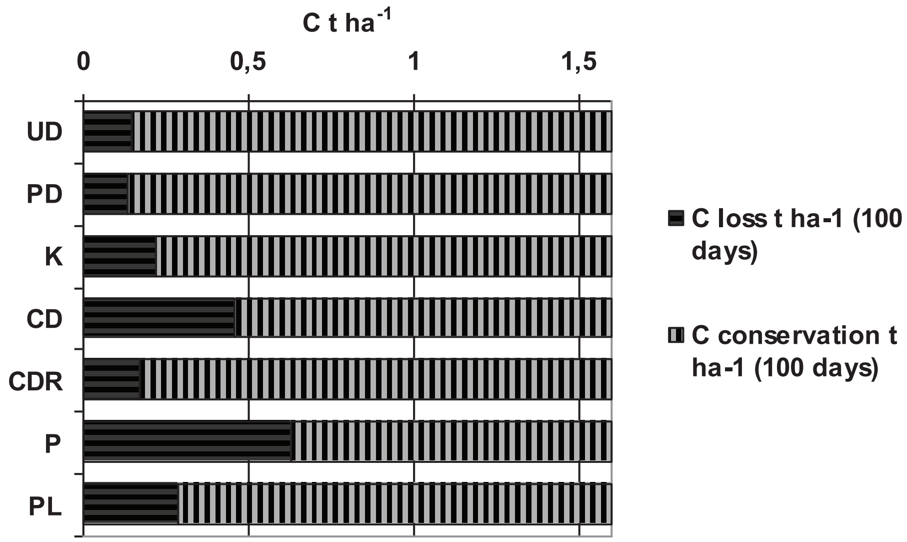

Figure 2: C loss and conservation during 100 days after harvest (2009)

Legend: UD: undisturbed stubble, PD: use plate disk (with roll), K: tine (with roll), CD: use conventional disk, CDR: conventional disk + roll, P: ploughing, PL: ploughing + pressing
C input (from residues): 1.6 t ha^{-1}

Data resulting from continuous measuring helps setting up a ranking order that makes it easier decide what tillage techniques are to be applied under the given conditions of the site, which is expected to help the farming community widely accept and adopt carbon conserving tillage.

Organic residues mixed into the soil can decompose in the presence of air (*aerobic* mode) or without the presence of air (*anaerobic* mode). Decomposition by aerobic microbes is most active when soil moisture, temperature and aeration are in the optimum range, while anaerobic organisms are active at airless soil condition. Microbial activity is affected by the soil condition through its aeration (Birkás and Biro et al. 2011).

Soil tillage affects the *ratio of water intake and water loss* that is of the soil moisture transport. The importance of the soil state lies in its impacts on the ratio of the water taken and stored in the soil, relative to utilised and wasted water. Intake is the part of precipitation that ends up in the soil, most often some 65-70 %, rarely exceeding 80 %. Intake and storage depend on the depth of the loosened layer and on the water permeability of the soil underneath the disturbed layer. The extent of water loss is affected outside the growing season by the shape of the tilled surface, surface cover and the depth of disturbance. A drought-induced loss cannot be avoided in soils where water wasting tillage has been applied for multiple years (Birkás et al. 2012, Várallyay 2013).

Biologically mellowed soil is a result of a favourable combination of physical, chemical and biological attributes in the soil. The resulting *biological structure* is rather fragile and as biological activity is impeded and the soil structure is degraded by tillage-induced soil defects. The qualitative order of organic materials that are of importance from the aspect of structure building is as follows: crop resides > green manure > stable manure > compost.

Earthworms prepare the microbial decomposition of plant residues by reducing them to smaller and smaller particles. They eat plant and animal residues together with the soil, thus their excrement contains nutrients available for plants. The soil and its state determine the suitability of a habitat (see Figure 1). Soils that are frequently disturbed, soils of a clumpy structure, desiccated soils and soils without sufficient aeration, compacted soils and soils regularly submerged under water, do not make suitable habitats either. Undisturbed soils, soils that are not subject to traffic and soils under preserving tillage, along with suitably covered soils as well as those under perennial papilionaceous plants and grasses, are suitable habitats (Birkás et al. 2004, Birkás and Stingli et al. 2010). *Surface cover* is crucial on warm and hot days (Table 2), during the summer months. For example, an approx. 35 % cover is adequate, but 45-55 % is even better, on a field after stubble tillage.

Soil quality is focused on dynamic soil processes and properties influencing plant production risks even in the long term. Any method of tillage may be considered as beneficial if the soil is not damaged while fulfilling plant demands or if the soil physical and biological quality is improved. The differences between tillage modes are sown in Table 3.

Table 3: Considerations between conventional and sustainable soil tillage

Factors	Sustainable	Conventional
Tillage goal	Soil quality improvement	‘Plant requirements’
Depth	Different (required)	extremes (deep/shallow)
Method	Considering soil state	Inverting
Surface	Covered (to sowing, to….)	Clean
Stubble residues	Valuable matter	Tillage limiting matter
OM	Conservation	Decreasing (?)
Tools	Cultivator, subsoiler, (disk?)	On way plough
Sowing	Special	Conventional (?)
Energy demand	Real	Extreme
Adoption on different soils	Well	Constrained
Risks	Weed , pests, diseases (?)	Soil quality deterioration
Impacts on soil	Conservation, regeneration	Changeable
Impacts on plants	Favourable	Favourable (?)
Long-term effect	Decrease climate harms	Sensitivity to climate

Standpoints of the climate damage mitigating and sustainable tillage

Particular attention should be paid to soil states caused by tillage in a short run and in a longer run as well. Close interactions can be found between soil quality and degree of climate damage. The first step in the adaptation in tillage involves recognition of the risks – wrong practices or habits, poor soil quality, extreme climate phenomena etc. – and an urge for improvement, while the second step involves improvement of the soil quality, in harmony with ecological, mechanisation and the farm management conditions. The long term goal of adaptation is to enhance the soil resistance by reasonable controlling of the soil moisture and carbon balance (Birkás, 2011). The principles of sustainable tillage – from stubble tillage to sowing, based on long term trials and soil condition monitoring – as follows (Birkás and Kisic et al., 2010, Jug and Birkás et al. 2010, Birkás and Kisic et al., 2011, Várallyay 2013):

(1) The shading that was removed by harvest must be replaced by a new protective layer, for which the well-chopped and evenly spread crop residues are highly suitable (*primary* protection). The decomposing cover layer can then be replaced by the residues of the sprayed weeds and volunteers that have emerged by that time (*secondary* protection). The purposes of stubble tillage include alleviating heat and rain stress, conserving soil moisture and protecting the soil structure and useful soil-borne organisms as well as naturally deepening the depth of the biologically active layer. Conserving organic matter is a key element of the alleviation of climate induced damages.

(2) The depth and mode of stubble tillage as well as the surface left behind should be soil regeneration: shallow disturbance, 35-55 % covered and a pressed surface is required. Mulch material should be incorporated in the soil after the critical period as it is OM source. If little amounts of residues are left on the surface after the harvest a crumbly insulating layer should be created to protect the soil (*substitutive* protection).

(3) Soil condition should be checked four times in fields under highly valuable crops and where the soil was damaged by water-logging and/or droughts during the preceding five years.

(4) Soil state defects are important facts to the planning of the tillage before the next crop. Compaction impeding the water transport to the root zone must be eliminated and the soil's harmonious water transport mechanisms must be restored.

(5) Climate extremes call for continuous soil moisture storage, for optimising the soil water intake and for minimising the loss of water. Maintaining the favourable water transport and balance in the soil or even improving it is crucial (regardless of the type of tillage or sowing).

In the case of regular irrigation particular attention is to be paid to maintaining the soil's capacity to take in and to store water. The occasional rainy periods do not decrease the importance of moisture conservation. Tillage should encourage the water infiltration from the soil surface (capable of taking water in) and the retaining of soil moisture (evaporation minimising surface).

(6) Minimising the water-waste soil surface should be aimed at in all seasons. In the summer the soil surface should be pressed while before wintering an evened surface should

be created. It should be pointed out – in contrast to previously prevailing views – that the evened soil surface does take water in but it reduces the water lost in mild and windy winter days. Snow may or may not be 'caught' by the furrows in the field after ploughing but after a mild winter the soil will definitely lose a lot of its moisture content if its surface is not evened. A dust layer of at least 10 mm is formed in the wake of the frosts on the large ploughed soil surface.

(7) The depth of the loosened layer is not the result of the most recent tillage activities; the deep loosened layer is, indeed, a result of conserving land use over a long term period. Varying the depth of primary tillage and alternating the use of pan forming and loosening tools are indispensable for avoiding tillage pans. Tools conducive to pan forming should not be used in wet soils. The optimum soil moisture range for driving over the land and for its cultivation must be known.

(8) Circumstances leading to clod or dust forming should be prevented, i.e. a dry soil may be disturbed only in a careful way, gradually deepening the working depth. Crumb forming requires tillage focused on conserving the soil structure and its moisture and organic matter content, along with earthworm activity.

(9) The well-workable soil can be evened without causing damage, thereby reducing the surface affected by frost and the amount of dust (15-25 % of a given amount of soil) so formed. A wet (trafficable) soil should be tilled causing the least possible damage (e.g. tine).

(10) Documentation of climate phenomena and investigation of the circumstances leading to damage should make more effective preparations for protection.

Conclusions

The first step in the process of adaptation in sustainable tillage involves recognition of the risks – wrong practices/habits, poor soil quality, extreme climate phenomena etc. – and an urge for improvement, while the second step involves improvement or conservation of the quality of the soil, in harmony with ecological conditions, mechanisation and the farming and management conditions. The authors consider it fairly safe to declare that climate-induced damage could be effectively mitigated by employing adequate expertise and sustainable tillage.

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SOIL QUALITY PROBLEMS INDUCED BY EXTREME CLIMATE CONDITIONS

Pósa Barnabás

Introduction

In Hungary – the total precipitation in 2010 was 969 mm that is 71% more than the 1971-2000 average. In the region of our experiments (Hatvan) 962 mm (63% more than the average) while in some parts of the basin, a total of 1100-1200 mm precipitation was recorded; most rain (over 100 mm) fell in the months of May, June and September. Soils, independently of their physical characters, were really deteriorated (Várallyay, 2011).The average precipitation was 404.4 mm in Hungary in 2011 (29% deficit, National Meteorology Service /OMSZ/) with significant variances across micro-regions, e.g. our experiment site received a total of 297 mm precipitation (49% deficit). Year of 2012 saw similarly extreme and dry, and the phenomena accompanying the shortage of precipitation, with adverse impacts on the soils included natural desiccation out of and through the growing season (Kren et al., 2012). Based on the soil assessments in the rainy year we found that improvement may be expected to take place after the passage of 2-3 years, in the wake of soil conserving tillage. The dry seasons brought newer natural and tillage-induced damages and soil remediation was regrettably postponed in the drought-stricken fields (Birkás et al., 2012).

Material and methods

The problem referred to in this paper was studied in the Soil quality–climate, and in Stubble–climate experiments that has been underway since 2002 at Hatvan-Józsefmajor. The research site is flat and the soil is moderately sensitive to compaction (Csorba et al., 2011; 2012). The continuous soil condition studies were comprised the possible soil state variants, e.g. shallow and deep tillage, good and bad stubble tillage, pan free and pan presence in soil, clean and covered (0, 15, 25, 35, 55 %) surface, cloddy and levelled surface etc. which gave chance to learn more about soils sensitivity to the climate stresses (Kalmár et al., 2011). Soil assessment was extended to the surrounding area of an approx. 10 km radius with also chernozem type soils (Chernic Calcic Chernozem, WRB 2006). The measurements were taken and evaluated in accordance with the applicable standards (Mesic et al., 2012; Spoljar et al., 2011); Soil Sampling Protocol, JRC, 2010). This study is the summary of a series of articles therefore the scientific goal is accordingly formulated that is studying the rain and the drought stress impact on soils condition

Results and discussion

The rain stress impact on soils condition

Due to the continuous soil condition studies six types of soil state damage were observed in the rain-stricken fields (Table 1.).

Table 1. The rain stress impact on soils' condition

Phenomenon	Situation on soils (on average)*		Medium-heavy soil (kept in good state)*	
	Heavy	Medium-heavy	Clean surface	Covered surface (55 %)
Surface silting (%)	xxx	xx	xx	x
Surface crusting (%)	xxx	xx	xx	x
Crumb reduction (%)	xxx	xxx	xxx	x
Dust leaching (%)	xx	xxx	xx	x
Extension of compacted layer (mm)	xxx	xxx	xx	x
Settling (mm)	xxx	xxx	xx	x
Earthworm activity	low	adequate	medium	sufficient

*n= 250; x: negligible, xx: dangerous, xxx: very dangerous

Considering the degree of phenomena, appreciable differences appeared between heavy and medium heavy soils, and the preserving effect of the clean and the covered surface. However, the degree of soil deterioration was a specific modifying factor (Table 2.). The most exposed situation – high rate of silting and crusting, dust leaching and great settling was found in the degraded soil and bare surface variant. The dust ratio had significantly decreased in the tilled, and it had increased in the bottom layer from early season till the end season. At the same time the former compact layer had also been extended, probably been caused by the dust leaching from the tilled layer. The rain stress proved to be moderate on soils kept in good state in long-term, however the difference between minimum and maximum values were lasted. As Várallyay (2011) noted, the long term soil conservation and the effectual surface cover have really been mitigated the rain damage; differences between minimum and maximum values were also tightened. Both assessed factors, namely surface silting, crusting, crumb reduction, dust leaching, compaction occurrence, and settling showed lowest degree in this soil state variant. Either variant gave evidences for landowners farming in the surrounding area of the trial (preferring tine tillage to ploughing, leaving levelled surface for wintering etc.). On the other hand, as authors stressed, organic material conservation tillage is highly recommended (Birkás, 2011; Beke et al., 2012).

The drought stress impact on soils condition

Trace soil state deterioration back to the rain stress has prolonged for the next seasons. Those six types of soil state damage were adjusted to the dry circumstances (Table 3.).

The drought induced problems occurred both in the experimental fields, and in the region has really been offered new research challenges. Some of the most important results are listed in the following manner (considering short of text length):

1) Water loss from soil (mm day^{-1}) in average of 5 warm days (Oct., 2011): Cloddy and full of cavities in the tilled layer, clean (4.9), Cloddy and full of cavities in the tilled layer, covered (4.2), Smooth, clean (2.2), Smooth, covered (1.9).
2) Decrease of water content (%) of soil top (0-20 cm) layer in average of 5 warm days: (7 a.m. - 15 p.m., Oct., 2011, Hatvan): Cloddy and full of cavities in the tilled layer, clean (42), Cloddy and full of cavities in the tilled layer, covered (35), Smooth, clean (24), Smooth, covered (19).
3) Water deficit (mm) in soils early in the season (April, 2012): Ploughed, pan (120), Ploughed (104), Ploughed, spring planning (87), Ploughed, spring levelling (78), Ploughed, autumnal crumbling (66).

Table 2. The rain stress impact on medium-heavy soils’ condition (n = 510 case)

Phenomenon	Clean surface		Covered surface (55%)	
	Deteriorated	Preserved	Deteriorated	Preserved
Surface silting (%)	73.9 ± 8.4	50.1 ± 11.6	43.1 ± 9.6	5.7 ± 1.8
Surface crusting (%)	75.0 ± 10.0	48.5 ± 11.5	42.0 ± 10.0	5.0 ± 1.5
Crust thickness (mm)	37.5 ± 5.5	21.0 ± 4.0	14.5 ± 2.5	9.0 ± 2.0
Crumb reduction (%)	48.0 ± 6.0	26.0 ± 5.0	28.0 ± 6.0	7.0 ± 2.0
Dust % in the disked layer (%): early in season	21.9 ± 5.7	8.1 ± 2.3	16.3 ± 4.3	3.7 ± 1.5
Dust % below 12.5 cm (early): and end of season	(3.45 ± 0.75) 24.35 ± 7.15	(2.0 ± 0.6) 13.75 ± 2.45	(2.65 ± 0.55) 10.9 ± 4.6	(1.75 ± 0-35) 7.1 ± 2.1
Dust % in the ploughed layer (%): early in season	24.8 ± 4.4	14.75 ± 1.85	12.75 ± 1.45	8.6 ± 1.9
Dust % below 30.5 cm (early): and end of season	(10.75 ± 1.55) 34.7 ± 8.1	(3.05 ± 0.65) 8.5. ± 1.1	2.25 ± 0.35) 15.3 ± 0.9	(0.85 ± 0.25) 13.65 ± 1.85
Extension of disk-pan (mm)	29.0 ± 3.0	18.5 ± 3.5	21.0 ± 3.0	13.0 ± 3.0
Extension of plough-pan (mm)	40.0 ± 8.0	17.0 ± 2.0	25.0 ± 3.0	15.0 ± 3.0
Settling (mm) in ploughed soil	65.0 ± 7.0	48.0 ± 6.0	40.0 ± 2.0	34.0 ± 2.0
Settling (mm) loosened soil	41.0 ± 5.0	23.5 ± 6.5	28.0 ± 2.0	24.0 ± 2.0

Table 3. The drought stress impact on soils' condition

Phenomenon	Situation on soils (on average)*		Medium-heavy soil (kept in good state)*	
	Heavy	Medium heavy	Clean surface	Covered surface (55%)
Surface crusting (%)	xxx	xx	xx	x
Cracking (> 10 cm, db/m^2)	xxx	xxx	xx	x
Crumb reduction (%)	xxx	xxx	xx	x
Water loss in the season	xxx	xxx	xx	x
Increasing penetration resistance (%)	xxx	xxx	xx	x
Prone to clod formation	xxx	xx	xx	x
Earthworm activity	no	low	medium	good

*n= 260; x: negligible, xx: dangerous, xxx: very dangerous

4) Water content (± mm) in an undisturbed soil layer (0-65 cm) in the 44th rainless day after harvest (July-Aug., 2012; water content at harvest: 270 mm): Clean (- 33), Covered10 % (- 9.3), Covered 25 % (+ 9.7), Covered 35% (+ 16.1), Covered 55 % (+ 19.5).
5) Typical penetration resistance values of an undisturbed – pan free – soil layer in a dry season (July-August, 2012): Clean (5.56) Covered10 % (4.42), Covered25 % (3.82), Covered 35% (3.37), Covered 55 % (3.15).
6) Crumb fraction (%) in the upper layer of stubble soil tilled differently in the 85th day in a dry season (July-Oct., 2012): Undisturbed, clean (17), Undisturbed, covered (29), Disturbed shallowly, clean (36), Disturbed shallowly, covered (38), Disturbed deeply, clean (16), Disturbed deeply, covered (30).

Conclusions

According to the continuous soil condition studies the following types of damage were observed and proven by measurements: Factors aggravating rain stress: 1) shallow loosen layer, tillage pan occurrence, 2) pulverised soil surface, 3) dust leaching, 3) aggravation of compaction status, 4) clean, exposed surface; drought stress worsening factors: 1) large, cloddy, water wasting surface, 2) cloddy, full of cavities in the tilled layer, 3) deep cracks in soil promoting evaporation, 4) pan layer close to the surface, 5) clean, rough surface. We strongly recommend using organic material conservation tillage and land management to reduce the soils sensitivity to the probable climate stress.

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POPULARIZATION OF SOIL FERTILITY CONTROL AMONG LANDUSERS

Cvjetkovic Sinisa, Komesarovic Branka, Milena Andrisic, Daniel Rasic

Introduction

Soil testing has been an accepted agricultural management practice for decades. Interpretations and fertility recommendations based on soil analyses and the information obtained with soil samples on cropping systems, tillage practices, soil types, manure use, and other parameters have contributed to the increased efficiency of agricultural production (Sims et al., 2000). In 2003 Institute for soil – Osijek (today as part of Agricultural land agency) in cooperation with Faculty of agriculture Osijek has started project „Soil fertility control on family farms“. Over 10 years it was taken about 17400 of soil samples and cover about 108000 ha of arable land. Project involved arable land with different types of crops (annual and perennial) and farmers with different management of soil cultivation. Main goals of this project was that land users get soil analysis and fertilizations recommendations for low prices, also increase popularization of soil fertility control through soil chemical analysis among land users and establishing the information system of the soil features.

Material and methods

Average soil samples for soil analysis are taken by probe. Average soil sample makes 25 subsamples took at random locations throughout one field or area. For areas in which field crops are grown, samples were collected at the same depth that the field is ploughed (0-30cm) because this is the zone in which lime and fertilizer have been incorporated. Soil sampling sites are located with Global positioning system (GPS) and all data are in GIS database.

Soil analysis was with emphasis on amount of phosphorus, potassium, percentage of organic matter and soil reaction in top layer (0-30 cm). The AL-method - extraction with ammonium-lactate was used for determination of available phosphorus (Test method: Determination of ammonium lactate extractable phophorusexpress as P2O5- spectrophotometric determination-In house method) and potassium (Test method: Determination of ammonium lactate extractable potassium express as K2O –- flamefotometric determination-In house method).

The percentage of organic matter (%) was determined spectrometricaly using bichromate method (Test method: Determination of humus bysulfochromic oxidation spectrophotometric determination – In house method) and the results were classified according to Vukadinovic (Vukadinovic, V., Vukadinovic, V., 2011). Soil reaction, pH was determined according to HRN ISO10390:2005).

Results and discussion

Perhaps the most important property of soil as related to plant nutrition is its hydrogen ion activity, or pH. Knowledge of soil acidity is useful in evaluating soils because pH exerts a very strong effect on the solubility and availability of many nutrient elements (G.W. Thomas, 1967). Over a 37% of soil samples from this project had pH strongly acid, 18% moderately acid and rest of the soil samples had neutral to slightly alkane. Results of soil pH analysis we can see in **Figure 1**.

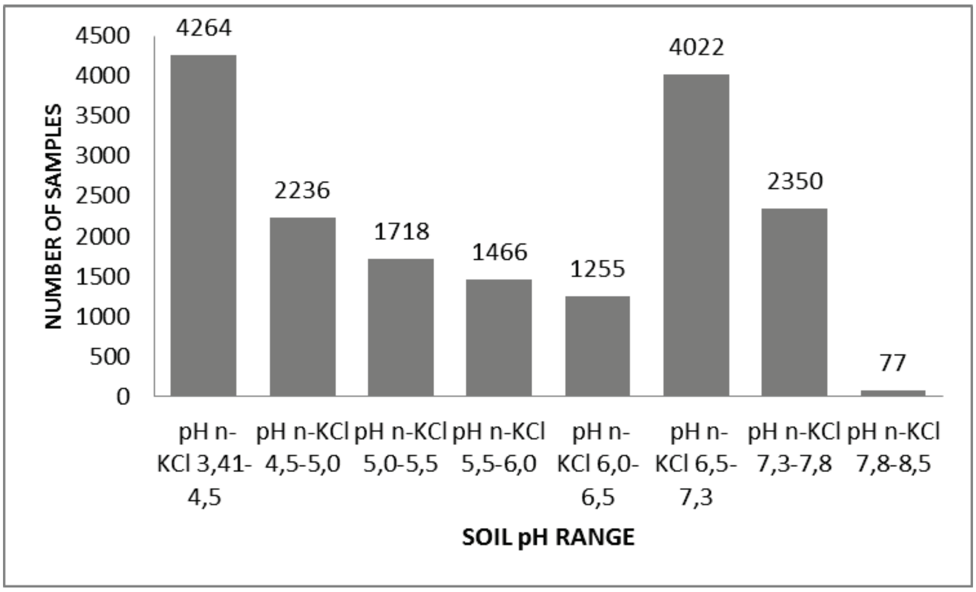

Figure 1: Results of soil pH analysis n-KCl

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. Phosphorus is one of the three nutrients generally added to soils in fertilizers. One of the main roles of P in living organisms is in the transfer of energy (Lowell Busman, 2009).

From this project 15% of soil samples had low values of available phosphorus less than 10 mg /100g of soil, 41% of soil samples had between 11 and 20 mg/100g of available phosphorus, 44% of samples had over 20 mg /100g of available phosphorus.

Increased amount of available potassium is closely linked with intensive fertilization and low values of available phosphorus can be linked with strong acidity of more than half soil samples. Results of soil chemical analysis for available phosphorus we can see in **Figure 2**.

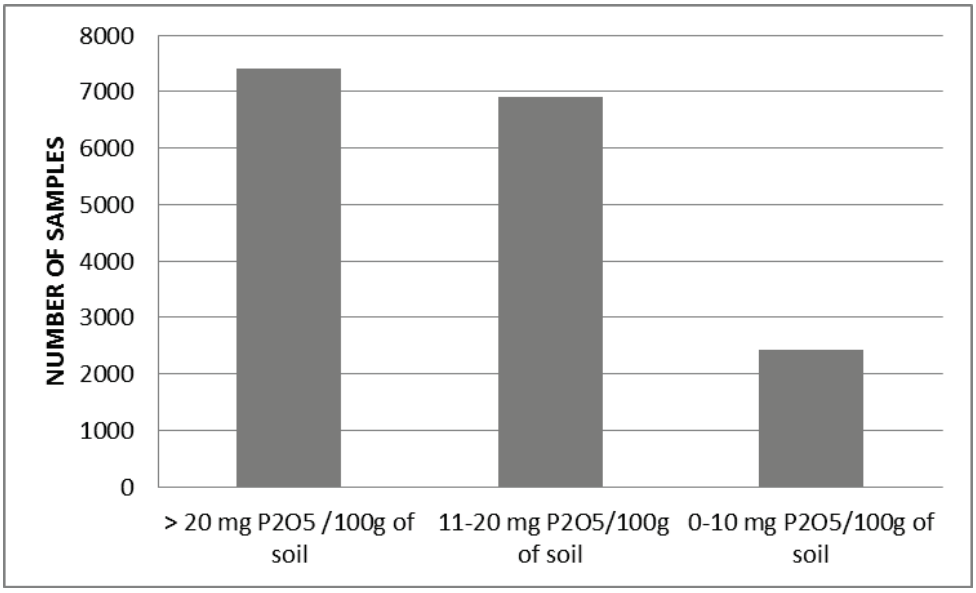

Figure 2: Available phosphorus in soil

Potassium is one of the principle plant nutrients underpinning crop yield production and quality determination. (William T. Pettigrew, 2008).

Available potassium situation is a little bit better. Only 4% of samples had less than 10mg/100g, 31% of samples had 11 to 20mg/100g of soil, 64% samples had over 20 mg/100g. Results of chemical analysis for available potassium are shown in **Figure 3**.

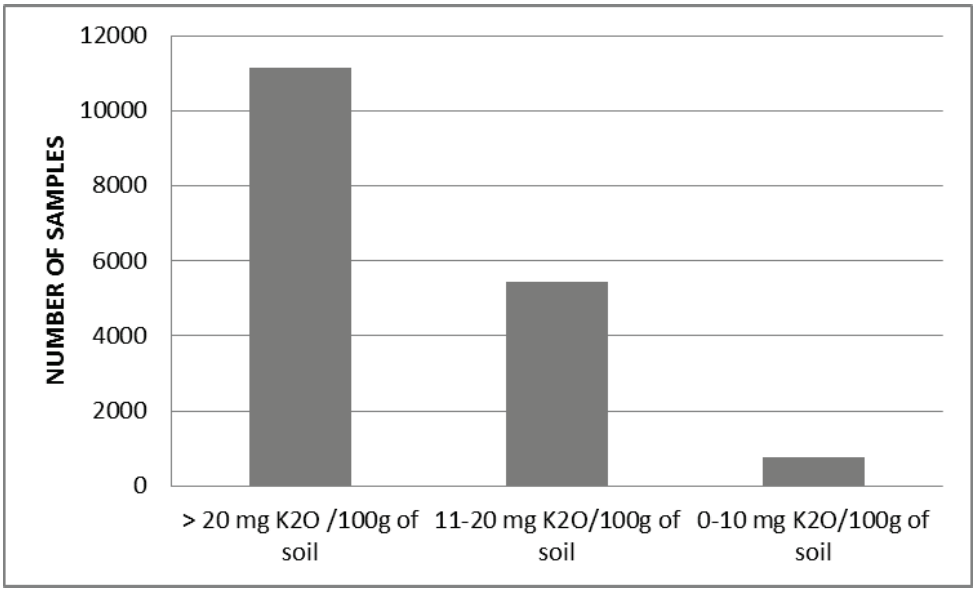

Figure 3: Available potassium in soil

There is more reason for unevenness in availability of phosphorus and potassium. The factors can be relate to pH of soil (soil acidity can affect P-sorption), soil mineral type, temperature or it could be because of excessive use of mineral fertilizers.

Land using and management practices can affect dramatically on losses of humus and decreases of soil organic matter also very little or no application of manure. (Alexandra Bot, 2005). Various types of human activity decrease soil organic matter contents and biological activity (Seput et. al., 2006). For 90% surfaces that have been sampled had humus content between 1 and 3 percent. Results of chemical analysis for humus are shown in **Figure 4.**

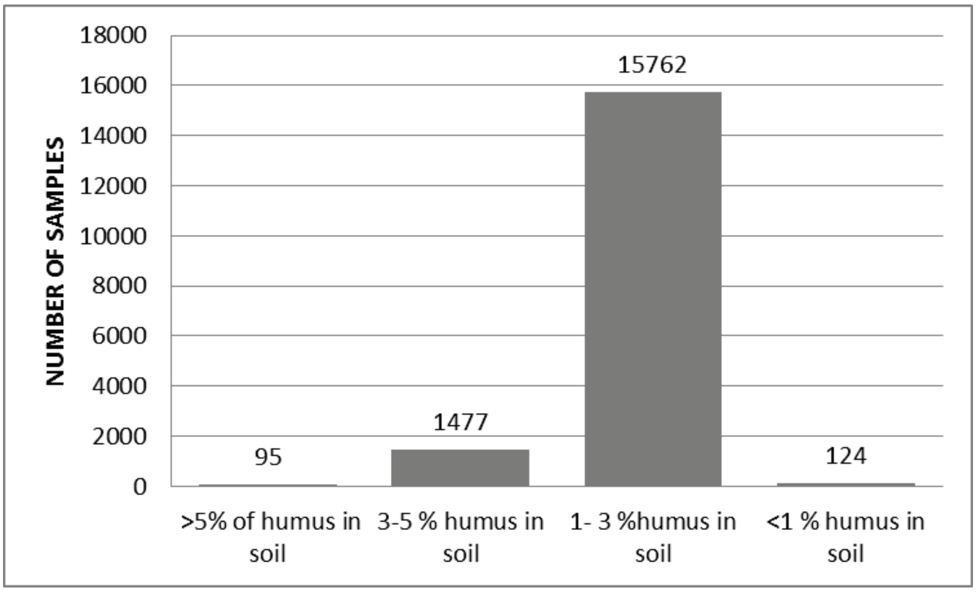

Figure 4: Percentage of humus in soil

Conclusions

Main goals of this project was that land users get soil analysis and fertilizations recommendations for low prices, also increase popularization of soil fertility control through soil chemical analysis among land users and establishing the information system of the soil features. After 10 years of doing this project is still going and the farmers are well satisfied. They get chemical analysis and fertilizations recommendations at low prices (they paid 20% of total price and rest is cover with budget of Osijek – Baranja County) and savings in costs of mineral fertilizers with positive effects on their management inputs. Also they learned importances of different chemical properties of a soil interact in complex ways that determine its potential fitness or capacity to produce healthy and nutritious crops.

In scientific way what we have noticed that are increased amount of available potassium is closely linked with intensive fertilization. Low values of available phosphorus can be linked with strong acidity of more than half soil samples. Also results for content of soil humus is a very disturbing, 90 % surfaces has humus content between 1 and 3 percent, average 1,7 %. Therefore, low soil organic matter has influence on soil compatibility, friability, and soil water-holding capacity while aggregated soil organic matter has major implications for the functioning of soil in regulating air and water infiltration, conserving nutrients, and influencing soil permeability and edibility.

Results and data that we got from this project serve us and to crop producers, farmers to get early warning indicators of soil degradation and how they relate to the sustainability of agricultural.

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THE ROOTS OF WATER AND NUTRIENT (P) EFFICIENCY

Kaul Hans-Peter, Bodner Gernot, Manschadi Ahmad M.

Abstract

Efficiency is the relation between a desired output and the necessary input of any limited resource. For water use efficiency, the ratio of biomass produced and water transpired is the primary agronomic target. Plants apply different strategies to cope with drought. Their success for yield improvement depends strongly on the environmental drought regime. For phosphorus (P) use efficiency we distinguish acquisition efficiency and physiological P utilization efficiency. Highest efficiency is achieved at a "critical P" supply level of the easily available soil P pool that allows for maximum yield. Water and P both are natural resources with increasingly restricted availability. Water scarcity is assumed to be one of the major future risks for human health and wellbeing. There is also a need to significantly reduce P losses in order to avert a future P crisis. Water and nutrients are acquired via the plant roots and root architecture determines soil exploration and therefore water and nutrient access. Root growth angle and root length density play an important role for acquisition efficiency of soil water and nutrients. For water supply-driven environments, high topsoil rooting density suggests the highest capacity to benefit from occasional rainfalls. In contrast, for summer dry environments deep rooting is likely to be more effective. The critical P level can be reduced through improved "root foraging" and "soil mining". Crop genotypes with shallower root growth exhibit enhanced topsoil foraging and hence P acquisition. Developing crop genotypes with a dimorphic root system permitting vigorous rooting both in the surface and deep soil horizons appear to be a promising strategy to overcome root architectural tradeoffs.

What is water and nutrient (P) efficiency?

Efficiency in general is defined as a relation between a certain desired output and the input of any limited resource necessary to obtain that output. With view to agronomy, crop yield is usually taken as the relevant output parameter, and water and nutrients are inputs that drive crop growth and yield formation. In general efficiency can be improved by either increasing the output at a given amount of input or by obtaining a given amount of output by less input or by a combination of both.

Water use efficiency (WUE) can be observed on different scales from single leaf to crop canopy and analyzed with several mathematical models (Raza et al. 2012). From an agronomic viewpoint, it is reasonable to focus on transpiration efficiency, i.e. the ratio of obtained biomass and transpired water. It is a rather conservative measure when targeting vegetative biomass under given environmental conditions, and it depends mainly on the photosynthetic pathway (Steduto et al. 2007). Better WUE can be achieved by improving water availability to crops while reducing unproductive water losses (Raza et al. 2012).

Any resource use efficiency is important only in case of limited resource availability. Thus, in case of water knowledge on drought tolerance mechanisms is of high relevance to improve crop production and water use in water limited environments (see Farooq et al. 2009). Three main responses to water stress can be distinguished, i.e. (i) drought escape, (ii) dehydration tolerance, and (iii) dehydration avoidance (Levitt 1980). Phenological adaptation by early maturity, a kind of drought escape, e.g. might reduce vegetation time unnecessarily in early drought environments, while being useful in (late) summer-dry regions. Dehydration avoidance by "water saving" might prevent the complete use of available water and impair CO2 uptake, while in other environments a "conservative" water use can save water for grain filling and yield formation (Mori et al., 2011).

Obviously, successful yield improvement by these mechanisms depends strongly on the environmental drought regime (Blum, 2011). Soils with high water holding capacity and climates with low proportion of rainfall during the growing season are storage driven. It is most important for yield then to secure off-season moisture for the main crop. In contrast, soils with low storage capacity and high proportion of rainfall during the growing season are supply driven. Then, all measures for a productive use of incoming rainfall are essential for yield.

Variation in **phosphorus (P) use efficiency** among plants can be attributed to differences in efficiency of absorption (acquisition efficiency) and in efficiency with which the absorbed nutrient is utilized to produce yield (utilization efficiency). Plants typically employ three strategies to improve P use efficiency: (i) "root foraging" to increase P acquisition, (ii) "soil P mining", i.e. extracting P more efficiently by root exudates (organic anions, enzymes), and (iii) improving internal P utilization efficiency to produce more biomass and yield per unit of P uptake. The latter has only minor prospects (Ramaekers et al. 2010, Lynch 2011, Richardson et al. 2011).

Any fertilizer P that enters the soil becomes rapidly distributed between a readily available (surface adsorbed) and a strongly bonded or absorbed pool with restricted availability (Syers et al. 2008, McLaughlin et al. 2011). The level of readily available soil P at which the yield asymptote is approached is considered to be the "critical value or critical P requirement" (i.e. a supply level corresponding to 90-95% of maximum yield). This critical P value is specific to each individual combination of crop, soil, climatic condition, and management system (Syers

et al. 2008). The critical value approach is the key to sustainable use of P in cropping systems because soil P at this level is used with maximum efficiency and no further increase in crop yield can be achieved with additional P fertilizer applications. In terms of sustainable P management, the critical value represents the upper boundary, while the risk of nutrient exhaustion due to endured "nutrient mining" sets the lower sustainability boundary (Simpson et al. 2011).

Why is water and nutrient (P) efficiency important?

Worldwide water is a natural resource with decreasing availability. Consequently the need for a "blue revolution" is claimed, allowing for "more crop per drop of water". In many places drinking water for man is only available in limited amount and impaired quality. Agriculture is the sector consuming most of the available water in the world either by natural plant uptake or due to additional irrigation supply. In the future water scarcity is assumed to be one of the major risks for human health and wellbeing (Raza et al. 2012). In 2030, 47% of the world population will be living in areas of high water stress (WWAP 2009). In Central Europe, spring and summer droughts likely will increase with significant implications for the productivity of rain-fed cropping systems (Eitzinger et al. 2008, Trnka et al. 2011). Climate change induced drought stress combined with higher temperatures will have an overall negative effect on crop productivity and quality by also reducing nutrient acquisition (St.Clair & Lynch 2010). Both, convective transport of non-adsorbing solutes (e.g. nitrate) as well as diffusive transport of adsorbing nutrients (e.g. phosphate) is impaired with increasing water shortage. Decreasing transpiration flux can cause nutrient deficiency in leaves due to reduced xylem transport of dissolved nutrients from roots to the aboveground plant parts (Alam 1999).

Phosphorus (P) is a major plant nutrient. The use as fertilizer is most prominent, but other industrial uses are competing with agronomy for the limited resource. Phosphorus fertilizers are manufactured from phosphate rock (PR, mined from natural deposits). Recent estimates suggest that the global commercial PR reserves will be depleted in 50-400 years (Cordell et al. 2009, Dawson & Hilton 2011). The European Union (EU) is almost entirely dependent on imports of P (1.4 Mt in 2010) (Jasinski 2011). Despite being a finite natural resource, P use in the pathway from "mine to fork" is very inefficient: only one fifth of the P mined in the world is consumed by humans as food (Schröder et al. 2010). Therefore, there is a pressing need to significantly reduce P losses in order to avert a future P crisis. Developing crop genotypes with enhanced P use efficiency will make a key contribution to sustainable use of P resources (Lynch 2007, Manschadi et al. 2013). Recent field studies with contrasting common bean genotypes clearly demonstrated that lines with improved P acquisition efficiency (i.e. lower critical P requirement) provide additional benefits including greater soil organic matter deposition, greater biological nitrogen fixation, reduced topsoil erosion due to better ground cover, and better water utilization (Henry et al. 2010).

How can water and nutrient (P) efficiency be improved - the role of roots?

If we focus on agricultural crops, yield is the primary output and water and nutrients are important inputs that are necessary to drive crop growth processes. As water and nutrients are acquired via plant roots, the importance of this plant organ is evident. While high input conditions tend to discriminate against dense root systems (Waines and

Ehdaie 2007), crops will have increasing competitive advantage from intense rooting of the soil where water and nutrients are scarce.

Root architecture is critically important by determining soil exploration and therefore water and nutrient acquisition. Architectural traits include basal-root gravitropism, adventitious root formation and lateral branching. Also length and density of root hairs are important for nutrient acquisition. Root cortical aerenchyma formation and secondary development ("root etiolation") allow for reducing the metabolic costs of root growth and soil exploration. Genetic variation in rhizosphere modification through the efflux of protons, organic acids and enzymes is important for the mobilization of nutrients such as phosphorus. Manipulation of ion transporters may be useful for improving the acquisition of nitrate and for enhancing salt tolerance. Most of these traits are under complex genetic control (Lynch 2007).

Raza et al. (2012) suggest that redistribution of soil evaporation to plant transpiration is a key to improved **water use efficiency** and root system management seems most promising for a better water use and sustainable productivity in agriculture. Additionally, surface runoff and drainage should be reduced. Also Blum (2009) points to water uptake maximization as a focus for breeding because of its general compatibility with high yield. Plants showing dehydration avoidance via uptake maximization – termed "water spenders" by Levitt (1980) – promise better drought resistance. The advantage of a large root system for improved water uptake is obvious.

Additionally, root growth angle has been associated with acquisition efficiency of soil water in many crop species (extensively reviewed by Manschadi et al. 2013). In wheat, genotypes with a narrower angular spread of seminal roots develop a compact, uniform and deep root system, which increases access to water from deeper soil layers. In contrast, genotypes with a wider seminal root angle develop a shallow root system with greater potential for water extraction early in the season (Manschadi et al. 2006, Christopher et al. 2008). Substantial genotypic diversity for growth angle of seminal roots has been observed in wheat germplasm (Manschadi et al. 2008), and this architectural trait is currently being exploited to develop drought tolerant cultivars (Christopher et al. 2013).

The number of seminal roots may also affect the degree of adaptation to drought stress. Seminal roots tend to grow in deeper soil horizons and can therefore make a significant contribution to water uptake from subsoil (Watt et al. 2008). Thus, a greater number of seminal root axes may result in more intensive root branching and root length density at depth. Wheat root system architecture is also affected by the development of nodal or adventitious roots. However, little is known about genotypic variation in the number and gravitropic response of nodal root axes in crop plants.

When screening diverse wheat germplasm in the field, we found topsoil root length density as the most effective root character in positive relation to soil water depletion (Nakhforoosh et al., unpublished). Root electrical capacitance (Chloupek 1972) is a fast and effective screening trait with close correlation to root length density. Also low root tissue density, incurring less investments of dry matter in root expansion, improved water extraction. In soybean, drought adaptation has been associated with a dominant, rapidly elongating taproot (Manavalan et al. 2010), but scientific knowledge on functional implications of variation in taproot growth for drought adaptation and P efficiency in legumes is scarce. For supply driven semi-arid to sub-humid temperate environments, improved drought resistance can be achieved through high topsoil rooting density. This rooting strategy suggests the highest capacity to benefit from occasional rainfalls throughout the growing season. In contrast, for summer dry, Mediterranean environments with higher relevance of stored soil moisture, deep rooting is likely to be most effective for better drought resistance (Nakhforoosh et al., unpublished).

Plants with lower critical **phosphorus (P)** requirements, i.e. with greater P acquisition efficiency, would allow for keeping soils at lower P concentrations than those required today. This would substantially improve internal P cycling and crop productivity in low-input and organic cropping systems and reduce the inefficient use of P fertilizers and environmental problems associated with P losses to water bodies in fertilized and intensive systems (Simpson et al. 2011, Weaver & Wong 2011). The critical P level is strongly affected by root system growth and soil exploration capacity. Due to relative immobility and heterogeneous distribution of P in arable soils, enhancing P acquisition efficiency through improved “root foraging” and “soil mining” appears to be an effective strategy for increasing the P use efficiency and reducing the critical P requirement of crop varieties (Lynch 2007). P efficient crops with lower critical P requirements promise immediate benefits in terms of increased crop productivity and reduced P fertilizer application rates, but it needs to be examined whether they eventually impair soil fertility by endured soil P mining (Henry et al. 2010, Lynch 2011).

It is well established that root morphological and architectural traits play a crucial role in P acquisition in both monocot and dicot crop species (de Dorlodot et al. 2007, Den Herder et al. 2010, Manschadi et al. 2013). The growth angle of root axes, basal root whorl number, adventitious rooting, number of axial roots, lateral root branching pattern, root hair length and density, and root cortical aerenchyma are among the most promising traits for enhanced acquisition of soil P (Lynch 2011, Richardson et al. 2011). In common bean (Phaseolus vulgaris), the existence of large genotypic variability in basal root growth angle has been exploited to develop new bean cultivars in Latin America, Africa, and southern China with substantially greater yield under low soil P conditions (Liao et al. 2004, Wang et al. 2010, Lynch 2011). Recent research on physiological trait dissection for P acquisition efficiency, particularly on common bean, has confirmed several P-adaptive root traits, including the growth angle of root axes, basal root whorl number, lateral branching pattern, adventitious rooting, root etiolation, root hair density and length, and exudation of organic anions (Lynch 2007, 2011).

Manske et al. (2000) reported that wheat genotypes with higher root length density are able to take up more phosphorus. Root diameter and root hair density are also important determinants of P acquisition efficiency in wheat (Jones et al. 1989). Extensive glasshouse and field studies suggest that root deployment in soil is senior to other root traits affecting P acquisition because it also determines the placement of root exudates and symbiosis with microorganisms in specific soil domains, and thereby their functional benefits (Lynch & Brown 2001, Lynch 2011). The growth angle of root axes appears to be again a very important trait, as it strongly influences root architecture (Liao et al. 2001, Lynch 2007, Manschadi et al. 2013). Crop genotypes with shallower root growth exhibit enhanced topsoil foraging and hence P acquisition (Lynch 2007).

Symbiosis with arbuscular mycorrhizal fungi (AMF) is also known to increase root absorption surface and hence acquisition of mineral nutrients. But field research with common bean has shown that AMF colonization does not alter the value of root traits for P acquisition efficiency. Root traits, such as root hair length and density, are important for phosphorus acquisition regardless of the mycorrhizal status of the plant (Miguel, 2004). Results of extensive investigations suggest that root traits act additively or synergistically with AMF (Lynch 2011).

Crop plants grown under field conditions must co-optimize their resource allocation for acquisition of several limiting resources, which may be unevenly distributed in space and time. But there are trade-offs for P acquisition efficiency and drought tolerance, e.g. P efficient plants with enhanced topsoil foraging appear to be susceptible to drought stress, because concentration of foraging in topsoil may reduce exploitation of other soil domains (Lynch 2011). Such root architectural trade-offs for P and water acquisition have been demonstrated for growth angle of basal roots in bean. Shallow rooted genotypes had greater biomass and total P accumulation under P stress while deep rooted genotypes performed better under terminal drought stress with sufficient P supply (Ho et al. 2005). Soil water deficit, or drought stress, directly impacts root growth and function, but also reduces P use efficiency by its influence on P availability and transport in the soil. Developing crop genotypes with a dimorphic root system permitting vigorous rooting both in the surface and deep soil horizons appear to be a promising strategy to overcome these root architectural trade-offs (Ho et al. 2005, Lynch 2011).

Conclusion

Water and nutrient efficiency at whole plant level are complex traits governed by interactions between genetic, environmental, and management factors (G x E x M). Investigating the trade-offs between different strategies to improve water and nutrient acquisition and efficiency and their implications for crop productivity has received little attention, and interactions among various efficiency traits in terms of their metabolic costs and benefits at whole-plant and crop levels are still poorly understood. Co-optimization of root architecture for the acquisition of multiple soil resources is a challenging problem in root research. Root architectural attributes that enhance P acquisition may also be beneficial for the acquisition of other immobile soil nutrients, whereas traits optimizing water uptake would also increase the capture of soluble, mobile nutrients such as nitrate N.

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INFLUENCE OF SOWING DATE (AUTUMN VS. SPRING) ON CROP DEVELOPMENT, YIELD AND YIELD STRUCTURE OF WHEAT AND TRITICALE

Hall Rea-Maria

Introduction

The sowing date is one of the most important management factors affecting cereal production and quality. Especially under Pannonian climate conditions with its low winter temperatures, the risk of occasional spring frost and terminal stress caused by high temperatures and water deficit the productivity of small grain cereals is limited (Santiveri et al., 2003). According to the mean results of numerous studies reporting the effects of temperature on yield, an increase of 1 °C during the grain filling period can result in a 570 to 620 kg/ha yield reduction. Particularly, if drought or heat stress occurs during the post-anthesis (grain filling period), it negatively influences the movement of photosynthetic products to develop kernels and inhibits starch synthesis, resulting in lower grain weight and lower yield by altering the grain quality (Yildirim et al., 2011).

This is also related to the nitrogen use efficiency which is still very low, around 33 kg/ha dry matter (DM) N for most cereals. In order to optimize the use of N fertilizers by the crop and minimize N volatilisation and the risk of surface and ground water pollution it is necessary to find the optimum sowing date for each cultivar. For example, Widdowson et al., 1987 detected large differences in N accumulation in wheat as a consequence of different sowing dates which led to significant differences of environmental conditions during the grain filling (higher temperatures, diminished moisture conditions).

According to the importance of the sowing date for many agronomic factors of different field crops, the aim of the presented one-year field experiment was to determine the influence of autumn- and spring-sowing on crop development, yield and yield structure of different cultivars of wheat (Xenos), triticale (Agrano, Trimmer), einkorn (Terzino) and pea (Cherokee) in the Pannonian climate region and to detect all advantages and disadvantages of these two cropping systems.

Wheat

Wheat is a widely adapted crop – it is grown from temperate, dry to high-rain-fall areas and from warm, humid to dry, cold environments. This wide adaptation has been possible due to the complex nature of the plant's genome, which provides great plasticity to the crop. Generally the minimum water content required in the grain for wheat germination is 35 to 45 % by weight. Germination may occur between 4 and 37 °C, optimal temperature being from 12 to 25 °C (Evans et al., 1975).

The time-span of each development phase essentially depends on genotype, temperature, day-length and sowing date. Especially environmental stresses, particularly heat and water stress shorten the wheat grow phases (Acevedo, 2002).

For example, the duration of the vegetative stage in wheat may vary from 60 to 150 days depending on sowing date and genotype, both influencing the rate of leaf appearance and the time when floral differentiation occurs which are induced by photoperiod and vernalization (Acevedo, 2002).

As with all cereals, wheat should be planted into a firm seedbed and placed near moisture. The optimal sowing depth is between 2 and 4 cm, depending on the moisture conditions. In Austria, winter-types are usually sown between the middle of October to the beginning of November. In any event, the plants should reach the five-leave-stadium before winter-frost occurs.

In contrast, summer-types should be planted as soon as possible, with a view to using the vegetation period to full capacity. Furthermore, an early seeding date could have a positive impact on the yield potential (Aufhammer, 1998).

Cultivar Xenos

The wheat cultivar Xenos had been registered as winter form in Germany in 1998. Since this variety is also capable for spring sowing, Xenos is currently listed as facultative form in the Austrian Variety List (AGES, 2013).

Triticale

Currently, there are three categories of triticale:

1) spring types that do not require a cold treatment/vernalization to move from the vegetative to reproductive phase.
2) intermediate or facultative types that have some cold treatment requirements but will go into the reproductive phase without a cold treatment, too.
3) winter types that require a cold treatment after germination to go into the reproductive phase.

Both, winter and spring types can be grown in most environments which have a sufficiently long growing season and adequate moisture, as well as in areas where winter conditions are not severe. Thereby, the winter types require a long period of time (4-8 weeks) of low temperatures (above freezing but below 9 °C) to cover the vernalization requirements as well as to ensure adequate development of cold tolerance. In contrast, the facultative types are particularly suitable for cultivation in areas that do not have strong vernalizing conditions and do not require cultivars with high levels of hardiness (Salmon et al., 2004).

Although triticale responds very similar to wheat grown under a wide range of environments, it is general superior under stress conditions. For example in areas with drought, extreme temperatures or high nutrient deficiency, triticale has consistently shown to be very competitive compared to other cereals species (Salmon et al., 2004).

As with all cereals, triticale should be planted into a firm seedbed and placed near moisture. The optimal sowing depth is between 2 and 4 cm, depending on the moisture conditions. As triticale seed size is generally lager than that of other wheat varieties, especially spring forms can be seeded more deeply than other small cereals and therefore benefit from stored moisture in the soil, which allows better crop-establishment early in the season, particularly in drought-prone areas. Furthermore, triticale has a very extensive root system and can mine the soil more efficiently in conditions where fertility is poor (Salmon et al., 2004).

Cultivar Agrano

The triticale cultivar “Agrano” developed by Saatzucht Donau, Austria, is a facultative form that could be cultivated in autumn as well as in spring. According to the breeders information it is characterized by a very good stability and a high resistance to various plant disease. Furthermore, it is also described as Austrias most productive triticale cultivar.

Material and methods

Site

The one-year field trial was conducted in Raasdorf, on one of the agricultural areas of “Versuchswirtschaft Groß Enzersdorf”, the experimental farm of the University of Natural Resources and Life Science, Vienna. Raasdorf is situated in the Gänserndorf District of the federal state of Lower Austria in the Marchfeld basin. Geographically, Raasdorf is located 153 m above sea level and on the coordinates 48° 15’ latitude north and 16° 34’ longitude east of Greenwich, 5.3 km from the border of Vienna.

Climate

The whole Marchfeld basin is strongly influenced by the semi-arid Pannonian climate, characterized by cold winters with fluctuating heavy frost periods and irregular snow crusts. In contrast, the summer periods are hot and intermittently dry. The average annual temperature amounts to 9.8 °C. With a long-term average annual precipitation of around 515 mm, the Marchfeld is one of the driest regions in Austria. This is additionally intensified by the majority of the agricultural areas in the Marchfeld basin being open to wind.

Another characteristic of the Marchfeld basin is the above-average long vegetation period which starts in the middle of March and reaches until the middle of November with

1,900 hours of sunshine. Therefore, the Marchfeld basin is one of the most important agricultural production areas in Austria, comprising an area of about 900 km². Traditionally the Marchfeld basin is dominated by cereal production - not for nothing it is called Austrias “bread-basket”.

Soil types

The Marchfeld basin is characterized by chernozem fluvisols, colluvial and alluvial soils with high humus levels and varying levels of loam and loess. Especially the chernozems have been built up by silty and/or loamy floating debris from the Danube river which have overlied the gravel over thousands of years. Additionally, in old river channels also deep and nutrient-rich humid black soils have developed. A main characteristic of the majority of the soils in the Marchfeld basin are the high lime contents for which reason the soils can be seen as pH neutral, respectively weakly alkaline. Especially on the observation plots in Raasdorf, the soil has been classified as a chernozem fluvisol.

Experimental design

The plots were arranged in a randomized complete block split-plot design with two main blocks, which were corresponded to the main plot factor “sowing date”. These main plots were divided in 40 double-plots. Four replications (20 double-plots for autumn-sowing) of each cultivar of wheat, triticale, einkorn and pea were sown on October 18th 2011, the remaining 20 double-plots (spring-sowing) were sown on March 13th, 2012 in the same arrangement. Thereby each plot comprises an area of 15 m² net.

Cereal seeds were sown at a density of 300 kernels per squaremeter, the pea cultivar had a seeding rate of 80 seeds per squaremeter, using a 10-row-planter (Wintersteiger DC 52) with 12.5 cm-rowing spacing. The sowing depth was approximately 4 cm.

Crop management

All experimental plots were prepared with a field cultivator (Kerner Galaxy, approx. 15 cm working depth) and a short disc harrow (Pöttinger, approx. 7-10 cm working depth) just before the first sowing in October 2011. N-fertilization was applied with 50 kg/ha pure nitrogen in the form of Nitramoncal (27 % N), which was shared in 25 kg/ha pure nitrogen on October, 15th 2011 (pre-sowing) and 25 kg/ha pure nitrogen on May 5th, 2012 on all cereal plots (wheat, triticale, einkorn) whereas the pea plots were not fertilized at all.

There was no use of herbicides – all weed control activities were strictly manual. Due to a vertiable aphid invasion (Acyrthosiphon pisum) in the pea stands it was necessary to apply insecticides on June 4th 2012.

Measurements

All measurements on the plants and all samples were taken from the left plot of each double plot and each cultivar in all replication (sample-plots). The right plots of each double plot and each cultivar were defined as “threshing plot”, those plots which were harvested at the end of the vegetation period on July 3rd 2012.

Phenological development stages

Between March 19th 2012 and July 3rd 2012 the phenological development of the plants was conducted seven times. For an exact determination of the phenological stage of each cultivar the BBCH-scale (BBCH = Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) was used.

Above-ground biomass

The development of the above-ground biomass was measured seven times between March 19th 2012 and June 11th 2012 by cutting out 0,3 m² of plants from the left side of each double plot with a pair of scissors, 1 cm above the soil surface. This biomass was dried in a drying cabinet at 105 °C for two days and then weighed. Furthermore, at the same dates, the average height of the plants was measured on the right plot of each double plot with a folding rule which was put vertically in the middle of the stands. By running the hand over the stand the average heights of the various plants was determined.

Leaf area index (LAI)

The LAI was measured seven times between March 19th 2012 and June 11th 2012. As the development of the leaves was not sufficient for in-field-measurements until the end of May, from March 19th to May 14th the LAI recording was executed destructively with the LI-3100 Area Meter. As the spring sowing was carried out on March 13th, on the sample date March 19th only the LAI of the autumn-sown plants could be measured.

After the plants reached a certain development stage by the end of May the two left LAI recordings could have been made in-field with the SunScan Canopy Analysis System.

Harvest

All above mentioned measurements were also executed on the harvest date, 3rd July. At this juncture, it should be noticed, that due to an extraordinary drought in spring 2012 the ripening of all examined crops was accelerated. Thus, the winter crops as well as the summer crops were harvested on the same day. For the determination of the yields of the various cultivars, on July 3rd 1.2m² above ground biomass was harvested from each sample-plot, dried in the drying cabinet and weighed. To define the mean height, the length of ten plants was measured with a folding rule. Afterwards the ears, respectively the pods were counted. Subsequently, the ears were threshed with a standing combine, the peas were segregated from the pods manually.

After air purification of the kernels the thousand grain weight was measured. Furthermore, 100 g of wheat and triticale were sieved in order to determine the grain-size distribution.

After all measurements had been made, the straw and the kernels as well as all the biomass taken during the seven sample dates were milled in order to determine the nutrient distribution inside the plant.

Statistical Analyses

All data was analysed for statistic significance using the statistical programme SAS 9.2. For the graphical visualisation of the data the programme Sigma Plot 12.5. was used.

Results

Phenological development

Earlier sowing of autumn-sown crops resulted in faster development (Fig. 1). On the spring-seeding date (March, 13th 2012) the autumn-sown crops already reached the BBCH macro-stage 2 “tillering”. During the whole vegetation period the spring-sown wheat and triticale were not able to make up this developmental edge. On average, the spring-sown crops lagged 10 days behind the autumn-sown crops during the whole trial period. This is also evident in the later harvest date (July, 11th 2012) of the spring-sown wheat and triticale, compared to the harvest date of the autumn-sown crops (July, 3rd 2012).

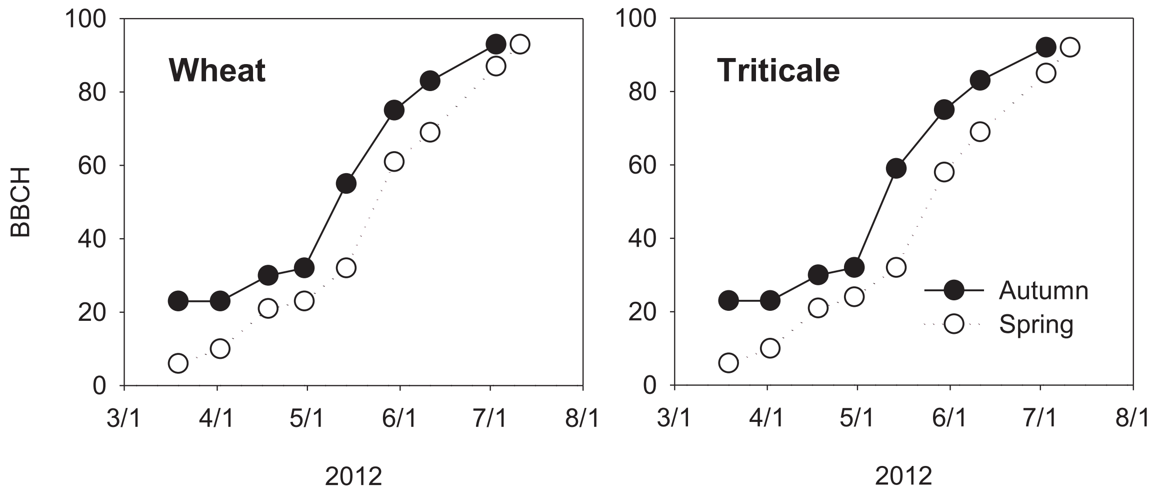

Figure 1: BBCH-stages of wheat and triticale depending on the sowing date (autumn vs. spring)

Stand height

The stand heights of wheat and triticale during the vegetation period are shown in figure 2.

The autumn-sown wheat reached its maximum stand height of 78 cm on May, 30th 2012. The spring-sown wheat was with a maximum stand height of 63 cm clearly shorter. A similar picture is provided by the autumn-sown and spring-sown triticale. Whereas the autumn-crops showed a maximum stand height of 100 cm (May, 30th 2012), the spring-crops reached a much lower maximum stand height of 89 cm (June, 11th 2012).

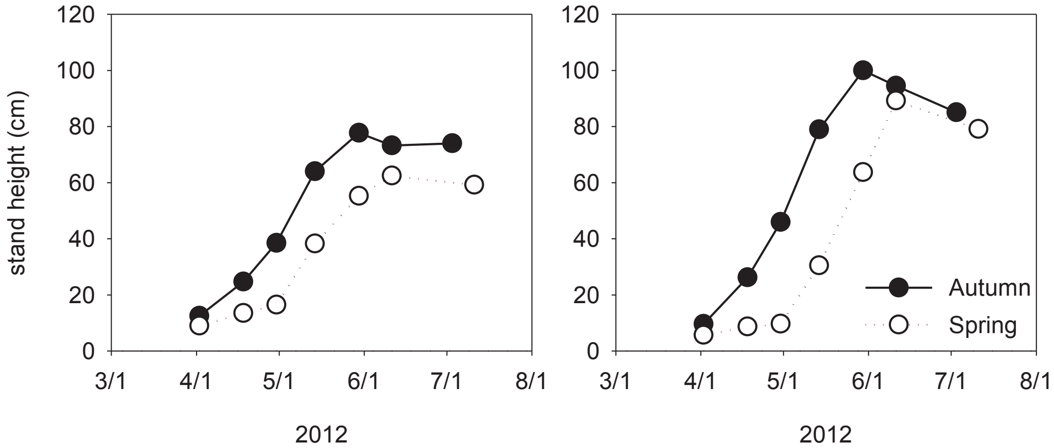

Figure 2: Development of the stand heights of wheat and triticale depending on the sowing date (autumn vs. spring)

Above-ground dry matter

Autumn-sowing of wheat and triticale resulted in higher above-ground biomass production throughout the vegetation period compared to spring-sowing. At final harvest, autumn-sown wheat and triticale had produced much higher above-ground dry matter than spring sown variants (wheat: 997 vs. 661 g m-2, triticale: 972 vs. 748 g m-2; Fig. 3).

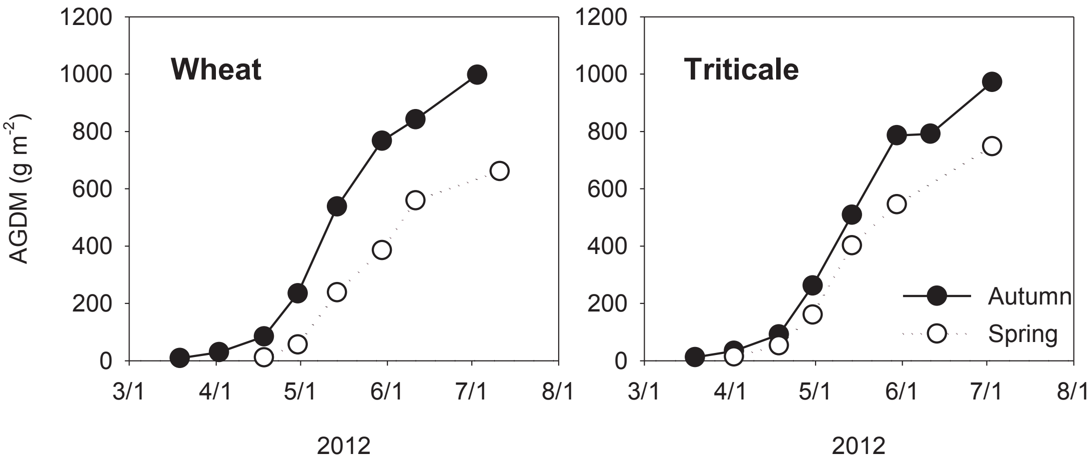

Figure 3: Development of the above-ground dry matter of wheat and triticale depending on the sowing date (autumn vs. spring)

Crop growth rate

The crop growth rate of the autumn-sown wheat had a substantial peak in the first two weeks of May between BBCH macro-stages 3 “stem elongation” and 5 “Inflorescence emergence, heading”, followed by a sharp decline which flatten in the middle of June (BBCH macro-stage 8 “ripening”). In contrast, the growth rate of the spring-sown wheat shows a fluctuating line, with a slight peak in the middle of May (BBCH macro-stage 3” stem elongation”) and another slight peak in the middle of June (BBCH macro stage 6 “flowering, anthesis), the latter followed by sharp decline until harvest on July, 11th 2012.

The crop growth rate of the autumn-sown triticale showed a high increase between the middle of April (BBCH macro-stage 2 “tillering”) and the beginning of May (BBCH macro-stage 5 “Inflorescence emergence, heading”). After a short phase of a steady high crop growth rate until the end of May (BBCH macro-stage 7 “development of fruit”) there was a dramatically sharp decrease to an almost zero-crop growth rate in the middle of June. In contrast, the spring-sown triticale showed a strong increase of growth from the beginning of May (BBCH macro-stage 2 “tillering”) until the end of May (BBCH macro-stage 5 “Inflorescence emergence, heading”) where it reaches its peak. Afterwards the crop growth rate steady decreases until harvest on July, 11th 2012 (Fig. 4).

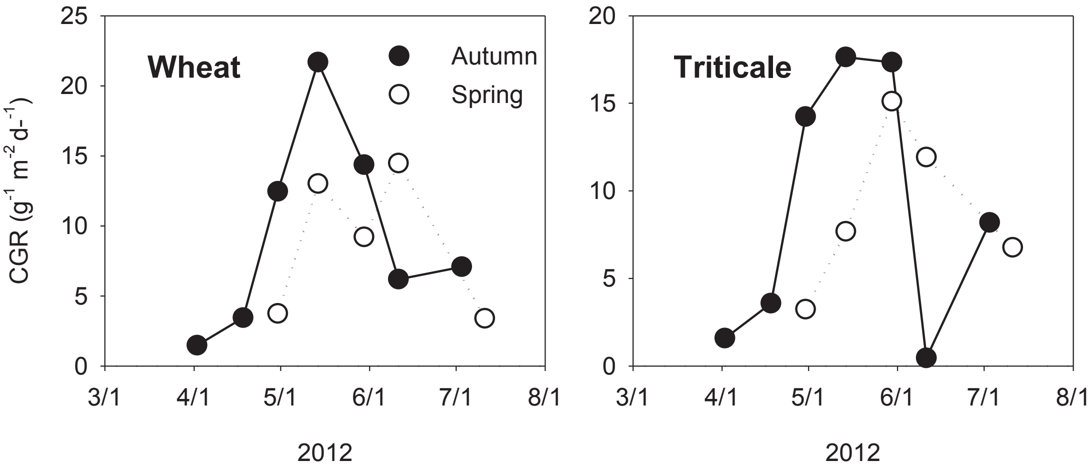

Figure 4: Crop growth rate for wheat and triticale depending on the sowing date (autumn vs. spring)

Relative crop growth rate

The relative growth rate (RGR) of the spring-sown crops was substantially higher than those of the autumn-sown wheat and triticale in the observed periods. Both, the RGR of spring-sown wheat and triticale reached their maximum level at the beginning of May (at BBCH macro-stage 2 “tillering).

In contrast, the relative rowth rate of the autumn-sown wheat reached its maximum value at the beginning of April (at BBCH macro-stage 2 “tillering”), followed by a decline and another peak at the beginning of May (at BBCH macro-stage 3 “stem elongation; Fig. 5).

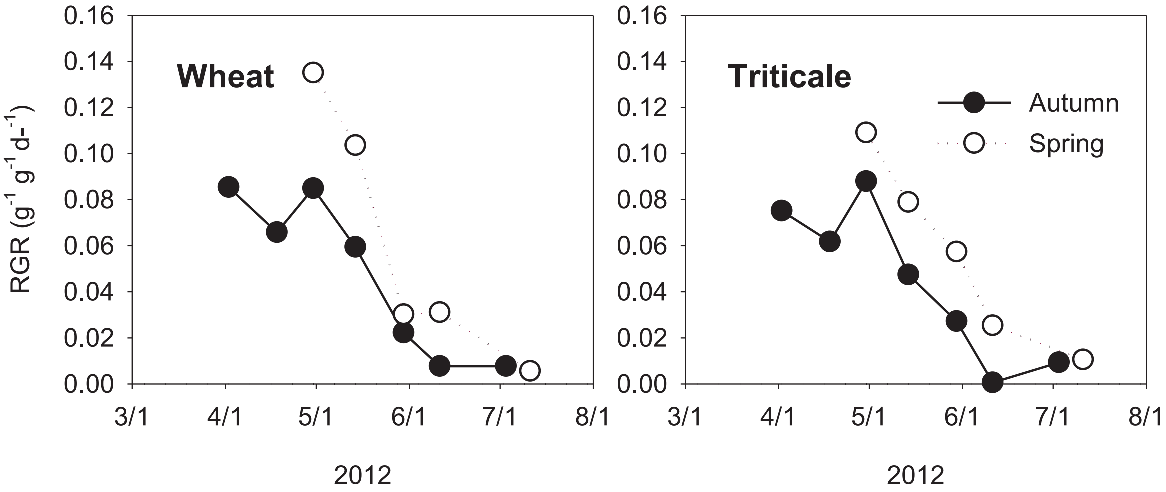

Figure 5: Progression of the relative crop growth rate for wheat and triticale depending on the sowing date (autumn vs. spring-seeding)

Yield parameter

Grain, yield and yield components (harvest index, ear density, hectoliter weight, grains/ear-1, grains/m-2 and thousand kernel weight (TKW) are summerized in Table 1. Accordingly, the yield parameters of the autumn-sown wheat and triticale are both, significantly higher than the yield parameters of the spring-sown wheat and triticale.

Table 1: Yield and yield components of wheat and triticale depending on the sowing date (autumn vs. spring)

Parameter	Unit	Wheat		Triticale	
		Autumn	Spring	Autumn	Spring
grain	$g\ m^{-2}$	356^a	204^b	327^a	220^b
harvest index	%	$0,43^a$	$0,37^b$	$0,40^a$	$0,35^b$
ear density	m^{-2}	380^a	313^b	295^a	320^b
hectolitre weight	kg	81	$76,64^b$	$75,8^a$	$68,98^b$
grains	ear^{-1}	24^a	19^b	28^a	20^b
grains	m^{-2}	8.950^a	5877^b	8.235^a	6534^b
TKW	g	$43,00^a$	$35,74^b$	$41,13^a$	$35,05^b$

Discussion & Conclusion

Autumn sowing of wheat and triticale resulted in a faster development and faster ripening than spring sowing. The spring-sown crops lagged 10 days behind the autumn-sown crops during the whole trial period. The spring-sown wheat and triticale also showed substantial lower crop stand heights and above-ground dry matter production throughout the vegetation periond, leading to significantly lower yields and yield parameters.

These results are confirmed by various studies, indicating that crops with longer development cycles could be able to produce higher biomass. For example, Jaliya (2008) reported for maize that higher dry matter and higher yield and yield parameters were observed by early sown. This might be due to the longer time available for the early sown crops to utilize available growth resources (light, nutrients, moisture etc.) which are used to produce and partition more assimilates to the sinks, leading to the production of higher yield and yield components.

In wheat, spike weight at anthesis is well correlated with kernel number, which is a prime determinant of grain yield (Fischer, 1975). Spike weight is dependent on both phenology and the radiation supply in the 30 days preceding anthesis. Varying the sowing date affects the duration of the growth of the spike and the environmental conditions experienced during this phase of the plant’s development. The lengthening of spike growth duration clearly provides a greater supply of photoassimilates to the spike and thereby increases spike weight and kernel number (Slafer et al., 2001). Furthermore, Santiveri (2004), stated that especially under the dry conditions – as prevailed during the trial period – yield of triticale greatly depends on translocation of pre-anthesis assimilates to the grain (Santiveri, 2004).

High temperature after anthesis can dramatically reduce grain yield of small grain cereals. As temperature rise, photosynthesis reaches a maximum at about 20°C while respiration continues to increase, hence the available assimilates for growth are reduced (Gusta and Chen, 1987).

Ferrise (2010) reported that delaying the sowing date of wheat causes significant differences of environmental conditions during grain filling, usually causing grains to grow with increasing temperatures and diminishing moisture conditions. By changing the relative duration of the pre-anthesis period and the environmental conditions during the grain filling period, the sowing date significantly modifies the contribution of the post-anthesis dry matter to grain dry matter, respectively, as well as the efficiency to vegetative dry matter. The differences in grain yield due to sowing date were primarily the consequence of crop growth prior to anthesis, which determines both the number of grain per unit ground area and the capacity of the crop to accumulate dry matter and N during the grain filling period (Ferrise, 2010).

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FACULTATIVE CROPPING OF WHEAT IN THE CONTEXT OF THE RISKS POSED BY PESTS, WEEDS AND DISEASES

Wenda-Piesik Anna, Piesik Dariusz, Lemańczyk Grzegorz, Pańka Dariusz

Introduction

Production of wheat (*Triticum aestivum* L. emend. Fiori et Paol.) provides food for millions of people around the world. It covers 17% of the global crop area and provides 35% food and 20% of calories. In addition to maize and rice is one of the three major crops in the world. Over the next 50 years there is a need to increase yields in order to prevent uncontrolled prices or increasing the area planted (Rosegrant et al 2001). Wheat is the major crop in Poland with the area getting close to 2 mln ha, in which the winter form prevails above the spring one. Wheat is grown in various geographical areas and different habitats. The world grows about 220 million hectares of wheat, of which 75 million ha of winter wheat and facultative form (Braun and Saulescu 2002). Facultative form of wheat compared to winter wheat are less resistant to frost and winter hardiness, require a shorter period of vernalization, faster start vegetation in the spring and bloom and ripen faster (Stelmakh 1998). They are grown mainly in areas with milder winters or late autumn rainfall occurring. Are planted mainly in Central Asia, the Middle East, Australia (Oztruk et al 2006), as well as in Slovakia and the former Yugoslavia (Okic 1995, Hnilička et al 2005). Varieties of winter wheat forms outweigh yielding varieties of spring by about 1 t ha (Fotyma 2003), but in comparison to the form of spring, facultative exhibit higher yield, as evidenced by results of both foreign and domestic (Oztruk et al 2006, Grocholski et al, 2007). In the national survey, in 2003-2005, of the six cultivars facultative forms, all reacted positively to autumn sowing, and the resulting yield was higher than 1.14 (*cv*. Hen) to 2.93 tons per hectare (*cv*. Triso) than within the spring (Grocholski et al, 2007). In addition to grain yields in the study of facultative forms also takes into account the following indicators: water stress tolerance index (STI), the index of vulnerability to water stress (called SSI), and the general tolerance (Tol) and their values are based on the study of wheat grain yield as a criterion for the suitability of these varieties (Shafazadeh et al 2004). An important factor in agricultural technology in favor of cultivation of spring wheat in the autumn period is possible late date of sowing, inappropriate as the winter form, and necessary due to the rotation of crops (Bewick et al 2008). In terms of conventional farming and integrated farming in Poland facultative forms of wheat is justified after harvest of corn for grain or sugar beet harvest. It can also be an alternative to monoculture cultivation of wheat. Instead of winter wheat each other, rotation winter wheat / facultative wheat may be justified, if only for reasons of value obtained grain. It is known that the varieties of spring are characterized by better quality parameters than the winter and mostly belong to the group A (quality variety) (COBORU 2012). So far we do not have the facultative cultivars, but we practice the facultative term of sowing rather or the cultivars dedicated to the facultative crop. In Polish field cropping of facultative wheat spring form is using with classification of utility: qualitative, bread and for general quality. Cultivars have the genes responsible for the resistant to frost in the early stages of development, BBCH 07-13, the hardiness greater than the other cultivars, and they are useful for the late autumn sowings.

The aim of the study was to diagnose the threats of wheat pests such as insects, fungal diseases and weed infestation while their control depending on the intensity of chemical plant protection. In accordance to the principles of sustainable agriculture the risks should be well recognized and the intensity of chemical protection effectively limited but do not exceed neither the number of applications nor the doses.

Material and methods

Three strict field experiments have been carried out in 2010 – 2013 in the Kujavia-Pomerania region, Poland (17°13' E; 53°13' N). Two experiments were conducted at Mochełek Experimental Station, UTLS in Bydgoszcz, one at Experimental Station for Cultivar Evaluation in Chrzastowo. The spring wheat *cv*. Monsun (qualitative, group A) was planted.

In the 1st experiment the following factors are performed: A - Term of sowing of spring wheat: a1 – early facultative (October 2nd decade), a2 – late facultative (November 3rd decade), a3 - spring (March 25 - April 5), B – Treatments against pests: b1- control, lack of insecticidal seed treatment + no interventional insecticides, b2 – lack of insecticidal seed treatment + interventional mixtures of insecticides, b3 - insecticidal seed dressing + no interventional insecticides, b4 - insecticidal seed dressing + interventional mixtures of insecticides. The diagnosis of the bird cherry grain aphids (holocyclic and anholocyclic forms) which can cause infection with the virus BLDV as well as the cereal leaf beetle were conducted. The modern seed treatment Astep FS 225 for wheat having a double track: against diseases (prothioconazole) and against pests (imidacloprid) was involved. The substances: chlorpyriphos + cypermethrin + dimethoate + pirimicarb towards control of cereal leaf beetles and aphids was applied at BBCH 31-34.

The 2nd experiment has been carried out at Mochelek Experimental Station and it is dealing with the factors as following: A - Weed control during post-harvest of fore-crop: a1 - glyphosate (e.g. Roundup Energy 450 SL at a dose of 2.0 l per ha), a2 - lack of glyphosate, B - application and herbicide active ingredient b1 - no herbicidal control, b2 - MCPA (Chwastox Extra 300 SL 1.5 l per ha) + sulfosulfuron (Apyros 75 WG 15g per ha) + adjuvant Atpolan 80 EC at 25-29 BBCH, b3 - fluoksypyr and florasulam (Starane Super 101 SE 1l) + sulfosulfuron (Apyros 75 WG 15g per ha) + adjuvant Atpolan 80 EC at 25-29 BBCH, b4 - diflufenican and isoproturon (Mustang 600 SC 1.25 l per ha) at 23-25 BBCH, b5 - thifensulfuron-methyl and chlorsulfuron (Chisel 75 WG 40 g per ha) + sulfosulfuron

(Apyros 75 WG 15g per ha) + adjuvant Trend 90 EC, b6 – tribenuron methyl (Helmstar 25 g per ha) + adjuvant Atpolan 80 EC at 25-29 BBCH. Results concerned the occurrence (numbers and weights of monocot and dicotyledonous) of weeds dependently of the control s.a.

The 3rd experiment which has been carried out at Chrzastowo Experimental Station for Cultivar Evaluation is aimed to determine the effect of various intensity of chemical protection against fungal diseases on the health of roots, stem base, leaves and heads of wheat sown as facultative (late autumn) and in the spring term. The first experimental factor A: - Fore crop of spring wheat: a1 - monoculture of wheat forms, a2 - seed corn crop, a3 – sugar beet. The factor B - Term for sowing: b1 – facultative b2 – spring, C factor was established as variants of protection against fungal diseases: c1 - control, without protection treatments of leaves and heads, c2 – low intensive program consist of one treatment at T2 stage (BBCH 32-65) with prothioconazole and fluoksastrobine, c3 - middle intensive program based on the two applications performed at the T1 stage (BBCH 30-32) and T2 (BBCH 41-65) with spiroxamine and prothioconazole mixture, and the mixture of fluoksastrobine and prothioconazole, c4 - a very intensive program of disease control based on the three treatments performed in T1 stage (BBCH 29-31), T2 (BBCH 37-51) and T3 with tebuconazole (BBCH 65-69) for the full protection of root rot, leaf and head. Results will be concerned to the indexes of diseases of root rot and crown rot caused by *Fusarium* sp. and *Rhizoctonia* sp.

Results and discussion

The incidence of wheat pests as a response to the term of sowing and intensity of control

In the three years of the study repeated pest on wheat plants was cereal leaf beetles with harmful larval stage damaging leaves at the stage BBCH 30-50 and cereal aphids found on heads. The occurrence of *Oulema* sp. pests on wheat was under the influence of both the sowing terms and intensity of protection (Fig. 1 C-D) while the incidences of cereal aphids were affected by control intensity merely (Fig. 1 A-B).

The same level of the number of aphids (3-10 per 30 heads) were noted when the control included insecticidal seed treatment or the lack of insecticidal seed treatment + interventional mixtures of insecticides consist of chlorpyriphos + cypermethrin + dimethoate + pirimicarb. The significantly greater number of aphids (70-80 per 30 heads) were noted on wheat plants while sown both in November and April and no application of insecticidal treatments were used. The percentages of anholocyclic aphids were also determine to estimate the threads towards BYDV (barley yellow dwarf virus). The vector of the virus are aphids, mainly of the genus *Rhopalosiphum padi*, which as a species two-domestic and holocyclic during harvest flew to wheat from bird cherry. Since 1989, reports of changes in the development cycle of this species, consisting of the creation of anholocyclic forms that inhabit the form of winter wheat and barley. Warm autumn, the period during which the critical temperature (-6°C) favours the spread of viral infection BYDV (Ruszkowska 2002, Ruszkowska and Strążyński 2007). In this research we noticed only one year with anholocyclic forms with the ratio of 1/10 to 1/3 of total numbers. No harmful effects on wheat plants in next season occurred and any viral infections.

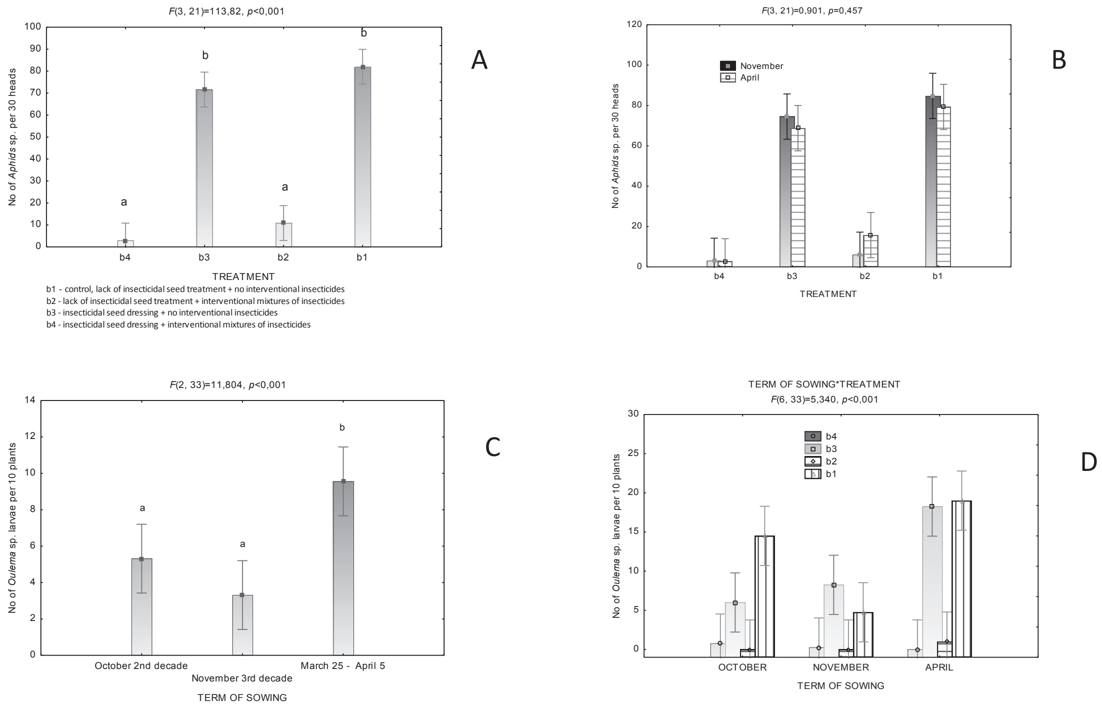

Figure 1: The occurrence of pests in wheat depending on sowing date and intensity of plant protection.

The larvae of *Oulema* sp. at much higher amounts occurred in the spring sowing than in facultative terms, about 5-7 larvae per 10 plants more (Fig 1 C). The occurrence of cereal leaves was also affected by the interaction between term of sowing and control intensity (Fig. 1D). In October sowing the greater number (15 per 10 plants) was recorded in control without any treatments, while in November term of sowing no difference was recorded between lack of insecticidal and insecticidal treatments. On wheat planted in April the significantly greater numbers of larvae were recorded in control and in the treatment without insecticidal application. The seed treatment with imidachloprid did not protect sufficiently against cereal leaf beetle.

The weed infestation in facultative wheat crop as the response to herbicidal active substances

The use of glyphosate on the stubble after harvesting the wheat's fore-crop optional resulted in a significant reduction in the number of dicot and monocot weeds on the plantation of facultative wheat. Biomass of dicotyledonous weeds after the application of glyphosate reached 48.79 g per sqm and was twice lower than in the control without glyphosate (84.86 g per sqm), while the monocot weeds less than 3-fold with 5.27 g sqm to 15.90 g per sqm, respectively (table 1). All active substances of herbicides applied in growing season resulted in a decrease of dicotyledonous weeds compared to the control, but their effectiveness varied in the control with the number of weeds. Two combinations revealed the most effective reduction: thifensulfuron-methyl + chlorsulfuron + sulfosulfuron, and tribenuron methyl. The number of individuals per square meter amounted to 10.2 and 18.0 (table 1). The weakest control of dicotyledonous weeds was observed after fluoksypyr + florasulam + sulfosulfuron (34.7 plants per sqm). However, given the dicotyledonous weed biomass should be noted that all of the tested substances showed equal percentage herbicidal relative to the control without herbicide.

Table1. Number of individuals and the weights of weeds in dicot- and mono-cotyledon classes depending on the herbicidal control in facultative wheat.

Glyphosate post-harvest (A)	Herbicide post emergency (B)*	Number of dicotyledonous per sqm	Weight (g) of dicotyledonous per sqm	Number of monocotyledons per sqm	Weight (g) of monocotyledons per sqm
Control	b1	77.9±7.4	351.7±135.2	79.3±32.6	26.48±7.14
	b2	32.3±3.0	11.81±3.22	19.9±13.6	1.87±1.28
	b3	38.5±9.0	120.5±85.3	35.8±22.3	3.48±1.38
	b4	20.6±6.6	10.32±6.58	90.5±74.9	13.23±6.44
	b5	9.9±3.9	2.35±0.63	93.9±82.5	35.32±25.11
	b6	19.9±6.0	7.12±2.15	216.9±101.6	15.07±5.21
Mean		33.2±5.4 B[#]	84.86±35.31 B	89.3±25.6 B	15.90±4.74 B
Roundup Energy 450 SL 2.0 l per ha	b1	61.9±7.6	246.36±72.74	9.6±7.2	7.19±5.03
	b2	23.0±3.8	13.97±4.74	34.7±23.6	4.50±2.40
	b3	30.9±5.2	21.60±4.24	9.7±4.3	1.23±0.49
	b4	22.1±3.7	5.59±2.10	31.1±9.8	6.56±3.06
	b5	10.5±2.7	1.31±0.24	21.5±5.9	3.46±1.95
	b6	16.1±4.9	3.92±1.19	39.9±10.2	8.69±3.97
Mean		27.4±3.9 A	48.79±21.39 A	24.4±6.0 A	5.27±1.26 A
Mean	b1	69.9±5.7 d	301.7±72.19 b	44.4±20.3	16.84±5.44
	b2	27.6±5.7 bc	12.89±2.63 a	27.3±12.9	3.18±1.36
	b3	34.7±5.0 c	71.03±43.75 a	22.6±11.6	2.36±0.8
	b4	21.4±3.5 abc	7.95±3.32 a	60.8±37.6	9.89±3.54
	b5	10.2±2.2 a	1.83±0.37 a	57.7±41.2	19.39±13.12
	b6	18.0±3.7 ab	5.52±1.29 a	128.4±57.9	11.88±3.26
$F_A(1,33)$ $F_B(5,33)$ $F_{AxB}(5,33)$		4.16 $p = 0.05$ 37.4 $p < 0.001$ ns	2.84 $p = 0.05$ 13.1 $p < 0.001$ ns	9.39 $p = 0.004$ 2.18 $p = 0.08$ ns	5.40 $p = 0.026$ ns ns

*b1 - no herbicidal control, b2 - MCPA + sulfosulfuron, b3 - fluoksypyr and florasulam + sulfosulfuron, b4 - diflufenican and isoproturon, b5 - thifensulfuron-methyl and chlorsulfuron + sulfosulfuron, b6 – tribenuron methyl

[#] the same letters indicate the homogenous group according to HSD Tukey's test at $p = 0.05$.

For monocotyledonous weeds limiting the number of individuals was not statistically verified at $p = 0.05$, although revealed a trend to a better control of weeds by two combinations of s.a.: MCPA + sulfosulfuron, and fluoksypyr + florasulam + sulfosulfuron, giving respectively 27.3 and 22.3 monocots per sqm. The use of herbicides of the same mechanism of action may lead to changes in the floristic composition of communities and the selection of weed biotypes resistant to s.a. Herbicidal effectiveness of herbicides depends primarily on the species spectrum of weeds (Idziak et al 2007).

Health status of the roots and stem base of wheat as the response to fore-crops, term of sowing and various intensity of fungal control

The data for root rot complex of wheat showed that DI after fore-crop of wheat exceeded three fold the indexes for wheat planted after corn and sugar beets, reaching respectively 66.4% vs 18.1% and 13.8% (table 2). The DI of root rot complex at various intensity of plant protection within terms of sowing were similar, thus the control of root was merely disturbed by the for-crops as all levels of control had the seed treatments. In the contex of sustainable protection against soil diseases the intensification of the control program to T2 and T3 was not justified. The severity of Rhizoctonia sp. was low and not exceeded 10% in this study. The greater tendency of eye-spot was observed after wheat then after corn or sugar beet. This is in accordance to the references of Wachowska (2000) and Korbas et al (2001) who state that the threat of Rhizoctonia cerealis is very rare in Poland to proove the need of chemical control. The warmer winter condition favours the significance of this pathogen increasing on wheat stem base (Häni et al 1998). From the soil born pathogens the most severe and dengerous for the quality of wheat grain are Fusarium species. The incidences of the crown rot disease were twice higher on wheat cultivated after wheat then after corn or sugar beet, the DI were respectively 43.3% vs 17.3% and 17.0% (table 2). The chemical control against fungal pathogens that included the T2 program significantly reduced the incidences of Fusarium crown rot on wheats planted after corn or sugar beet. This may be promising for the further limitation of ears infections and mycotoxins production by Fusarium sp. The infection of heads occurrs at flowering stage with favourable high humid condition (Bai and Shaner 1999, Lacey et al 1999).

Table2. Disease indexes (DI) depending on the for-crops, term of sowing and fungicidal control of wheat.

<table>
<tr><th>Fore-crop (A)</th><th>Facultative/spring term of sowing (B)</th><th>Control of fungal diseases (C)</th><th>DI of Fusarium crown rot (%)</th><th>DI of root rot complex (%)</th><th>DI of Rhizoctonia sp. (%)</th></tr>
<tr><td rowspan="4">Wheat</td><td rowspan="4">Spring</td><td>C1*</td><td>48.3±5.5 z[#]</td><td>56.0± 12.3</td><td>11.3±1.0</td></tr>
<tr><td>C2</td><td>45.3±6.7 z</td><td>61.3±15.5</td><td>10.3±0.9</td></tr>
<tr><td>C3</td><td>40.3±10.4 z</td><td>71.3±20.4</td><td>6.0±0.6</td></tr>
<tr><td>C4</td><td>39.0±8.7 z</td><td>77.0±22.4</td><td>6.3±0.8</td></tr>
<tr><td colspan="3">Mean</td><td>43.23±6.9 B</td><td>66.40±14.5 B</td><td>8.48±0.9</td></tr>
<tr><td rowspan="10">Corn</td><td rowspan="4">Facultative</td><td>C1</td><td>17.0±2.3 z</td><td>12.0±3.2</td><td>4.7±0.5</td></tr>
<tr><td>C2</td><td>17.0±2.6 z</td><td>10.7±0.9</td><td>4.0±0.5</td></tr>
<tr><td>C3</td><td>16.3±1.4 z</td><td>12.7±2.1</td><td>1.0±0.2</td></tr>
<tr><td>C4</td><td>13.7±2.0 z</td><td>11.7±1.6</td><td>0.3±0.1</td></tr>
<tr><td colspan="2">Mean</td><td>16.00±1.9</td><td>11.78±0.8 a</td><td>2.50±0.2</td></tr>
<tr><td rowspan="4">Spring</td><td>C1</td><td>23.7±7.8 z</td><td>20.0±4.5</td><td>10.3±3.0</td></tr>
<tr><td>C2</td><td>20.7±6.5 z</td><td>19.7±4.3</td><td>12.7±1.2</td></tr>
<tr><td>C3</td><td>12.7±3.5 y</td><td>29.7±5.6</td><td>1.3±0.3</td></tr>
<tr><td>C4</td><td>15.3±4.0 y</td><td>28.3±5.0</td><td>0.7±0.4</td></tr>
<tr><td colspan="2">Mean</td><td>18.10±3.5</td><td>24.43±3.5 b</td><td>6.25±1.2</td></tr>
<tr><td colspan="3">Mean</td><td>17.05±2.2 A</td><td>18.10±3.3 AB</td><td>4.38±1.1</td></tr>
<tr><td rowspan="10">Sugar beet</td><td rowspan="4">Facultative</td><td>C1</td><td>16.0±1.1 z</td><td>15.7±3.2</td><td>5.3±0.8</td></tr>
<tr><td>C2</td><td>17.0±1.3 z</td><td>12.7±1.2</td><td>5.7±0.6</td></tr>
<tr><td>C3</td><td>6.7±0.6 y</td><td>14.3±1.3</td><td>0.7±0.1</td></tr>
<tr><td>C4</td><td>6.3±0.5 y</td><td>13.3±1.4</td><td>0.7±0.1</td></tr>
<tr><td colspan="2">Mean</td><td>11.50±0.9 a</td><td>14.00±1.1 a</td><td>3.10±1.2</td></tr>
<tr><td rowspan="4">Spring</td><td>C1</td><td>33.7±6.7 z</td><td>24.0±3.2</td><td>3.7±0.8</td></tr>
<tr><td>C2</td><td>33.0±8.5 z</td><td>10.7±1.0</td><td>3.0±1.0</td></tr>
<tr><td>C3</td><td>14.0±3.2 y</td><td>12.0±2.1</td><td>2.3±0.7</td></tr>
<tr><td>C4</td><td>11.7±2.5 y</td><td>8.0±0.6</td><td>2.7±0.8</td></tr>
<tr><td colspan="2">Mean</td><td>23.10±4.5 b</td><td>13.68±1.3 a</td><td>2.93±0.6</td></tr>
<tr><td colspan="3">Mean</td><td>17.30±3.4 A</td><td>13.84±0.7 A</td><td>3.01±0.5</td></tr>
</table>

*c1 - control, c2 - prothioconazole and fluoksastrobine at T2 stage, c3 - spiroxamine and prothioconazole at T1 stage + fluoksastrobine and prothioconazole at T2 stage, c4 - T1 + T2 (as above) + T3 (tebuconazole).
[#] the same letters indicate the homogenous group according to HSD Tukey's test at $p = 0.05$.

Conclusions

For sustainable production and protection of wheat in facultative crop important issue is the use of chemical control in the appropriate phase and procedure whereby the most effective active ingredients.

1. Wheat sown in facultative terms was less susceptible to *Oulema* sp. larval damage than sown in April due to faster growing in the spring.

2. Anholocyclic form of cereal aphids occurred in one year at the ratio 1/10 – 1/3 not giving any damaged effect in the next year.
3. The number of aphids on wheat heads under insecticidal control (chlorpyriphos + cypermethrin + dimethoate + pirimicarb) was 7-8 fold lesser than on wheat treated with imidachloprid in seed dressing.
4. Significant efficacy of imidachloprid in control of cereal leaf beetles without application of insecticides was proved only in the earliest term of facultative sowing.
5. The use of herbicides in facultative wheat plantation only within the spring does not guarantee effective protection against weeds.
6. The glyphosate (e.g. 2.0 l per ha of Roundup Energy 450 SL) controlled effectively mono and dicotyledonous weeds by reducing their numbers and biomass in more than 50%.
7. The most effective active substances against dicotyledonous weeds revealed two combinations: thifensulfuron-methyl + chlorsulfuron + sulfosulfuron, and tribenuron methyl.
8. The application of sulfosulfuron in mixture with MCPA or fluoksypyr + florasulam reduced the monocot weeds more efficient than the other herbicidal substances.
9. The highest severity of *Fusarium* crown rot pathogens performed on wheat plants cultivated after wheat regardless on the intensification of the fungal control.
10. The severity of soil-borne pathogens was more pronounced after fore-crop of wheat than after corn or sugar beet. The strongest symptoms were related with the root rot.
11. Intensive chemical protection with the spiroxamine and prothioconazole at T1 stage + fluoksastrobine and prothioconazole at T2 stage resulted in better reduction of wheat infection by *Fusarium* sp.

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PRODUCTIONAL AND ENVIRONMENTAL EFFICIENCY OF AGRO-PRACTICES APPLIED IN WINTER WHEAT MONOCULTURE

Kulpa Dariusz

Introduction

Last decade in Poland has been characterized by increasing share of cereals in crop structure, that leads to the planting of cereals in monoculture. We observe a marked reduction in yields, that also depends on the amounts of plant species, habitat conditions as well as the agricultural management.

Monoculture contributes to the occurrence of many pests in wheat such as: cereal leaf beetles, aphids and trips [Mrówczyński et al 2005]. Miętkiewski et al [1991] found that feeding trips cause the kernels of grain weight lesser and protein content reduction. This does not affect the germination of seeds. Winter wheat is one of the species that are most responsive to a decrease in the yield when grown in monoculture [Małecka et al 2005]. Common wheat cultivation during few consecutive years increases the amounts of weeds. Proper selection and the dose of herbicides significantly reduce weed infestation, meanwhile their application in wheat monoculture effects on herbicidal effectiveness and causes it very low [Blecharczyk et al 2007]. Cropping of the cereals in rotation after each other is also very important for the quality of the grain. Wozniak [2004a] found that the monucultural cropping of spring wheat caused the reduction of the quality of grain to compare to the cropping when the fore-crop were root or bean plants.

To mitigate the effects of monoculture crops and improve the quantity and quality of the grain yield are implementation to the practice the various kinds of agricultural bio-preparations which contain in their composition effective microorganisms and organic ashes used to fertilize the soil [Murkowski and Stankowski, 2002; Kuczyńska 2005]. In addition the "no chemical" measures in agricultural techniques to improve soil fertility, which translates into increased crop biomass plant is used in the form of fragmented straw residues [Poplawski 1996] and green manures such as white charlock [Mazur et al 2003]. The manure is also good natural complement to fertilization, that improves the water-air soil properties [Wacławowicz and Tendziagolska 2008].

Material and methods.

The static, three-way field experiment was conducted in 2011 on the plantation of winter wheat. In this trial the impact of effective microorganisms (EM) used in post-harvest straw or stubble (factor A), and in particular interactive effects of treatments with crop cultivation method (factor B), as well as the application of biostimulators (factor C) on the properties of the soil, growth and yield of wheat and occurrence fitofagic entomofauna in terms of increasing monoculture were determined. Experiment will be continued for three consecutive years – up to 2014.

Static system of this experimentation allows to determine and compare the reaction of winter wheat on harvest treatments, the tillage method - in many cases highly reduced, however, to the application of different types of biomass and biostimulator application during growth. Factors A and B determine the response of wheat in the cumulative effect of various degrees of interdependent tillage simplifications, the type of biomass and operation of effective micro-organisms and allow to optimize these factors depending on the duration of wheat cropping after another species. It is possible to compare the effects of environmental conditions. These treatments would be designed to: promote at least maintaining the amount of organic matter in the soil (soil incorporation of manure e.g. straw), limits the mineralization (simplification of cultivation) and reduce the release of carbon dioxide from the soil to the atmosphere, reduce nitrate leaching (using a straw), the soil microbial balance (vaccine EM), to reduce the effects of stress plants (biostimulator), create the benefit population of entomofauna.

Objects of experiment are placed in a mixed (split-plot-split-block) design, in triplicate. As a result, the above-mentioned experiment will be analyzed 32 also arranged in 96 experimental units.

FACTORS AND LEVELS:
Factor A - PRACTICE AFTER HARVESTING:
a1 leaving the chopped straw,
a2 leaving the chopped straw + EM[3)],
a3 removing straw + EM,
a4 removing straw,
Factor B - METHOD OF GROWING ROLE:
b1 the crop stubble cultivator + plowing seed
b2 plowing,
b3 Manure[1)] + cultivator + plowing seed
b4 direct seeding cultivation of winter wheat after no cultivation[2)]
Factor C - USE BIOSTIMULATOR:
c1 use biostimulator[4)]
c2 without biostimulator.

1) - the dosage of manure in both experiments is 30 t·ha^{-1},
2) - assumed to be pre-applied glyphosate for example ROUNDUP Max 680SG dose of 2 kg·ha^{-1}
3) - it was assumed that the dose of effective microorganisms (the active form - the preparation of EM-A derived directly from a licensed manufacturer, GREENLAND TECHNOLOGY EM Sp. z o.o) shall be in accordance with the manufacturer's recommendations and will be 40.0 dm3 EM-A·ha $^{-1}$, for each of two experiments carried out,
4) - in both experiments is assumed to foliar application biostimulator ½ twice the total dose, 2·0.5 dm3·ha^{-1}. The first term is the phase full tillering cereals (BBCH 23-25), the second is the flag leaf stage (BBCH – 39).

Results and discussion

Overall the factor A using the effective microorganisms resulted in the higher yielding of winter wheat when this treatments was applied without straw. In the case where the objects were with straw, regardless of whether there EM used or not, a high concentration of stem base diseases was noticed on wheat plants. Similar effects of straw incorporation also received Smagacz and Sowiński [2005] where they did not notice a significant difference in the yielding of winter wheat on the objects of plowing straw. Some of the varieties tested by these authors, including *cv*. Korweta responded to yield reduction because it was strongly attacked by stem base pathogens. However, effective microorganism preparation did not directly affect crop plants while have a positive effect on the soil, which then spread to better crop yield [Kucharski and Jastrzębska 2005].

In the case of tillage the best results in terms of yield obtained on plots where have been applied the manure mixed with the help of cultivator and then plowed. The lowest yield was obtained on the plots where the cultivator was used and where in general abandoned the treatments (no-tillage). The resulting low yield was due to high competition from weeds within grown plants.

In case of application of biostimulator each of the treatments revealed an increasing effect on the yield compared to those objects where biostimulator was not apply. More advantage results were obtained in the soil conditions with lower qualification. There are only few references describing the impact of bio-stimulators, such as Asahi SL on cereals. In the case of oilseed rape the best results are obtained when the application of Asahi SL is using during the occurrence of adverse weather conditions such as after hail, drought or frost [Kozak and Painter 2007].

Conclusions

After the first year of field study the following conclusions can be stated:

1. Incorporation of the soil with straw contributes to a significant incidence of fungal diseases, caused by pathogens that are able to overwinter on wheat residue, so leading to reduction of grain yields due to strong infestation.
2. The highest yield was obtained using traditional farming methods or skimming along with the ploughing the organic fertilizers (manure for instance).
3. Biopreparation contributed to improve the yield of grain although it should not be treated on an equal footing with mineral or organic fertilizers because bio-substances bring nutrients to the soil and they only improve the health status of soils.

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EFFECT OF POST-HARVEST CULTIVATION USING STRAW AND BIO-COMPOUNDS IN MONOCULTURE OF WINTER WHEAT IN ASPECT OF WHEAT PRODUCTIVENESS, SOIL QUALITY AND HERBIVOROUS INSECTS

Walczak Dorota

Introduction

Cultivation of cereal crops, especially winter forms, in repeated locations is a need resulting from greater participation of this group of plants in the sowing structure. Cereal crops are also being planted on plots which have been temporarily excluded from agricultural production, which is an effect of socioeconomic conditions, as well as lying farmlands fallow intentionally. [Marks and aka 2000, Weber and Hryńczuk 2005, Nowicki and aka 2007]. Pawlonka and Ługowska [2010] stated that winter wheat was a crop reacting strongly to the cultivation in monoculture by crop reduction. The repeated cultivation of the same plant also adversely affects properties of the soil. Jaskulski and Jaskulska [2004] report that planting crops with similar agroecological requirements, limited rotations of plant species and limiting the plant biodiversity on farmland are the cause of soil degradation, and reversing the process is difficult. Changes in soil conditions include macro- and microelement content, deteriorating physical and biological properties and increased weed growth so compensation for troublesome genii is required [Janowiak 1994, tempt with 1998, Deryło and Szymankiewicz 2000]. Simplification of plant structure and the cultivation of cereal crops in monocultures also leads to changes of the yield, the species structure and the activity of organisms, including those responsible for the circulation of matter and the fertility of the soil.

Seeking effective ways of reducing negative effects of cereal crops monoculture requires not only increasing fertilization and plant protection expenditures, but also other, more environmentally friendly elements and agrotechnological treatments. Jaskulski and Jaskulska [2004] point at the significance of plant biomass introduced into the soil. It becomes a precursor for long-lasting organic matter, an energy source for micro - organisms and exerts influence on physical and chemical properties of the soil. Straw can also fulfil such a role [Malicki and Michałowski 1994, Smoliński and aka 1997, Anchor and aka 1998, Andrzejewska 1993]. The influence of plant mass on properties of the soil and plant crops is multifaceted and depends, among other factors, on the kind of soil, its chemical composition as well as the timing and manner of introducing the plant mass into the soil [Jaskulski and aka 1997, Jaskulski 2000, tempt and Jończyk 2000, Jaskulski and Tomalak 2001].

It is possible to achieve beneficial properties of the soil and sustain them by using a treatment of micro-organisms, especially in conditions of inflow of postharvest remains, including straw. Though effectiveness of this treatment in domestic conditions has not yet been sufficiently investigated, the few studies and farming practice are encouraging and suggest the issue should be explored further [Kaczmarek and aka, 2007, 2008, Anchor and aka 2011, Piskier 2006]. Studies indicate that introducing selected micro-organisms into the soil can improve and direct its microbiological activity, [Kaczmarek and aka 2007, 2008b, Javaid 2010, Schenck and Müller 2009] increase the rate of organic matter transformation [Zydlik and Zydlik 2008], change the physical properties of the soil [Higa 1998, Kaczmarek and aka 2007 and 2008 ah, Schenck and Müller 2009, Valariani and aka 2003, Piskier 2007] or limit pathogen development [Stępień and Adamiak 2009]. Moreover, a positive effect of preparations containing micro-organisms on plant productivity has been demonstrated [Chaudhry and aka, 2005, Hussain and aka, 1999, Khaliq and aka, 2006, Anchor and aka 2011].

Hypothesis

Scientific literature about complementary, interchangeable and interdependent influence of particular agrotechnologies supports an assumption that soil properties, winter wheat crop yield and herbivorous insect population will depend on the use of straw and biopreparations. The expected reaction of the winter wheat to the way of applying research factors will most probably be a diversification of the final effects of the cultivation of winter wheat: production, environmental, energy and economic.

Purpose of research

The scientific purpose of the projected study is determining the effects of different methods of applying straw and biopreparations on winter wheat productivity, specific soil properties and herbivorous insect populations in short term monocultures.

Specific objectives are:

- determining the influence of different ways of introducing straw and biopreparations on winter wheat production,
- evaluation of soil properties change and harmful weed growth after introducing straw and preparations containing micro-organisms,
- determining the influence of experimental factors on most important herbivorous insect species populations in winter wheat,
- evaluation of the difference of energy yield by comparing the crop production and costs with and without straw and biopreparation application.
- determining and comparing the direct surplus of winter wheat depending on experimental factors.

Material and methods

Experiment set-up

In 2010 a static, two-factor field experiment was established on a prepared plot where winter wheat was previously cultivated. The experiment will determine the influence of applying straw (factor A) and biopreparations (factor B) on soil properties, winter wheat height and yield as well as the population of herbivorious insects in the growing monoculture. Experiments are carried out during three consecutive years - ending with summer of 2013. The static arrangement of the experiment will allow for determination of winter wheat reaction to introducing straw and/or micro-organism preparations into the soil. Objects of factors A and B will determine the reaction of winter wheat to the intensifying interdependent effect of different ways of applying straw and biopreparations. A comparison will be possible not only of the yield effects of the examined agrotechnological treatments but also environmental effects. Treatments applied in the experiment can influence the content of the organic matter in the soil, macroelement content of the soil, its pH, microbiological properties as well as the population of herbivorous insects.

Objects of experiments were arranged in a dependent layout of equivalent subblocks (split-block), with four repetitions. As a result, 15 objects placed on 60 experimental individuals are being analysed.

Factors and levels

Factor A - Way of straw introduction::

1. fragmented straw + mineral nitrogen + postharvest cultivation + ploughing cultivation,
2. fragmented straw +postharvest cultivation +ploughing cultivation,
3. postharvest cultivation+ ploughing cultivation,

Factor B - Way of applying biopreparations::

1. EM-1 into the soil** in the period of postharvest cultivation,
2. EM-1 into the soil (in the period of postharvest cultivation) and on the leaf surface (in the spring after growth begins)
3. UGmax into the soil. *** in the period of postharvest cultivation
4. UGmax into the soil (in the period of postharvest cultivation) and on the leaf surface (with spring after growth begins)
5. without biopreparations (control)

** * - it is assumed that the vaccine dose of effective micro-organisms (concentrated EM-1 form) will match of manufacturer's recommendations and will amount to 5.0 dm^3 EM-1 ha^{-1} of grinded down straw or stubble field or 3.75 dm^3 EM-1 · ha^{-1} of ground straw or stubble field and 1.25 dm^3 EM-1 · ha^{-1} on the leaf surface in the spring after growth of winter wheat begins.*

** * * - dose in accordance with manufacturer's recommendations i.e. 1dm^3 ha^{-1} of UGmax preparation - of ground straw or stubble field* ***or*** *0.7 dm3 ha^{-1} of UGmax preparation. in the postharvest period into ground straw or into the soil of the stubble field and 0.3 dm^3 ha^{-1} of UGmax preparation on the leaf surface in the spring after growth of winter wheat begins.*

	EM with post-harvest cultivator	EM with post-harvest cultivator + on the leaf surface in the spring	UG_{max} with post-harvest cultivator (0,9)	Ugmax with post-harvest cultivator (0,6) + on the leaf surface in the spring (0,3)	CONTROL
Straw + cultivator + ploughing					
Straw + N + cultivator + ploughing					
cultivator + ploughing					

Figure 1. Arranging objects of experience on experimental individuals as part of isolated repeating

After postharvest cultivation, basic cultivation on all experimental plots consists of ploughing and sowing at an average depth and of seasoning the field directly before sowing with a double pass of a passive cultivation unit.

Location and scope of the field experiment

Experiments are carried out in the Mochełko Research Station which belongs to University of Technology and Life Sciences in Bydgoszcz, on good rye soil. Agrotechnological treatments in field experiments are performed according to principles of medium-intensive cultivation of wheat: fertilizing with nitrogen in the dose of $120 kgN \cdot ha^{-1}$, phosphorus-potassium fertilization in accordance with soil affluence, improved sowing material, herbicide protection against weeds. After marking the degree to which stalks and leaves are affected by illnesses one mycocide treatment in the phase BBCH 37-39 shall be performed. Before the start of the experiment (2010) soil samples were taken from each individual plot. The samples were examined for:

- $pH_{in\ KCl}$ (PN-ISO 10390:1997),
- organic carbon content (Tiurin method),
- nitrogen content (Kjeldahl method),
- assimilable forms of phosphorus, potassium, magnesium content (Egner-Riehm method PN-R- 04023: 1996, PN-R- 04022: 1996 and Schucht Schabel method PN-R- 04020: 1994),

After the conclusion of the experiment in the summer of 2013 a similar procedure will be performed.

Results and discussion

The measurement and biometric marking results will be subjected to variance analysis using models appropriate for isolated experiments as well as syntheses of repeated two-factor experiments, in the layout of equivalent subblocks. The significance of average value differences on individual plots will be estimated with the Tukey test with a p value of 0.05. An Excel spreadsheet will be used for keeping inventory, preliminary preparation of results, calculations of the energy effect and the direct surplus.

The average yield of wheat grain on the experimental plots in 2012 amounted to 3.37 t $\cdot ha^{-1}$. The greatest grain yields were achieved on the plot from which straw was removed and soil fertilizer was administered twice (to the soil and to the leaf). The smallest grain yield occured where cultivation using straw was conducted and no micro-organisms preparations were applied (tbl. 1). Statistical verification of achieved yield results showed that wheat grain yield was significantly influenced by the method of developing the stubble field (factor A) and application of micro-organism preparations (B factor) (tbl. 1). On the plot into which straw was ground ahead of sowing the crop, yield (2.82 • ha-1 t) turned out to be significantly smaller in comparison with the two other methods of developing the stubble field. The yield was about 24% smaller than on plots on which in the course of the postharvest cultivation straw was removed and smaller by 21.2% than on plots on which mineral nitrogen was applied before mixing straw with the soil (tbl. 1).

Table 1: Wheat grain yield depending on the way of postharvest cultivation using straw and applications of microorganism preparations in 2012

POSTHARVEST CULTIVATION USING STRAW (A)	APPLICATIONS OF PREPARATIONS CONTAINING MICRO-ORGANISMS (B)					Average for A
	control	EM 1x	EM 2x	$UG_{max.}$ 1x	$UG_{max.}$ 2x	
cultivator + ploughing	3,29	3,64	3,89	3,66	4,06	**3,71**
Straw +cultivator +ploughing	2,61	2,92	3,16	2,68	2,74	**2,82**
Straw+N+cultivator+ploughing	3,47	3,42	3,84	3,46	3,76	**3,59**
Average for B	**3,12**	**3,33**	**3,63**	**3,27**	**3,52**	**3,37**

$NIR_{p=0,05}$ for: A = 0,768 B = 0,361 A/B = n.i. B/A = n.i.

Differences in wheat grain yield observed during the course of the experiments on plots where microorganism preparations were being administered were confirmed statistically. The average yield of the grain from these objects was 10.2% larger than on control plots. They proved, that two-time application of preparations (in the period of the postharvest cultivation to the soil and to the leaf in the spring) increases the yield of wheat grains siginificantly- in the case of EM preparation by 16.3% and in the case of UGmax applied to the soil by 12.8%. The test plots where straw was removed after harvest showed significantly smaller quantities of harmful weeds (tbl. 2). The average weed population determined in such conditions was 27.2% smaller than on plots where ground straw of the previous crop was mixed with the soil. No significant influence of biopreparation application on harmful weed populations was observed.

Table 2: The number [units per m^2] of wild weeds depending on the way of developing the stubble field and the application of biopreparations - autumn 2012

POSTHARVEST CULTIVATION USING STRAW (A)	APPLICATIONS OF PREPARATIONS CONTAINING MICRO-ORGANISMS (B)					Average for A
	Control	EM 1x	EM 2x	$UG_{max.}$ 1x	$UG_{max.}$ 2x	
cultivator + ploughing	58	55	50	45	51	51
Straw +cultivator +ploughing	70	70	71	74	73	72
Straw+N+cultivator+ploughing	69	69	67	71	63	68
Average for B	66	65	62	63	62	64

$NIR_{p=0,05}$ dla: A = 12,2 B = n.i. A/B = n.i. B/A = n.i.

The amount of carbon dioxide released by the soil turned out to be greater, compared to the test plot, on plots where during postharvest cultivation microbiological preparations were administered into the soil (fig. 1). Moreover a tendency for carbon dioxide emission reduction over time was observed on test plots after application of biopreparations during postharvest cultivation.

Chlorophyll content was determined based on the leaf greenness index (SPAD). This indicator is universally recognised as the measure of plant nitrogen saturation. Table 3 contains averages of three SPAD readings on dates in the spring period (BBCH 23-25; BBCH 39-49; BBCH 62-66). A statistical analysis of achieved results showed a significant influence of biopreparations application on the chlorophyll content and their coordination with the method of developing the stubble field.

Straw introduction into the soil without additional application of mineral nitrogen increased the SPAD value, although the increase was statistically insignificant (tbl. 3). Biopreparation use increased the value of the SPAD indicator, including especially a two-time application of UGmax (tbl. 3). If this trend continues in the third year of examinations, it can point to better plant nitrogen saturation on plots where biopreparations are applied.

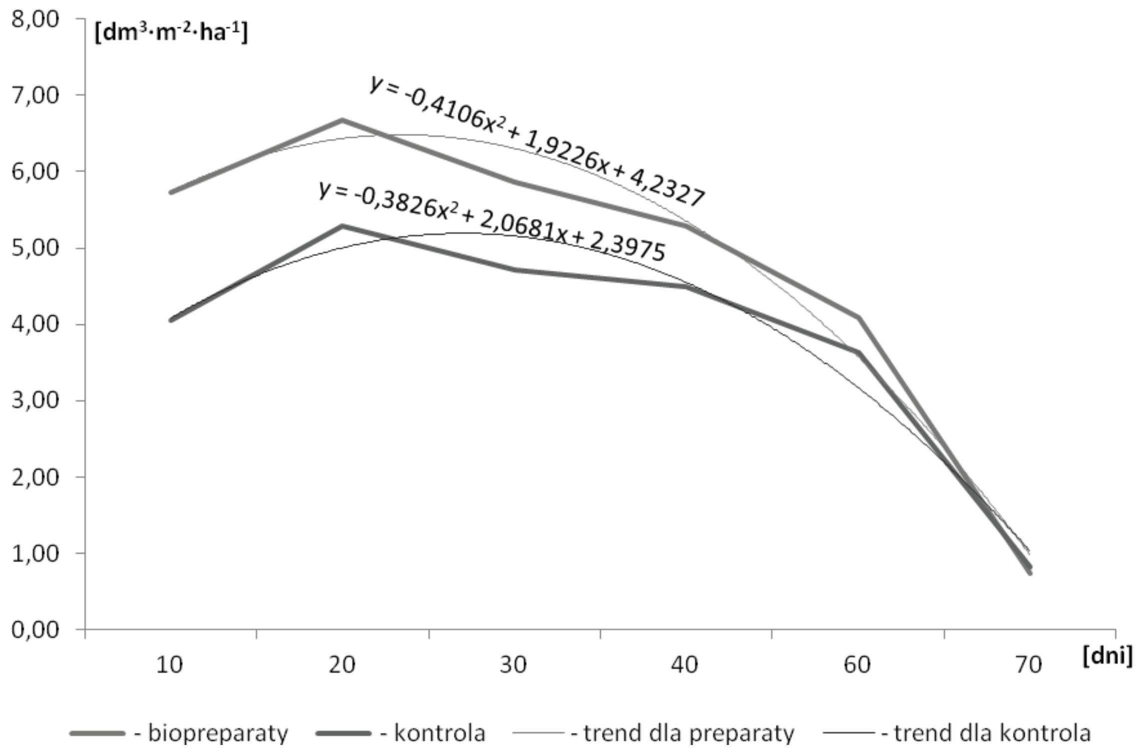

Figure 1: Carbon dioxide emission from the soil after biopreparation application with regard to the amount of days passed from their application.

Table 3: Value of the SPAD indicator in wheat, depending on methods of developing the stubble field and application of biopreparations in the spring of 2012.

POSTHARVEST CULTIVATION USING STRAW (A)	APPLICATIONS OF PREPARATIONS CONTAINING MICRO-ORGANISMS (B)					Average for A
	Control	EM 1x	EM 2x	$UG_{max.}$ 1x	$UG_{max.}$ 2x	
cultivator + ploughing	640	647	612	627	663	638
Straw +cultivator +ploughing	498	609	621	637	667	606
Straw+N+cultivator+ploughing	589	638	651	663	681	649
Average for B	576	631	628	642	670	629

$NIR_{p=0,05}$ dla: A = n.i. B = 11,1 A/B = 101,3 B/A = 30,6

Biopreparation application increased the SPAD value by 135 units on average where ground straw was introduced into the soil without the addition of mineral nitrogen and only by 69 units when straw was added. An interesting observation can be made - in conditions of the traditional postharvest - pre-sowing cultivation the application of biopreparations did not affect the value of the SPAD indicator. Moreover, taking into account the differences of SPAD values on control plots differing in stubble field cultivation method, it can be theorised that the application of micro-organisms is beneficial especially when straw is introduced into the soil - this thesis requires the verification in the consecutive vegetative season, however (tbl. 3).

Soil thickness analysis performed in the autumn period of 2012, after two years of applying experimental factors on individual plots in static arrangement, showed a significant relation of the way of developing the stubble field and the application of biopreparations on this soil property. Introducing ground straw into the soil in the consecutive year as well as application of biopreparations reduced the soil thickness in the 0-25cm layer (tbl. 4). Two-time application of biopreparations - into straw before introducing it into the soil and in the spring on growing wheat was shown to significantly reduce potential resistance of the soil to machines and cultivation tools.

Table 4: Average soil thickness [$kN \cdot cm^{-2}$] in the 0-25cm layer from three autumn measurements, depending on the way of developing the stubble field and the application of biopreparations - in autumn 2012.

POSTHARVEST CULTIVATION USING STRAW (A)	**APPLICATIONS OF PREPARATIONS CONTAINING MICRO-ORGANISMS (B)**					**Average for A**
	Kontrol a	EM 1x	EM 2x	$UG_{max.}$ 1x	$UG_{max.}$ 2x	
cultivator + ploughing	0,56	0,47	0,38	0,48	0,40	0,46
Straw +cultivator +ploughing	0,43	0,35	0,34	0,36	0,36	0,37
Straw+N+cultivator+ploughing	0,36	0,32	0,32	0,32	0,29	0,32
Average for B	0,45	0,38	0,35	0,39	0,35	0,32

$NIR_{p=0,05}$ dla: A = 0,069 B = 0,076. A/B = n.i. B/A = n.i.

Conclusions

After the second year of the experiment: "Effect of postharvest cultivation using straw and bio-compounds in monoculture of winter wheat in aspect of wheat productiveness, soil quality and herbivorous insects " some previously observed trends were confirmed, others rejected. This concerns especially the possibility of relieving the increasing monoculture effects by way of methods analysed during the experiments. 2012 results confirmed the previous years' observations of disadvantageous influence of introducing straw of the previous harvest - especially without the addition of mineral nitrogen - on the yield of wheat grain and the population of harmful weeds. The plots where biopreparations are applied show tendencies towards bigger wheat grain yield, more intensive soil respiration and an increase of the SPAD value which require this factor's impact further examination. Additionally, ambiguous findings of 2012 can be attributed to conditions of the 2011-12 vegetative season - a very frosty winter (I-II 2012) and poor state of the plants in the initial period of spring growth. Presented results and whether observed trends will continue shall be verified during the third year of lasting examinations.

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THE ROLE OF PRECISION AGRICULTURE IN SUSTAINABLE CROP MANAGEMENT

Lukas Vojtech, Neudert Lubomir, Kren Jan, Novak Jaroslav

Introduction

Precision agriculture or *site specific crop management* is internationally unified term for directions of land management using new technologies that began to be developed in the eighties and early nineties of the twentieth century. The aim of precision agriculture is an optimization of production inputs (fertilizers, pesticides, fuel, etc.) based on the local crop requirements and plants requirements. Crop management in this way can lead to the effective use of agrochemicals and avoid of environmental risks. Site specific management, known as a precision agriculture, takes into consideration spatial variability within fields and optimizes the production inputs, thus fulfilling the objectives of sustainable agriculture (Corwin and Plant, 2005).

The aspects of precision agriculture (PA) are described by Pierce and Nowak (1999). They defined precision agriculture as “the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production for the purpose of improving crop performance and environmental quality”. Gebbers and Adamchuk (2010) describe three goals of precision agriculture: 1. to optimize the use of available resources to increase the profitability and sustainability of agricultural operations, 2. to reduce negative environmental impact, 3. to improve the quality of the work environment and the social aspects of farming, ranching, and relevant professions.

Assessment of variability

Pierce and Nowak (1999) consider assessing variability as the critical first step because one cannot manage what one does not know. The factors and properties that regulate crop growth and yield vary in space and time. The higher is the spatial variability of a soil conditions (or crop properties), the higher is the potential for precision management and the greater its potential value. The degree of difficulty, however, increases with higher dynamics of temporal component.

The consequences of site variability are most reflected in the crop yield. The variability of yield represented by yield maps can serve as input information for decision about site specific management. If there is not known the cause of yield variability, the uniform crop management is suggested (Adamchuk et al., 2010, see Figure 1). Site specific management can be recommended if the spatial structure of yield differences are consistent over multiple years and correspond to some agronomically important phenomena (nutrient supply, topography, land use history, ...).

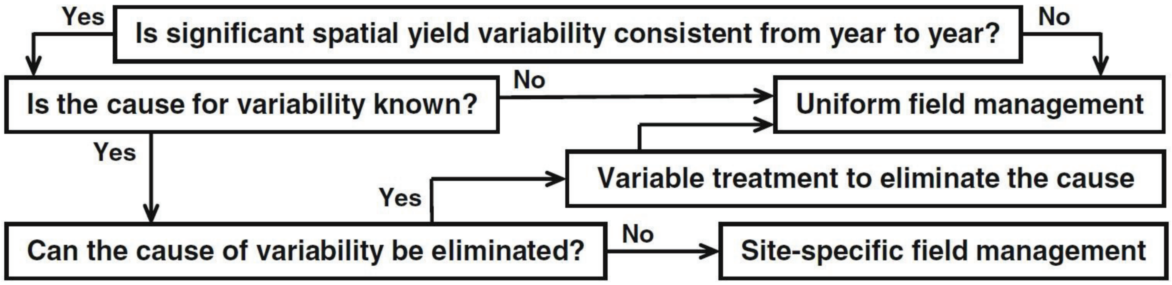

Figure 1: Yield-based decision making tree for application of site specific management (Adamchuk et al., 2010).

Techniques for assessing spatial variability are readily available and have been applied extensively in precision agriculture. The conventional techniques of soil variability mapping are slowly replaced by indirect methods such as the on-the-go systems (see overview by Adamchuk et al., 2004) or remote sensing. These methods have more intense spatial coverage but are less accurate compared to laboratory procedures (Christy, 2008). Soil electrical conductivity (EC) has become one of the most frequently used measurements to characterize field variability for application to precision agriculture (Corwin and Lesch, 2003). The soil electrical conductivity is influenced by combination of physico-chemical properties including soluble salts, clay content and mineralogy, soil water content, bulk density, organic matter, and soil temperature (Corwin and Lesch, 2005). A number of factors complicate the direct application of EC in site specific management, because the interpretation of EC maps requires the determination of the dominant soil factor.

Other category of sensor mapping is remote sensing. These techniques use the spectral characteristics of soil surface to determine the soil heterogeneity. Baumgardner et al. (1986) present an overview of spectral properties of soil. Like the EC methods, remote sensing cannot be used to determine specific soil properties without additional soil survey.

Techniques for assessing temporal variation also exist but the simultaneous reporting on spatial and temporal variation is rare and the theory of these types of processes is still in its infancy (Pierce and Nowak, 1999).

Modern technologies utilized in precision agriculture

Basic principles of precision agriculture are not new, the spatial and temporal variability of soil and crop was recognized by farmers centuries ago. Smaller parcels with natural boundaries allow changing the agrotechnical treatments manually. With the merging of parcels and intensification of production and mechanization in the middle of the last century, it was no longer possible to take into account the spatial variability. These technologies include global navigation satellite systems (GNSS), geographic information systems (GIS), information and communication technologies (ICT) and sensors.

Figure 2: Graphical list of modern technologies utilized by precision agriculture (Author: V. Lukas)

Global Navigation Satellite Systems (GNSS) provide autonomous geo-spatial positioning with global coverage. It allows to determine using GNSS receiver precise real-time localization on Earth surface. Currently (August 2013) only the United States *NAVSTAR Global Positioning System* (*GPS*) and the Russian *GLONASS* are global operational GNSSs. China is in the process of expanding its regional *Beidou* navigation system into the global *Compass* navigation system by 2020. The European Union's *Galileo* positioning system is a GNSS in initial deployment phase, scheduled to be fully operational by 2020 at the earliest. France, India and Japan are in the process of developing regional navigation systems. There are many free or commercial services available for navigation of agriculture machinery based on the required accuracy and technology of correction signal broadcasting.

Geographical Information Systems (GIS) are widely used for processing and analysis of geospatial data and their representation in form of maps. In addition to spatial (graphic) representation of the object is important their description in the form of attribute table. Track logs of machinery, field boundaries, soil sampling data and yield maps – that are all spatial data, which are created and displayed using GIS.

Sensor systems are an alternative to conventional (and expensive) techniques **for** mapping of soil and crop variability. Pierce and Nowak (1999) consider that sensors are critical to success in the development of a precision agricultural system for three important reasons: 1. Sensors have fixed costs, 2. sensors can sample at very small scales of space and time, and 3. sensors facilitate repeated measures. Disadvantage of sensor measurement is lower accuracy compared to laboratory procedures. However, it is compensated by more intense spatial coverage (Christy, 2008).

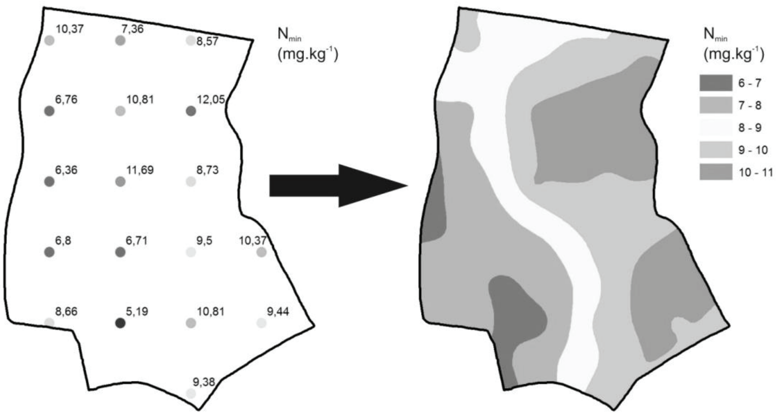

Figure 3: An example of creating continuous soil map from sampling point data using spatial interpolation techniques (Author: V.Lukas).

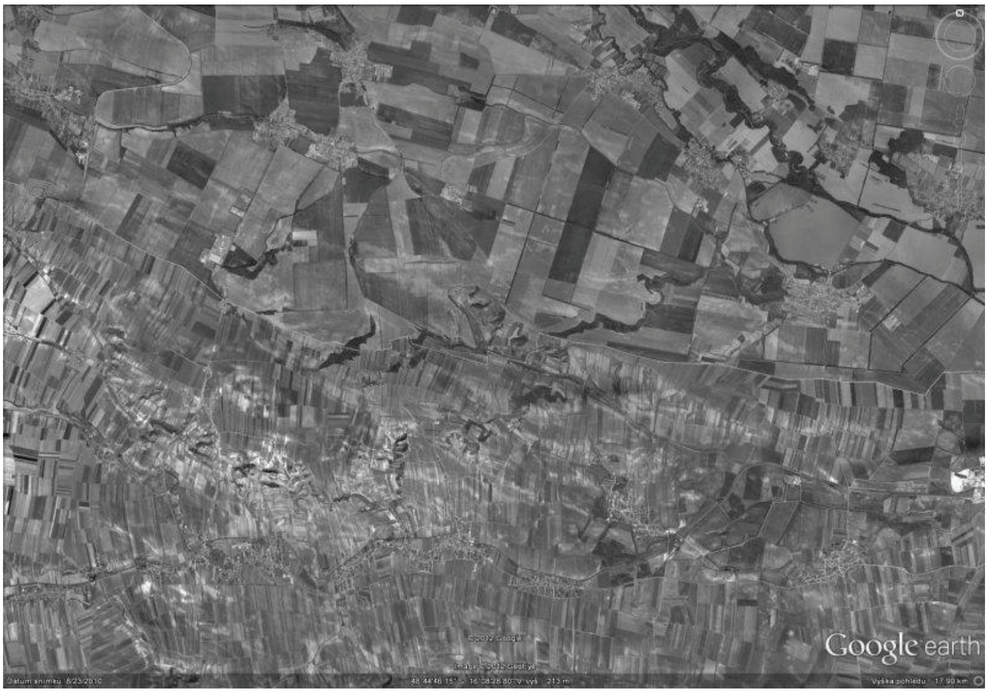

Figure 4: Satellite image of Czech (upper part) - Austrian border line with obvious differences in field size (Source: Google Earth).

Implementation of site specific crop management in Czech Republic

Precision agriculture is developed mainly in agriculturally advanced countries, but also can be seen worldwide trend of growing interest in this method of farming. In practice, the largest application is in the USA, which can be explained by specific agrarian structure (large area farms) and high level of utilization of technologies. Unlike Western Europe, the Czech agrarian structure suitable for the application of PA technologies – domination of large farms and fields, diversity of geological, pedological, hydrological and climatic conditions together with combination of topography). A disadvantageous is the prevailing unfavourable economic situation of the farms, which complicates the purchase of new (often very expensive) technologies (machinery) and payment PA services. The implementation of precision agriculture technologies is under considerable economic pressure. For all that the interest for PA technologies is increasing and also suppliers of agricultural machinery, fertilizers and pesticides take this system into account in near future. The focus is currently in providing the services for farmers.

Precision agriculture and sustainability

Most of the papers reviewed by Bongiovanni and Lowenberg-Deboer (2004) indicate that precision agriculture can contribute in many ways to long-term sustainability of production agriculture, confirming the intuitive idea that site specific management should reduce **environmental** loading by applying fertilizers and pesticides only where they are needed, when they are needed. As the authors remark, only a few studies actually measured directly the environmental indices, such as leaching with the use of soil sensors; most of them estimated indirectly the environmental benefits by measuring the reduced chemical loading. Due to the benefits for the farm economy, for the environment and on the long run for the region and its people, the technology of precision farming can bring a substantial step for land use towards a more sustainable development in land use. Local resources can be easier managed properly, due to detailed and abundant information and specific control possibilities (Werner et al., 2005).

Table 1: The relevance of site specific measures for crop production and environmental protection (Werner et al., 2005).

Cropping measure	**Varying effects on yield formation**	**Relevance for**	
		Crop production	Environment / nature
Primary soil tillage	Depth	++	+
	Intensity	+++	++
Sowing	seed bed preparation	++	+
	sowing rate	+++	++
	Distribution of plants over the field area	++	0
	sowing depth	+++	0
Fertilisation	nutrient type	++	+++
	nutrient amount	+++	+++
Weed control	type of weed control	0	++
	Selection of herbicide and additions	++	+++
	Spraying rate	+++	+++
Application of	type of action	+	+++
Insecticides	Selection of pesticide and additions	+	+++
Fungicides	Spraying rate	+++	+++
Plant growth regulators	Application rate	+++	++
Work flow	action control (trafficability due to soil moisture etc.)	+++	+
	Production related information flows	+++	0
	Supervision of the farm	+++	+++

0 = no relevance; + = weak influence, ++ = moderate influence, +++ = strong influence

In case of **economic** evaluation is presumed a decrease of total amount of chemical or other farm inputs and its more efficient use by variable rate application. Koch et al. (2004) reports in their study that variable rate N application utilizing site-specific management zones are more economically feasible than conventional uniform N application. But for complete analysis of economic benefits of PA, there is not yet enough experience with this new technology and especially too few farms use this technology at the moment (Werner et al., 2005).

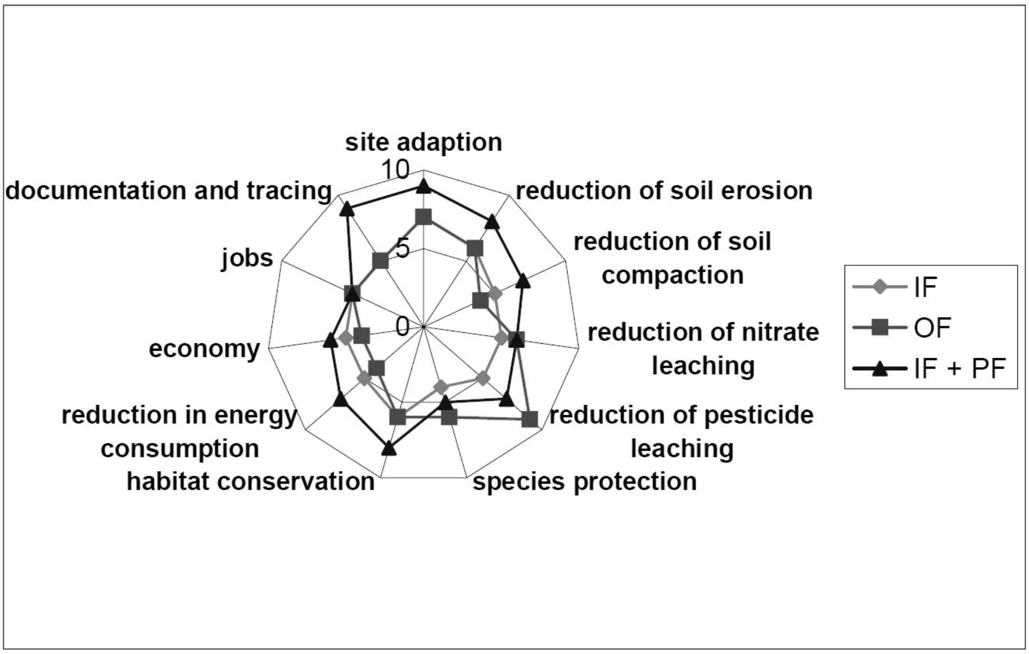

Figure 5: Impact of the crop management strategy ‚integrated farming' (IL), ‚organic farming' (OL) and ‚integrated farming with precision agriculture' (IL + PA) onto indicators of sustainable development in agricultural land use (qualitative assessment based on expert judgement according to the actual available knowledge in literature; mark1 up to mark 9; mark 9 = best state), (Werner et al., 2005)

Precision agriculture research issues

McBratney et al. (2005) describe six critical research issues which require urgent and ongoing attention by researchers to develop the PA concept to its full potential (besides the crucial policy issues):

Appropriate criteria for economic assessment of PA

Perhaps the biggest generic barrier is a well-constructed quantitative formulation of optimisation criteria for cropping management that includes environmental impact. A complete criterion would encompass all aspects of the PA concept: spatial and temporally induced variability of yield, profitability of the agricultural enterprise, sustainability of the resource base (soil and water), environmental issues and the value of information. These criteria may be designed specifically for different management hypotheses (e.g. uniform, zone and continuous management) and assessed in a single loop of sequential testing. Negative (or positive) environmental effects that are associated with the farming practice have to be taken into account when conducting an analysis from a social perspective.

Insufficient recognition of temporal variation

The assessment of spatial variability within the field becomes very familiar by various mapping techniques and sensors, but there is a lack of information about temporal variation. As McBratney et al. (2005) remark, that if we look at the variation of yield across a field and across years, half of the variation comes from year-to-year variation. Knowledge of this temporal aspect needs to be greatly increased. Some have recognised parts of fields which are temporally stable and others which vary from year to year—this allows better management of weather and climatic risk. A second issue is within-season management. Fine-tuning of within-field operations with split applications using feedback from crop monitoring is clearly a promising way of optimising inputs.

Lack of whole-farm focus

Most of studies consider single or several fields on experimental farms. The challenge for precision agriculture is to become an integral part of the normal farming process. It is necessary to be able to distinguish management zones cost effectively at large scales to select the fields which are most suitable for precision management.

Crop quality assessment methods

Some of the competitive advantage of precision agriculture will come from the in-field separation of product into quality classes. Economic benefits will come especially if there are non-linearities in the payment of quality premiums for high-value crops.

Product tracking and traceability

Consumers are demanding more information on the food products they purchase, especially in Europe by the GMO issue. Precision agriculture offers the possibility of tracking product through a system. Currently there is a limited amount of product tracking.

Environmental auditing

The ability of farmers to demonstrate the operations and associated fertiliser/chemical rates that have been applied across a farm. The audit of environmental effects should be focused rather on the environmental goals to be achieved than on the *means* to achieve environmental objectives. Research is needed to develop protocols for using data gathered through PA technologies and this requires inclusion of lawyers and institutional experts in the research teams.

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ENVIRONMENTAL AND YIELDING ASPECTS OF CONVERSION TO ORGANIC FARMING – A CASE STUDY

Tyburski Józef, Stalenga Jarosław, Kopiński Jerzy

Introduction

Surface water bodies, both inland lakes and the Baltic See, are threatened by growing eutrophication. About 70 % of the total nitrogen (N) and phosphorus (P) load comes from human activities. This is the reason for the increased eutrophication of the Baltic See. Moreover most of this pollution (59% N and 55 % P) comes directly from agriculture and another part comes indirectly, through the food production as human wastes (data based on HELCOM, 2005). Therefore, it seems to be rationale strategy for reduction of N and P loads to water bodies to minimize the surplus of N and P in agriculture. This leads to initiative of Ecological Recycling Agriculture (ERA) and local food systems in the eight EU-countries in the Baltic See drainage area. Surplus of nitrogen was 36 kg per ha compared to the conventional farm average of 56 kg per ha for the eight countries today, which include low input agriculture in the Baltic States (Estonia, Latvia, Lithuania) and in a major part of Poland. All organic farms with an animal stocking rate below 1.0 LU per ha had a surplus below 50 kg N/ha and can be defined as ERA-farms with animal production based on minimum 85 % of own fodder.

The paper deals with the environmental and economic consequences of development of organic pig production in a family farm located on sandy soils near Gdansk, north Poland. The data were collected during realization of EU INTERREG IIII B project BERAS Implementation (Baltic Ecological Recycling Agriculture and Society) focused on the potential of reducing N and P load to the Baltic Sea by increasing the efficiency of nutrients recycling within the agricultural system according to the principles of organic farming with an integration of crop and animal production and self-sufficiency of fodder [Granstedt, 2000].

Material and methods

The study deals with the changes found on 130 ha family farm (73 ha of arable land) located on sandy soils of ca. 28 points (in a scale where the best quality soils receive a score of 100 points), in the region of Gdansk. Positive side of having sandy soil is a good possibility to mechanical weeding, although denuded countryside and lots of stones, make it somewhat more difficult (especially in of row crops). Besides low quality soils another problem is low precipitation which usually did not meet needs of most crops grown (especially in spring time). Sandy soils are also more prone to nutrient leaching. The content of available plant nutrients on the farm was medium in P, but content of K was low to very low. In order to meet crop needs (to make them more resistant to dry periods and receive good yields) mineral K fertilizers allowed in organic farming have to be used. The soil pH values were between 4.1 and 6.1. As on prevailing pH was much too low liming of subsequent fields was initiated in 2012. Although sandy soils have low yielding potential, it is commonly acknowledged that heavy soils are not suitable for organic farming as they are difficult to cultivate and their high yielding potential is better exploited in the conventional high input system.

An inquiry study was made to collect data on farm management before the conversion and development of organic methods of production after the conversion. They were two sets of data: the first related to crop and animal husbandry (yields) and the second related to inputs and outputs of nutrients to calculate nutrient balance. The balance was calculated according to IUNG Pulawy (Institute of Soil Science and Plant Cultivation – Sate Research Institute) nutrient balance calculation programme "Mcrobil".

Results and discussion

Changes in crop husbandry

During conventional management the main crops grown were cereals and blue lupine (tab. 1). The cereals were grown rather intensively (ca. 130 kg of N per ha) with frequent application of herbicides and fungicides. The average yields of cereals were ca. 3.6 t per ha. Own cereals were used for feed enriched with high protein supplements (mainly with imported GM soybeans). Pigs were kept in a no-bedding system, so slurry was the main organic manure. The stocking rate was over 2.0 LU per ha.

Table 1: Yielding of main crops during conventional managemnet (2004) and after conversion to organic system, t per ha

Specification	Data for:			
	2004*	2011	2012	2013
Winter triticale	3.5	-	-	2.0
Winter rye	-	1.2	-	1.5
Cereals mix	4.0	-	1.8	2.5
Spring wheat	-	2.5	3.0	-
Grain maize	-	-	8.5	9.0**
Cereal / pulses mix	-	2.0	1.5	1.5
Blue lupine	1.8	-	-	-
Soybean	-	-	2.2	2.3

* last year of conventional management ** as estimated on 23 September 2013

It is a visible lack of appropriate organic management which resulted in very low yields. Just after the conversion the farmer believed that in organic system the nature will do the job instead of him. As a result average cereal yields has dropped below 2.0 t per ha.

He has “forgotten” to regulate the soil pH and to keep at least a medium level of available nutrients. Moreover weed infestation (especially with Elymus repens) was high.

In 2012 the farm joined EU BERAS Implementation project and started to co-operate with an organic agricultural adviser. First of all soil pH was adjusted to neutral level and soil was fertilized not only with FYM but also with mineral K and Mg fertilizers. After introduction of red clover (mainly for N fixation and humus building), cereals were grown on smaller part of arable land. As because traditionally grown cereal species as rye, triticale, mixture of oats and barley are not responding well to FYM fertilization the farmer started to grow grain maize. The yields of maize grain in 2012 were promising (ca. 8.5 t per ha) and for this year seems to be even higher.

Before convesrion to organic farming blue lupine was one of the main crops of the farm (utilizing 22% of land) and a major source of protein for pigs. Unfortunatelly after outbreak of anthracnose (Gloesporium sp.) its yields dropped from 1.8 to 0.5 t per ha, so it was decided not to grow it any more. It means that farm had to rely on externat protein sources for pigs fodder. No pulse crops were grown untill 2012 when the farmer successfully started to grow soybeans (the crop was completely unknown in the area). At the beginig it was just 0.5 ha and in 2013 soybeans acreage was increased to 4.5 ha. Yields are very promising, so self-sufficiency in protein will be reached (table 2).

Table 2: Harvested and purchased cereals and pulses and fodder self-sufficiency level.

Years	Cereals			Pulses		
	harvested, t	purchased, t	Self-sufficiency, %	harvested, t	purchased, t	Self-sufficiency, %
2004*	180	20	90%	25	15	**63%**
2011	79	12	87%	0	10	**0%**
2012	88	10	90%	1	8	**11%**
2013	120	0	100%	10	0	100%

* last year of conventional management

The volume of harvested cereals and protein crops affect fodder self-sufficiency of the farm. During conventional management the level of 85% of grain self-sufficiency was met and was almost met in a case of protein crops (table 2). During organic management beside low yields of cereals due to dramatic decline in animal husbandry the self-sufficiency criteria for grain were met. In 2011 and 2012 because of stopping of lupine growing almost all pulses had to be purchased. Thanks to successful introduction of soybeans in 2013 full self-sufficiency in protein crops was obtained. So the changes in cropping pattern and namely introduction of new crops enable to achieve higher yields and full fodder self-sufficiency. It is worthy to emphasize that in organic system maize gives grain yields 4-times higher than typical cereals of the region and soybeans give seed yields 3-4-times higher than lupines.

Changes in animal husbandry

The dramatic decline in grain and pulses production strongly affected animal husbandry. In the the last year of intensive conventional production (2004) they were 40 sows kept and 684 heavy hogs sold yearly and in 2011 there was a dramatic decline in the number of sold pigs (table 3). It was clear that the Polish pig cross-bred of the Large White Polish x Polish Landrace (WBP♂ × PBZ♀) was not right for free range system and the main problem was low number of piglets weaned per 1 sow – the farm was close to bankrupcy. It made the farmer to switch from the Polish to Danish cross-bred Danhybryd x Duroc. After the change of breed number of weaned piglets per 1 sow increased from 12 to 20.

Table 3: Livestock production during conventional management and after conversion to organic system.

Specification	Data for:		
	2004*	2011	2012
No of weaners sold	-	272	-
No of heavy hogs sold	684	58	240
Total liveweight sold, t	72	13**	35
Stocking rate, LU per ha	2.03	0.5	0.94

* last year of conventional management ** including total liveweight of sold weaners

After the conversion there was a dramatic decline in liveweight of pigs sold (from 72 t in 2004 to 13 t in 2011). In general, in 2012 a good improvement was observed thanks to changes made (pig breed and type of pasture - from forest to red clover pasture), so the total liveweight of sold hogs increased to 35 t. During conventinal managemnet livestock density was 2.03 and after convesrsion droped to 0.5 LU per ha. In 2012 it raised to 0.94 LU per ha. At present the level of sold prok is half of the production during the conventional management, but taking into account environmental constrains it should not be higher. It is believed that stocking density on ERA organic farm should not exceed 1 LU per ha.

Changes in the environment

The farm fields are bordering a small 2 ha lake. During the time of conventional management of the farm the lake was contaminated. There were two reasons for the situation:

1) use of no-bedding system and thus slurry application on the fields,

2) high stocking rate and high rates of synthetic N application (ca. 135 kg N per ha) with rather low grain yields (3.6 t per ha).

Slurry as a liquid form of manure is very prone to loses, also in the form of surface run-off (the farm is located in denuded countryside) and the utilization rate efficiency of N is also very low. After the conversion pigs are kept on straw bedding so FYM is produced, which is easy to storage and its utilization is more effective.

Nutrient balance of cereals mix and grain maize

During conventional management 135 kg of N per ha was applied in mineral form plus 50 kg per ha in slurry. Taking into account the yield of 3.6 t of grain and 4 t of straw it gives ca. 95 kg of N surplus per ha. In a case of P the surplus was ca. 5 kg and in the case of K 0 kg per ha. Organic cereal mix yields only 2 t of grain per ha and 3 t of straw, and due to low yields it gives a surplus of 73 kg of N, 20 kg of P and 15 kg of K. On the farm the surplus of P and K is not a problem for the environment due to low level of available form of these nutrients in the soil.

In the organic production system, a switch from low yielding cereal mix (2 t per ha) to high yielding grain maize (8.5 t per ha) made a substantial difference. Nitrogen surplus drops from + 73 kg to a shortage of – 15 kg N per ha and that means that in successive years of crop rotation it has to be compensated. P balance from being positive in case of organic cereal mix (+20 kg per ha) dropped to 0, which is good for keeping the quality of water bodies (both lakes and the Baltic See). And K balance from surplus in the case of organic cereals mix (+15 kg per ha) dropped to – 27 kg per ha. The later means that on soils with low K content one has to apply mineral K fertilizers to meet crop nutrient requirements and receive high grain yields. It is worth emphasizing that high yields mean good nutrient utilization and very low surpluses to the environment.

Conclusions

Feed self-sufficiency of the farm was fluctuating from high in the period of the conventional management to low in the organic one, due to sharp decline in grain yield. Surprisingly in the case of cereals mix growing, N surplus during conventional managemnet was only slightly higher than during organic mangement (due to high yields in the first and low in the second case). The switch from traditionally grown cereals to grain maize increased grain yields from 2 to 8.5 t per ha and thus bettered nutrient balance contributing to improvement of environment. The introduction of organic cropping of soybeans and grain maize not only brought fodder self-sufficiency but also purified the nearby lake (currently its water is clear enough to be used for swimming by the local community)

Farm livestock density was fluctuating from being too high during conventional management (2.03 LU per ha) to 0.5 in a critical 2011 year of organic managemnet. Finally stocking rate rose to 0.94 LU per ha which is assumed to be right for the organic system.

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STATUS, PERSPECTIVES AND SUSTAINABILITY OF CROPPING SYSTEMS PRACTICES IN CROATIA

Jug Danijel

Abstract

Croatian part of Pannonia region has approximately 48% of agricultural land and 75% of arable land in total land of Croatia. Croatia has favourable agro-climatic conditions which enable diverse agricultural production. In a relatively narrow agricultural area, due to diverse climatic conditions, relief and soil, a large number of agricultural crops, starting from wheat and industrial crops to wine grapes and Mediterranean fruits and vegetables, are successfully cultivated.

Croatia has a three main Crop Production Regions (Pannonian, Mountain and Adriatic) and eleven sub regions, and mainly because of that, in different regions are applied different approaches to crop production. The most important region for crop production are Pannonian region with approximately 70% of total Croatian cereal production. Average yields of major crops in Croatia, such as maize, wheat, sunflower, soybean, sugar beat etc., are relatively low. Average crop yields vary from year-to-year mainly because of climate aberrations, but also because of many other problems, which every single or/and all together lead to reduction of production and low productivity, for example:

- Irrigated area is less than 1% of the total arable land
- Large fragmentation of agricultural land (property - estate)
- Not defined Inheritance of farmland (further fragmentation)
- A large proportion of the agricultural population in total of active population
- Aging of the agricultural households
- The low level of applied knowledge of farmers (education) - the traditional approach
- Low level of science implementation
- Low and inadequate investment

Out of the total registered farms, 63% avail of less than three hectares of land, and medium to large farms (from 20 to 300 hectares) avail about 32% of agricultural land. The number and importance of these farms is increasing in the last decade, which applied three main systems of crop production: conventional, organic and integrated production.

Soil tillage, as a one of the main technology operations in crop production, in Croatia are mostly conventional. With proper application of appropriate soil tillage systems, yields could be significantly improved. In the Pannonian region, reduced or conservation tillage is not a novelty (the first survey conducted in the mid-70s of last century). Unfortunately, this technology is still used very occasionally and in small areas, with rarely examples in practice, but with tendency to grow in last ten years.

Reduced/conservation tillage in most cases apply only from economic reasons (cheaper production) or as an alternative system. Unfortunately, the other positive effects arising from the application of reduced/conservation tillage systems are still in the background, such as: reduction of soil erosion, increase biogenity and quality of soil, less traffic and soil compaction alleviation, nutritional status an quality traits of crops, weed infestation etc. Main reasons for this situation can be divided on two different group: Economic and social development (knowledge, tradition, technics, technology, science implementation etc.) and Agro-ecological conditions (climate, soil, water, crop, biology etc.).

In this regard, investigations of conservation/reduced tillage should be extended to all the main soil types and crops, especially to those who are expecting a positive response from conservation tillage.

Key words: Croatia, crop production, average yields, reduced and conservation tillage.

Current status of Croatian agriculture

Total land area of Croatia are 5 660 000 ha, from which utilized agricultural area are 1 326 000 ha or 23%.

Toward regionalization, Croatia are divided on three main Crop Production Regions (Pannonian, Mountain and Adriatic) and eleven sub regions, and mainly because of that, in different regions are applied different approaches to crop production. Most important grown crops in Croatia are: w. wheat, maize, sunflower, soybean, sugar beat, barley etc. and production of this crops are mainly in the lowland area (Pannonian region). In this region are almost all arable land of total (892 000 ha or 67%) on which grown predominantly cereals (576 000 ha or 65%), (Statistical Yearbook, 2012). Importance of this area in crop production arise mainly from favorable agroecological conditions but also from tradition. But, importance of this region is not justified with amount of average yield. Average yields of main crops are relatively low and vary from year-to-year (Table 1) mainly because of climate aberrations, but also because of many other problems, which every single or/and all together lead to reduction of production and low productivity (Jug et al., 2010).

There are many problems plaguing the Croatian agriculture, but can be counted most important:

- Irrigated area is less than 1% of the total arable land. Drought in Croatia on average occurs every three to five years, and the reduction in yield caused by drought, depending on the intensity and duration can be from 20-90%. Reduction in yield of crops grown without irrigation, in average climate years amount 10-60%, and in dry years up to 90% in relation to biological potential of grown crops, soil type and region (agroecological conditions), (Romić et al., 2007).

- Large fragmentation of agricultural land (property - estate). In almost every part of Croatia exist a large number of small size plots making it difficult application of modern technology in crop production on large scale. The average size of farms is 2.4 ha, the average size of a family farm is 1.9 ha, and the average size of their productive land unit is 0.45 ha (Tomić et al., 2007).
- Not defined inheritance of farmland which leads to further land fragmentation and further reduction in yield.
- A large proportion of the agricultural population in total of active population and aging of the agricultural households. In agriculture are employed about 20% of the active population while in developed countries is around 2%. Aging of family farms is a big problem because older agricultural population usually difficult adopt a new technology. Rural population is 47.6% of total population (Croatian Agriculture, 2009).
- Low level of knowledge applied by farmers and poor science implementation (know-how). In many aspect of crop production prevail traditional approach without continuity in education. Is not sufficiently well-developed system of knowledge transfer from research institutions to farmers.
- Low and inadequate investment in further development.

Table 1: Area under cultivation and production of some important crops

Crop	Harvested area (000 ha)	Yield per ha (t)
Maize	305	5.7
Wheat	150	5.2
Barley	48	4.0
Sunflowers	30	2.8
Soybean	59	2.5
Sugar beets	22	53.8
Rape seed	18	2.8

Statistical Yearbook (2012)

Out of the total registered farms, 63% avail of less than three hectares of land, and medium to large farms (from 20 to 300 hectares) avail about 32% of agricultural land. The number and importance of these farms is increasing in the last decade, which applied three main systems of crop production: conventional, organic and integrated production (Croatian Agriculture, 2009).

Current status of soil tillage in Croatia

Predominant approach in crop production is still conventional approach, with all positive and negative consequences. According this, soil tillage, as a one of the main technology operations in crop production, are mostly conventional (Jug et al., 2010). Main paradigm for that approach is *"...Soil need to plough for high yields…"*, or "… *"if these low yields are with application of ploughing, how low would have been with application of reduced soil tillage?!..."*.

Proponents of traditional approach to conventional tillage enumerating many advantages of ploughing as most important and indispensable tillage treatment in that approach, for example: incorporation of crop residue, weeds, organic and mineral fertilizers, loosening of root zones, the accumulation of moisture in the autumn-winter period, control of diseases and pests, etc. (Jug et al., 2010). But, in the lights of the newest research this approach are not sustainable. According this traditional approach to conventional tillage has many negative sides, especially in the domains of physical, chemical and biological complexes of soil. Most important changes are in domain of compaction, loss of humus and stable soil structure, undesirable changes in soil reaction, cation exchange capacity and soil microbial activity, external and internal erosion, risk of environmental pollution, unprofitable, etc.

These problems are very easy to see in many agricultural areas of Croatian, but may be the most intense in eastern Croatia. This area, as has already been mentioned, is the main production area of arable crops and right here is the most intense and most frequently in used a conventional tillage with ploughing in primary tillage. On this small are has over 40 soil types (especially in Baranja region) and almost every of these are mainly specific with specific technology approach in crop production.

In history frames, reduced soil tillage is not a novelty at this region. Farmers started to use reduced tillage and direct seeding, practiced since the beginning of the conscious cultivation of plants, but not in ways what we today perceive under reduced and/or conservation tillage (first or primitive or very extensive crop production). Invention of the first efficient ploughs in the 18th century marked a revolution in agriculture, with whom it had also come to the partial abandonment of "reduced tillage" (Jug et al. 2010).

First conceptions of reduced or conservation soil tillage in line of history, occurred as a logical consequence after many inventions (key inventions) in agriculture (eg. chemicals, fertilizers, mechanization etc.), but also because of many degradation caused by ploughing (Figure 1).

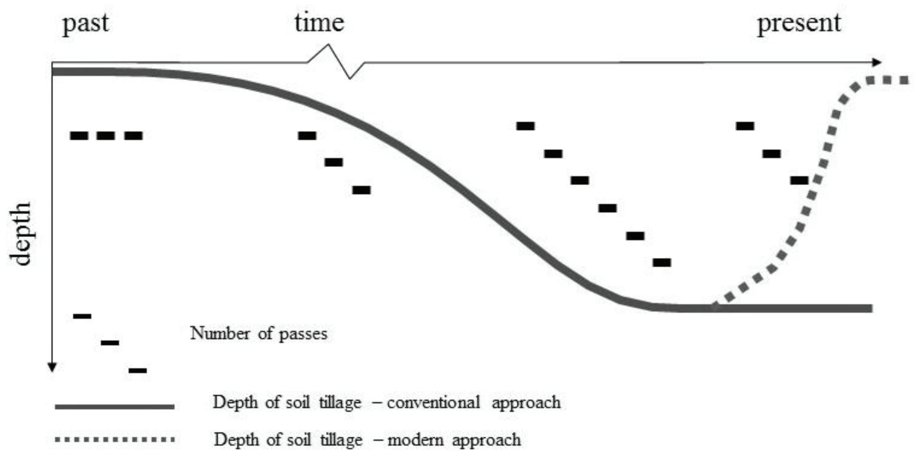

Figure 1: Depth and traffics during the course of history of soil tillage

Sayings of "farmers truth" - "*more intensive tillage treatment - higher yields*", leads to "really truth" - "*more intensive tillage treatment - more soil degradation*". Unfortunately, in many case, the main reason for adoption of reduced soil tillage are not raising awareness for environment protection, but greater economic profitability.

At the present time in the Republic of Croatia in the crop production almost always used conventional tillage (Jug et al., 2006), and reduced soil tillage in most cases the only economically feasible for reasons of production (Kanisek et al., 1999; Košutić et al., 2001), or as an alternative system (Jug et al., 2007).

In the region of Slavonia and Baranja are still ploughing as a primary soil tillage treatment, applied to about 94% of the area (Košutić et al., 2005). However, the estimate is that at last few years some form of reduced tillage is applied from 10-15% (Jug et al., 2010).

Soil tillage trends in Croatia

One of the most prospective ways to solve many of accumulated problems in agriculture is in the domain of reduced or/and conservation soil tillage. The first survey of reduced soil tillage in Croatia was conducted in the mid-70s of last century, quite late in comparison with some more developed countries.

In last ten years in Croatia, research of reduced and conservation tillage are significantly intensified from many aspects (Kisić et al., 2005; Sabo et al., 2006; Jug, 2006; Jug et al., 2006a, 2006b, 2007a, 2007b, 2008, 2009a, 2009b, 2010a, Vukadinović and Jug, 2010) but in many times with divergent results (Butorac et al., 2006), which imply on needs for further and more intensive approach to research.

But, adoption of reduced or conservation tillage systems in Croatia are still relatively slow, and one of the most important reasons is delaying synergistic approach in relation scientific community – Agricultural Advisory Service – farmers.

As already mentioned, main encouragement to adoption reduced tillage systems are positive financial effect, and unfortunately, the other positive effects arising from the application of reduced tillage systems are still in the background.

The most common and most applied reduced tillage system is diskharrowing as basic tillage treatment for winter wheat, and the period of application of reduced tillage on a field is usually one growing season, and then re-applies system with conventional ploughing. For this reason, in eastern part of Croatia is very "popular" discontinuous tillage systems (Jug, 2006), which include the application of the reduced system in the inning with a conventional system every two years. However, some farmers applied continuous reduced tillage systems with different success (Jug et al., 2010).

Soil chiseling applied instead ploughing is usually performed as a measure of repair of compacted soil mainly breaking tillage pan, which followed by diskharrowing, and very rare as a primary tillage systems. Other applied tillage systems which exclude ploughing are more in the domain of rational tillage systems (few tillage operation in one pass), and less in the domain of reduced and/or conservation tillage.

Application of No-tillage systems are very rare and on a very small area, which is primarily the result of insufficient knowledge of farmers, but also the lack of quality tools and machinery for direct sowing. And in these smaller areas, where applicable no-tillage technology the usually applies discontinuous tillage systems, and there is no continuity in the application of technologies required in the cultivation of field crops.

With regard to reduced or conservation tillage systems, especially on a large number of soil types on which the production of crops takes place in Croatia, is still a lot of unknowns, primarily with the physical, chemical and biological aspects.

Frequency occurrence of the extreme rainfall, longer dry periods and shorter rainy periods suggests tillage technique keeping arable soils free of tillage-induced soil compaction, maintaining soils water infiltration and storing capacity and others.

Final remarks

Plough, who had saved humanity from hunger, opened the way for many degradation processes in soil. More developed countries were willing and open to acceptance of reduced tillage technologies. Such approaches have made a big step forward in resolving its large and accumulated problems concerning the ecology, energetic, production, organization, and economic aspects.

Also it should be noted that in most European countries, reduced tillage is not accepted in proportions that were realistic to expect based on their climatic and soil conditions. For such a state partially "culprit" are economic ability of individual countries in adopting new scientific knowledge and new technical and technological achievements, and partly a different approach to the treatment of soil, as well as the burden of tradition. Europe, especially Eastern, has the greatest potential for expansion of this technology.

In order to apply new technologies for soil tillage (and beyond) and successful as accepted, much greater openness and connection between farmers and scientific institutions are required. Unfortunately, it is often the case that primary crop production is going ahead of the scientific practice of verification possibilities of a technology without a sufficiently strong experimental basis, given the great diversity of agroecological conditions and opportunities.

Climatic changes, with primary changes in water and temperature regime, have large and perhaps the greatest impact on crop production. Regarding this, the soil tillage is necessary to be changed in order to achieve a safer and more stable production. Simplified, cheaper, more rational conservation and reduced tillage is one of the possibilities of overcoming the upcoming unfavorable climate (all the more extreme vegetation years), economic, market, organizational, socio-economic and other changes.

Reduced/conservation soil tillage is a result of serious scientific research and practical testing, and it is the result of better and more comprehensive observation and understanding of the natural environment. This remark leads to question: *„What is the main demand of soil tillage?"* to answer: *„Depth of soil tillage and number of passes machinery and tools for tillage, should be harmonized with the natural conditions, and adjust the level of production must be economically justified"* and conclusion: *„No unique optimal basic soil tillage treatments !!!"*.

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SUSTAINABILITY OF AGRICULTURE IN THE MOST VULNERABLE AREAS OF WATER MANAGEMENT (BŘEZOVÁ NAD SVITAVOU) - THE USE OF BIOLOGICAL METHODS OF EVALUATION.

Plošek Lukáš, Záhora Jaroslav, Kintl Antonín, Elbl Jakub, Tůma Ivan, Hynšt Jaroslav, Urbánková Olga

Introduction

The quality of water is currently determined by human influences on the landscape. The status of the environment, especially that of soil quality has significant consequences to the human health. Therefore, the soil quality/health (according to Doran et Parkin (1994) and Pankhurst, Doube et Gupta (1997)) was identified as the primary indicator of the sustainability of landscape system. Healthy soil is a milieu through precipitation water permeates and which has a finite capacity to accept and retain nitrogen compounds excess (reactive nitrogen). And thus healthy soil can protect underground sources of drinking water (Sherwood et Uphoff, 2000).

The area of our interest Březová na Svitavou is the main source of drinking water for the Brno and its neighborhood. It is a very good source of drinking water. However, despite the radical reduction of using of mineral fertilizers in the second half of ninetieth years the concentration of nitrates slightly but steadily increases (Nohel et al., 2008).

There are many factors which influence basic properties and quantity of ground water. Some of them are permanent – composition and structure of parent material, terrain morphology, infiltration area etc. Others factors are variable in time – soil microbial activity, immobilization of nutrients in different parts of the growing and non-growing seasons, the distribution of rainfall during the year, the annual course of temperatures, etc (Nohel et al., 2008).

Another determining factor is the man which has influenced properties of ground water in the last age. These are especially input of mineral and organic fertilizers, pesticides, dry or wet atmospheric deposition, changes in crop rotations etc. Long-term excessive nitrogen load exhausted of the storage capacity of the ecosystem (Galloway et al., 2003) and ecosystem stability lost (Bobbink et Roelofs, 1995). These is followed by increased amount of N leached out from the ecosystem in the form of nitrates (underground water) and by increased amount of N releasing from the ecosystem in the form of gaseous emissions. The leaching of nitrates from the ecosystem is extraordinary good indicator of disturbations in relatively closed nitrogen cycle (Záhora et al., 2011).

The area of interest – Water protection area Březová nad Svitavou is located in the Pardubice region in the vulnerable area of water resources (according the Directive of Nitrate). The presented results are fromtwo water catchment areas – “Banínský potok” and

“Radiměřský potok”. Both catchment areas have a high proportion of arable land (up to 81 %). Soil type is especially acidic brown soil.

The aim of this contribution is to highlight the disturbances of the soil nitrogen cycle and on how to estimate in methodically simple way above mentioned overloading in soil nitrogen transformations.

Material and methods

For measuring of leaching nitrates was used the method of flat horizontal cases of ion exchange resins in selected soil depths (Šrámek *et al.*, 2004, Nohel *et al.*, 2008).

The availability (more or less in the case of ammonia-nitrogen) and movement of percolated nitrogen (mainly in the case of nitrate-nitrogen) was estimated „*in situ*” according to Binkley at Matson (1983) by the trapping of mineral N into the ion exchange resin (IER) inserted into special cover. The special annular flat cover (disc) for trapping inorganic nitrogen was made from PVC tubes (diameter 5 cm, thickness 1 cm). Nylon mesh (grid size of 0.1 mm) was stuck on the PVC ring. Mixed IER (CER and AER in ratio 1:1; CER, cation exchange resin No. Purolite C100E, and AER, anion exchange resin no. Purolite A520E; exchange sites of IER were saturated with Cl^- and Na^+ ions) were then placed into the inner space of annular flat cover. The annular flat IER cover was inserted into the soil in the depth of 20 and 50 cm in the experimental plot. Accumulation of N took about 26-week and it included wet season (October-April) and dry season (May-September).

For the quantification of NH_4^+-N and NO_3^--N trapped by the resin, the IER were allowed to dry at room temperature. Absorbed NH_4^+-N and NO_3^-N were eluted from IER using 100 ml 1.7 M NaCl and determined by distillation and titration method (Peoples et al., 1989). Results from the ion exchange resin bags were expressed as mg of NH_4^+-N.10 ml^{-1} IER and NO_3^--N.10 ml^{-1} IER. The results from the ion exchange resin discs were expressed as mg NH_4^+-N.m^{-2} and NO_3^--N.m^{-2}. Statistical evaluation was performed by means variance analysis (ANOVA P>0.05).

Results and discussion

The nitrogen moves in ecosystem along typical ways, through many transformations and fluxes and remains unequally long time in different sinks. We are talking about a characteristic nitrogen cycle. Movement and transformation between the N sinks in the ecosystem can be depicted graphically (Fig.1). It is clear that the overall N cycle is significantly affected by human activities, by the level of various inputs from human activities (N-fertilizers, emission of N-compounds), while the possibilities to control outputs (nitrate leaching or losses of nitrogen in gaseous form) is for human limited, if not impossible.

The vast majority of nitrogen is recycled within an ecosystem. The linking of "internal processes" with the surrounding "inputs" and "outputs" throughout the year represents only a minor fraction of the amount of nitrogen passing through internal part of nitrogen cycle (Fig. 1).

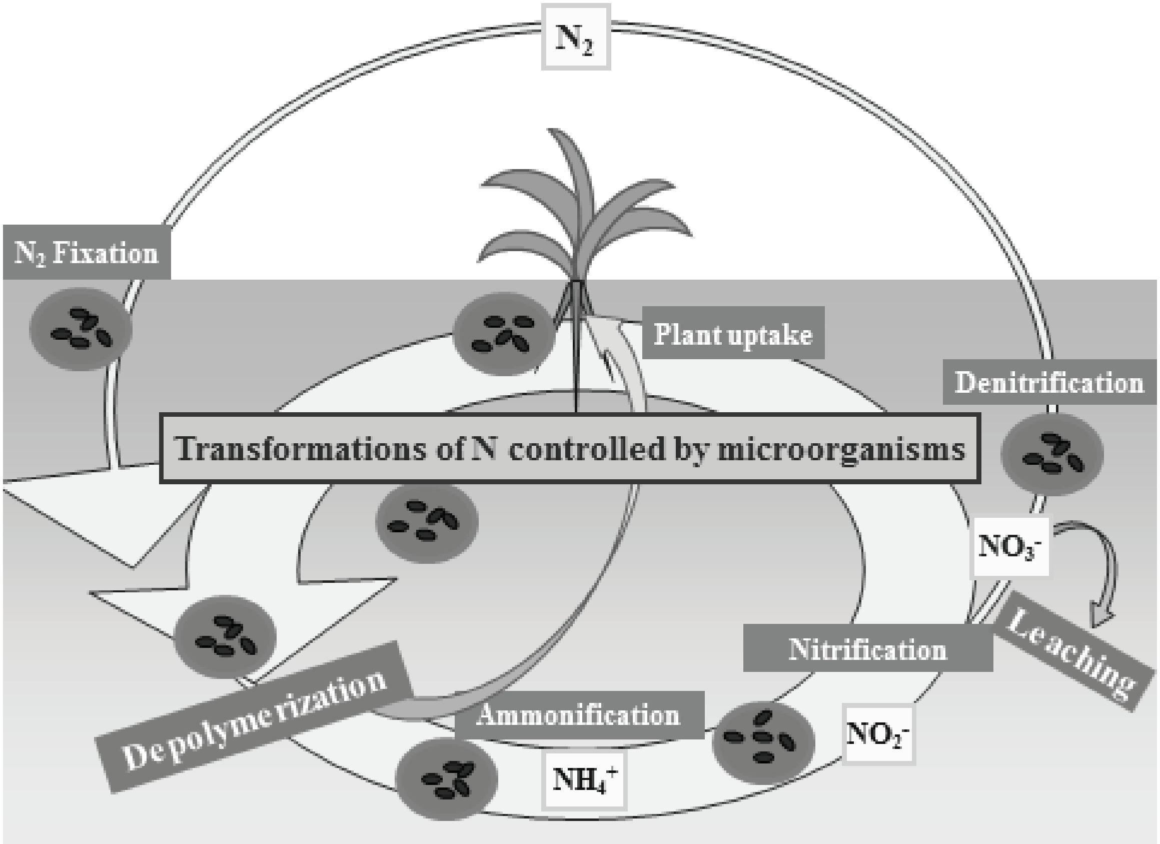

Figure 1. The simplified nitrogen cycle in the ecosystem - the internal connection of the individual processes in nitrogen transformation as well as the cycle inputs and outputs into the surrounding environment (into the external cycle of N) are shown

In natural or semi-natural ecosystems up to 99% of soil nitrogen is bound in soil organic matter. Only a part of it may serve as a key nutrient to plants if and only if the soil microorganisms get for their own activities sufficient amount of simple, easily decomposable carbonaceous compounds from plants. The offers of easily decomposable carbonaceous compounds lead to the "demand" for the corresponding nitrogen availability and stimulate microbial mineralization (ammonization) of soil organic nitrogen. According to the above mentioned pattern the release of soil mineral nitrogen is proportional to plant stimulation through plant "investment" (by attractive carbonaceous compounds). In such a soil environment, the potential for leaching of mineral nitrogen is strongly limited.

The nitrogen leaving the ecosystem is therefore: (a) extraordinary suited indicator of disturbed relations in the N cycle, (b) the output of nitrogen from oversaturated (agro) ecosystems in the form of nitrates is extremely important in terms of water management.

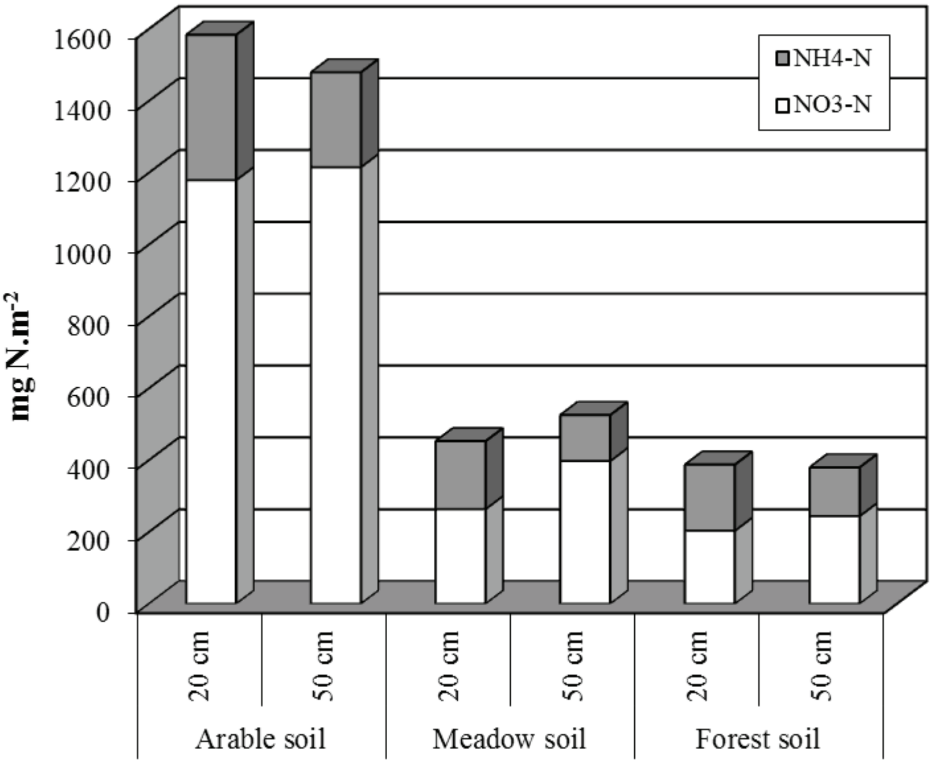

Figure 2 Cumulative trapping of soil mineral N (ammonia- and nitrate-nitrogen) into ion exchange resin embedded in special disc covers in soils from three different types of ecosystems (in two depths - 20 cm and 50 cm) for observation period from March 2005 to March 2010

Based on the results of the five-year monitoring of mineral nitrogen leaching from arable, meadow and forest soils in the area can be stated that the source of nitrates are mainly arable land, from which approximately three times more nitrogen than from the meadow and forest were washed out, taking into account that much of the captured nitrogen in grassland and forest soils originated and is caused by subsurface flow from arable soils that are situated in higher altitudes (Fig. 2).

Conclusions

The authors concluded that the arable soils in the area fertilized with mineral nitrogen are no longer able to retain nitrogen as efficiently as in the past, probably due to changes in the biological activity of the soil. The work was supported by the project NAZV No. QJ1220007.

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