ECOMIT

Proceedings of the 5th International Scientific Conference on Sustainable Farming Systems

November 5–7, 2008 in Piešťany, Slovakia





Edited by Zuzana Lehocka, Marta Klimekova and Wijnand Sukkel

Zuzana Lehocká, Marta Klimeková, Wijnand Sukkel (editors)

ECOMIT

5th International Scientific Conference on Sustainable Farming Systems

November 5-7, 2008 in Piešťany, Slovakia

ECOMIT – Proceedings of the Fifth International Scientific conference on sustainable farming systems, 5-7 November 2008 in Piešťany, Slovakia. Slovak Association for Sustainable Agriculture, Slovak Agricultural Research Centre – Research Institute of Plant Production Piešťany in cooperation with Wageningen University and Research Centre the Netherlands, International Society of Organic Agriculture Research (ISOFAR), European Conservation Agriculture Federation (ECAF), Institute of Organic Agriculture (IOL), Research Institute of Organic Agriculture (FIBL), Slovak No–till club (SNTC), Ministry of Agriculture of the Slovak Republic.

1st Edition

Piešťany, 2008

ISBN: 978-80-969603-1-6

Layout: Zuzana Lehocka and Jarmila Poništová
Layout technical support: Kios, s.r.o.

Printed by: 3xK, Slovakia

Distribution: Paper copies may be ordered from the Slovak Association for Sustainable Agriculture, Považany 124, 916 26 Považany, Slovakia, zuska_l@inmail.sk

Table of contents

Plenary session

Scientific session I. A Soil cultivation systems

Scientific session I.B Soil management and soil quality

Scientific session I.C. Energy production and soil compaction

Scientific session II.A Soil biology and biodiversity

Scientific session II.B Soil pollution and water management

Scientific session II.C Soil conservation and policy

Posters

Dear Ladies and Gentlemen,

I am very pleased to greet YOU, the participants of the 5th International Scientific Conference on Sustainable Farming Systems ECOMIT and Welcome all of you to Slovakia.

I would like to welcome all the delegates from the various countries. I realized that the program is very interesting and you are fully dedicated to it but I also do hope you will have chance to enjoy the pearl in the heart of Europe, beauteous Slovakia.

ECOMIT is focusing on the key issues which are challenging today's European agriculture. I believe that in time of great global challenges both in term of climate protection and nature sources conservation, it is not possible to be economically successful without soil, climate and environmental protection.

Ecology is turning more into a driving force also for the Slovak economy. The fact is that agriculture is very dependent on natural cycles, probably much more than any other sectors of economy. It works in the natural environment and uses it. From this point of view we have to be very aware how the natural sources are and will be used. The adoption of sustainable agricultural methods is the key element to the total process of sustainable development. We have to use the methods according which we will be able to feed the raising human population but on the other hand these methods can not cause any environmental damage.

In principle the objectives of the conference are focused on presenting and promoting research results and experiences in the field of sustainable agricultural systems with the emphasis on soil and climate change.

The conference also provides an invaluable opportunity for networking and fruitful contacts among countries, researchers, experts, specialists and is expected to create an "informational bridge" among European scientists and researcher.

I hope that the conference will bring a great opportunity for information, knowledge and inspiration sharing.

I am looking forward to the ECOMIT conference conclusions which will also help the Ministry of Agriculture of the Slovak Republic to answer the question what is necessary from the point of view of nature sources protection and conservation, what can be achieved by using the instruments of policy and agriculture, what are the benefits of different farming systems?

Dear Delegates, allow me to wish you a very productive and successful meeting.

Sincerely yours.

Dr. Jarmila Dubravská

General Director of the Session of Agriculture
Ministry of Agriculture of the Slovak Republic

Dear Reader,

Ecomit is the name of the conference on sustainable agriculture that has been organized for the 5th time in Slovakia. Ecomit stands for ecological meeting and these motives been the leading motives for the organizers and supporters of Ecomit. Meeting of people is essential for learning and understanding. Meeting of ideas, beliefs and cultural backgrounds. A meeting of people from Eastern, Central and Western Europe. People with different historical backgrounds and different life experiences. Meeting the central European hospitality and habits which are often much closer to the origin of our food than in the Western part of Europe. But it’s not only about culture and history. The conference was focused on knowledge about sustainable agriculture and created an “information bridge” among European research communities which will contribute to the strengthening of partnerships and scientific collaboration.

Ecology and sustainability is a leading motive for the two agricultural movements represented at the conference. These two movements are conservation agriculture and organic agriculture. Both movements originating from the search to counteract the detrimental effects of modern agriculture. Both movements can learn a lot from each other, having overlapping objectives but partly complementary ideas of the way to a more sustainable agriculture.. Combination of these various strategies involved is a potential answer to the challenges agriculture is facing. The conference objective is to bring together experiences and research results of different sustainable approaches in agriculture.

Mitigation and adaptation to climate change and depletion of our resources as soil, biodiversity, fossil energy and phosphorus are major challenges the world is facing. Agriculture plays a central role in these challenges. How can agriculture be less dependant of fossil energy? Should agriculture produce energy? Or should the organic substance it produces mainly be used for food, fibers and for the maintenance of our soils. Conservation and organic agriculture might be able to give part of the answers. The Ecomit conference provided a platform to meet and exchange the knowledge and experiences these two agricultural movements have to offer. Therefore we invite you to read about the results of the Ecomit conference 2008 in these proceedings.

We thank the contributors of papers and posters in these proceeding to share their knowledge and experience. Without them Ecomit would not have been possible. We would also like to express our gratitude to the organizations and sponsors that have supported Ecomit. They are: the Ministry of Agriculture of the Slovak Republic, The Wageningen University and Research Centre the Netherlands, The European Conservation Agriculture Federation (ECAF), The International Society of Organic Agriculture Research (ISOFAR), The Institute of Organic Agriculture (IOL), The Research Institute of Organic Agriculture (FIBL), The Town Piešťany, The Piešťany Town Cultural Centre, the Slovak No–till club, Louis Bolk Institute the Netherlands, Ematech Technológie, Ekotrend Myjava, Bioaspa Kúty, Legusem Horná Streda, Sartorius Servis, s.r.o., Stredná Záhradnícka škola Piešťany, Natural Domin & Kušický, Agrokarpaty, s.r.o. Plavnica, Sema HŠ, s.r.o. Sládkovičovo, Stredná škola obchodu a služieb, Reštaurácia u Juhása, Hotel Satelit Piešťany, Hotel Magnólia Piešťany.

Zuzana Lehocka, Marta Klimekova and Wijnand Sukkel

Aknowledgements

We would like to thanks to the members of the scientific and advisory committee for their active help and support:

Gottlieb Basch, ECAF, Crop Science Department, University of Evora, Portugal
Ion Toncea, Research Institute for Cereals and Industrial Crops, Romania
Jan Gadus, Slovak Agricultural University, Slovak Republic
Joszef Zsembery, Karcag Research Institute of Debrecen University, Hungary
Nabil Rifai, Nova Scotia Agricultural College, Canada
Jaromir Kubat, Crop Research Institute Praha, the Czech republic
Urs Nigglli, Research Institute of Organic Agriculture (FiBL), Switzerland
Ulrich Köpke, Institute of Organic Agriculture, ISOFAR, Germany
Eric Wyss, Research Institute of Organic Agriculture (FiBL), Switzerland
Viliam Novak, Institute of Hydrology, Slovak Academy of Sciences, Slovak Republic
Wijnand Sukkel, Wageningen University and Research Centre, Netherlands
Winfried Schafer, Animal Production Research, MTT Agrifood Research, Finland

We would also like to thank very much to the following reviewers:
Wijnand Sukkel, Netherlands; Gottlieb Basch, Portugal; Ulrich Köpke, Germany; Daniel Neuhoff, Germany; Winfried Schäfer, Finland; Jaromír Kubát, Czech Republic; József Zsembeli, Hungary; Viliam Novák, Slovakia; Ion Toncea, Romania.

Our gratitude belongs also to the organizing committee staff:
Rastislav Bušo, Ivana Gubová, Jarmila Poništová, Michaela Havrlentová, Eva Urbanová, Ľubica Cziborová, Miriam Burzalová, Danica Palkovičová, Pavol Stanko.

Plenary session

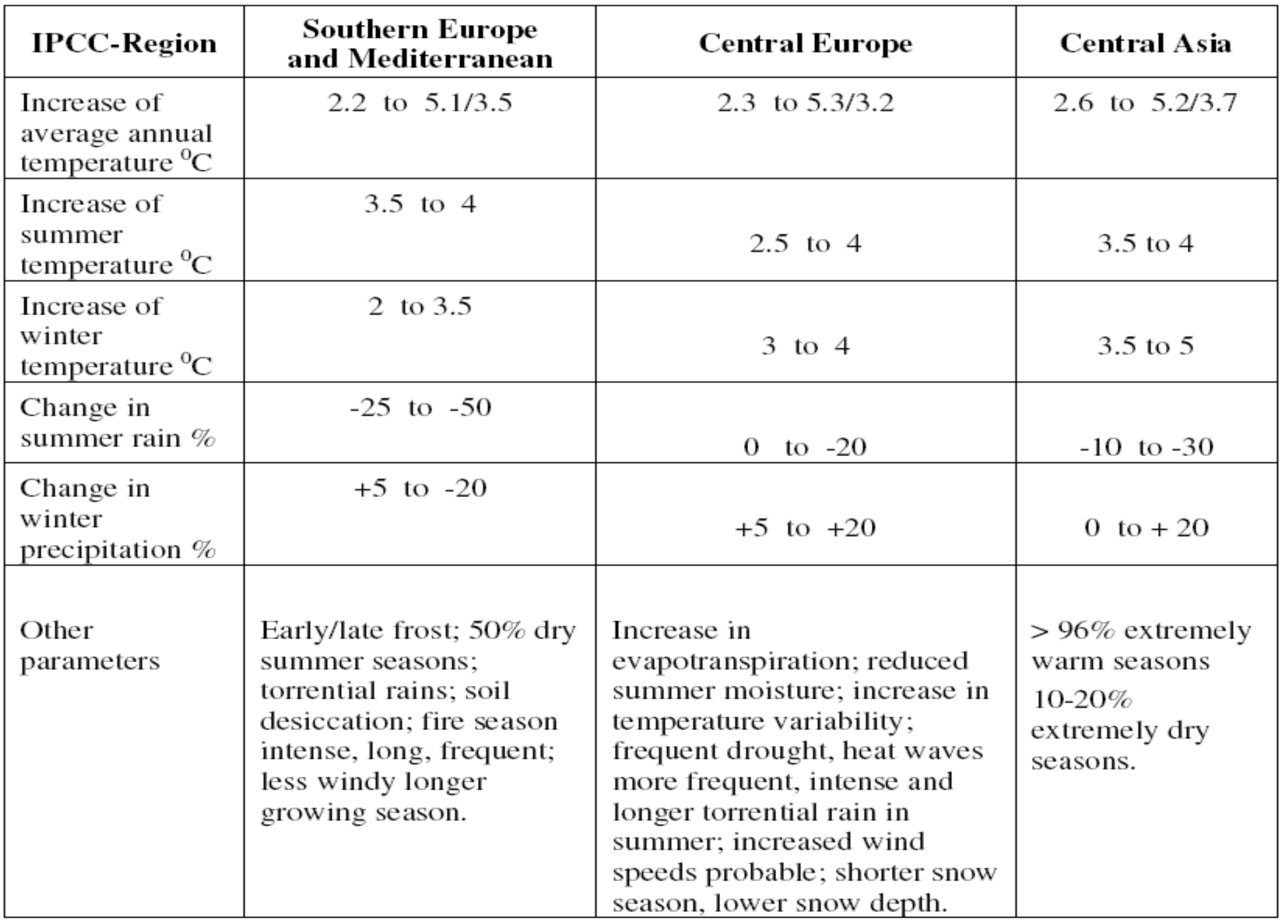
FAO ON CLIMATE CHANGE IN THE EUROPEAN REGION

Volker Sasse –Tomasz Lonc
FAO Sub-regional Office for Europe and Central Asia

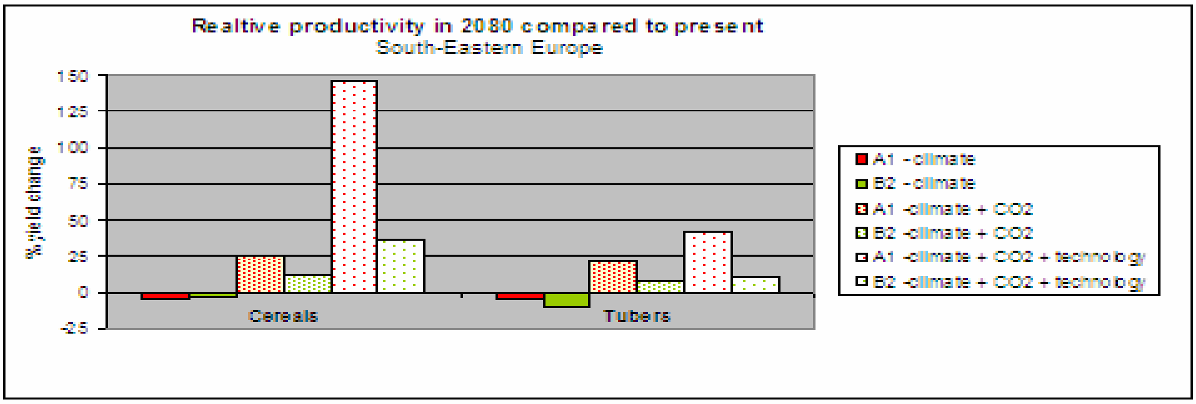
Climate change and adaptation to it are a major challenge that agriculture, forestry, fisheries and rural areas in the European region will face in the coming years

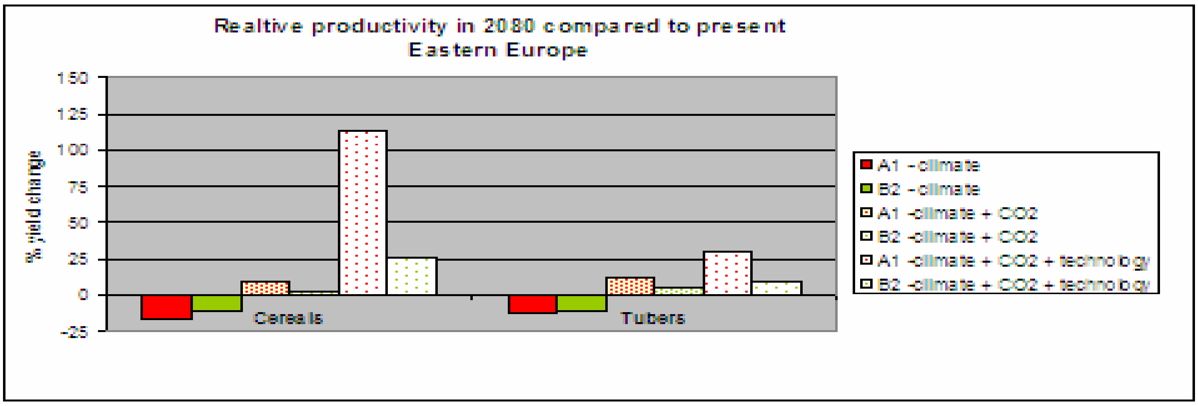
The projected climate changes in the European region will affect:

- Forms of land use (urban/agriculture/forestry)
- Location of production, tree species composition and fish populations
- Productivity in agriculture, forestry and fishery
- Result in important risks for income and employment



IPCC-Region	Southern Europe and Mediterranean	Central Europe	Central Asia
Increase of average annual temperature ^{o}C	2.2 to 5.1/3.5	2.3 to 5.3/3.2	2.6 to 5.2/3.7
Increase of summer temperature ^{o}C	3.5 to 4	2.5 to 4	3.5 to 4
Increase of winter temperature ^{o}C	2 to 3.5	3 to 4	3.5 to 5
Change in summer rain %	-25 to -50	0 to -20	-10 to -30
Change in winter precipitation %	+5 to -20	+5 to +20	0 to + 20
Other parameters	Early/late frost; 50% dry summer seasons; torrential rains; soil desiccation; fire season intense, long, frequent; less windy longer growing season.	Increase in evapotranspiration; reduced summer moisture; increase in temperature variability; frequent drought, heat waves more frequent, intense and longer torrential rain in summer; increased wind speeds probable; shorter snow season, lower snow depth.	> 96% extremely warm seasons 10-20% extremely dry seasons.





The High-Level Conference on World Food Security:

Challenges of Climate Change and Bioenergy, 3-5 June 2008, Rome

- Addressed the nexus between food security, climate change and bioenergy
- Identified the process for institutional action for the integration of food security safeguards into multilateral climate-related agreements
- Defined FAO's response through field interventions, partnerships and multilateral and regional cooperation

FAO European Region's priorities are:

- Poverty reduction, through support to sustainable rural livelihoods and food security
- Food safety and quality
- Sustainable management of natural resources
- Facilitate the transition to market economies in the rural sectors

TWENTY-SIXTH FAO REGIONAL CONFERENCE FOR EUROPE MINISTERIAL ROUND TABLE, Innsbruck, Austria, 26-27 June 2008

Proposed adaptation measures and options for FAO activities

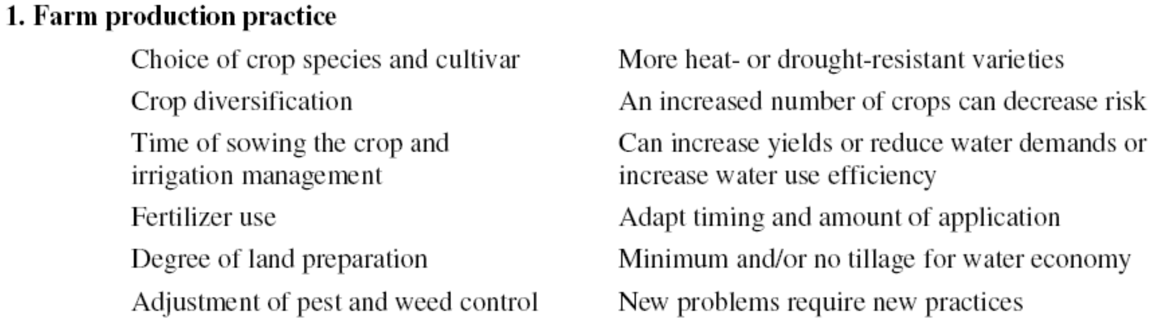
- Focus on areas where FAO has a comparative advantage;
- Support to rural areas and household livelihoods;
- National policies regarding agriculture, forestry and fisheries
- National and regional assessments for food security

Adaptation in agriculture varies depending on

- the climatic stimuli
- farm type and location
- economic, political and institutional conditions.

Adaptation strategies include a wide range of
- forms (technical, financial, managerial),
- scales (global, regional, local) and
- actors (governments, industries, farmers).

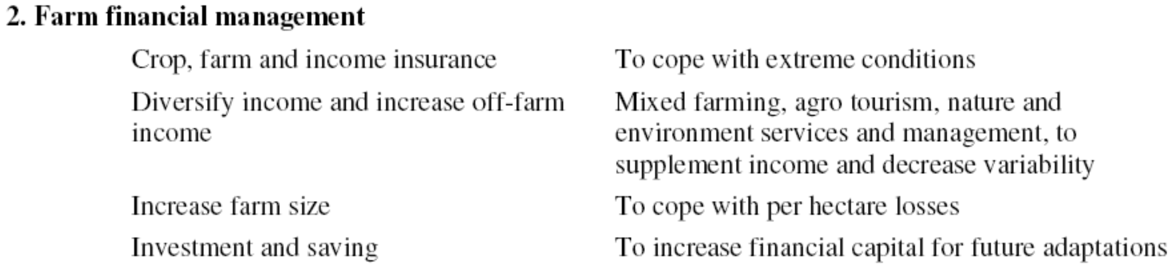
Adaptive Capacity and Adaptation Strategies (1/4)



1. Farm production practice

Choice of crop species and cultivar	More heat- or drought-resistant varieties
Crop diversification	An increased number of crops can decrease risk
Time of sowing the crop and irrigation management	Can increase yields or reduce water demands or increase water use efficiency
Fertilizer use	Adapt timing and amount of application
Degree of land preparation	Minimum and/or no tillage for water economy
Adjustment of pest and weed control	New problems require new practices

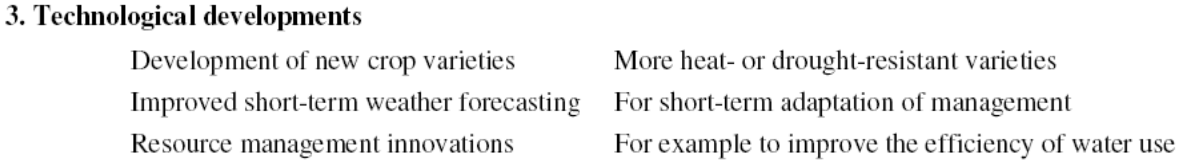
Adaptive Capacity and Adaptation Strategies (2/4)



2. Farm financial management

Crop, farm and income insurance	To cope with extreme conditions
Diversify income and increase off-farm income	Mixed farming, agro tourism, nature and environment services and management, to supplement income and decrease variability
Increase farm size	To cope with per hectare losses
Investment and saving	To increase financial capital for future adaptations

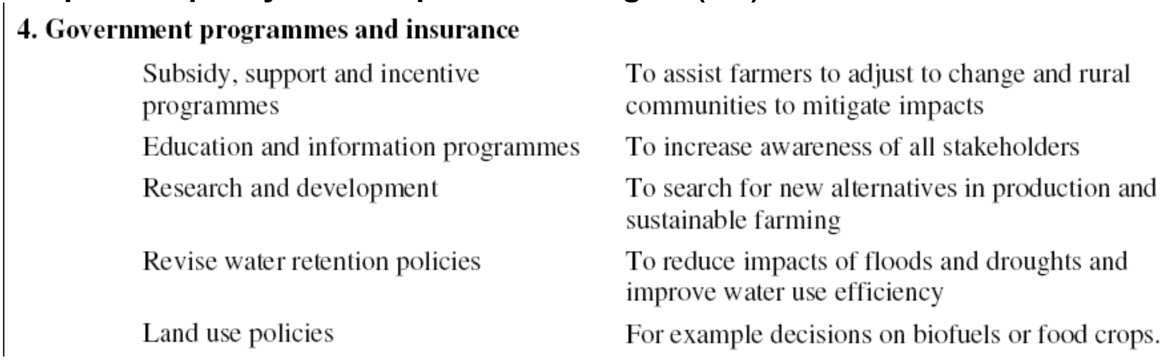
Adaptive Capacity and Adaptation Strategies (3/4)



3. Technological developments

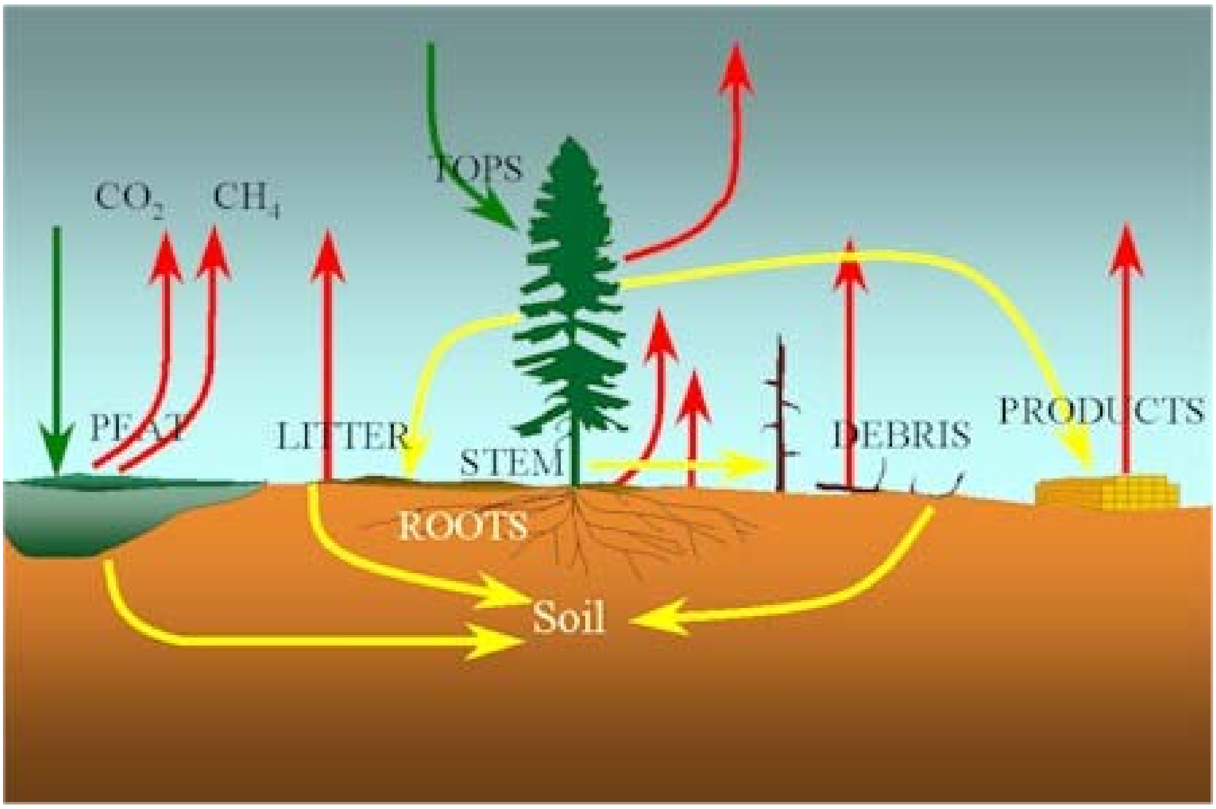
Development of new crop varieties	More heat- or drought-resistant varieties
Improved short-term weather forecasting	For short-term adaptation of management
Resource management innovations	For example to improve the efficiency of water use

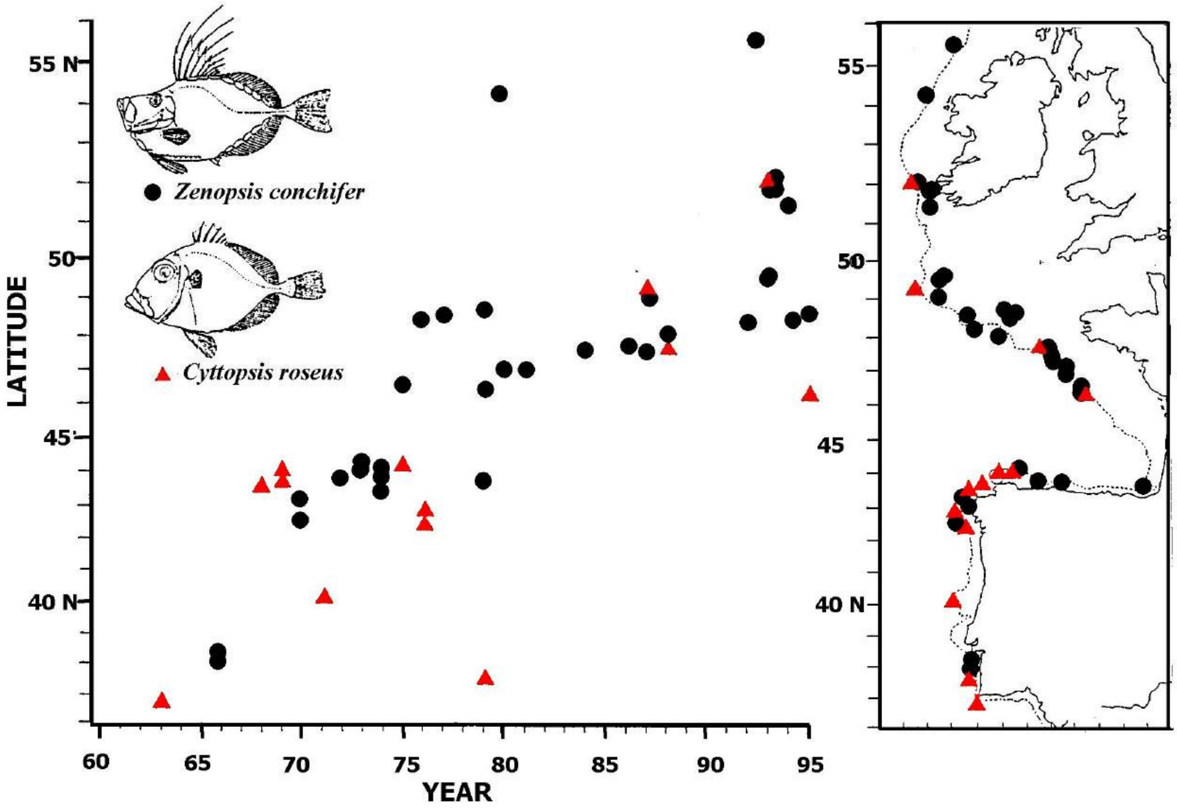
Adaptive Capacity and Adaptation Strategies (4/4)



4. Government programmes and insurance

Subsidy, support and incentive programmes	To assist farmers to adjust to change and rural communities to mitigate impacts
Education and information programmes	To increase awareness of all stakeholders
Research and development	To search for new alternatives in production and sustainable farming
Revise water retention policies	To reduce impacts of floods and droughts and improve water use efficiency
Land use policies	For example decisions on biofuels or food crops.


CO$_2$
CH$_4$
TOPS
PEAT
LITTER
STEM
DEBRIS
PRODUCTS
ROOTS
Soil


● Zenopsis conchifer
▲ Cyttopsis roseus
LATITUDE
55 N
50
45
40 N
60
65
70
75
80
85
90
95
YEAR
55
50
45
40 N

FAO and adaptation to climate change in the European Region

For the attention of Governments (1/2)

- Underlined the role of the European region in both climate change mitigation and adaptation strategies;
- Highlighted the importance of reliable assessments of impacts on agriculture, forestry and water management
- Contribute to the mitigation of greenhouse gas emissions, through
  - focus on products with low climate change impacts (bioenergy!)
  - nature oriented technologies (e.g. organic farming)
  - diversification of production
  - carbon sequestration (e.g. in forests and forest products);

Methods and resources to improve impact assessment

The priorities and resources required to improve climate change assessment may be grouped as follows:

1. Raise awareness in the agricultural sector and government
2. Discuss the issue with stakeholders across groups and institutions
3. Adopt a local approach
4. Devise regional scenarios
5. Improve baseline data and develop a meaningful aggregation framework and
6. Ensure continued investment in scientific methods.

For the attention of Governments (2/2)

- Deregulation of trade and agricultural production, referring to unfair competition from countries with high subsidies for agriculture and barriers to trade
- Further studies be focused on measures for mitigation of greenhouse gases
- Specific adaptation measures would be required to alleviate climate change impacts on farm costs, incomes, employment and migration

For the attention of FAO (1/2)

- Set a high priority and allocate sufficient resources for activities in the field of climate change
- Special integrated programme on climate change issues and collaborate on this subject with other specialized United Nations agencies such as UNFCC, IPCC and GEF
- Need for additional resources for the implementation of a special programme on climate change issues
- Proposal to establish an FAO intergovernmental trust fund for these activities

For the attention of FAO (2/2)

- Include the East European and Central Asian region in its analyses, in close collaboration with the European Commission on this subject
- A specialized FAO Climate Change Assessment Unit should initiate the elaboration of a region-specific “Strategy on FAO activities related to climate change mitigation and adaptation”
- Organize workshops and a high-level meeting on climate change impacts and adaptation measures for Europe

ORGANIC AND CONSERVATION AGRICULTURE, THE BEST OF BOTH WORLDS?

Wijnand Sukkel
Wageningen University and Research Centre, Department of Applied Plant Research (PPO-agv), P.O. Box 430, 8200 AK Lelystad, The Netherlands.

Plant use solar energy, carbondioxide, water and nutrients to make long chains of carbon. These carbon chains are used for the production of carbon hydrates proteins, fats and other organic substances. We use these for our human and animal food, for fibers, building materials and as an energy resource. Part of this organic material is returned back to the soil to make it capable of growing these same plants.

In millions of years huge amounts of organic matter were stored in the soil as organic matter or fossil energy carriers as oil, gas and coal. We make use of these stocks to supply us with energy and to be able to grow plants for our needs. However what has been stored in our soils for millions of years we now are depleting in a few hundred years. Thus blowing the stored carbon back in the air as CO_2 which is generally considered to be the main cause of climate change. The amount of organic matter we return back to the soil is in general too low to maintain its capacity for plant production on the long term. Various studies show there is a decrease of organic matter in arable soils all over the world. The depletion of organic matter in our soils and the way we cultivate it, is causing susceptibility to physical influences such as erosion and run off and is disturbing the water household.

There are different strategies to cope with this decrease of soil organic matter. They come down to returning more organic matter to the soil or decreasing the speed of respiration of organic matter. Thus preserving soil organic matter at a level on which the soil can fulfill its various beneficial functions. But what level of soil organic matter should we strive for, considering the different functions to be fulfilled? What is the minimum necessary, what is the maximum? Too high organic matter levels can also have adverse effects like leaching of nutrients and emissions of methane or laughing gas emissions. Agricultural science has until now not given very clear answers to these questions.

Winning energy from organic substances as plant oils, wood, organic waste material and crop residues is considered to be partly an alternative for the use of fossil energy. Here the discussion arises if we should win energy from organic materials or we had better use them as food, fibers or building materials or use it to maintain our soils. The authors’ opinion is that in general we should focus on developing other sources of energy for our daily needs. The world will already have enough trouble to feed itself in the future and moreover the plant is not very efficient in storing the energy of the sun. We should rather use organic substances dominantly to feed us, to give us clothes and building materials. Only the residues that serve no other purpose could be used to win energy from. Agriculture should rather use its space for winning energy in another way. By placing windmills or solar panels on the roofs, to at least provide in its own energy needs. In due course also tractors could run on home made electricity instead of on fossil or plant derived fuels. The developments in storage of electricity in batteries and in electro traction are going fast.

Should organic residues be returned back to the soil instead of winning energy from it? Another question on which research could try to give answers is for example what should we do better, compost organic residues and manure or should we turn it back directly to the soil or maybe first win energy from it and turn the leftovers back to the soil? For example, compost is considered a very valuable soil improver. However composting is a process where organic matter partly breaks down. In this process warmth is produced and mostly lost. Also a part of the organic nitrogen is turned into gaseous nitrogen compounds and is lost. Shouldn't we rather use the energy that is lost in the composting process? Or should we better use closed anaerobic fermentation in which the produced methane is used for energy and the nitrogen is not lost. And what is the value of residue of fermentation (digestate) for soil improvement? Research on this topic has only recently started but there is no clear answer yet. There are many reports on the positive value of compost although not often compared with adding the same material directly to the soil before the composting process. Also the effect of using the digestate as a fertilizer and soil improver hasn't been very well compared and evaluated. From digestate the fluid fraction has a high content of nitrates which can be used in a similar way as a chemical nitrogen fertilizer. The solid fraction contains a quite stable form of organic matter. At least it would be worth while to consider fermentation of organic matter instead of composting.

I would like to go back to strategies to cope with the degradation of our soils. Two major strategies are conservation agriculture and organic agriculture. From both strategies there is a great deal of evidence that they are able to maintain or improve soil quality.

Conservation agriculture focuses on minimal soil mechanization and on returning fresh crop residues to the top soil or to the soil surface. The rejection of intensive soil cultivation also reduces the use of fossil energy.

Organic agriculture has it focus more on (re-)using organic materials such as compost and manure for fertilization and soil improvement. In most cases this manure and compost is incorporated in the soil with a mechanical soil treatment. Also the rejection of the use of synthetic pesticides and fertilizers is considered to be beneficial for the soil. Another important effect of the rejection of synthetic nitrogen fertilizer is a strong reduction of fossil energy use and emission of laughing gas, both caused by the production of synthetic nitrogen fertilizers.

Both strategies have in common the focus on the use of cover crops and green manures thus cover crops serve as protection of the soil and as input of organic matter in the soil.

The claims of both strategies for a higher soil organic matter level in the soil have been proven to be right in many experiments and studies. Although in some case studies no differences were found between organic and conventional or conservation and conventional systems. The result of the strategy strongly depends on the way it is applied and on the environmental circumstances and soil status. But in general, both strategies showed to have positive effects on the soil quality.

There are also claims from both strategies to reduce laughing gas emissions although the evidence for these claims is fragmented and sometimes contradicting.

So what if both strategies could be combined? Is this possible and would this give an additional positive effect? Theoretically there could certainly be additive effects. A lower energy use for soil cultivation would be additional for organic agriculture. The decrease of energy use and laughing gas emissions because of the zero input of synthetic nitrogen fertilizer would be additional for conservation agriculture, but what about soil organic matter? None or very few long term experimental results are available for this combination.

Several organic and conservation farmers already are using part of each others strategies. Organic farmers tend to reduce their intensity of soil cultivation. There are also farmers who are successfully combining conservation and organic agriculture. Most examples however, deal with systems with only mowing crops in the rotation. The main challenges for the combination of the organic and conservation strategy are in growing root crops, in the control of weeds, in preventing a decrease of soil structure by compaction and in a sufficient soil temperature in spring. Part of the solution might lie in the application of modern techniques, like GPS for controlled traffic systems and to be able to mechanically control weeds very close to the plant, sensors to recognize weeds from culture plants followed by mechanical removal of the weed.

There are also a lot of other effects of the combination we don’t know of. What about yields, pests and diseases, biodiversity etc?

Considering the possible additive effects of combining both strategies it would be worth while to explore this combination under different conditions, with different crops and making use of what modern techniques have to offer. The first step would be to bring the organic and conservation movement together and to exchange knowledge, experiences and ideas.

CONSERVATION AGRICULTURE: THE SUSTAINABLE RESPONSE FOR SOIL CONSERVATION AND OTHER CHALLENGES FACING EUROPEAN AGRICULTURE

G. Basch
Inst. of Mediterranean Agr. Sci., Univ. of Évora, Crop Science Dept., 7002-554 Évora, Portugal

Abstract

Conservation Agriculture (CA) based on the principles of minimum soil disturbance, permanent soil cover through crop residues or cover crops and the use of diversified crop rotations is a concept for resource-saving crop production that matches productivity and environmental sustainability. Today's demand for a competitive but yet environmentally friendly European Agriculture requires a change in the traditional crop production processes to overcome the drawbacks of soil erosion, water pollution, energy consumption and CO_2 emissions, reduced cost efficiency, a.s.o.. The objectives established by the Common Agricultural Policy (CAP), reinforced but also adapted in the ongoing health check, draw the direction in which European policy makers and stakeholders want agriculture to develop and make it more sustainable, in the very holistic sense of this adjective. The benefits deriving from the adoption of CA, outlined and documented with references from worldwide experience, would meet most of the objectives set out by CAP. However, whereas adoption of no-tillage based CA has advanced tremendously in overseas regions, especially in South American countries, CA and no-tillage in Europe lag far behind. Recognition of CA and no-tillage as both an economical and ecological sustainable method for crop production and its promotion within the measures that will have to be taken to implement successfully the coming Soil Framework Directive, may contribute to close the gap between European and overseas CA adoption levels.

Introduction

Today, European Agriculture faces the biggest challenge since the establishment of the Common European Market. Unlike other economic sectors European Agriculture was much less exposed to market rules and competition and thus not forced to adapt step by step to new conditions. Now, globalization opened the European Market also for agricultural products produced under completely different premises. Farmers and consumers, but also politicians are deeply confused in the presence of so many uncertainties; farmers, because they do not know what and how to produce due to enormous fluctuations of prices and legislative restrictions; consumers, because they are not sure whether food safety is guaranteed buying food at reasonable prices from a global market; politicians and decision makers, because they have to find the balance between farmer and consumer demands mixed up with environmental concerns.

The need for food and the demand for raw materials from agricultural products will increase constantly, independently of the use of crops for biofuels. To match this demand a global effort has to be undertaken and Europe cannot stay aside in this struggle. European Agriculture has to continue to be highly productive and must not rely on its economic strength to supply its demand from a cheap global market. However, more and more restrictions due to environmental and consumer concerns bring limits to agricultural productivity.

Common Agricultural Policy changed a lot over decades as a response to the change of conditions and requirements, internal and international political and economical pressures, etc.. Today the general prevailing trend is the reduction of subsidies while increasing environmental restrictions regarding farming activities. In between these pressures European mainstream agriculture will have to change and search for “new” approaches to comply with the demands and conditions of a world market and within the production standards of EU.

Objectives of CAP

The European CAP has been subject to ongoing reform since it was implemented in the second half of the last century. Since the early 1990s, there has also been a concerted effort to link agricultural and environmental policy. In the recent past a transition from production-linked subsidies to a farm payment system that is separate from production has been introduced. Presently farm subsidies are also subject to deductions called modulation whereby increased percentages of a farmer’s overall payment are redirected towards alternative rural development and environmentally sensitive initiatives. Coupled with annual inflation, the net value of farm subsidies is decreasing annually. After 2013 it is highly likely that any future payments will be strongly linked towards environmental protection.

With the CAP the European Commission set a number of objectives whose achievement will confront the agricultural sector with the biggest challenge since the existence of the Common Market:

- Reduction of subsidies
- Protection of soil, water, air, biodiversity, etc.
- Competitiveness of European agriculture
- Globalization of agricultural markets
- Food safety (quality and quantity) at acceptable prices
- Production of bio-energy crops
- Reasonable farm income
- Landscape management

The simultaneous achievement of all these goals seems impossible and is hardly imaginable under the actual set of traditional agricultural practices.

In addition to the already existing legal framework regarding environmental protection, and despite the fact that nine Member States have specific soil protection legislation in place, it is anticipated that the Soil Thematic Strategy ratified by the European Commission in September 2006, will be adopted as a Soil Directive by the EU Parliament within two years. This directive based on the already identified major threats to European soil (Jones et al 2006) will further restrict agricultural activity unless production methods complying with the new requirements are adopted.

With CAP striving for the achievement of all these objectives, European agriculture has to adapt and to adopt alternative production methods to withstand the multiple pressures it will be subject to in the near future and to attain real and overall sustainability. The question is how?

Deliverables of Conservation Agriculture

In order to address problems of soil degradation (mainly wind erosion) conservation and no-tillage systems started to be used in the middle of the last century. The concept of crop, grassland or pasture establishment without turning the soil or even without any kind of previous tillage turned out to be successful and was adopted on an exponentially growing area, mainly in North and South America and Australia. Permanent or at least semi-permanent soil cover through crop residues or cover crops and the perception of the need of diversified crop rotations to reduce the pressure from pests, diseases and problem weeds, were considered necessary supplements to build up the concept of Conservation Agriculture (CA).

However, the reasons for the fast spreading uptake of conservation tillage and no-tillage as the main pillar of the concept of conservation agriculture are manifold and well documented (Cavalli et al 1996, Tebrügge & Böhrnsen 1997, Tebrügge & During 1999, Tebrügge 2000, Tebrügge 2003, Holland 2004; Pagliai et al 2004, Lipiec et al 2006, Bravo et al 2007, Cantero-Martinez et al 2007, Hobbs 2007, Lal et al 2007, Soon et al 2007, Thomas et al 2007, Wang et al 2007, Withers et al 2007, Casa & Lo Cascio 2008, D'Emden et al 2008, Hobbs et al 2008, Sainju et al 2008) and can be summarized as follows:

- Reduction of soil erosion of up to 90%;
- Reduction of surface runoff of up to 70%;
- Reduction of off-site transport of nutrients and plant protection products through lower surface runoff and sediment transport and improved adsorption;
- Improvement of soil water availability through higher infiltration rates, reduced evaporation and higher water holding capacity;
- Increase of soil organic matter through reduced mineralization rates and crop residues;
- Reduction of CO_2 emissions through carbon sequestration into soil organic matter and fuel savings;
- Reduction of production costs through lower machinery and repair costs, a higher labour productivity, less fuel consumption and, in the medium and long term, through reduced fertilizer inputs possible through the increase of soil organic matter;
- Improvement of trafficability and reduced subsurface compaction through improved soil structure and higher soil bearing capacity;
- Improved timing and more available days for field operations through better trafficability;
- Improved soil and aboveground biodiversity (micro and macro fauna);
- Enhanced degradation of plant protection products through higher microbial activity;
- etc.

Some of these potential benefits of CA are immediately available with a change to these practices; others may take years to develop.

CA can be compared to a set-aside system where the soil is not subject to tillage, and permanently covered by divers species of dry or growing plants. The only difference consists in the fact that the land continues to produce. At least, the environmental benefits of set-aside land are recognised by the European Commissioner for Agriculture stating during the discussion of the “health-check” that “I also want to assure that we retain the environmental benefits it (set-aside land) has brought”.

Adoption of Conservation Agriculture

The initial adoption of conservation tillage was driven by different motives in the regions where these techniques are widely applied today. In the US it was mainly the concern of the degradation of the highly erodible soils subject to both wind and water erosion. Soon, the economical benefits of reduced and no-tillage crop production systems became as relevant as the concern of soil conservation for the massive adhesion of farmers to the new technology for crop establishment and grassland renovation. Despite the occurrence of severe soil erosion in many regions of Brazil, there it was mainly the economic aspect that drove farmers to initially adopt no-tillage in the early 1970s (IAPAR 1981).

In 2004/05 the worldwide adoption of no-tillage (not conservation tillage) was almost 100 Mha with the largest area to be found in North and South America and Australia (table 1). According Derpsch (2005), the area under no-tillage almost doubled between 1999 and 2005. Especially in South American countries the percentage of the total cropland under no-tillage is over 50% reaching around 65% in Paraguay.

Table 1: Extent of no-tillage adoption worldwide (after Derpsch, 2005)

Country	Area under No-tillage (ha) 2004/2005
USA	25.304.000
Brazil	23.600.000
Argentina	18.269.000
Canada	12.522.000
Australia	9.000.000
Paraguay	1.700.000
Indo-Gangetic-Plains	1.900.000
Bolivia	550.000
South Africa	300.000
Spain	300.000
Venezuela	300.000
Uruguay	263.000
France	150.000
Chile	120.000
Colombia	102.000
China	100.000
Others (Estimate)	1.000.000
Total	95.480.000

In Europe, although intensive research on the different aspects of conservation tillage was carried out after the invention of Paraquat in 1955 and its commercial release in 1961, no-tillage and even reduced tillage were applied at a very small scale until the end of the last century. The only exception was UK where in the early 80s almost 300.000 ha were sown under no-tillage. However, the straw burn ban caused farmers to abandon this technique due to increasing problems of weed control and volunteer cereals (Christian 1994).

Nevertheless, it appears that a “renaissance” of conservation tillage has occurred during the last few years in a number of countries throughout Europe. In addition to conservation tillage practices the two other main principles of Conservation Agriculture are becoming more and more important amongst European farmers: permanent soil cover both in annual and perennial crops and the utilization of balanced but market-oriented crop rotations to reduce the input of agro-chemicals and to overcome a potential increase of problem weeds, pests and diseases. Still, Europe lags far behind in the uptake of Conservation Agriculture when compared to other regions in the world. In the member countries of ECAF this percentage reaches only around 1%.

Table 2: Area of Arable Land under Conservation Tillage (CT) and No-Tillage (NT) in Member Countries of the European Conservation Agriculture Federation (2005) (Basch et al 2007)

Country	CT (incl NT) (1000 ha)	No-Till only (1000 ha)	Arable Land (1000 ha)*	% in CT	% in NT
Belgium	140	0	815	17.2	0.0
Denmark	230	0	2276	10.1	0.0
Finland	1150	150	2199	52.3	6.8
France	3870	150	18449	21.0	0.8
Germany	2500	200	11791	21.2	1.7
Greece	430	200	2717	15.8	7.4
Hungary	500	10	4614	10.8	0.2
Ireland [1]	10	0	401	2.5	0.0
Italy	560	80	8287	7.7	1.0
Portugal	418	80	1990	21.1	4.0
Russia	15500	500	123465	12.6	0.4
Slovak Rep.	179	37	1433	12.6	2.6
Spain	2400	600	13738	18.0	4.4
Switzerland	102	12	409	25.4	2.9
UK	2680	180	5753	45.6	3.1
	30669	**2199**	**198337**	**15.5**	**1.1**

* FAO Statistics 2003 on www.faostat.fao.org

[1] Government Statistics (2005) and data supplied by Conservation Agriculture Ireland Survey (2007)

Conclusions

Reduction of direct payments and the increase of funds for Rural Development Schemes are thought to be way to implement the objectives of CAP into agricultural practice. But the recent past showed that European member states did not make use of all available funds to support new production methods capable to fulfil both the objectives and requirements as established by CAP and the market demand for agricultural products at a competitive price.

It is exactly the concept of Conservation Agriculture that is able to fill this gap of producing crops in a more competitive way while safeguarding the need for soil and water protection and contributing strongly to the mitigation of CO_2 emissions. The most competitive agricultural producers in the world rely on the concept of CA and have shown that this approach works under the most divers conditions. Now they are decades ahead of Europe in the practice and development of locally adapted forms of CA. They were forced by environmental and economic pressure to adopt CA systems. Maybe, under the pressure of a globalized market and the restrictions imposed by the EU, it will be recognised that CA is the most sustainable compromise to achieve best the very different goals set out for European Agriculture. The use of still available funds for making CA systems work also in Europe is certainly a political option that should be taken as soon as possible. Even outside EU Member States other national governments on mainland Europe are placing increased emphasis on environmentally sensitive practices and climate change strategies and are willing to fund such initiatives with public money (Schwarz et al 2007).

A widespread adoption of no-tillage would guarantee the realization of many of the objectives set out in the Soil Thematic Strategy especially on our most vulnerable soils. The implementation of a European Soil Framework Directive is considered to be an important step towards the recognition that conservation tillage and no-tillage is both an economical and ecological sustainable method for crop production.

References

Basch, G., Geraghty, J., Streit, B. & Sturny, W.G. (2007). No-Tillage in Europe – State of the Art: Constraints and Perspectives. In: *No-Till Farming Systems*. Goddard, T., Zoebisch, M., Gan, Y., Ellis, W., Watson, A.& Sombatpanit, S. (Eds.). World Association of Soil and Water Conservation, Special Publication Nº.3.

Bravo, C. A., Giraldez, J. V., Ordonez, R., Gonzalez, P., and Torres, F. P. (2007). Long-term influence of conservation tillage on chemical properties of surface horizon and legume crops yield in a vertisol of southern Spain. *Soil Science* 172, 141-148.

Cantero-Martinez, C., Angas, P., and Lampurlanes, J. (2007). Long-term yield and water use efficiency under various tillage systems in Mediterranean rainfed conditions. *Annals of Applied Biology* 150, 293-305.

Casa, R., and Lo Cascio, B. (2008). Soil conservation tillage effects on yield and water use efficiency on irrigated crops in Central Italy. *Journal of Agronomy and Crop Science* 194, 310-319.

Cavalli, R., Borin, M., Bonari, E., Basch, G., Tebrugge, F., Frede, H. G., and Hummel, H. E. (1996). Soil and water quality as affected by agrochemicals under different soil tillage systems. *Environmental Fate of Xenobiotics*, 605-615.

Christian, D. G. (1994). Experience with direct drilling cereals and reduced cultivation in England. In: *Proceedings of the EC- Workshop- I-,* Giessen, 27-28 June, 1994, Experience with the applicability of no- tillage crop production in the West-European countries, *Wissenschaftlicher Fachverlag, Giessen,* 1994, 25- 31

D'Emden, F. H., Llewellyn, R. S., and Burton, M. P. (2008). Factors influencing adoption of conservation tillage in Australian cropping regions. *Australian Journal of Agricultural and Resource Economics* 52, 169-182.

Derpsch, R. (2005). The extent of Conservation Agriculture adoption worldwide: Implications and impact. *Proceedings of the III World Congress on Conservation Agriculture*, 3–7 October 2005, Nairobi, Kenya.

Hobbs, P. R. (2007). Conservation agriculture: what is it and why is it important for future sustainable food production? *Journal of Agricultural Science* 145, 127-137.

Hobbs, P. R., Sayre, K., and Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society B-Biological Sciences* 363, 543-555.

Holland, J. M. (2004). The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture Ecosystems & Environment* 103, 1-25.

IAPAR (1981). Plantio direto no estado do Paraná. *Fundação Instituto Agronómico do Paraná*, Brazil, Circular N° 23, 244 pp

Jones, C.A., Basch, G., Baylis, A.D. , Bazzoni, D., Biggs, J., Bradbury, R.B., Chaney, K., Deeks, L.K., Field, R., Gomez,J.A., Jones, R.J.A., Jordan, V.W.L, Lane, M.C.G., Leake, A., Livermore, M., Owens, P.N., Ritz, K., Sturny, W. and Thomas, F. (2006). Conservation Agriculture in Europe: An approach to sustainable crop production by protecting soil and water? *SOWAP*, Lealott's Hill, Bracknell, RG42 6EY, UK.

Lal, R., Reicosky, D. L., and Hanson, J. D. (2007). Evolution of the plow over 10,000 years and the rationale for no-till farming. *Soil & Tillage Research* 93, 1-12.

Lipiec, J., Kus, J., Slowinska-Jurkiewicz, A., and Nosalewicz, A. (2006). Soil porosity and water infiltration as influenced by tillage methods. *Soil & Tillage Research* 89, 210-220.

Pagliai, M., Vignozzi, N., and Pellegrini, S. (2004). Soil structure and the effect of management practices. *Soil & Tillage Research* 79, 131-143.

Sainju, U. M., Senwo, Z. N., Nyakatawa, E. Z., Tazisong, I. A., and Reddy, K. C. (2008). Soil carbon and nitrogen sequestration as affected by long-term tillage, cropping systems, and nitrogen fertilizer sources. *Agriculture Ecosystems & Environment* 127, 234-240.

Schwarz, R., Chervet, A., Hofer, P., Sturny, W. G., and Zuber, M. (2007). Canton of Berne promotes conservation of natural resources in agriculture. *Revue Suisse D Agriculture* 39, 117-122.

Soon, Y. K., Arshad, M. A., Haq, A., and Lupwayi, N. (2007). The influence of 12 years of tillage and crop rotation on total and labile organic carbon in a sandy loam soil. *Soil & Tillage Research* 95, 38-46.

Tebrugge, F. (2000). Interactions of conservation tillage and no-till on soil properties: Environmental and economic benefits. *Conservation Tillage: a Visible Option for Sustainable Agriculture in Eurasia*, 101-115.

Tebrugge, F. (2003). No-tillage visions-protection of soil, water and climate and influence on management and farm income. *Conservation Agriculture: Environment, Farmers Experiences, Innovations, Socio-Economy, Policy*, 327-340.

Tebrugge, F., and Bohrnsen, A. (1997). Interrelation of different tillage intensities on soil structure, biological activity, yield and profit. *Actual Tasks on Agricultural Engineering - Collection of Papers*, 129-138.

Tebrugge, F., and During, R. A. (1999). Reducing tillage intensity - a review of results from a long-term study in Germany. *Soil & Tillage Research* 53, 15-28.

Thomas, G. A., Titmarsh, G. W., Freebairn, D. M., and Radford, B. J. (2007). No-tillage and conservation farming practices in grain growing areas of Queensland - a review of 40 years of development. *Australian Journal of Experimental Agriculture* 47, 887-898.

Wang, X. B., Cai, D. X., Hoogmoed, W. B., Oenema, O., and Perdok, U. D. (2007). Developments in conservation tillage in rainfed regions of North China. *Soil & Tillage Research* 93, 239-250.

Withers, P. J. A., Hodgkinson, R. A., Bates, A., and Withers, C. L. (2007). Soil cultivation effects on sediment and phosphorus mobilization in surface runoff from three contrasting soil types in England. *Soil & Tillage Research* 93, 438-451.

SUSTAINABLE SOIL CULTIVATION STRATEGIES: APPROACHES IN CONVENTIONAL AND ORGANIC AGRICULTURE

U. Köpke[1]
ISOFAR, c/o Institute of Organic Agriculture, Univ. of Bonn, Katzenburgweg 3,
D-53115 Bonn, Germany, E-Mail: iol@uni-bonn.de

Abstract

Sustainable soil cultivation aims to maintain or increase soil fertility, preventing erosion and soil compaction, improving soil trafficability and saving labour as well as energy costs and greenhouse gas emissions. Conservation tillage (CT) approaches include several tillage types, such as mulch-tillage, reduced tillage, strip-tillage, and the extreme no-tillage/direct seeding treatments. CT avoids deep turning and loosening of the soil but depends in the majority of cases on non-selective herbicides used prior to sowing to clear the ground of weeds and volunteer plants. Under the conditions of Organic Agriculture (OA), adjusting the time and type of tillage is a main tool for sustainable soil and nutrient management. In OA a combination of 'shallow soil inversion' and deep soil loosening performed with so-called two-layer ploughs or on-land ploughs still seems to be a good compromise for controlling weeds, enhancing mineralisation and nitrification, root growth and nutrient uptake. Since climate change might shorten the time slots given for tillage and sowing, CT in OA might at least be performed temporarily in the crop rotation by using mulch- or direct seeding of pulses or maize into mulch layers of precrops that might additionally deliver allelopathic effects enabling sufficient weed suppression. Pressure of perennial weeds might possibly require the use of bio-herbicides.

Introduction

All approaches of sustainable soil cultivation have to consider the following main targets: to maintain or increase soil fertility, to prevent erosion and soil compaction, to improve soil trafficability, to save labour as well as energy costs and greenhouse gas emissions. Approaches of conservation tillage (CT) include several tillage types, such as no-tillage, reduced tillage, mulch-tillage or strip-tillage. CT defines firm soil mulch husbandry systems (FSMH) avoiding deep turning and loosening of the soil but depends in the majority of cases on non-selective herbicides used prior to sowing to clear the ground of weeds and volunteer plants. If conservation agriculture (CA) is viewed and evaluated in a broader sense as including numerous other aspects of nature conservation, we need to consider the approaches and effects of very different competing agricultural systems.

Mainstream Agriculture/Integrated Agriculture

In Central Europe, so-called conventional or mainstream agricultural systems (MAS) have, during the last 3 decades, progressively developed to systems of so-called integrated agriculture systems (IAS). One key element of IAS is to maximise farmers' income by reducing the input of fertilisers and pesticides within defined thresholds. If integrated production is defined as 'a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming' (El Titi et al 1993), then the aim of achieving CA with standard application of total herbicides conflicts with the objective of using thresholds for herbicide application. Meanwhile the pressure of decreasing product prices has led conventional farmers to leave diversified system-stabilising rotations. Glyphosate is the second most used herbicide in Germany. No doubt this calls the IAS approach into question.

When arable soil is seen as an important and slowly regenerating resource, reduced tillage or no-tillage systems are regarded as the main tools to avoid soil erosion and soil compaction in simplified farming systems which no longer depend on sophisticated diversified rotations for success. Nevertheless, compared with North America, Southern Brazil or Paraguay (Derpsch 2008), CT is currently not widely adopted in MAS or IAS in Central Europe. CT as well as FSMH often appear to be less productive and more risky. Often, a higher mineral nitrogen input is necessary to maintain yields due to reduced net mineralisation in the early growing season, especially in the first years of continuous application of reduced tillage in temperate climates (Baeumer & Köpke 1989). Furthermore, non-inverted crop residues of maize or weeds increase the risk for *Fusarium* infestation and therefore Deoxynivalenol mycotoxin contamination in the following winter wheat (Köpke et al 2007).

Organic Agriculture

Ideally, organic agriculture systems (OAS) follow a 'whole-farm' approach to manage a (mixed) farm as far as possible as a nearly closed and integrated system (Köpke 1995). OAS depend more on specific site conditions and are therefore forced to combine the best adapted elements in a holistic approach. OAS must always be environmentally sound, locally adapted and individually site-specific. This is also valid for target-oriented soil cultivation.

All non-inverting tillage procedures usually show higher microbial activity or microbial biomass in the upper topsoil compared to the lower topsoil. Correspondingly, it is often suggested that tillage procedures in Organic Agriculture (OA) should avoid disturbance and mix of the different soil layers and that there is no room for the mouldboard-plough (MP) in OAS. However, the use of the MP in LSHS combined with secondary tillage is still common practice in OA.

The principles relating to soil cultivation in OAS have often been linked with the typical layering of forest soils. In a similar way, pioneer proponents of zero-tillage systems compared the soil structure of untilled soil with the stable structure frequently found under permanent pasture (Baeumer & Bakermans 1973). This contrasts with the more homogenous structure of a soil conventionally tilled with the MP. Nevertheless, only a few organic farmers are permanently using the extreme option of FSMH, i.e. direct seeding (DS), mainly due to three reasons:

i. Under temperate climate conditions, omitting deep loosening and thorough inversion of the topsoil result in cooler and wetter soils in early spring and hence in reduced mineralization and nitrification of soil-borne nitrogen and its transformation into crop yield of non-leguminous crops

The MP in OA is regarded as an effective and obviously essential tool for nutrient management, for inverting FYM, removing perennial leys, enhancing root growth, nitrogen mineralisation and nutrient uptake (Köpke 1993; Pekrun et al 2003). Availability of soil-borne nitrogen in OAS, especially in the early vegetation phase, is based on higher amounts of mineralized nitrogen, which in turn is a function of the higher tillage intensity normally achieved by using loose-soil husbandry (LSH), i.e. the MP (Baeumer & Köpke 1989, Vakali et al 2002). This statement is underlined by comparing the use of the MP with reduced tillage intensity performed with a two-layer plough and a layer cultivator in a long-term experiment. As a function of higher mineralisation and nitrification and enhanced rooting density, intensive tillage results in higher N-uptake, leaf area index, plant development and finally in higher yield, compared to reduced primary tillage systems (Vakali et al 2002; Vakali 2003).

ii. Tillage, and in particular ploughing, is one of the most effective tools for weed control

In contrast to IAS with its use of quite efficient herbicides, OAS has to combine different elements of indirect and direct methods of weed control within a more or less efficient site-specific weed management strategy. General preventive tools are, besides tillage hygiene, rotation, choice of cultivars, seeding date, seeding density, spacing and manuring, which all result in enhanced crop competitiveness. Direct mechanical methods are based on reducing the amount of light, water and nutrients available to weeds as well as on weakening the amount of assimilates in storage organs, roots and bulbs. E.g. use of the MP resulted in a significantly higher shoot mass in barley compared to reduced tillage intensity. When weeds were destroyed through herbicide application, this effect decreased and the differences were no longer significant, underlining that weed control is one of the top concerns of OA.
Problem weeds, especially perennials are less well controlled by heavy cultivators or other non-inverting primary tillage tools than by mouldboard-ploughing. Therefore, in OAS the MP should continue to be used in order to control rhizomatous weeds, but the unanswered question is: how deep does the ploughing have to be? Consequently, a combination of ‘shallow soil inversion’ and ‘deep soil loosening’ performed with so-called two-layer ploughs seems to be a good compromise for controlling weeds, enhancing mineralisation and nitrification, root growth and nutrient uptake, while reducing fuel consumption and physical disruption by deep inversion.

iii. Tillage can play a key role in a multi-functional agriculture approach

Although CT systems using total herbicides can be considered as more efficient in reducing erosion and fuel consumption, OA is still regarded as being the more sustainable agricultural approach, at least under the conditions of a temperate climate due to several other positive environmental impacts. For more than 20 years, the environmental impacts of MAS have been listed hierarchically (Haber & Salzwedel 1992): 1. Impacts on biotopes, 2. Contamination of ground water, 3. Impacts on soil, 4. Impacts on surface water, 5. Impacts on food quality, 6. Contamination of air. A seventh important category is given with the global warming potential (GWP). The multifunctionality and high process quality of OA can be determined by life cycle assessment (LCA) (Geier & Köpke 1998; Geier et al 1998)

Biodiversity
Several comparative studies have shown that compared to IAS, in most cases OAS resulted in enhanced biodiversity of crops and wild flora and fauna (Frieben & Köpke 1996, Hole et al 2005). Whilst yields in OAS are quite lower and weed thresholds higher compared to IAS, weeds are regarded as having positive effects, such as: reduction of monoculture effects, soil cover and shading, increased diversity of fauna, alternative nutritional source for pests and predators, source of organic matter, crop improvement through allelopathy. Additionally, the weed flora in OAS is generally more diverse, often consisting of legal protected species that increase the associated biodiversity in the fields and may be valued for aesthetic reasons (CA!).

Soil erosion and nutrient losses

Tillage operations that bury most of the crop residues might benefit weed and disease control but can cause serious soil erosion problems. Living mulches in the form of perennial grass/legume-mixtures, underseeds, catch crops and green manures are used in OA to fill the gap of uncovered soil between main crops which are generally harvested earlier in OAS compared to IAS. Consequently, the C-factor of the USLE is often calculated to be lower in OAS compared to IAS. Auerswald (1997) calculated a C-factor of only 0.06 for the 6-field rotation of our organic experimental farm Wiesengut, which integrates many of the elements for optimising soil cultivation in OAS as outlined above. This C-factor equals the C-factor calculated for a maize-smallgrain-meadow-rotation by Stewart et al (1976) and is clearly lower than that calculated for conventional arable farms in Bavaria, Germany (0.16), varying between 0.20 (leafy crops > 50%) and 0.12 (cereal crops only) (Auerswald & Schmidt 1986).

Thus, the risk of soil and nutrient losses through erosion and surface run-off is not necessarily higher in OAS compared to IAS when LSH is performed. Soil conservation has been an issue in OA right from the beginning. This is realised by fertility building, using diversified rotations with longer periods of rest for the soil achieved with grass/legume-leys, and application of FYM, which can result in a SOM content up to 20% higher than in intensive conventional farming (Haider 1992, Mäder et al 1995, Lehocka et al 2008), resulting also in higher microbial activity and aggregate stability (Mäder et al 2002).

Soil structure improved by SOM can provide an integrative expression of soil biological, physical and chemical processes. Schwertmann (1991) presented results from a diploma-thesis showing that aggregate stability was higher in organic loess soil, resulting in about 1.5 times higher water percolation through soil columns. Siegrist (1995) also found higher percolation stability for biodynamic and organic treatments compared to conventional treatment in the long term DOK-trial near Therwil, Switzerland, on a Luvisol from loess. When visiting the experiment in November 1995 the author of this contribution was able to differentiate the (encoded) treatments in all 4 replications under conditions of bare soil. Surface soil of the biodynamic and organic plots appeared to be darker brown and capped to a lesser extent due to larger amounts of earthworm casts. Earthworm biomass and density of the DOK-trial were found to be significantly higher in the organic than in the conventional plots (Mäder et al 2002).

However, under conditions of high soil erodibility, intensive use of living mulch established as perennial leguminous forage crops undersown in cereals and cover crops, which increase Ct-contents, biomass and abundance of earthworms, is considered as not sufficient to control erosion. Consequently, bi-cropping or strip-cultivation systems have to be developed further, taking biodiversity and other aspects of nature conservation into account.

Energy consumption and greenhouse gas emission

In the industrialised countries, emission of CO_2 is caused mainly by fossil energy consumption. The fuels used by farmers comprise direct (diesel, heating oil, etc.) and indirect (operating materials) forms of energy supply. Since the early studies of Lockeretz et al (1976), OAS have been recognised as farming systems that use less fossil energy due to the non-use of mineral N-fertilizers.

In general, due to the high proportions of forage plants and longer periods of rest for the soil, together with the addition of stable manure, equal or higher amounts of CO_2 are bound in OAS compared to MAS. Long-term trials have revealed that when conducted over a period of years, OA apparently leads to changes in the composition of the soil microflora, resulting in a detectably increased proportional assimilation of CO_2 through the higher microbial biomass in the soil. In contrast, the amount of exhaled CO_2, referred to biomass has been found to be greater in conventionally cultivated soils (Haider 1992, Mäder et al 1993).

The absolute input of fuel and lubricants is almost equal in both OAS and MAS when the MP is used, but can be reduced to about 30% in no-till wheat. Nevertheless, the fact that about 50 % of the total energy used in OAS is bound in fuel and lubricants indicates a need for action to reduce this relatively high energy input.

Potential solution: Temporary use of CT in OA

Mulch layers of precrops may suppress weeds. For efficient weed suppression Barberi (2002) considers homogeneous distribution of at least 4-6 t ha^{-1} crop residues necessary. Several approaches to use mulch layers for weed control combined with reduced or no-tillage meanwhile have been documented. Porter et al (2005) have shown that autumn sown rye gave an excellent weed suppressing winter cover crop enabling no-till organic soybean production under the conditions of Minnesota, USA. Regrowth of rye can be avoided when mowed or knocked down by using a front mounted cover-crop roller/crimper at anthesis prior to or following soybean seeding. The latter equipment allows direct seeding of maize into hairy vetch cover crop residues, too (Moyer 2008).

Allelopathic action of some oats genotypes has been assumed (Chou 1986). Unfortunately, no equivalent tool such as the use of the allelopathic effects of black oats (*Avena strigosa*) residues to control weeds in Southern Brazil (Derpsch et al 1988) is available in the Northern hemisphere. For the conditions of European temperate climate, competitiveness of *Avena sativa* L. is considered as relatively high when compared with other cereals (Davies & Welsh 2001). Own previous experiments have confirmed that *A. sativa* performed better, i.e. more residues and higher crop ground cover were produced when compared with *A. strigosa*. Research on the allelopathic effects of sunflower and buckwheat is in progress (Gawronski et al 2002, Neuhoff unpubl.).

In contrast to non-legumes, grain legumes do not depend on soil-borne nitrogen due to their ability to fix nitrogen symbiotically. Competitiveness against weeds is often high for faba beans (FAB) which additionally can satisfy their high demand for water to germinate in wetter no-tilled soil. Based on the experience in 2004, when hail-shattered grains reduced yield of yellow oats by 60%, leaving the field with a thick mulch layer of straw and shattered germinating seeds weed-free, we are running field trials in order to test the following hypotheses: (i) Direct seeding of FAB into a mulch layer of precrop oats enables sufficient control of annual weeds. (ii) Increasing density of autumnal germinating oats can further increase weed suppression. (iii) Perennial weeds can limit FAB grain yield also in a system that omits tillage only temporarily. First results were promising if weed pressure of perennials was low (Köpke & Schulte 2008).

Nevertheless, if weed pressure of perennials is large, synthetic total herbicides that enable mainstream farmers to conduct no-till systems over years and which are not allowed to be used in OA, should be substituted by natural counterparts, so-called bio-herbicides. Natural vinegar, corn gluten and pine wood extracts that are officially certified in other regions of this globe are to date not considered as adequate to be used in Europe's OA. Their temporary use would enable more organic farmers to perform judicious tillage coupled with organic soil improvement and to efficiently prevent soil from erosion and further improve soil quality.

Conclusions

Currently, on highly erodible soils of the southern hemisphere, CA is predominantly based on CT. In the northern hemisphere, CA has a wider aspect and is currently best realised by OA, where CT is only of minor importance for preserving nature. The LCA method enables identification and evaluation of differences among agricultural production intensities according to their environmental impact and currently indicates OA as being the most sustainable approach, at least under the conditions of a (humid) temperate climate.

Judicious temporary use of direct seeding or mulch seeding is considered as a suitable approach to save labour and fuel in those cases where perennial weeds do not play an important role or can be accepted for one season due to sufficient crop competitiveness. Failure of clear effects of weed suppression assumed for the amount of crop residues and vagueness of allelopatic effects make further investigations necessary. In all cases where perennials limit FSMH in OA henceforth 'bio-herbicides' should be regarded as a useful exceptional option but not considered as a standard measure in OA.

References

Auerswald K and Schmidt F (1986). Atlas der Erosionsgefährdung in Bayern - Karten zum flächenhaften Bodenabtrag durch Regen. Bayer. Geol. Landesamt in : GLA-Fachberichte 1, 74.

Auerswald K (1997) Personal communication.

Barberi P (2002) Weed management in organic agriculture: are we addressing the right issues? Weed Research 42, 177-193.

Baeumer K & Bakermans WAP (1973) Zero-tillage. Adv Agron 25, 77 – 123.

Baeumer K & Köpke U (1989) Effects of nitrogen. In: Commission of the European Communities (editor): Energy Saving by Reduced Soil Tillage. EC-workshop 10. - 12.06.1987, Goettingen, West-Germany, 145-162.

El Titi A, Bolla E & Gendrier JP (1993) Integrated production, principles and technical guidelines, IOBC/WPRS Bull. 16, 1, 1993.

Derpsch R (2008) No-tillage and conservation agriculture: a progress report. In: Goddard et al (eds.) No-till farming systems. Spec. Public. No.3, World Ass Soil Water Conserv, Bangkok, p 7- 39.

Frieben B & Köpke U (1996) Effects of farming systems on biodiversity. In: ISART J & JJ LLERENA (eds): Biodiversity and Land Use: The Role of Organic Farming. Proc First ENOF-Workshop Bonn, 1995, 11-21.

Gawronski SW, Bernat W and Gawronska H (2002) Allelopathic potential of sunflower mulch in weed control. Third World Congress on Allelopathy, 26-30 August 2002, Tsukuba, Japan, Sato Printing Co. LTD, Tsukuba, Japan, 160.

Geier U & Köpke U (1998) Comparison of Conventional and Organic Farming by Process-Life Cycle Assessment. A Case Study of Agriculture in Hamburg. In: CEUTERICK D (ed): Int Conf Life Cycle Assessment Agric, Agro-Industry Forestry. Proc Intern Conf 3-4 Dec 1998 Brussels, Belgium, 1998/PPE/R/161. 31-38.

Geier U, Frieben B, Haas G, Molkenthin V & Köpke U (1998) Ökobilanz Hamburger Landwirtschaft - Umweltrelevanz verschiedener Produktionsweisen, Handlungsfelder Hamburger Umweltpolitik. Schriftenreihe I O L. Berlin: Dr. Köster, ISBN 3-89574-6.

Haber W and Salzwedel J (1992) Umweltprobleme der Landwirtschaft – Sachbuch Ökologie. Hrsg. Der Rat von Sachverständigen für Umweltfragen. J.B. Metzlersche Verlagsbuchhandlung und Carl Ernst Poeschel Verlag, Stuttgart.

Haider K (1992) Biochemische Prozesse der Bildung und der Dynamik von Huminstoffen im Boden. Ber ü Landw 206. Sonderheft, 45-62.

Hole DG, Perkins AJ, Wilson JD, Alexander ICH, Grice PV & Evans AD (2004) Does organic farming benefit biodiversity? Biological Conservation 122, 113-130.

Köpke U (1993) Nährstoffmanagement durch acker- und pflanzenbauliche Maßnahmen. Ber ü Landw 207. Sonderheft, 181-203.

Köpke U (1995) Nutrient management in Organic Farming Systems: The case of nitrogen. Biological Agriculture and Horticulture (BAH), Vol 11/1995, 15-29.

Köpke U, Thiel B & Elmholt S (2007) Strategies to reduce mycotoxin and fungal alkaloid contamination in organic and conventional cereal production systems. In: Cooper J, Niggli U & Leifert C (eds): Handbook of organic food safety and quality. Woodhead Publishing Ltd. Cambridge, England, p. 353 – 391.

Köpke U & Schulte H (2008) Direct Seeding of Faba Beans in Organic Agriculture. In: D. Neuhoff et al (Eds) Cultivating the Future Based on Science. Vol 1 Organic Crop Production. Proc 2nd Sci Conf ISOFAR18-20 June 2008, Modena, Italy. ISOFAR, Bonn, 418-421.

Lehocka Z, Klimekova M & Bielikova M (2008) Soil quality indicators in organic and conventional farming systems in Slovakia. In: D. Neuhoff et al (eds) Cultivating the Future Based on Science. Vol 1 Organic Crop Production. Proc 2nd Sci Conf ISOFAR18-20 June 2008, Modena, Italy. ISOFAR, Bonn, 44-47.

Lockeretz W, Klepper R & Commoner B (1976) Organic and conventinal crop production in the corn belt: A comparison of economic performance and energy use for selected farms. Center for the biology of natural systems (ed), Washington University St. Louis, Missouri.

Mäder P, Pfiffner L, Jäggi W (1993) DOK-Versuch: Vergleichende Langzeituntersuchungen in den drei Anbausystemen biologisch-dynamisch, organisch-biologisch und konventionell. III Boden: Mikrobiologische Untersuchungen. Schweiz. Landw. Forschung. 32, 509-545.

Mäder P, Hüsch S, Niggli U, Wiemken A (1995) Metabolic activities of soils from bio-dynamic, organic and conventional production systems. In: Cook HF &Lee, HC (eds.): Soil Management in Sustainable Agriculture. Proc 3rd Int Conf Sust Agric, Wye College, Univ London 31 Aug to 4 Sep 1993 No 79: 584-590.

Mäder P, Fließbach A, Dubois D, Gunst L, Fried P and Niggli U (2002): Soil fertility and biodiversity in organic farming. Science 296, 1694-1697

Moyer J (2008) Organic no-till. In: Goddard et al (eds.) No-till farming systems. Spec. Public. No.3, World Ass Soil Water Conserv, Bangkok, p 83-89.

Pekrun C, El Titi A and Claupein W (2003) Implications of Soil Tillage for Crop and Weed Seeds. In: Adel El Titi (ed): Soil Tillage in Agroecosystems, CRC Press, Boca Raton, 2003, p 115 – 146.

Porter P., G. Feyereisen, J. De Bruin & G. Johnson, 2005: No - till in organic soybean production following a fall - planted rye cover crop. In: U Köpke et al (eds.) Researching Sustainable Systems. Proc 1st Sci Conf Int. Soc. Org. Agric. Res.

(ISOFAR) Adelaide, South Australia 21-23, 2005. International Society of Organic Agriculture Research (ISOFAR), Bonn, Germany, 26-30.

Schwertmann U (1991) Aktuelle Probleme der Bodenerosion - Eine Einführung. Ber ü Landw. 205. Sonderheft, 9-15.

Siegrist S (1995) Experimentelle Untersuchungen über die Verminderung der Bodenerosion durch biologischen Landbau in einem NW-schweizerischen Lößgebiet. In: Die Erde 126: 93-106.

Stewart BA, Woolhiser DA, Wischmeier WH, Caro JH & Frere MH (1976) Control of water pollution from cropland, Vol. II. U.. S. Dep. Agric. and Environ, Protection Agency. 187 p.

Vakali C, Sidiras N, Bilalis D and Köpke U (2002) Possibilities and limits of reduced primary tillage in Organic Farming. In Thompson R (ed): Proc 14th IFOAM Organic World Congress, Aug 21-28, 2002, Victoria, Canada, p. 27.

Vakali C (2003) Sproß- und Wurzelentwicklung von Getreide bei reduzierter Grundbodenbearbeitung im Organischen Landbau in Deutschland und Griechenland. PhD thesis Univ Bonn, Schriftenreihe Institut für Organischen Landbau, Hrsg Prof Dr Ulrich Köpke, Verlag Dr Koester Berlin, 112p.

Scientific session I. A Soil cultivation systems

THE INFLUENCE OF DIFFERENT TILLAGE SYSTEMS ON CONTENT AND DISTRIBUTION OF NUTRIENTS AND ORGANIC COMPONENTS IN SOIL

[1]Šoltysová B., [1]Danilovič M.
[1]*Slovak Agric. Res. Centre – Inst. of Agroecology, Špitálska 1273, Michalovce, Slovak Rep., 07101,*
E-mail: soltysova@scpv-ua.sk, danilovic@scpv-ua.sk

Abstract

In 1998–2004 were observed effect of soil tillage technologies on changes of nutrients, humus and humous substances in the soil. Field treatments were carried out on Eutric Fluvisol located in Vysoka nad Uhom. Changes of soil properties were observed at rational fertilized field variant under two soil tillage systems: traditional tillage (CT) and no-till (NT) in two soil profiles (depth 0 – 0.3 m and 0.3 – 0.6 m). Tillage system influenced content and distribution of available nutrients in soil profile, but not significantly. There was found higher accumulation of available potassium in the topsoil at NT than at CT. Higher influence on nutrient content had depht of soil. Content of available nutrients was lower in the deeper layer of the soil profile than in the shallower layer. Content of available phosphorus was lower in subsoil on average by 23.2 mg.kg^{-1} P and available potassium content by 65.3 mg.kg^{-1}. Humus content and quantity of both main constituents of humus was not depended on tillage system but was statistically high significant depended on depth of soil sampling. Humus content was higher at average by 4.78 g.kg^{-1} in comparison topsoil to subsoil. Humic acid carbon content was higher by 0.77 g.kg^{-1} and fulvic acid carbon content by 0.61 g.kg^{-1} in comparing topsoil and subsoil. Humus content in soil was significantly higher at the end of research period (year 2004) in comparison with initial stage.

Key words: Eutric Fluvisol, soil tillage systems, soil profile, nutrients, humus, humous substances

Introduction

Soil cultivation is complex of operations, which participate markedly on changes of soil properties. The depth of cultivation and soil tillage intensity relate with unlocking and intake of nutrients. Important role take crops, because their postharvest remains have different quality and quantity parameters and they have non-constant uptake of nutrients and water (Fialová, 1994).

Soil technologies are important, because they provide long-term maintenance of soil fertility (Kováč, Žák, 1999). The no-tillage technology exploitation is one of the ways how to achieve mentioned aim.

Many authors which are interested in the effect of soil cultivation on nutrients content and their distribution in the soil (López-Fando, Almendros, 1995; Bauer et al., 2002) found out that no-tillage technologies increased content of available soil phosphorus and potassium in comparison with traditional technology (ploughing).

At the same time the intensity of organic matter decomposition decreased by using minimum tillage technology of soil cultivation. This manifests on higher content of total carbon in the soil (Horáček et al., 2001, Šoltysová, Kotorová, 2002).

The aim of this work was obtained experimental notions about influence of various tillage systems on content and layout of nutrients, humus and humous substances at condition of Eutric Fluvisols.

Material and Methods

In 1998–2004 field treatment was carried out on experimental place of the Slovak Agricultural Research Centre – Institute of Agroecology Michalovce. Experimental locality is situated in Vysoka nad Uhom on the Eutric Fluvisols. Observed soil type is characterised as middle heavy soil, containing clay particles in rate over 30 %.

Experimental place belongs to the warm, strong dry, lowland, continental climatic region characterised by long-term average (1951 – 1980) annual air temperature 9.0 ^{o}C, for vegetation period 16.1 ^{o}C and sum of precipitation 584 mm, for vegetation period 344 mm.

Soil samples were taken after harvest in autumn, first date in 1998, and second date in 2004. Samples were used to observe available soil nutrient content (phosphorus, potassium), content of humus and humus substances (humic acids, fulvic acids). Changes of soil parameters were studied at the following cropping sequence: clover-grass mixture (1998), grain maize (1999), field bean (2000), winter wheat (2001), soybean (2002), grain maize (2003), spring barley (2004).

The field treatment was realized in conditions with rational fertilization under two soil technologies:

CT – conventional soil tillage, i.e. with ploughing

NT – no-tillage technology, i.e. direct sowing without soil cultivation.

Area of each field variant was 50 m^2 (5 x 10 m) and all variants were repeated four times. Soil samples were taken from the depths of soil profile 0 – 0.3 m and 0.3 – 0.6 m. Chemical soil parameters were determined as follows: available phosphorus and potassium by Mehlich II, humus content by Tjurin, composition of humous substances (HA – carbon content of humic acids, FA – carbon content of fulvic acids) by Konovova and Beľčikova.

The obtained data were tested by statistical methods and are listed in tables.

Results and Discussion

Plants utilize nutrients from the topsoil (0 - 0.3 m) as well as from subsoil (0.3 - 0.6 m). Nutrients applied in form of mineral fertilizers are located at different soil depths in dependance on a grotechnics. In observed period content of available phosphorus in topsoil was in range beetween 38.6 mg.kg^{-1} to 47.3 mg.kg^{-1} and potassium content in the range of 148.3 – 162.8 mg.kg^{-1}. Content of nutrients in the subsoil was lower than content in the topsoil. Phosphorus content range was 17.4 mg.kg^{-1} to 23.5 mg.kg^{-1} and potassium content range between 80.6 mg.kg^{-1} to 97.2 mg.kg^{-1} (table 1). Available phosphorus content in subsoil was lower by 23.2 mg.kg^{-1} and available potassium content by 65.3 mg.kg^{-1} comparing with content in topsoil. Decreasing of soil nutrients content resulting from the soil depth was recorded by Salinas–Garcia et al. (2002).

From plant nutrition point of view lower content of available nutrients in subsoil is still good nutrients reserve. Many field crops intake the nutrients also from deeper soil layers therefore it is possible to modify levels of applied mineral fertilisers with respect to contents of available nutrients in subsoil.

Surface application of fertilizers at no-tillage technology effected soft increase (not significant) of available potassium contents in topsoil in compare with the conventional technology. It was found that, changes of available phosphorus contet in topsoil was not affected by technology, but in the subsoil was found lower decrease of phopshorus content at no-tillage technology in compare with conventional technology.

Table 1: The effect of soil tillage on content of available nutrients (phosphorus, potassium), humus, humic acids and fulvic acids in the soil profile

Parameter of soil	Depth of soil	CT			NT		
		1998	2004	difference	1998	2004	difference
P [mg.kg^{-1}]	0 – 0.3	45.7	38.6	-7.1	47.3	40.2	-7.1
	0.3 – 0.6	23.5	17.4	-6.1	20.1	18.1	-2.0
K [mg.kg^{-1}]	0 – 0.3	148.3	156.8	+8.5	150.6	162.8	+12.2
	0.3 – 0.6	85.1	97.2	+12.1	80.6	94.1	+13.5
H [g.kg^{-1}]	0 – 0.3	16.56	19.44	+2.88	16.19	17.44	+1.25
	0.3 – 0.6	11.96	12.57	+0.61	13.06	12.94	-0.12
HA [g.kg^{-1}]	0 – 0.3	2.18	1.52	-0.66	2.14	1.63	-0.51
	0.3 – 0.6	1.12	1.11	-0.01	1.12	1.07	-0.05
FA [g.kg^{-1}]	0 – 0.3	1.78	1.87	+0.09	1.82	1.87	+0.05
	0.3 – 0.6	1.29	1.19	-0.10	1.33	1.18	-0.15

P – available phosphorus, K – available potassium, H – humus content, HA – carbon content of humic acids, FA – carbon content of fulvic acids, CT – conventional tillage, NT – no-tillage

The most important parameter of humus regime in soils is content of humus and its composition. During observed period humus content in soil profiles was in the range of 11.96 – 19.44 g.kg^{-1} and it was statistically high significant depended on the depth of soil sampling and year (table 2).

Table 2: The variance analysis of nutrient contents, humus and humous substances in soil profiles

Source of variation	Degrees of freedom	P		K		H		HA		FA	
		F – ratio									
tillage systems	1	0.1	-	0.1	-	0.6	-	0,0	-	0.2	-
years	1	114.9	++	153.9	++	15.4	++	28.8	++	0.6	-
depth	1	1991.4	++	4910.4	++	261.7	++	179.4	++	562.4	++
repetition	3	0.0	-	0.1	-	0.0	-	0.0	-	0.0	-
residual	25										
total	31										

P – available phosphorus, K – available potassium, H – humus content, HA – carbon content of humic acids, FA – carbon content of fulvic acids

Humus content in soil was significantly higher at the end of research period (year 2004) compared with initial stage. Higher increase of humus content was found under conventional technology than under no-till. Humus content in topsoil was higher, in comparison with content in subsoil, at average by 4.78 g.kg^{-1}.

Composition of humus substances (humic acid and fulvic acid) is responsible qualitative characteristic of organic matter in soil. It was observed that humic acids carbon content was in the range 1.07 g.kg^{-1} to 2.18 g.kg^{-1} and fulvic acid carbon content in the range of 1.18 – 1.87 g.kg^{-1} (table 1).

Quantity of both main constituents of humus was high significantly depended on depth of soil sampling (table 2). In the depth 0 – 0.3 m was humic acid carbon content higher by 0.77 g.kg^{-1} and fulvic acid carbon content by 0.61 g.kg^{-1} compared with the depth 0.3 – 0.6 m. Higher content of humic acid in topsoil probably relates to higher quantity of organic matter and better soil conditions (air space of soil).

Conclusions

Conclusions resulting from observations of content and composition of available nutrients, humus content and humous constituents in the soil at no-till and conventional technology are:

1. Tillage system influenced distribution of available nutrients in the soil, but not significantly. The potassium accumulation at topsoil was higher in no-till than in conventional technology.
2. Content of available nutrients was lower in the deeper layer of the soil profile than in the shallower layer. Contents of available phosphorus was lower in subsoil on average by 23.2 $mg.kg^{-1}$ P and available potassium content by 65.3 $mg.kg^{-1}$ K.
3. Humus content and contents of both humous constituents were not statistically significant dependent on tillage technology.
4. There was high significant relationship between the humus, humus constituents content and depth of soil. Humus content was on average higher by 4.78 $g.kg^{-1}$ in the topsoil than in the subsoil. Content of humic acid carbon was higher by 0.77 $g.kg^{-1}$ and content of fulvic acid carbon by 0.61 $g.kg^{-1}$.

References

BAUER, P. J. et al. 2002. Tillage effect on nutrient stratification in narrow and widerow cropping systems. In: Soil and Tillage Research, vol. 66, 2002, N. 2, pp. 175-182.

FIALOVÁ, J. 1994. Změny agrochemických vlastností půdy. In: Úroda, vol. 42, 1994, N. 3, pp. 2-13.

HORÁČEK, J. – LEDVINA, R. – RAUS, A. 2001. The content and quality of organic matter in Cambisol in a long-term no-tillage system. In: Rostl. Výr., vol. 47, 2001, N. 5, pp. 205-210.

KOVÁČ, K. – ŽÁK, Š. 1999. Vplyv rôznych spôsobov obrábania pôdy na jej fyzikálne a hydrofyzikálne vlastnosti. In: Rostl. Výr., vol. 45, 1999, N. 8, pp. 359-364.

LÓPEZ-FANDO, C. – ALMENDROS, G. 1995. Interactive effects of tillage and crop rotations on yield and chemical properties of soils in semi-arid central Spain. In: Soil and Tillage Research, vol. 36, 1995, N. 1-2, pp. 45-57.

SALINAS–GARCIA, J. R. et al. 2002. Tillage effect on microbial biomass and nutrient distribution in soil under rain–fed corn production in central–western Mexico. In: Soil and Tillage Research, vol. 66, 2002, N. 2, pp. 143-152.

ŠOLTYSOVÁ, B. – KOTOROVÁ, D. 2002. Vplyv obrábania pôdy na zmeny jej fyzikálnych a chemických vlastností In: Agriculture (Poľnohospodárstvo), vol. 48, 2002, N. 6, pp. 304-312.

HYDROPHYSICAL PROPERTIES OF A CLAYEY SOIL AS AFFECTED BY DIFFERENT TILLAGE SYSTEMS

[1]Kotorová, D., [1]Mati, R.

[1]Slovak Agric. Res. Centre – Inst. of Agroecology, Špitálska 1273, Michalovce, Slovak Rep., 07101, E-mail: kotorova@scpv-ua.sk, mati@scpv-ua.sk

Abstract

In years 2000–2005 field treatments were carried out on clayey soil in central part of the East Slovak Lowland (experimental workplace Milhostov). Effect of conventional tillage and no-tillage systems on soil porosity, maximum capillary capacity, available water capacity and non-capillary porosity were observed. Experimental years from point of view of annual rainfall were valued mainly as normal till wet and by average annual air temperature as normal till warm. In average at conventional tillage values of observed parameters were higher in comparison to no-tillage about 1.68 % at porosity, 0.93 % at maximum capillary capacity, 0.93 % at available water capacity and 0.75 % at non-capillary porosity. Effect of soil tillage on non-capillary porosity was statistically no-significant. At other soil parameters this effect was statistically significant ($\alpha = 0.01$).

Introduction

Soil cultivation is one from basic elements of technological systems at agricultural crops cultivation on arable land. In generally it is important arrangement with large scale possibility to regulate soil environment and many others elements of produce area and landscape area. Conventional tillage of soil is according to some ecologist main disturbing factor and negative influences components of ecosystem and its functionality (Lacko-Bartošová et al., 2005). Soil protective technologies has significantly place at sustainable cropping systems and direct sowing without ploughing (no-till), too.

Effect of different tillage systems of soil on physical and hydrophysical soil properties were studied by Husnjak et al. (2002), Kováč – Švančárková (2003) and Sasal et al. (2006). At various soil-ecological conditions these authors determined tendencies of deterioration of properties for variants with protective soil tillage in comparison to conventional tillage, but these negative changes were no-significant. For the East Slovak Lowland considerable acreage of heavy soils (43 % from acreage of farm land) with high content of clay particles is typical.

In this paper are presented results from study of changes of some physical and hydrophysical properties of clayey soil (very heavy soil) at its long-time tillage with different technologies.

Material and Methods

In years 2000 – 2005 the field experiments with different soil tillage were carried out on clay soil. The experimental locality Milhostov is situated in central part of the East Slovak Lowland and continental climate is typical for this area.

Soil texture on experimental site by Novák classification scale (Vilček et al., 2005) is characterized as very heavy clayey soil with content of clayey particles (I. category < 0.01 mm) 62.87 %. Granulometric composition of experimental site is shown in table 1.

Table 1: Average granulometric composition of topsoil of soil (by Novák)

Diameter of particles [mm]	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.25	0.25 – 2.00	< 0.01
Soil particles	clay	fine and medium dust	coarse dust	fine sand	medium sand	clayey particles
Content of soil particles [%]	34.14	28.73	25.27	10.95	0.91	62.87

During experimental season the field crops were arranged into crop rotation as follows: grain maize – faba bean – winter wheat – soybean – winter wheat – grain maize.

In field experiment two tillage technologies of clay soil – conventional tillage (CT) and no-tillage system (NT) – were examined. Conventional tillage consists of current tillage operations: stubble ploughing, ploughing to 0.20 m, smoothing, harrowing and sowing. No-tillage system use direct sowing without ploughing by sowing machine Great Plains.

Hydrophysical properties of clay soil were determined from undisturbed soil samples taken once a year in spring (at spring crops 14-day after sowing, at winter crops in April). Core sampling to determine total porosity, maximum capillary capacity, available water capacity and no-capillary porosity was carried out at 0.0 – 0.3 m depth. Total porosity (P) and maximum capillary capacity (Θ_{MKK}) were determined as it described Kobza et al. (1999). Wilting point (Θ_V) was calculated according to method of Solnář. Available water capacity (Θ_P) was calculated from maximum capillary capacity and wilting point (Fulajtár, 2006). Non-capillary porosity (Θ_{NK}) was calculated as the difference between total porosity and maximum capillary capacity (Kutílek, 1978).

Sum of precipitation and air temperature were taken from meteorological station of Slovak Hydrometeorological Institute, in Milhostov. Arithmetic means for measured values were used for analysis of variance.

Results and Discussion

In years 2000 – 2005 annual rainfall was 490 – 655 mm and average annual air temperature was 9.2 – 10.4 °C. The 30 year mean annual precipitation in locality Milhostov is 559 mm and that from point of view of annual rainfall years with sum of precipitation on level of long-time normal (N) were prevailed, respectively humid (105.9 – 117.2 % N), but year 2003 was valued as dry (87.7 % N). The 30 year mean annual air temperature is 8.9 °C. From point of view of average annual air temperature all observed years are valued as normal respectively warm with range of air temperature on level 103.4 – 116.9 % N.

At these meteorological conditions and at two tillage systems average values of observed physical and hydrophysical soil properties are shown in tables 2 – 5.

Table 2: Average total porosity [%] of clayey soil in Milhostov

Soil tillage	Year						
	2000	2001	2002	2003	2004	2005	x
CT	52.33	45.29	46.87	47.17	49.35	53.97	49.16
NT	45.02	42.48	47.96	48.10	47.36	53.98	47.48
Δ CT - NT [%]	7.31	2.81	-1.09	-0.93	1.99	-0.01	1.68

During observed years average values of porosity (table 2) were higher at conventional tillage in comparison with no-tillage system (Δ CT - NT = 1.68 %). At both tillage systems the highest total porosity was determined in year 2005 (in average 53.98 %) and the lowest in year 2001 (in average 43.89 %) and maximum difference between years 2001 and 2005 was 10.09 %, between tillage technologies it was 7.31 % in year 2000 for conventional tillage. From multiple LSD-test for porosity resulted statistically significant ($\alpha = 0.01$) effect of observed years and soil tillage systems (table 6).

Similarly in valued years also average maximum capillary capacity was higher at conventional tillage in comparison with no-tillage system (table 3.). In average maximum difference between years 2001 and 2004 was 10.05 % and between tillage systems it was 2.40 % in years 2005 for conventional tillage. Statistically significant effect ($\alpha = 0.01$) was kept between years and tillage systems (table 6).

Table 3: Average maximum capillary capacity [%] of clayey soil in Milhostov

Soil tillage	Year						
	2000	2001	2002	2003	2004	2005	x
CT	44.22	35.03	39.83	41.31	44.51	39.88	40.80
NT	42.88	34.29	39.92	39.72	44.91	37.48	39.87
Δ CT - NT [%]	1.34	0.74	-0.09	1.59	-0.40	2.40	0.93

Available water capacity is existential interval of soil water content for plant cover. Its values are shown in table 4. In average during experimental years level of this soil parameter was higher at conventional tillage (Δ CT - NT = 0.93 %) in comparison with no-tillage. Similarly results published Gomez et al. (2001).

Table 4: Average available water capacity [%] of clayey soil in Milhostov

Soil tillage	Year						
	2000	2001	2002	2003	2004	2005	x
CT	18.02	8.83	13.63	15.11	18.31	13.68	14.60
NT	16.68	8.09	13.72	13.52	18.71	11.28	13.67
Δ CT - NT [%]	1.34	0.74	-0.09	1.59	-0.40	2.40	0.93

From point of view of minimum air capacity on heavy soils no-capillary porosity is important characteristics. Its values are shown in table 5. Similarly as at higher shown parameters, values of no-capillary porosity were higher at conventional tillage (in average 8.37 %) in comparison with no-tillage (in average 7.62 %).

Table 5: Average non-capillary porosity [%] of clayey soil in Milhostov

Soil tillage	Year						
	2000	2001	2002	2003	2004	2005	x
CT	8.11	10.26	7.04	5.86	4.84	14.09	8.37
NT	2.14	8.19	8.06	8.38	2.45	16.50	7.62
Δ CT - NT [%]	5.97	2.07	-1.02	-2.52	2.39	-2.41	0.75

Maximum difference (Δ = 11.63 %) was determined between years 2004 and 2005. Between tillage systems maximum difference was 5.97 % determined in year 2000 and no-capillary porosity at conventional tillage was almost four-times higher than at no-tillage variant. Statistically significant evidence was determined only between years. From results in table 6 influenced, that soil tillage systems had no-statistically significant evidence on non-capillary porosity not even at significant level 95 % LSD ($\alpha = 0.05$).

Conclusion

On clayey soil in average values of all observed physical and hydrophysical parameters were higher at conventional tillage than at no-tillage system.

Tillage systems (conventional tillage, no-tillage) used on clayey soil had statistically significant effect on porosity, maximum capillary capacity and available water capacity.

At no-capillary porosity effect of used tillage technologies was statistically no-significant and statistically significant evidence was determined only between years.

Table 6: Analyses of physical parameters variance

Parameter	Source of variation	Degree of freedom	Calculated F-value	α
P	year	5	32.998	++
	soil tillage	1	12.767	++
	residual	38		
	total	47		
Θ_{MKK}	year	5	349.907	++
	soil tillage	1	35.100	+
	residual	38		
	total	47		
Θ_{P}	year	5	349.833	++
	soil tillage	1	35.128	++
	residual	38		
	total	47		
Θ_{NK}	year	5	45.427	++
	soil tillage	1	2.285	+
	residual	38		
	total	47		

$^{++}\alpha = 0.01$ $^{+}\alpha = 0.05$

References

FULAJTÁR, E., 2006. Physical properties of soil. Bratislava : VÚPOP, 2006. 142 pp. ISBN 80-89128-20-3

GOMEZ, E. et al., 2001: Changes in some soil properties in a Vertic Argiudoll under short-term conservation tillage. In: Soil Tillage Res., vol. 61, N. 3-4, p. 179-186. ISSN 0167-1987

HUSNJAK, S., FILIPOVIĆ, D., KOŠUTIĆ, S., 2002: Influence of different tillage systems on soil physical properties and crop yield. In: Plant Production, vol. 48, 2002, N. 6, p. 249-254. ISSN 0370-663X

KOBZA, J. et al., 1999: Partial monitoring system – soil : Valid methods. Bratislava : VÚPOP, 1999. 138 pp. ISBN 80-85361-55-8

KOVÁČ, K., ŠVANČÁRKOVÁ, M., 2003: The influence of various agrotechnical factors on soil physical properties. In: Agriculture, vol. 49, 2003, N. 12, p. 608-618. ISSN 0551-3677

KUTÍLEK, M., 1978: Hydropedology. Praha : SNTL, 1978. 296 pp.

SASAL, M. C. et al., 2006: Soil porosity characteristics and water movement under zero tillage in silty soils in Argentinian Pampas. In: Soil and Tillage Research, vol. 87, 2006, N. 1, p. 9-18. ISSN 0167-1987

VILČEK, J. et al. 2005. Environmental pedology. Nitra : SPU, Bratislava : VÚPOP, 2005. 299 pp. ISBN 80-8069-501-6

DIFFERENT SOIL TILLAGE AND FERTILIZATION AND ITS INFLUENCE ON THE SPRING BARLEY YIELDS

[1]Danilovič M.,[1]Šoltysová B.
[1]*Slovak Agric. Res. Centre – Inst. of Agroecology, Špitálska 1273, Michalovce, Slovak Rep., 07101, E-mail: danilovic@scpv-ua.sk, soltysova@scpv-ua.sk*

Abstract

The experiment was conducted in Institute of Agroecology Michalovce, during the years 2006 and 2007, to study the effect of three soil cultivations (conv., red., dir.) and two variants of fertilization (F1, F2). The difference between fertilization variants was that there was applied 15 kg per hectare of nitrogen in variant F1 at growing phase 3 - 4 leaves. The doses of pure nutrients applied in both variants before sowing were 15 kg.ha^{-1} of nitrogen, 28 kg.ha^{-1} phosphorus and 90 kg.ha^{-1} of potassium. Planting rate was 5.0 mil. grains per hectare and the forecrop was maize.

It is consequential from the results that soil cultivation effect was significant and higly influenced on barley grain yield and not significant on crude protein content. On the average, the no-till variant and variant with reduced soil cultivation gave lower yield production.

The fertilization intensification effect can be seen the best at reduced and no-tillage variant, with 0.33 t.ha^{-1} in favour of variant F1. Nitrogen aplication at growing phase 3 - 4 leaves significantly increased barley grain yield. It was found that fertilization had a highly significant effect on barley yield and significant on crude protein content. Nitrogen aplication at growing phase 3 - 4 leaves increased content of crude protein in barley grains.

Key words: spring barley, gleyic Fluvisol, soil tillage system, fertilization, grain yield, crude protein content

Introduction

Conservation tillage systems offer pronounced advantages over moldboard plow of conserving soil and water, sustaining soil productivity, reducing labor and energy requirements, and possibly, more timely planting in years when wet soils delay conventional tillage operations (Unger, McCalla,1980). Conservation tillage practise, which are systems of managing crop residues on the soil surface with minimum or no tillage, are crucial in efficiently saving more precipitation for crop production (Halvorson et al., 2000).

Because no tillage results in less soil disturbance and greater residue coverage on the soil surface than other conservation tillage systems, it offers more significant benefits to the environment and is the most effective soil protecting farming system (Kováč, 1994).

In cases when soil moisture limits plant growth, no tillage has been reported to produce crop yields similar to (Carter, Rennie, 1984) or higher than (Tessier et al, 1990) conventional tillage.

We studied the influence of no-till and reduced soil cultivation in comparison with conventional and fertilization on spring barley grain yield and crude protein content.

Material and Methods

The field treatments were carried out on the experimental place of Institute of Agroecology Michalovce during the years 2006 and 2007. Spring barley was cultivated on the gleyic Fluvisol (locality Milhostov) under the climatic conditions of the East-Slovak Lowland.

The climatic region is the lowland with the altitude of 101 m above see level and warm and very dry weather. The average annual rainfalls through the years 1951 to 1980 counts 559 mm and average temperature is 8.9 °C.

Spring barley (variety Ezer) was grown in natural conditions without irrigation. The planting rate was 5.0 mil. grains per hectare. The experiment was conducted to study the effect of three different types of soil cultivation and two variants of fertilization. Tested variants were:

conv. – conventional tillage: ploughing to depth 0.24 m in the autumn after maize harvesting, pre-sowing soil treatment was made using sweep plough-harrow, sowing was done with sowing machine Great Plains

red. – reduced cultivation: shallow soil cultivation using sweep plough-harrow after maize harvesting, sowing was done with sowing machine Great Plains

dir. – no-tillage technology: direct sowing without soil cultivation with special sowing machine Great Plains

F1 – 15 kg.ha^{-1}N, 28.0 kg.ha^{-1}P, 90.0 kg.ha^{-1}K+ 15 kg.ha^{-1}N at growing phase 3-4 leaves

F2 – 15 kg.ha^{-1}N, 28.0 kg.ha^{-1}P, 90.0 kg.ha^{-1}K

Evaluation of grain yield, agrochemical analyses of grain were done annualy using standard methods. Detected data were evaluated statistically by the analysis of variance.

Results and Discussion

The influence of various soil cultivation and fertilization were evaluated in field trials, obtained data are presented in table 1. The grain yield of spring barley were moved in the range 1.71 – 3.1 t.ha^{-1}. Higher influence on spring barley grain production had variant of soil cultivation than variant of fertilization (table 2). Effect of mentioned factors were highly significant. On the average, the no-tillage variant gave lower yield production by 0.6 tons per hectare comparing with conventional tillage and by 0.17 tons per hectare comparing with reduced cultivation. Similar results about no-tillage soil cultivation effect on grain yield production published also Nyborg et al. (1995), Kováč, Žák (2000), Candráková (2002). The highest influence on spring barley grain yield had experimental year.

The fertilization intensification effect can be seen the best at reduced and no-tillage variant, with 0.33 t.ha^{-1} in favour of variant F1.

Table 1: Spring barley grain yields (86 % dry matter) and content of crude protein (100 % dry matter)

Soil cultivation	Fertilization	Grain yields [t.ha^{-1}]			Crude protein content [%]		
		2006	2007	$\bar{x}$	2006	2007	$\bar{x}$
conv.	F1	2.51	3.10	2.81	9.02	11.17	10.10
	F2	2.67	2.97	2.82	8.85	10.35	9.60
red.	F1	2.44	2.63	2.54	9.05	10.99	10.02
	F2	1.82	2.60	2.21	8.76	10.37	9.57
dir.	F1	2.13	2.61	2.37	9.24	10.22	9.73
	F2	1.71	2.36	2.04	9.26	10.44	9.85

The results also indicated that the experimental year had a highly significant effect on crude protein content. Determining share of experimental year in content of crude protein founded also Užík and Žofajová (2006). Fertilization had only significant effect on crude protein. Higher content of crude protein was found at F1 variant than at F2 variant (table 2 and 3).

Table 2**:** Evaluation of spring barley grain yield and crude protein content by analysis of variance.

Factors	d.f.	Grain yield			Crude protein content		
		F vyp	P	Order	F vyp	P	Order
soil cultivation	2	15.1	++	2.	0.1	-	3.
fertilization	1	8.3	++	3.	4.5	+	2.
year	1	27.9	++	1.	145.4	++	1.
residual	40	40					
rotal	47	47					

$^{+}$P<0,05 $^{++}$P<0,01

d.f. – degrees of freedom, F_{vyp} – calculated F-ratio, P – effect of a factor

Presented data also indicated that there was no significant difference between the variants of soil cultivation which were compared in field experiment (table 3). Average content of crude protein were moved in the range 8.76 – 11.17 %.

Table 3**:** Evaluation of spring barley grain yield and crude protein by LSD test.

Parameter of yield		Grain yield				Crude protein content					
Factor		$\bar{x}$	Homogenous group			Factor		$\bar{x}$	Homogenous group		
soil cultivation	dir.	2.20	x			Soil cultivation	dir.	9.79	x		
	red.	2.37	x				red.	9.79	x		
	conv.	2.81		x			conv.	9.85	x		
fertilization	F2	2.33	x			fertilization	F2	9.67	x		
	F1	2.60		x			F1	9.95		x	
year	2006	2.21	x			year	2006	9.03	x		
	2007	2.71		x			2007	10.59		x	

Conclusions

The trials with different soil tillage demonstrate a highly significant effect of soil cultivation on spring barley grain yield. On the average, the no-till variant and variant with reduced soil cultivation gave lower yield production. The results also indicated that the spring barley fertilization had a highly significant effect on grain yield, too. Nitrogen aplication at growing phase 3 - 4 leaves significantly increased barley grain yield.

It is consequential from the results that soil cultivation effect was not significant on crude protein content and effect of fertilization was significant. Nitrogen aplication at growing phase 3 - 4 leaves significantly increased content of crude protein in barley grains.

References

CANDRÁKOVÁ, E. 2002. Vplyv spracovania pôdy, odrody a hnojenia na úrodu jačmeňa jarného. In: Agriculture, vol. 48, 2002, no. 7, p. 350-357.

CARTER, M.R. – RENNIE, D.A. 1984. Nitrogen transformations under zero and shallow tillage systems. In: Soil Sci. Soc. Am. J., no. 48, p. 1077-1081.

HALVORSON, A.D. et al. 2000. Spring wheat response to tillage system and nitrogen fertilization in rotation with sunflover and winter wheat. In: Agron. J., no. 92, p. 288-294.

KOVÁČ, K. 1994. Vplyv ochranného obrábania pôdy na zmenu jej fyzikálnych vlastností. In: Pôdoochranné technológie pestovania rastlín : Zborník referátov z odborného seminára. Piešťany : VÚRV, 1994, p. 36-41.

KOVÁČ, K. – ŽÁK, Š. 2000. Využívanie minimalizačných technológií pri zakladaní porastov jačmeňa jarného. In: Jačmeň – výroba a zhodnotenie : Zborník z odborného seminára so zahraničnou účasťou. Nitra : SPU v Nitre, 2000, p. 69-73. ISBN 80-7137-681-7.

NYBORG, M. et al. 1995. Influence of long-term tillage, straw and N fertilizer on barley yield, plant-N uptake and soil-N balance. In: Soil and Tillage research, vol. 36, 1995, no. 3-4 p. 165-174.

ŠOLTYSOVÁ, B. 1999. Tvorba úrody a kvality cukrovej repy v závislosti od jej výživy v interakcií s rastovými stimulátormi v podmienkach ťažkých pôd VSN : Doktorandská dizertačná práca. Michalovce : OVÚA Michalovce, 1999. 118 p.

TESSIER, S. et al. 1990. Conservation tillage for spring wheat in semi-arid Saskatchewan. In: Soil Till. Res., no. 18, p.73-89.

UNGER, P. – McCALLA, T.M. 1980. Conservation tillage systems. Adv. Agron., no. 33, p. 1-58.

UŽIK, M. – ŽOFAJOVÁ, A. 2006. Reakcia genotypov jačmeňa jarného na hnojenie dusíkom v úrode zrna a znakoch kvality v generáciách F_3, F_4, a F_5. In: Agriculture, vol. 52, 2006, no. 1, p. 24-37.

MULCHING EFFECT ON WEED SUPPRESSION IN ORGANIC VEGETABLE CULTIVATION

S. Kołosowski, A. Szafirowska
Res. Inst. of Vegetable Crops, ul. Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland e-mail: slawek_kol@yahoo.com

Introduction

Weeds are the major factor limiting the crop production in organic farming. Since the chemicals are prohibited in this method of production there must be other tools for weed control found. One of them is plant mulching. Mulches can prevent weed germination and growth and ultimately reduce time and labor required to remove weeds. Except for weed control mulches help to increase soil moisture retention, enhance soil warming and improve the crop quality. Materials used for mulching fall into two categories: organic which are derived from plant materials and decompose naturally in the soil: inorganic mulches which do not decompose and must be removed from the soil. The most commonly used organic materials are : manures, bark chips, ground corncobs, sawdust, grass clipping, leaves, newspapers and straw. Among inorganic mulches the most frequently used is the black polyethylene plastic. It is allowed to use in organic farming, but recently more environment friendly materials are recommended such as polypropylene fleece permeable for water and air material. In respect to weed suppression vegetable species can be divided in three groups (Adamicki *et al.*2004). The most susceptible are those of a long germination process produced from direct sowings (onions, leek, umbelliferous), the most resistant group are those cultivated from transplants, planted later in the season, producing big mass of leaves (tomato, pepper, cucurbits, cabbages).

The aim of the study was to asses the effect of surface mulches in weed suppression and the composition of weeds in bean and sweet pepper organic cultivation.

Material and Methods

The study was conducted on the certified organic field at the Research Institute of Vegetable Crops in Skierniewice. Two experiments were set. One concerning bean produced for dry seeds (2005-2006). The second one concerning sweet pepper cultivation in 2007 - 2008.

In bean experiment following treatments were applied : date of seed sowing (10, 25 May,10 June) and row mulching. Seeds were sown in three rows on 8.1 m^2 plots in randomized design in 4 replications. At the stage of 4 true leaves of bean half of the plots were mulched with 10 cm layer of cut rye straw. Another half of the plots were not mulched.

In the sweet pepper experiment following mulches were applied: chopped clover , black polypropylene fleece (50g/m^2) and not mulched control. The sweet pepper transplants were planted on first days of June each year in 45 x 45 cm distance.

Red clover used as a fresh cut material was spread on the plots in a 10 cm layer thus providing about 0.15 kg of nitrogen (150N kg/ha) . The weed coverage of plots and the weed species composition was examined at the beginning, middle and at the end of the growing season. The plots were hand weeded after each observation done. Experiments were set at the randomized blocks in four replications.

Results and Discussion

In the bean experiment the highest percent of weed coverage was observed at the beginning of the season. The average weed cover of non-mulched control amounted 27.6 and 36.0% in the first and second year respectively (table1). As the season progressed the weed population diminished down to 15.9 and 15.4 % of control ground. The delay of sowing caused lower weed occurrence. Likewise other authors Rasmusssen(2000) and Du-Hoi Choi (2004) stated a tendency for less weeds as the sowing date delayed in winter wheat and rice cultivation. In Poland the strongest weed germination usually occurs during May and June, therefore the biggest mass of weeds can be easy destroyed by pre-sowing tillage manners. The later the sowing the more successful control of early spring germinating weeds.

Row mulching by chopped rye straw prevented the weed spreading on bean plots during all vegetation season. More than twice less weeds were found on mulched plots in comparison to non-mulched control. The data confirm results of Derek *et. al.* (2006), who pointed out the straw as the best mulching material in bell pepper cultivation. The rye straw layer restricted weed emergence mainly by limiting light access. On the other hand rye is known from it's allelopathic properties. According to Monks *et. al.* (2000*)* straw residue of rye can inhibit early season germination of some weeds like *Chenopodium album Portulaca oleracea, Amaranthus retroflexus*. In our experiments some differences in weed occurrence appeared in respect to weather conditions. Rainfalls at the end of May stimulated weed emergence in 2006 more than in 2005.

In the sweet pepper experiment both kinds of mulches revealed good protective effect until the middle of the season (table 2). Black fleece as well as chopped red clover suppressed weed development until 25 July in both years. As the season progressed the weed suppression effect was pronounced only on plots covered by fleece, where the weed percentage amounted 1.2 and 1.5% in the first and the second year of research. At the same time on the plots covered with clover a strong weed development was noticed. The degree of weed coverage at the last observation amounted at 22.7% in 2007 and 26.1% in 2008. During the season the clover layer diminished, thus allowing the weed seed to germinate. Similar phenomenon observed Kivijarvi *et al* (2005) Most likely by this time nitrogen released from decomposition of red clover material stimulated weed development on these plots.

Table 1: Percentage of weed coverage in dependence on sowing dates of organic bean cultivation

Sowing date	Mulching	2005			2006		
		20 .06	12 08.	9.09	22.06	16.08	12.09
May 10 th	Straw	11.8	4.3	6.2	26.9	2.8	5.3
	Control	27.6	12.6	15.9	36.0	8.0	15.4
May 25 th	Straw	7.2	2.8	4.5	8.4	3.5	4.0
	Control	9.9	8.9	8.3	8.6	5.9	7.8
June 10 th	Straw	0.0	4.3	4.9	2.6	4.6	4.8
	Control	1.9	6.1	7.6	4.0	2.6	4.0

Table 2: The percentage of weed coverage in organic sweet pepper cultivation

Kind of mulching	2007			2008		
	28.06.	25.07.	15.09.	26. 06.	10.07.	9.09.
Black fleece	0,0	0,1	1.2	0.0	0.2	1,5
Chopped clover	0,0	3,0	22,7	1.8	2.1	26,1
Control	0,2	13,6	21,3	10.1	15.1	20.4
average	0.1	2.6	14.7	4.0	5.8	15.6

Table 3: The composition of dominating weed species at the end of growing season in dependence on mulching materials .

	Weed species	Non - mulched	Chopped clover	Rye straw	Black fleece
1	Agropyron repens	+	+	+	-
2	Amaranthus retroflexus	+	+	-	-
3	Capsella bursa-pastoris	+	+	+	+
4	Chenopodium album	+	+	+	-
5	Galinsoga parviflora	+	+	-	-
6	Lamium amplexicaule	+	+	-	-
7	Matricaria discoidea	+	+	-	-
8	Matricaria inodora	+	+	-	-
9	Poa annua	+	+	+	+
10	Senecio vulgaris	+	+	-	-
11	Setaria glauca	+	+	-	-
12	Stellaria media	+	+	+	+
13	Taraxacum officinale	+	+	-	-
14	Tlapsi alvense	+	+	+	+
15	Urtica urens	+	+	+	-

The composition of weeds on control plots observed at the end of growing season consisted on 15 species, 3 monocotyledonous and 12 dicotyledonous, annual and perennials (table 3). Natural mulches , the rye straw and chopped red clover only delayed, but not prevented the weed development. It was especially true for perennials. A 10 cm layer of chopped clover or cut straw later in the season became translucent for weed seed germination. Black fleece was totally protective for weed seeds weed and perennials. The only weed found were those germinating in a closest nearness of pepper plants.

Conclusions

The materials used for row mulching in organic sweet pepper cultivation revealed good efficacy in the weed suppression. Rye straw mulching sufficiently reduced weed development in bean cultivation. Black fleece was the excellent mulch for weed control in sweet pepper cultivation. A new technology with the sue of red clover seems very interesting as a weed suppressor and also as a source of nutrients. The latest aspect is very important in organic production, because of the lack of nitrogen fertilizers allowed for this kind of production.

Since the literature on the red clover mulching is very scarce, therefore the continuation of the research is planned by the authors.

References

Adamicki F et al.2004. Ekologiczne metody uprawy warzyw . Krajowe Centrum Rolnictwa Ekologicznego- RCDRR I OW w Radomiu.

Derek M.L., Rowell A.B., Snyder J.C. 2006. Weed control efficacy of organic mulches in two organically managed bell pepper production systems. HortTechnology 16(2): 225-232.

Du-Hoi C, Goh H.G., Lee Y.J.2004. The modern technique for organic rice cultivation in Korea. 6th IFOAM – Asia Scientific Conference "Benign Environment and Safe Food". 7th – 11th September 2004. Yangpyung/Korea: 61-74.

Kivijarvji P., Touvinen T., Kemppainem R. 2005. Mulches and pheromones – plant protection tools for organic black currant production. www.orgprints.org/5219

Monks D.W., Bass L. 2000. Cultural and mechanical weed control in vegetable gardens. www.uri.edu

Rasmussen I.A. 2000. Sowing time, false seedbed, row distance and mechanical weed control in organic winter wheat. 4th EWRS Workshop on Physical Weed Control, Elspeet, The Netherlands, 20-22 Mrach 2000: 5-7.

CROP YIELD AND RESPONSE OF SOIL QUALITY INDICATORS TO NO TILLAGE PRACTICE IN A LOAM DEGRADED CHERNOZEM ON LOESS IN SLOVAKIA

Zuzana Lehocká – Marta Klimeková – Magdaléna Bieliková – Štefan Žák
Slovak Agricultural Research Centre Nitra – Research Institute of Plant Production Piešťany,
Bratislavská cesta 122, Piešťany, 921 68 Slovak Republic, lehocka@vurv.sk

Abstract

In this study we compare crop yields and some chemical and biological soil properties using no tillage and conventional (tillage) systems. In 1999 – 2004 yields and soil characteristics were observed in a long term field experiment in Borovce (near Piešťany, in the western part of the Slovak Republic). The no tillage system showed to maintain soil organic matter at higher levels than conventional tillage. This increase is particularly relevant in the Slovak republic where on more than 59 % of the agricultural land the humus content is decreasing. No tillage management also positively affected microbial biomass and the amount and biomass of earthworms. During six years of no tillage management, there was a tendency of increased biological activity in the soil. The average yields in the no tillage system were 12 % lower than these in the conventional tillage system.

Introduction

Agronomic practices influence soil quality indicators, soil organic matter content, by altering above and below-ground biomass production, and the rates of top soil erosion and organic matter decomposition (Madejón, Moreno, Murillo and Pelegrín, 2006). Conservation and increase of soil organic matter levels are crucial for biological, chemical and physical soil functionality (Bradford and Peterson, 2000).

There is a modern alternative to conventional tillage that is called zero tillage, no-tillage or direct seeding. In this management practice, which is a part of the concept of conservation agriculture, the soil is never tilled and the last year's crop residue is left on the field. It is widely used all over the world to control wind erosion and maintain soil water content. No tillage brings many benefits with respect to soil and environmental conservation and energy saving (Pepó et al., 1997; Birkás et al., 2000; Berner, Hildermann, Fließbach, Pfiffner, Niggli, Mäder, 2008). The main goals for these new tillage systems are to meet crop demands with less energy and mechanical damage to the soil resources (Birkás, 1999).

In Europe, soil degradation has only recently been identified as a widespread problem (Holland, 2004), According to the Green report (2007) in the Slovak Republic more than 56 % of the land area is potentially endangered by water erosion, more than 59 % of the land shows a decline of the humus content and about 27 % of land is endangered by soil compaction. Soil degradation problems are becoming of cardinal importance also in Slovakia and therefore conservation tillage practices have a significant role in practice as well as in different research programmes. In most European countries implementation of conservation management regimes began only a few years ago. The development of conservation agriculture in Slovakia started already in the year 1991 when the first farm cooperatives tried to use minimum or no tillage systems.

The objective of our study was to analyze the crop yields and chemical and biological changes in soils in two different tillage systems (conventional vs. no tillage) in a loam degraded Chernozem on loess in Slovakia.

Material and Methods

The stationary field experiment was established in the experimental station of the Research Institute of Plant Production Piešťany in Borovce in the year 1998. The field experiment was located on Luvi–Haplic Chernozem on loess. The experiment was situated in an area with a moderate continental climate (average temperature per year: 9.2 ^{0}C, per vegetation period: 15.5 ^{0}C, precipitation depth per year: 593 mm, per vegetation period: 358 mm).

The experiment was a fully phased crop rotation in a randomized block design. The crops in the rotation were: pea, winter wheat + intercrop (phacelia, mustard and vetch), maize for grain, spring barley + intercrop (phacelia, mustard and vetch).

Tillage variants:

- *Conventional tillage system* (conventional technology) – the soil was cultivated by ploughing with a depth of 0.2 m followed by a surface treatment and seed-bed preparation. The crops were fertilized with synthetic fertilizers (balance method according to nutrient uptake and planned yields) and additional compost was used in the maize crop. The straw and crop residues were removed from the field; chemical plant protection against weeds and diseases was used.
- *No tillage system* (no till technology) – the soil was not ploughed. Crop residues of the previous crop as well as the added compost in the maize crop were left on the soil surface. The other crop management was the same as in the conventional system,

The soil samples were taken four times during the vegetation period, from the depth of 0.02 – 0.2 m. The air dried soil samples were used for the chemical analysis (pH/KCl, C_{org}). The biological properties were measured in fresh soil samples.

Used methods: pH/KCl measured by Ion Analyser (JENWAY, VB), C_{org} measured by analyser CNS-2000 (LECO, Corp. St. Joseph, MI, USA), and microbial biomass C_{mic} defined by fumigation – extraction method.

The data were statistically evaluated by non-parametric method by means of the Wilcoxon pair test. The crop yields were statistically evaluated by parametric method by variance analyses.

Results and Discussion

The results showed that crop yields were strongly affected by the year conditions (**P<0.01). In the no tillage system the grain yields, were 12 % lower than in the conventional system (Table 1). The lower yields in the no tillage system may be explained by the temporally different nitrogen mineralization and probably different N demand of the crops. Later N mineralization in no till managed soils was reported by Anken et al. (2003) and Zihlmann and Weisskopf (2006). We presume that under no tillage the N release from the soil, crop residues and compost is not synchronous with the crop nitrogen demand, leading to an N shortage. This hypothesis is in line with the statements of Berner et al. (2008). The first five years after converting to no tillage there was a decline in the yields varied from 2 to 17 % but the last year the yields were comparable with these obtained in the conventional system.

There was no significant difference between the systems in the soil pH (Table 1). Nevertheless, the pH in the conventional system was slightly higher than in the no tillage system. This probably relates to a higher intensity of tillage and soil mixing. The leaching of basic substances into deeper soil layers without ploughing may be another cause of pH decrease caused by no tillage (Berner et al., 2008).

A significant higher content of C_{org} after the period of 6 years was found in the no tillage system (Table 2). The higher amount of C_{org} can be explained by the higher amount of crop residues left on the field experiment plots, complementing the nitrogen input through compost.

The microbial biomass is related to the most labile pools of organic matter and it serves as an important reservoir of plant nutrients, such as N and P (Marumoto et al., 1982). Soil microbial biomass was significant higher under no tillage than under conventional tillage (**P<0.05). This enrichment was generally related with soil organic matter content. Similar results were obtained also by Muňoz, Lopez – Pineiro, Ramirez (2007) and Berner et al. (2008).

Earthworms are often referred to as ecosystem engineers due to their ability to alter the soil environment. Since earthworms influence a wide range of critical chemical and physical soil properties it is important to understand how their populations are affected by soil management. The number of earthworms and their biomass was significantly affected by tillage (**P<0.01) in our experiment (Table 3). The earthworms' number as well as their biomass in the no tillage systems was 3 times higher in comparison with conventional system. These results are in the line with Smith, McSwiney, Grandy, Suwanwaree, Snider, Robertson (2008), Anken et al. (2004).

Conclusions

This study on a loam degraded Chernozem on loess in Slovakia showed that in the average the yields in no tillage system were 12 % lower than these in the conventional tillage system. Long term no tillage resulted in higher organic matter content and more earthworms in the soil compared to conventional tillage. These improvements may greatly contribute to long term sustainability of agricultural systems by maintaining soil quality.

Acknowledgments

The results were obtained within the frame of the Project RVT 27-10-01-05-01 and the Project 2003 SP 27/028 OD 01/028.

References

Anken, T. – Weisskopf, P. – Zihlmann, U. – Forrer, H. – Jansa, J. – Perhacova, K. 2004. Long term tillage system effects under moist cool conditions in Switzerland. Soil & Tillage Research 78, p. 171 - 183.

Berner, A. – Hildermann, I. - Fließbach, A. - Pfiffner, L. - Niggli, U. – Mäder, P. 2008. Crop yield and soil fertility response to reduced tillage under organic management. Soil & Tillage Research 101, p. 89 – 96.

Birkás, M., 2000. Soil compaction occurrence and consequences in Hungary possibilities of the alleviation. D.Sc. Thesis. Hung. Acad. Sci., Budapest (in Hungarian).

Birkás, M. – Jolánkai, M. – Gyuricza, C. – Percze, A. 2004. Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. Soil & Tillage Research 78, p. 185 - 196.

Madejón, E. – Moreno, F. – Murillo, J. M. – Pelegrín, F. 2007. Soil biochemical response to long-term conservation tillage under semi-arid Mediterranean conditions. Soil & Tillage Research 94, p. 346 – 352.

Smith, R. G. - McSwiney, C. P. – Grandy, A. S. – Suwanwaree, P. – Snider, R. M. – Robertson, G. P. 2008. Diversity and abundance of earthworms across an agricultural lan-use intensity gradient. Soil & Tillage Research 100, p. 83 – 88.

Table 1: Grain yields of crops in no tillage and conventional tillage system in the experimental years 1999 – 2004 (cereal units, main and by product yields)

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
No tillage (NS)	6.48	4.41	5.55	6.81	4.09	7.20	5.75
Conventional tillage (CS)	6.61	5.35	7.93	7.59	4.65	7.22	6.56
No tillage (%) (100% = conventional)	98	83	70	90	88	100	88
LSD 0.05	0.34	0.41	0.38	0.36	0.17	0.44	0.16
LSD 0.01	0.46	0.55**	0.52**	0.48**	0.23**	0.59	0.22**

Table 3: Wilcoxon pair test (significance of differences between no tillage and conventional tillage system)

Indicator	Number of no-zero differences	Test value	P-value
pH/KCl	10	0.10	0.918
C_{org}	16	3.54	0.000397**
Microbial biomass	20	2.31	0.0209*
Number of eathworms	23	4.18	0.00002943**
Eathworms biomass	23	3.98	0.0000705**

Table 2: Soil chemical and biological characteristics in no tillage and conventional tillage system in the years 1999 - 2004

Indicator	Year	No tillage system	Conventional system
pH/KCl	1999	6.06	6.53
	2000	5.93	6.06
	2001	5.81	5.95
	2002	6.42	6.72
	2003	6.68	6.75
	2004	7.17	6.84
	Average	**6.34**	**6.47**
C_{org} (%)	1999	1.44	1.29
	2000	1.40	1.18
	2001	1.33	1.10
	2002	1.84	1.23
	2003	1.37	1.19
	2004	1.44	1.20
	Average	**1.47**	**1.20**
Microbial biomass ($C_{mic}.g^{-1}$ dry matter)	1999	572.0	623.1
	2000	512.1	576.8
	2001	596.6	582.5
	2002	590.9	528.9
	2003	816.3	720.8
	2004	700.3	628.3
	Average	**631.4**	**610.1**
Number of earthworms ($ks.m^{-2}$)	1999	137	86
	2000	16	0
	2001	53	13
	2002	91	3
	2003	33	9
	2004	33	5
	Average	**61**	**19**
Earthworms biomass ($g.m^{-2}$)	1999	68.0	33.3
	2000	5.1	0
	2001	23.7	9.3
	2002	41.1	4.5
	2003	24.6	8.1
	2004	23.6	0.6
	Average	**31.0**	**9.3**

EFFECT OF DIFFERENT TILLAGE SYSTEMS ON SOME SOIL PHYSICAL PROPERTIES OF A LOAM DEGRADED CHERNOZEM ON LOESS IN THE SLOVAK REPUBLIC

Marta Klimeková - Zuzana Lehocká – Rastislav Bušo
Slovak Agricultural Research Centre Nitra – Research Institute of Plant Production Piešťany,
Bratislavská cesta 122, Piešťany, 921 68 Slovak Republic, lehocka@vurv.sk

Abstract

Conservation tillage systems are useful to control soil degradation, soil erosion and they are affecting soil chemical, biological, and physical properties. This study compared different tillage systems (conventional, minimum, mulch and no till) and their effect on selected physical and hydrophysical soil properties in a loam degraded Chernozem on loess in Slovakia after six respectively seven years of conservation tillage. In the years 2006 – 2007 soil under conservation and minimum tillage had a higher content of soil water than the soil in the conventional, tilled system. There was also the trend in bulk density increase and higher aggregate stability in conservation tillage systems. Conservation and minimum tillage systems had a positive effect on the investigated hydrophysical soil properties.

Introduction

One of the most important negative consequences of modern agricultural production using intensive tillage practices is probably the soil physical degradation resulting in erosion and soil compaction (Esteve et al., 2004; Bronick and Lal, 2005; Hamza and Anderson, 2005).

Conservation tillage practices have become popular in recent years in Slovakia. Conservation tillage leaves most or part of the crop residues on the soil surface thus affecting soil chemical, biological, and physical properties. Soil temperature, water content, bulk density, porosity, penetration resistance, and aggregate distribution are some of the physical properties affected by tillage systems. Changes in soil physical properties due to the use of no-tillage depend on several factors including differences in soil properties, weather conditions, history of management, intensity, and type of tillage (Mahboubi et al., 1993).

Transmission of water into the soil profile depends on the number of larger pores and biochannels (Unger, 1991). Chaney et al. (1985) and Carter (2002) concluded from their experiments on loamy and fine sandy loam soils, respectively, that no-tillage not only may reduce total pore space, but also may change pore size distribution, with larger pores disappearing and the finer ones predominating.

In respect to soil water content, no-tillage systems offer significant advantages over conventional tillage. The greater water storage under conservation tillage may be attributed to reduced evaporation, and to changes in pore size distribution (Dao, 1993). Water, oxygen, temperature, mechanical resistance and these factors in combination directly affect seedling emergence and root growth.

The aim of thise the paper i was to evaluate the effects of different tillage systems (conventional, minimum, mulch and no till) on selected physical and hydrophysical soil properties in a loam degraded Chernozem on loess in Slovakia after six respectively seven years of conservation tillage.

Material and Methods

AThe stationary field experiment was established in the experimental station of the Research Institute of Plant Production Piešťany in Borovce in the year 2000. The field experiment was located on Luvi–Haplic Chernozem on loess. The experiment was situated in an area with a moderate continental climate (average temperature per year: 9.2 ^{0}C, per vegetation period: 15.5 ^{0}C, precipitation depth per year: 593 mm, per vegetation period: 358 mm).

The experiment was a fully phased crop rotation in a split plot design. The crops in the rotation were: winter wheat, maize for grain, spring barley and soya.

Tillage variants:

- *Conventional tillage system* (conventional technology CS) – the soil was cultivated by ploughing with a depth of 0.2 m followed by a surface treatment and seed-bed preparation. An Amazone and a KINZE (for corn) seeder were used.
- *Minimum tillage system* (MS) – the only soil cultivation here was the roto tiller after the harvestafter the previous crop harvest disk tiller was used, the soil surface was covered for by 15 – 30 % by the crop residues, A Great Plains seeder and a KINZE seeder (for corn) were used for seeding..
- *Mulch tillage system* (MulchS) – the soil cultivation was a after the previous crop stubble undercutting by a plough – harrow, the soil surface was covered for by more than 30 % with by the crop residues, A Concord seeder and a KINZE seeder (for corn) were used for seeding..
- *No tillage system* (NS) – the soil was not ploughed. Crop residues of the previous crop were left on the soil surface, thus the soil surface was covered by more than 30 % with crop residues. A Great Plains seeder and a KINZE seeder (for corn) were used for seeding.

The crops were fertilized with synthetic fertilizers (balance method according to nutrient uptake and planned yields) was used; chemical plant protection against weeds and diseases was used.

The soil samples were taken four times (soil moisture) respectively three times (bulk density, soil structure) during the vegetation period (4.4.2006, 5.6.2006, 18.7.2009 – only soil moisture, 16.10.2006; 13.3.2007, 4.6.2007, 28.6.2007 – only soil moisture, 29.10.2007), from the defined depths (detailed info in the tables).

Used methods: soil moisture by weight according todefined by the gravimetric method, bulk density (reduced) withdefined by Kopecky rollers, soil structure withdefined by Analysette 2 equipment.

The data were statistically evaluated by Tuckey test.

Results and Discussion

The results showed that after six respectively seven years of conservation tillage the conventional technology had a lower content of soil moisture in all observed soil depths and also in averaged over the soil depths (**P<0.05). A sStatistically higher (**P<0.01) content of soil moisture was was found in the mulch till technology in comparison with the another technologies. There was not a significance difference in between soil moisture content between the in minimum and the no tillage technology (Table 1).

Table 1: Soil moisture content (%) in different tillage systems in the experimental years 2006– 007

	Depth								
System	**0,0 - 0,10 m**	**0,10 - 0,20 m**	**0,20 - 0,30 m**	**0,30 - 0,40 m**	**0,40 - 0,50 m**	**0,50 - 0,60 m**	**0,60 - 0,70 m**	**0,70 - 0,80 m**	**average**
CS	17.71	16.88	16.51	16.60	16.51	16.23	14.81	14.32	16,53^{a}
MS	18.05	17.49	17.18	16.86	16.93	17.03	16.03	15.44	17,15^{b}
MulchS	19.20	18.33	17.91	17.86	18.26	18.24	16.94	16.38	18,2^{c}
NS	17.91	17.62	17.02	17.37	17.49	17.19	15.54	15.35	17,18^{b}
Average	18,22a	17,58b	17,16bc	17,17bc	17,3b	17,17bc	15,83bc	15,37c	17.26

LSD 0.05 technology 0.23
LSD 0.01 depth 0.03

Several authors found a highergreater soil bulk density under conservation tillage than under conventional tillage (Hammel, 1989; Ferreras et al., 2000), while others did not find differences (Chang and Lindwall, 1989), or obtained lower values of bulk density under soils with a residue layer on the surface (Edwards et al., 1992; Lal et al., 1994). The results of our experiment showed the lowest value of soil bulk density in the conventional system although athe significant difference was found only in comparison with minimum system (**P<0.05). Decreasing tillage intensity from the conventional system to conservation tillage resulted in an increase in bulk density of the upper soil. This might be related to the presence of theexisting mulch layer on top of non-tilled soils which provide organic matter and food for the soil fauna, which loosens surface soil by burrowing activities.

Table 2: Soil bulk density (t.ha^{-1}) in different tillage systems in the experimental years 2006– 007

Systems	Depth			
	0.0 - 0.10 m	0.10 - 0.20 m	0.20 - 0.30 m	Average
CS	1.41	1.41	1.45	1.43 ^{a}
MS	1.34	1.49	1.53	1.45^{b}
MulchS	1.37	1.48	1.47	1.44^{ab}
NS	1.40	1.47	1.48	1.44^{ab}
Average	1.38^{a}	1.46^{b}	1.48^{b}	I.44

LSD 0.01 depth 0.034
LSD 0.05 technology 0.03

Crop management systems are generally regarded as having a strong influence on aggregate structural characteristics. Aggregate stability is considered as a key indicator to assess the sustainability of the agro ecosystems. The highest values of the soil structure coefficient was in the no tillage system (2.10) followed by the minimum (1.83) and the mulch till system (1.55). The lowest value of this indicator was measured observed in the conventional technology (**P<0.05). There were not statistical differences betweenamong the three different soil depths.

Table 3: Soil structure coefficient in different tillage systems in the experimental years 2006 – 2007

System	Depth			
	0.0 - 0.10 m	0.10 - 0.20 m	0.20 - 0.30 m	Average
CS	1.26	1.08	1.06	1,13a
MS	1.61	2.09	1.78	1,83c
MulchS	1.64	1.51	1.51	1,55b
NS	1.93	2.11	2.26	2,10d
Average	1,61 ns	1,7ns	1,65 ns	1.65

LSD 0.01 technology 0.27
LSD 0.05 depth 0.17

Conclusions

The results indicated that soil water content was always higher in the conservation and minimum tillage systems than in the traditional, conventional tillage system. Moreover the higher amount of crop residues left on the soil in the no tillage and mulch tillage system protected the soil against evaporation losses more effectively. Similar findings have been reported previously, where in which no-tillage increased the water content compared to traditional tillage or minimum tillage, especially in dry years (Benito et al., 1999). Five respectively six years of conservation tillage showed also an increase in bulk density of the upper soil and higher aggregate stability.

Acknowledgments

The results were obtained within the frame of the Project 2006 UO 27/091 05 01/091 05 10.

References

Benito, A. - Sombrero, A. - Escribano, C. 1999. The effect of conservation tillage on soil properties. Agricultura, Revista Agropecuaria 68, p. 538–541.

Bronick, C.J. - Lal, R. 2005. Soil structure and management: a review. Geoderma 124, p. 3–22.

Carter, M.R. 2002. Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. Agric. J. 94, p. 38–47.

Dao, H. 1993. Tillage and winter wheat residue management effects on water infiltration and storage. Soil Sci. Soc. Am. J. 57, p. 1586 - 1595.

Edwards, W.M. - Shipitalo, M.J.- Dick, W.A. - Owens, L.B. 1992. Rainfall intensity affects transport of water and chemicals through macropores in no-till soil. Soil Sci. Soc. Am. J. 56, p. 52 - 58.

Esteve, J.F. - Imeson, A. - Jarman, R. - Barberis, R. - Rydell, B. - Sanchez, V.C. - Vandekerckhove, L. 2004. Pressures and drivers causing soil erosion. In: Van-Camp. L., Bujarrabal, B., Gentile, A.-R., Jones, R.J.A., Montanarella, L., Olazabal, C., Selvaradjou, S.-K. (Eds.), Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection, EUR 21319 EN/2, Office for Official Publications of the European Communities, Luxembourg, p. 133–149.

Ferreras, L.A. - Costa, J.L. - García, F.O. - Pecorari, C. 2000. Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern Pampa of Argentina. Soil Till. Res. 54, p. 31–39.

Hammel, J.E. 1989. Long-term tillage and crop rotation effects on bulk density and soil impedance in northern Idaho. Soil Sci. Soc. Am. J. 53, p. 1515 – 1519.

Hamza, M.A. - Anderson, W.K. 2005. Soil compaction in cropping systems review of the nature, causes and possible solutions. Soil Till. Res. 82, p. 121–148.

Chaney, K. - Hodgsson, D.R. - Braim, M.A. 1985. The effects of direct drilling, shallow cultivation and ploughing on some soil physical properties in a long-term experiment on spring barley. J. Agric. Sci. Camb. 104, p. 125 - 133.

Chang, C. - Lindwall, C.W. 1989. Effect of long-term minimum tillage practices on some physical properties of a Chernozemic clay loam. Can. J. Soil Sci. 69, p. 443 - 449.

Lal, R. - Mahboubi, A.A. - Faussey, N.R. 1994. Long-term tillage and rotation effects on properties of a Central Ohio Soil. Soil Sci. Soc. Am. J. 58, p. 517–522.

Mahboubi, A.A. - Lal, R. - Faussey, N.R. 1993. Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J. 57, p. 506 – 512.

Unger, P.W. - Stewart, B.A. - Parr, J.F. - Shingh, R.P. 1991. Crop residue management and tillage methods for conserving soil and water in semi-arid regions. Soil Till. Res. 20, p. 219–240.

Scientific session I.B Soil management and soil quality

THE POTENTIAL OF NO-TILL AND RESIDUE MANAGEMENT TO SEQUESTER CARBON UNDER RAINFED MEDITERRANEAN CONDITIONS

G. Basch; J.F.C. Barros; J.M.G. Calado and M.L.C. Brandão
Inst. of Mediterranean Agr. Sci., Univ. of Évora, Crop Science Dept., 7002-554 Évora, Portugal

Abstract

Soil organic matter contents under Mediterranean climatic conditions frequently are low to very low, especially where extensive land use and thus low biomass production is predominant. Reducing tillage intensity and maintaining crop residues in the field are considered to be promising agricultural practices to counteract the decline in soil organic carbon. The objectives of this work were to study the combination of no-till and the use of different crops and amounts of residues and their management on the evolution of soil organic matter. In two trials, crops were established under no-till over 3 years using different levels of wheat straw and their management and one treatment with residues of chickpea. Initial and final soil organic matter contents were analysed. The results indicate that the higher the amount of residues returned to the field the higher the increase of soil organic matter. Maintenance of straw compared to *in situ* feeding enhances the build-up of soil organic matter. Chickpea as a low biomass producing crop with a low C/N ratio of its residues showed no positive effect in terms of soil organic matter improvement. The results suggest that the return of cereal residues instead of its removal or grazing in combination with no-till for crop establishment can contribute considerably to improve the low soil organic matter levels found in Mediterranean environments.

Introduction

Soils under Mediterranean climate are known to present low levels of organic carbon (Zdruli et al. 2004). Climatic effects inducing high mineralization rates of the organic matter, low biomass production under rainfed conditions, intensive soil tillage used for crop establishment, straw removal and grazing of the stubble and soil erosion can be pointed out as the main reasons for the soil organic carbon depletion of Mediterranean cropland. Average soil organic matter contents (SOM) in the top layer frequently are around 1%. These low soil organic carbon (SOC) contents affect crop and overall soil productivity in different ways; through a) reduced water infiltration and retention capacity, b) reduced cation exchange capacity and nutrient cycling efficiency, c) deficient soil structure and root growth. Furthermore, the frequent cycles of wetting and drying of the soil during the growing season not only favour decomposition of SOM and CO_2 emissions (Jarvis et al., 2007) but also silting and crust formation of the exposed soil layer leading to deficient gas exchange and plant emergence. In general, the extremely low SOM contents are responsible for the low resilience of Mediterranean soils to frequently occurring adverse conditions of scarce or excessive rainfall.

Thus the conditions for the build-up of SOM under the extensive rainfed Mediterranean cropping systems are very limited unless SOC mineralization rate is reduced and crop residues are left on the soil. Therefore, the aim of this work was to study both the effect of minimum soil disturbance and different type and management of crop residues on the build-up of soil organic matter under field conditions.

Materials and Methods

Site description

The experimental site is located near the town Reguengos de Monsaraz in the southeast of Portugal (38°28'N, 7°28'W) on a sandy clay loam (vertic Cambisol). The annual temperatures and precipitation averages are 16.1°C and 572mm, respectively. Table 1 shows the monthly values of temperature and precipitation both long-term and during the trial period. Before trial installation in 2004, the field had already been under not-till since 2001, and the crop rotation used was wheat-oats-fallow/sunflower. Until 2000, traditional soil tillage consisted in the use of a tine cultivator and a heavy disk harrow for primary soil tillage and a spring tine cultivator for seed bed preparation.

Table 1: Monthly mean temperature and precipitation both long term (Reguengos de Monsaraz) and during the trial period (on farm weather station).

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sum/Av
Mean temp. long-term (°C)	21,1	17,3	12,2	9,3	8,7	10,0	12,6	14,2	17,3	22,3	24,3	24,3	16,1
Precip. long-term (mm)	20,6	61,0	69,9	74,7	77,6	76,7	83,3	44,9	33,5	24,8	3,5	2,1	572,6
Mean temp. 2004/05 (°C)	22,2	17,2	11,6	8,3	6,9	7,4	12,5	14,9	18,7	24,2	24,8	25,8	16,2
Precip. 2004/05 (mm)	12,1	126,2	20,2	32,9	2,4	14,9	25,4	15,3	61,0	0,8	0,4	0,2	311,8
Mean temp. 2005/06 (°C)	21,9	17,7	10,7	8,5	6,9	8,2	11,7	14,9	19,2	22,3	25,8	25,8	16,1
Precip. 2005/06 (mm)	1,4	161,4	77,3	57,2	30,8	37,8	83,8	52,6	0,2	28,2	21,0	10,9	562,6
Mean temp. 2006/07 (°C)	22,7	18,5	14,3	8,3	7,7	10,8	11,4	13,4	17,0	20,6	24,5	23,6	16,1
Precip. 2006/07 (mm)	33,1	172,0	113,7	40,1	36,8	95,6	11,6	49,7	38,9	34,6	0,0	15,7	641,8

Treatments

The evaluation of the evolution of SOC was carried out in two field trials within a research project entitled “The potential of no-tillage for carbon sequestration on agricultural land”. The first one designated as “crop and residue management trial” consisted in the following five treatments:

- “*Chickpea*” as a leguminous, low residue producing crop with a low C/N ratio; the amount of residues left was approximately 750 kg of DM ha^{-1};
- “*Grazing*” - Wheat crop with removal of straw and stubble, and distribution of manure from sheep fed on wheat straw equivalent to 3000 kg ha^{-1}, in order to simulate the grazing of straw and stubble;
- “*Stubble*” - Wheat crop with straw removal but stubble maintenance (cut at a height of 15 cm);
- “*Straw*” - Wheat crop with stubble and uniform distribution of 2500 kg ha^{-1} of wheat straw (corresponding to an average production of wheat straw);
- “*2 x Straw*” - Wheat crop with stubble and uniform distribution of 5000 kg ha^{-1} of wheat straw (corresponding to twice the amount of wheat straw produced).

The main objective of the second trial was to study the effect of different amounts of wheat straw (stubble, stubble plus 2500 kg ha^{-1} and stubble plus 5000 kg ha^{-1}) on the evolution of the population of earthworms (“residue trial”). However, this paper only reports on the effects of the residue levels on the changes in SOC.

The plot size of each treatment in the first trial on crop and residue management was 15x 3m, using a randomized complete block design as experimental layout. The second trial was a simple split of four strips (replications) into 3 treatments of different amounts of residues of 3x3m each. Both trials were realized with four replications. The crops were installed with a Semeato direct drill, equipped with staggered double disc openers and repeated over 3 years on the same area in order to accumulate the effect of the residues and their management.

Sampling and analysis

Before crop installation in October 2004 all plots were subject to an initial assessment of SOC. According a fixed scheme, composite samples of 14 points per plot (15x3m) were taken for the crop and residue management trial. Due to the reduced dimension of the residue trial, 12 points per replication (11x3m, with 1 m between residue levels) were considered sufficient for the initial assessment of SOC. Samples were taken using a core sampler with a diameter of 5 centimetres to a depth of 20 centimetres. This depth limit was chosen because no considerable soil disruption through soil tillage would take place and thus no relevant changes of SOC were expected below this depth. The cores were subdivided into three layers: 0-5cm, 5-10cm and 10-20cm. At the end of the project period, in November 2007, an identical sampling was performed in the case of the crop and residue management trial. In the residue trial, sampling was split up into the different residue levels using 8 points per plot of residues. Samples were air dried, grinded and then analysed in an automated combustion furnace working at 1350°C (Leco SC-144DR) using 3 replicates per sample. Bulk densities were determined for each replication of the two trials at the beginning of the project, but no significant differences between the locations were detected. Average bulk densities were 1.52 and 1.55 for the layers 0-10cm and 10-20cm, respectively.

Results and Discussion

Despite the relatively small area of implantation of the crop and residue management trial (40 x 45m), the initial sampling revealed considerable and even significant differences with regard to the levels of SOM. The spatial variability of soil properties and especially soil carbon on even small areas is well documented (Arnold and Wilding, 1991; Wilding et al., 2001). Sampling, handling and analysis were carried out with utmost care and individual values were checked for their consistency. Nonetheless, SOM levels in the monitored soil layer showed significant lower values in the straw and grazing treatments when compared to the chickpea treatment (table 2). In 2007, only the treatment with the highest amount of residues (2 x straw) revealed a significantly higher level of SOM. Regarding the changes obtained in SOM within the 3 years' trial period (table 2 and figure 1), both "straw" treatments showed a considerable increase in SOM of almost 0.2%, which was significantly different when compared to the other treatments. The chickpea crop with its low amount of fast degrading residues showed even a slight decrease in SOM. The distribution of dry sheep manure showed a higher increase in SOM than the stubble treatment, although not significantly different.

Table 2: Soil organic matter contents under two crops and different residue management systems of wheat straw in the top soil layer (0-20 cm) before and after 3 years of differentiated management.

	Crop and residue management treatments				
Sampling	Chickpea	Grazing	Stubble	Straw	2 x Straw
2007	1.294 b	1.301 b	1.283 b	1.319 b	1.482 a
2004	1.318 a	1.221 bc	1.251 ab	1.140 c	1.285 ab
Diff. 2007-2004	-0.024 c	0.080 b	0.033 bc	0.179 a	0.196 a

Values followed by the same letter or letters are not significantly different at a 5 % level (Duncan Multiple Range Test)

Regarding the distribution in depth, all treatments showed an increase in SOM in the upper soil layer (0-5cm), which was highest in the two “straw” treatments, reaching an increase of around 0.35%. Astonishingly, the layer between 5 and 10 cm behaved worst with regard to the relative changes in SOM. In all five treatments the lower soil layer (10-20 cm) showed higher increases or lower decreases (chickpea), than the layer above. This result is hard to explain as sampling procedures were identical for both periods. Some authors refer to the changes of porosity and bulk density able to account for differences in the stratification of SOM over time (Kay and VandenBygaart, 2002), others refer to a lack of resolution regarding the changes of soil properties with depths Logsdon et al., 1999).

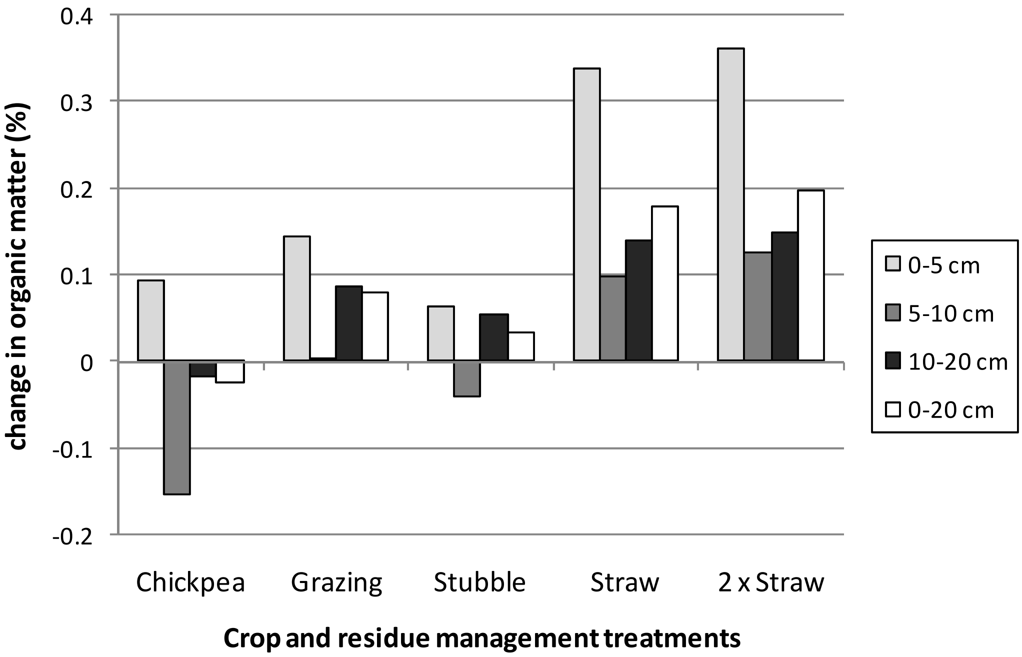


Figure 1: Relative changes in soil organic matter with depth under two crops and different residue management systems of wheat straw after 3 years.

However, the same phenomenon of a decrease of SOM between sampling periods in the 5-10 cm layer occurred in the residue trial, and the overall change of the SOM levels in the monitored soil layer was very similar to the one obtained in the crop and residue management trial (figure 2). Straw removal and the maintenance of stubble slightly increased the SOM content in the 20 cm top layer, whereas straw return and additional amounts of straw, which could occur under improved soil fertility conditions or irrigation, increased SOM up to 0.2% in the topsoil layer within a period of 3 years.

Both trials reveal the potential of the combination of no-till as non soil disruptive form of crop establishment and the return or maintenance of slowly degradable crop residues such as wheat straw for the increase of SOM on the highly organic carbon depleted Mediterranean soils. These findings are in accordance with results published by other authors (Dick et al., 1998; Clapp et al., 2000; Layese et al., 2002; West and Post, 2002) that report an increase of carbon incorporated into SOM when changing from intensive tillage to no-till, but only if harvestable carbon residues like straw or cornstalks were left in the field. However, contradictory results can be found in the review performed by Wilhelm et al. (2004), indicating that residue return may lead or not to an accumulation of SOM. Sanchéz et al. (2002), measuring the CO_2 flux from conventional and reduced tilled fields, found a reduction of 6660 kg CO_2 ha^{-1} $year^{-1}$ under reduced tillage. This amount of carbon dioxide corresponds to around 3000 kg SOM ha^{-1}, which is approximately the yearly SOM increase found in the most favourable treatments in the trials, assuming a bulk density of 1.5.

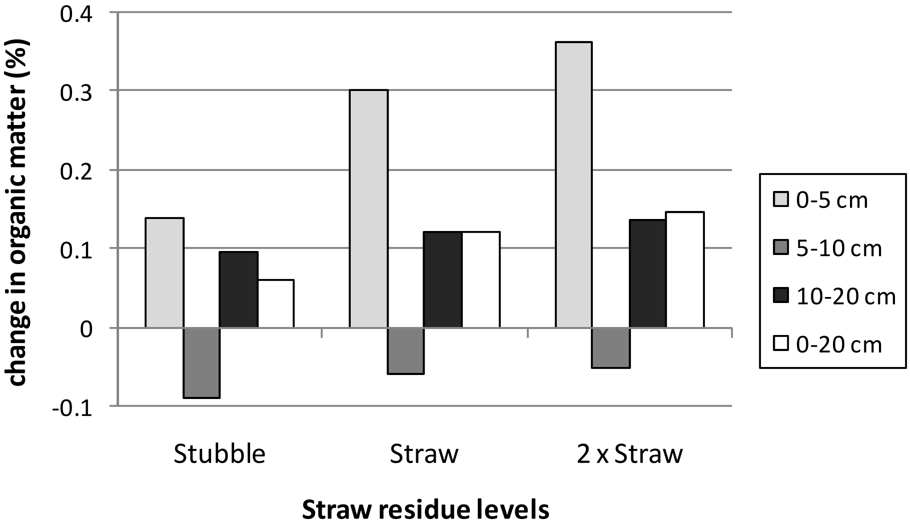


Figure 2: Relative changes in soil organic matter with depth under three levels of wheat straw residues after 3 years.

The evaluation of the total amount of SOC sequestered after only three years of differentiated treatments is certainly questionable. Nonetheless, the differences between crop type and residue levels and their management are considerable and give evidence of the potential contribution of the combined effect of no till and crop residue return to the build-up of SOM even under conditions of relatively low biomass production of Mediterranean rainfed agriculture. They also confirm that high C/N ratios of the residues are essential for the incorporation of crop carbon into SOM.

Acknowledgements
This paper has been produced within the project POCTI/AGG/46545/2002: Potential of no-tillage for carbon sequestration on agricultural land, and has been possible thanks to the financial support given by the European Union (FEDER) through the Foundation for Science and Technology (FCT).

References

Arnold, R.W. and L.P. Wilding. 1991. The need to quantify spatial variability. P. 1-8. In: M.J. Mausbach and L.P. Wilding (eds.), Spatial Variability of Soils and Landforms. Soil Sci. Soc. Am. Spec. Publ. 28. Soil Sci. Soc. Am., Madison, WI.

Clapp, C.E., R.R. Allmaras, M.F. Layese, D.R. Linden, and R.H. Dowdy. 2000. Soil organic carbon and 13-C abundance as related to tillage, crop residue, and nitrogen fertilizer under continuous corn management in Minnesota. Soil Tillage Res. 55:127–142.

Dick, W.A., R.L. Blevins, W.W. Frye, S.E. Peters, D.R. Christenson, F.J. Pierce, and M.L. Vitosh. 1998. Impacts of agricultural management practices on C-sequestration in forest-derived soils of the eastern Corn Belt. Soil Tillage Res. 47:235–244.

Jarvis, P., A. Rey, C. Petsikos, L. Wingate, M. Rayment, J. Pereira, J. Banza, J. David, F. Miglietta, M. Borghetti, G. Manca, and R. Valentini. 2007. Drying and wetting of Mediterranean soils stimulates decomposition and carbon dioxide emission: the "Birch effect". Tree Physiology 27:929-940.

Kay, B.D., and A.J. VandenBygaart. 2002. Conservation tillage and depth stratification of porosity and soil organic matter. Soil Tillage Res. 66:107-118.

Layese, M.F., C.E. Clapp, R.R. Allmaras, D.R. Linden, S.M. Copeland, J.A.E. Molina, and R.H. Dowdy. 2002. Current and relic carbon using natural abundance carbon-13. Soil Sci. 167:315–326.

Logsdon, S.D., T.C. Kaspar, and C.A. Cambardella. 1999. Depth-incremental soil properties under no-till or chisel management. Soil Sci.Soc. Am. J. 63:197-200.

Sanchez, M.L., M.I. Ozores, R. Colle, M.J. Lopez, B. De Torre, M.A. Garcia, and I. Perez. 2002. Soil CO_2 fluxes in cereal land use of the Spanish plateau: influence of conventional and reduced tillage practices. Chemosphere 47:837-844.

West, T.O., and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. Soil Sci.Soc. Am. J. 66:1930–1946.

Wilding L.P., L.R. Drees and L.C. Nordt. 2001. Spatial Variability: Enhancing the Mean Estimate of Organic and Inorganic Carbon in a Sampling Unit. In: R. Lal, J.M. Kimble, R.F. Follett and B.A. Stewart (eds), Assessment Methods for Soil Carbon. CRC Press, Boca Raton, Fl., pp. 69-86.

Wilhelm, W.W., J.M.F. Johnson, J.L. Hatfield, W.B. Voorhees, and D.R. Linden. 2004. Crop and soil productivity response to corn residue removal: A literature review. Agronomy Journal 96:1-17.

Zdruli, P., Jones, R.J.A. and Montanarella L.. 2004. Organic Matter in the Soils of Southern Europe. European Soil Bureau Research Report No. 15. Office for Official Publications of the European Communities, Luxembourg. EUR 21083 EN, 17pp.

ORGANIC FERTILISERS OF THE MAC TRIAL AND THEIR IMPACT ON SOIL QUALITY, ENVIRONMENT AND CLIMATE CHANGE

C.J. Koopmans[1], M. Zanen[1] & J.G. Bokhorst[1]
[1]Louis Bolk Institute, Hoofdstraat 24, 3972 LA Driebergen, The Netherlands, c.koopmans@louisbolk.nl

Abstract

After 8 years, the MAC field trial in Lelystad, the Netherlands, shows the effects of different fertiliser strategies, ranging from animal manure to plant compost to mineral fertiliser. The impact on yield, soil quality, soil health, environment and climate change is discussed. The trial is unique in monitoring the effect of so many types of fertilisers over so many years.

Introduction

Applying fertiliser is the easiest measure a farmer can vary to maintain soil health. Uncertainty about the different characteristics of fertilisers means that the choice of fertiliser varies widely between farms.

After a completed rotation of eight years (1999-2006), organic soils of the Manure as a Chance (MAC) trial were analysed for the effect of amendments on yields, soil quality and soil biodiversity properties.

Materials and Methods

The experiment (Lelystad, The Netherlands, 5° 30' East, 52° 32' North, precipitation 780mm), was set up as a randomised complete block with four replications and 7m x 9m plot size. The manure or compost addition (Tab. 1) is limited by:

- o a maximum of 100 kg N ha^{-1} $year^{-1}$
- o a mean net legal maximum of 80 kg P_2O_5 ha^{-1} $year^{-1}$
- o a legal maximum of 6000 kg dry matter ha^{-1} $year^{-1}$.

Table 1: Selected strategies of the MAC trial and nitrogen mineralised, P_2O_5 application, dry matter and organic matter from the amendments in kg.ha^{-1} $year^{-1}$.

Strategy	Nitrogen active*	P_2O_5*	Dry matter*	OM*
Deep stable manure (FYM)	67	66		4930
Cattle slurry (CS)	67	35		1530
Mineral fertiliser (MIN)	67	43		0
Household and slurry (HC+CS)	67	69		2910
Poultry manure (PM)	47	80		1680
Plant compost 1 (PC)	24	80		7870
Household compost (HC)	9	57	6000	1490
Plant compost 2 (GC)	8	48	6000	1770

* amendments are applied two years in three.

The organic vegetable rotation of the host farm includes red cabbage, potato, beet, carrot, parsnip, broccoli, squash and cauliflower in 2006. It is of common intensity for Dutch organic horticulture. The light sandy clay soil was analysed for soil physical, chemical and biological properties.

Microbial and fungal biomass, N mineralization, nematodes and basal respiration were determined according to Mulder et al., 2005. Data were analyzed by analysis of variance (ANOVA). Significant effects were separated by the least significant difference (LSD) at P = 0.05.

Results and Discussion

Yields suggest significant differences due to different organic amendments after 8 years (Fig. 1). In treatments receiving farm yard manure and household waste compost yields increased over time. Soil properties indicate changes, among others, in nitrogen mineralization, soil organic matter and biological properties like earthworm burrows and plant feeding nematodes. No significant changes in microbial and fungal biomass were found.

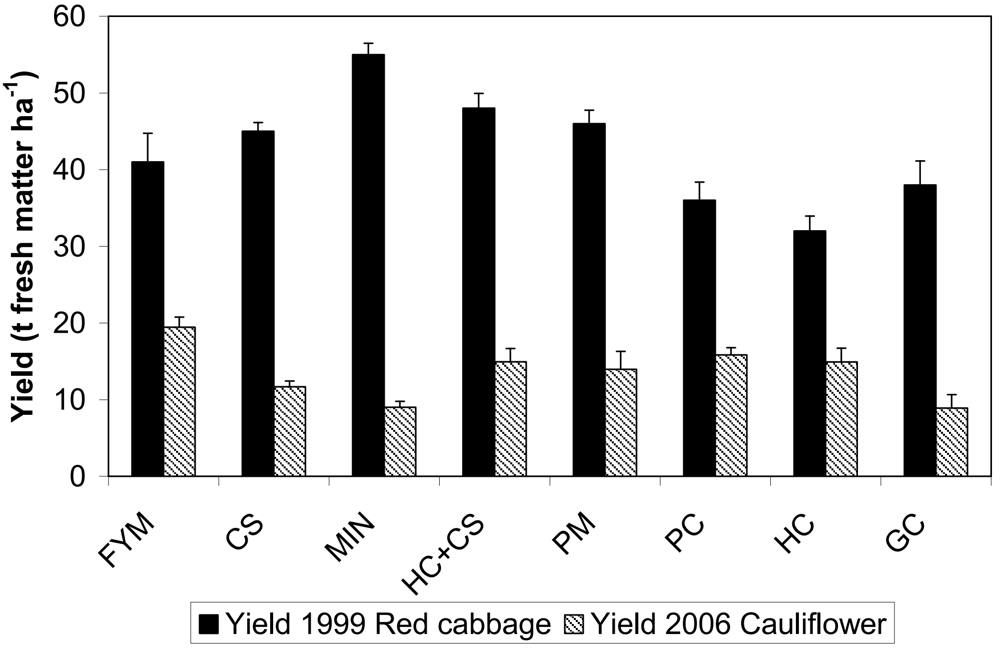


Fig. 1: Yields of red cabbage (1999) and cauliflower (2006) in the MAC trial. Bars indicate standard error of the mean.

The strategies were evaluated in terms of five challenges society is facing nowadays: Sustainable yields, a sustainable soil quality, soil health, prevention of environmental contamination and climate change. Tab. 2. links these challenges in a qualitative way to indicators measured in our evaluation.

From the evaluation it is clear that no strategy scores high in each of the five evaluation criteria. After 8 years deep stable manure results in highest yields. Fertilisers which supply little or no organic matter show a decline over the years. If soil quality is evaluated in terms of the capacity to supply nitrogen, the deep stable manure, slurry and composts score highest. The least harmful plant feeding nematodes were found in household waste combined with slurry and poultry manure. Plant based compost score highest in terms of low phosphate surpluses in a balancing approach and (modelled) nitrate leaching. In terms of climate change the deep stable manure and plant based compost show a slight increase in organic matter of the soil.

Table 2: Qualitative evaluation of the fertilization strategies in MAC trial linking soil indicators to challenges of society and yield.

Evaluation Criterion	Yield	Soil quality	Soil health	Environment	Climate Change
Indicator	Fresh yield 2006	Nitrogen supply	Parasitic nematodes	Phosphate surplus and nitrate leaching	Organic matter sequestration
FYM	+	+	0	0	+
CS	-	+	0	0	-
MIN	-	-	-	+	0
HC+CS	0	+	+	-	0
PM	0	0	+	-	0
PC	0	+	-	+	+
HC	0	-	0	+	+
GC	-	0	0	+	+

The study shows that organic amendments used within the legal framework of organic farming impact soil quality and soil biodiversity indicators within eight years. The results suggest a neutral or overall positive effect from deep stable manure in the long run on indicators linked to societal challenges. In terms of environment and climate change the different compost strategies seem to perform surprisingly well.

Acknowledgements

We thank the organic farmer Jan van Geffen for his work on the trial and allowing us to make use of his land, Coen ter Berg and Luc Steinbuch for their help with fertilization and sampling of the trial. The authors gratefully acknowledge funding from the Dutch Ministry of Agriculture, Nature and Food Quality and the IONA foundation.

References

Koopmans, C.J., Zanen, M. (2007): Organic soil management: impacts on yields, soil quality and economics. In Niggli, U., Leifert, C., Alföldi, T., Lück, L., Willer, H. (eds.): Improving Sustainability in organic and low input food production systems. Proceedings of the 3rd international congress of the European integrated project 'Quality Low Input Food' (Qlif). Fibl, Frick, p. 201-204.

Mulder, C., Cohen, J.E., Setälä, H, Bloem, J., Breure, A.M. (2005): Bacterial traits, organism mass, and numerical abundance in the detrital soil food web of Dutch agricultural grassland. Ecology Letters 8(1): 80-90.

Zanen, M., Bokhorst, J.G., Berg, C. ter & C.J. Koopmans (2008). Investeren tot in de bodem. Evaluatie van het proefveld mest als kans. Report no. LD11. Louis Bolk Institute, Driebergen, The Netherlands, 30 p. (In Dutch)

Zanen, M., Bokhorst, J.G., Berg, C. ter & C.J. Koopmans (2008). Soil fertility and biodiversity effects from organic amendments in organic farming (2008). In: Neuhoff, D. et al. (eds.) Proceedings of the second scientific conference of the International Society of Organic Agricultural Research (ISOFAR), 18-20 June 2008, Modena, Italy. p. 70-73.

SELECTED SOIL PROPERTIES BY DIFFERENT RATIOS OF CEREALS IN CROP ROTATIONS AND IN CONTINUOUS CROPPING

Babulicová M., Sekerková M.
Slovak Agricultural Research Centre Nitra – Research Institute of Plant Production Piešťany,
Bratislavská cesta 122, Piešťany, Slovak Republic, ZIP code 9 621 01, babulicova@vurv.sk,
sekerkova@vurv.sk

Abstract

In 1974 this field experiment was established on Luvi-haplic Chernozem in a warm and dry region of the Slovak Republic. There are crop rotations with 40 %, 60 % and 80 % share of cereals in the first part of this trial and continuous cropping of winter wheat and spring barley in the second part of the trial. In crop rotations only the mineral fertilization was applied and in continuous cropping mineral and organic fertilizations (straw and green manure incorporation) were applied. The paper presents the effects of different ratios of cereals in crop rotations and the effects of continuous cropping of spring barley and winter wheat on selected soil properties (bulk density, total porosity, maximum capillary capacity, structure coefficient, the content of humus). Obtained data were tested by statistical methods. Variance analysis was used. Bulk density was statistically lower by the continuous cropping of winter wheat (1.41 $t.m^{-3}$) than by the continuous cropping of spring barley (1.50 $t.m^{-3}$). The highest values of total porosity (44.99 %), structure coefficient of (5.83) and the content of humus (2.00 %) in the soil were determined in the variant with straw and green manure incorporation by continuous cropping of winter wheat (variant F).

Introduction

At present the crop rotation is one of the most important measures in plant production which don't increase the costs of the production. In addition the crop rotation plays other responsible roles: productive, economic and environmental. The main target of long-term experiments is the maintenance of soil fertility. Soil organic matter is the source of microorganism nutrition, it is very important in the tillage of soil, in the infiltration of air and water by promoting water retention and reducing erosion (Gregorich et al., 1994). The content and quality of soil organic matter positively affect physical, chemical and biological soil properties (Cerhanová et al., 2007). The soil fertility depends on the humus content, which is the result of crop rotation and organic fertilization (Kotorová – Šoltýsová, 1992). Nowadays the market economy is the most important argument for the option of agricultural crops. This situation in many cases results in increasing the concentration of one crop and limited crop rotations. Researchers in the Slovak Agricultural Research Centre Nitra – Research Institute of Plant Production Piešťany pursue the questions to what degree is it respectable to increase the share of cereals in crop rotations. In our field experiment the relationships between crop rotations, fertilization and selected soil properties are being investigated.

Material and Methods

The stationary trial was established in 1974 in the experimental station Borovce of the Research Institute of Plant Production in Piešťany. The field experiment was located on Luvi–Haplic Chernozem on loess. The depth of plow-layer was 0.24–0.28 m. The depth of molic horizon was 0.40–0.55 m; it was differentiated in the upper (eluvial) and lower (illuvial) layer. Molic horizon proceeds into calciferous loess in the depth of 0.50–0.85 m. The trial occurs in the area of continental climate; the average annual temperature is 9.2°C; the sum of the annual precipitation is 593 mm (30 years average). The trial consisted of two parts. In the first part, crop rotations were used with 40, 60 and 80% share of the cereals (Table 1). In crop rotation there was used the mineral fertilization. In the second part of the trial, winter wheat and spring barley were grown in continuous cropping. To decrease the negative impacts of continuous cropping, various measures were taken, e.g. incorporation of organic matter into the soil (cereal straw and/or cereal straw and green manure in the next variant) and the introduction of compensating crops (silage maize, grain maize, oats). White mustard (*Sinapis alba*) was ploughed into the soil as green manure. In the first sequence winter wheat and spring barley were grown in "net" monoculture. In the second sequence there are rotated winter wheat and spring barley. In first and second sequences was used incorporation of organic matter into the soil. At the control variant there were used only fertilizers. The third sequence: the continuous cropping of winter wheat was interrupted maize on silage each second year; grain maize followed in each second year in spring barley in continuous growing. In the fourth sequence there was sown oat in each second year in monoculture of winter wheat and spring barley.

On the selected soil samples physical soil parameters (bulk density, total porosity, maximum capillary capacity, structure coefficient) and the chemical soil parameter (the content of humus) in the years 1988 and 2007 observed and consequently evaluated. This was done on the selected soil samples. There was used variance analysis. The selected variants are presented in table 2.

Table 1: The composition of crops in the crop rotations with 40 %, 60 % and 80 % share of cereals

Crop rotations		
40 % of cereals	60 % of cereals	80 % of cereals
1. peas	1. peas	1. winter wheat
2. winter wheat	2. winter wheat	2. spring barley
3. maize on silage	3. winter barley	3. peas
4. spring barley	4. maize on grain	4. winter wheat
5 maize on grain	5. spring barley	5. winter barley

Results and Discussion

The selected physical soil properties and the grain yield of winter wheat were influenced by the different share of cereals in crop rotations and the different fertilization in a statistically significant degree (Table 4). The average dry bulk density (see Table 3) by continuous cropping of winter wheat (1.40 $t.m^{-3}$; 1.42 $t.m^{-3}$) was statistically lower than by continuous cropping of spring barley (1.50 $t.m^{-3}$). The highest average total porosity was reached by continuous cropping of winter wheat with straw and green manure incorporation (44.99 %) and in the variant where continuous cropping of winter wheat was interrupted by oats every second year (44.96 %). The lowest average total porosity was found by continuous cropping of spring barley in the G and H variants (42.24 %; 42.82 %). The incorporation of straw and green manure influenced the maximum capillary capacity. The lowest average maximum capillary capacity was found in the crop rotation with 80 % of cereals (32.77 %). The maximum capillary capacity was statistically lower by the continuous cropping of spring barley (34.20 %; 33.56 %) than by continuous cropping of winter wheat (37.17 %; 36.07 %). The highest average value of soil structure coefficient was reached in F (5.58). The soil structure coefficient was statistically higher by the continuous cropping of winter wheat (in variant E 5.35 and in variant F 5.83) than by continuous cropping of spring barley (in variant G 3.39 and in variant H 3.92). Within the years 1988 to 2007 the humus content was continuously decreasing in all variants except for the variants C and D (variants where continuous cropping of winter wheat and spring barley was interrupted by maize on silage or oats). In 2007 the humus content remained on the same level as in 1988 in the variant with straw and green manure (variant F). Rychlik et al. (2006) presented the content of organic matter in the soil plough layer (0 – 250 mm) in both 6-field crop rotations. The content of soil organic carbon in the crop rotation showed inconsiderable variation and, on average, amounted to 0.770 % in A, and 0.727 % in B, which in terms of humus constitutes 1.327 and 1.253 %, respectively. However, significant differences in the amount of organic carbon were recorded in the case of monocultures. Rychlik et al. (2006) conducted the field experimental, focused on the response of the most important plants in Poland to continuous cultivation. The experiment was located on Luvisols formed from silty light loam. Twelve plant species were cultivated in crop rotation A) potato – oats – flax – winter rye – faba bean – winter triticale; B) sugar beet – maize – spring barley – pea – winter rape – winter wheat, and each of the species in monocultures. In crop rotations reasonable increase was observed in the content of organic matter; similar tendencies appeared in most monoculture fields. The lowest content of organic C was recorded by the continuous cultivation of pea, maize and faba bean.

Comparing physical soil properties in 1988 with those in 2007 in our trial, the improvement of soil structure was observed in crop rotation with 40 % cereals and in short sequence with maize on silage (winter wheat – winter wheat – maize on silage). The soil structure coefficient was significantly higher by the continuous cropping of winter wheat than by continuous cropping of spring barley. The incorporation of organic matter (straw and green manure) positively contributed to the improvement of total porosity by growing both crops (winter wheat and spring barley). The soil structure coefficient in winter wheat was higher in the variant with organic fertilization (variant F). The incorporation of straw and green manure helps to keep organic matter in the soil throughout a long period by winter wheat growing.

Acknowledgments

This work was promoted by Agency for Supporting of Science and Research in Slovak Republic on the agreement APVV-0645-06.

References

Gregorich, E. G. – Carter, M. R. – Angers, D. A. – Monreal, C. M. – Ellert, B. H. 1994. Towards a minimum data set to assess soil organic matter quality in agricultural soils. Can J. Soil Sci. 74, p. 367–367.

Kotorová, D. – Šoltýsová, B. 1992. The influence of crop rotation with higher share of cereals on the changes of soil physical and chemical properties in The East Slovak lowland. In: Plant Production, vol. 38, 1992, no. 8, p. 671–676.

López-Fando, C. – Almendros, G. 1995. Interactive effect of tillage and crop rotations on yield and chemical properties of soil in semi-arid central Spain. In: Soil and Till Res., vol. 36, 1995, no. 1-2, p. 45–57.

Rychlik, B. – Adamiak, J. – Wójciak, H. 2006. Dynamic the soil organic matter in crop rotation and long-term monoculture. In: Plant Soil and Environment, vol. 52, 2006, (Special Issue), p. 15–20.

Table 2: The selected soil properties by the growing winter wheat and spring barley in crop rotation and by continuous cropping

Variant	Crop rotations with different share of cereals, short sequences, continuous cropping	Fertilization
A	Winter wheat in crop rotation with an 40 % share of cereals	mineral fertilization
B	Winter wheat in crop rotation with an 80 % share of cereals	mineral fertilization
C	The continuous cropping of winter wheat is interrupted maize on silage every second year	mineral fertilization
D	The continuous cropping of winter wheat is interrupted oats every second year	mineral fertilization
E	The continuous cropping of winter wheat (without any others crops)	mineral fertilization
F	The continuous cropping of winter wheat	mineral fertilization + straw + green manure incorporation
G	The continuous cropping of spring barley (without any others crops)	mineral fertilization
H	The continuous cropping of spring barley	mineral fertilization + straw + green manure incorporation

Table 3: The selected soil properties by the growing winter wheat and spring barley in crop rotation and by continuous cropping

S of C (1)	year	DBD (2) t.m^{-3}	TP (3) (%)	MCC (4) (%)	SC (5)	content of humus (%)
A	1988	1.51	41.85	32.53	3.96	1.899
	2007	1.43	44.48	37.28	5.58	1.583
B	1988	1.51	41.28	32.38	4.35	1.948
	2007	1.39	47.81	33.16	4.30	1.628
C	1988	1.49	41.28	32.98	4.66	1.856
	2007	1.39	46.95	36.62	5.08	2.026
D	1988	1.50	43.25	31.98	4,74	1.656
	2007	1.41	46.56	36.12	4.11	1.794
E	1988	1.48	41.83	32.65	5.83	1.937
	2007	1.32	47.94	41.70	4.86	1.761
F	1988	1,47	41.75	32.50	5.91	2.005
	2007	1.37	48.22	39.64	5.75	2.002
G	1988	1.51	41.25	32.63	3.50	1.937
	2007	1.50	43.23	35.77	3.28	1.728
H	1988	1.50	41.60	32.55	4.12	2.005
	2007	1.49	44. 03	34.57	3.72	1.633

(1) S of C – sequence of crops; (2) DBD – dry bulk density; (3) TP – total porosity; (4) MCC – maximum capillary capacity; (5) SC – structure coefficient

Table 4: Multifactorial analysis of variance

Source variability	f	F_{vyp} (2)	P(3)	$LSD_{0,05}$ (4)	F_{vyp} (2)	P(3)	$LSD_{0,05}$ (4)
		dry bulk density			total porosity		
S of C (1)	7	180805	++	0.0004	112514	++	0.0152
year	1	25491	++	0.0001	369946	++	0.00473
		maximum capillary capacity			structure factor		
S of C (1)	7	104315	++	0,0206	367457	++	0.0061
year	1	1993511	++	0.0064	2910	++	0.0019

(1) S of C – sequence of crops; (2) F_{vyp} – calculated F-value; (3) P – effect of a factor significant at the level α = 0.05 or α = 0.01; (4) LSD $_{0,05}$ – least significant α = 0.05.

CORRELATIONS OF SOIL MANAGEMENT AND CARBON STOCK CHANGE IN SOILS

J. Zsembeli [1], Gy. Kovács[1], N. Szőllősi [2] & Cs. Gyuricza[3]
[1] Karcag Res. Inst. of Univ. of Debrecen, 5300 Karcag, Kisújszállási út 166. Hungary
[2] Univ. of Debrecen, Dep. of Water- and Environmental Management, 4032 Debrecen, Böszörményi út 138. Hungary
[3]Szent István University, 2103 Gödöllő, Páter Károly u. 1. Hungary

Abstract

The carbon stock of the soil is under change in Hungary especially during the last decade. The change of the view in soil cultivation is taking place in a larger and larger extent recently. Full tillage of croplands was the only applied cultivation system until the end of 1990ies and it is still dominant, though the area cultivated with reduced tillage methods is increasing year by year. Some calculations were made in order to have an idea about the extent of the effect of the soil protective tillage methods on the carbon stock change in the soil. Beyond the calculations a new experiment was designed and set in 2007 to determine the effects of the different soil tillage operations as the elements of the prospective reduced tillage systems. The results we gained in the first year of the experiment call the attention to the complexity of the correlation of the soil state determined by tillage and the carbon stock change.

Introduction

Carbon stock change in soils

The carbon stock of the soil is under change in Hungary especially during the last decade. The change of the view in soil cultivation is taking place in a larger and larger extent recently. As soil - besides the climate and weather - is one of the main factors of production, which basically determines the quality and economical conditions of production, the knowledge of the effects of plant production on soil is very important. Among the land use practices the soil cultivation has the most radical effects on soil properties. The need for environmental friendly and energy saving soil tillage systems is increasing as the consequences of improper soil cultivation practice that characterised the last decades are manifested in unfavourable soil properties (Birkás et al., 2007). In accordance with the combat against the damages (soil degradation) due to the improper soil use, the conventional soil cultivation methods are prospectively replaced by conservation tillage, including different versions of reduced till, mulch-till, crop residue management etc. (Forgács et al., 2005). These new soil tillage methods aim the decrease of the depth of the regularly cultivated soil layer and the formation of a topsoil rich in organic matter, hence affect soil C stocks in croplands considerably. All over the world several soil cultivation methods were studied in order to investigate their effects on the soil state and properties including the water balance and C-cycle. Though in Hungary there are no extensive measured data yet, some results have been already achieved concerning the effect of reduced tillage systems on the CO_2-emission from the soil providing several valuable information in the respect of soil utilisation (Gyuricza et al., 2005; Tóth and Koós, 2006; Zsembeli et al, 2005, 2006; Zsembeli and Kovács, 2007).

In Hungary full tillage of croplands was the only applied cultivation system until the end of 1990ies and it is still dominant, though the area cultivated with reduced tillage methods is increasing year by year. From 1998, in accordance with the combat against drought damages and soil degradation, conventional soil cultivation was prospectively replaced by conservation tillage methods, among them mainly which aims the decrease of the depth of the regularly cultivated soil layer and the formation of a topsoil rich in organic matter. Among the main soil protective management practices that affect soil C stocks in croplands (e. g. residue management, reduced tillage, fertilizer management applying mineral fertilizers and organic amendments, irrigation management) reduced tillage is the most characteristic in Hungary recently. The newly introduced soil protective cultivation methods are used mainly in the case of cereal production. According to our judgement, the area cultivated by applying one of these alternative methods was extended approximately to 1850,000 hectares in Hungary by the recent years. We made some calculations in order to have an idea about the extent of the effect of the soil protective tillage methods on the carbon stock change in the soil. The calculations are based on the methods described in the IPCC Good Practice Guidance for LULUCF (2003).

Material and Methods

Since extended country-specific stock change factors are not available in Hungary, the estimation method we used is based on default factors given in IPCC Good Practice Guidance for LULUCF (2003). The categorisation of croplands is partly based on expert knowledge due to the lack of sufficient statistics mainly about the management and input of the recent Hungarian land use practice. Nevertheless the input factors can be judged well on the base of the actual composition of annual crops, while the change in the management practice can be followed by knowing the number of the tools and machines that are used in reduced tillage.

In order to gain relevant activity data, the area of croplands was stratified by soil type, climate, management and input. For the identification of the spatial extension and distribution of each sub-categories the area data from the Central Statistical Office were harmonised with the data originating from the Land Cover Database of CORINE project, both from the reference year of 1990 and from the up-dated version of 2000. Though land use change data are not available for the period before 1990 and after 2000, the transitions were estimated by the interpolation of the available data.

Soil type

The soil types were determined on the base of AGROTOPO data base and were harmonised with the land use types of CLC to determine the rate of land use types on different soil types. The Hungarian national soil classification system classifies soils by genetic types, and these types were corresponded to the WRB systems, which is used by the IPCC Good Practice Guidance for LULUCF (2003). In Hungary high activity clay mineral (HAC) soils are dominant and the most frequently used for reduced tillage, therefore only HAC soils are taken into account in this paper. Among the soils utilised as croplands chernozems, brown forest soils represent this group. Salt affected soils, which are also characteristic to Hungary, also belong to this group, but they are also used as grasslands, mainly depending on the extent of salinization.

Climate

The climatic classing, the determination of the spatial distribution of climate zones was made by the Hungarian Meteorological Service. Two categories were determined: namely Cold Temperate Dry (CTED), where the mean annual temperature (MAT) is just below 10°C and the annual precipitation is less than the evapotranspiration, and Warm Temperate Dry (WTED), where the mean annual temperature (MAT) is above 10°C and the annual precipitation is less than the evapotranspiration.

Management

In Hungary full tillage of croplands was the only applied cultivation system until the end of 1990ies and it is still dominant, though the area cultivated with reduced tillage methods is increasing year by year. From 1998, in accordance with the combat against drought damages and soil degradation, conventional soil cultivation was prospectively replaced by conservation tillage methods, among them mainly which aims the decrease of the depth of the regularly cultivated soil layer and the formation of a topsoil rich in organic matter. As the management of croplands considerably modifies soil C stocks, we estimated the area of the non-conventionally cultivated croplands. Among the main soil protective management practices that affect soil C stocks in croplands reduced tillage is the most characteristic in Hungary recently. To account for changes in soil C stocks of croplands we estimated the areas of the two main cultivation types at the beginning and end of the inventory time period. There are no sufficient data available to estimate the correct actual area of reduced tillage, hence the calculation is based on expert judgement. The newly introduced soil protective cultivation methods are used mainly in the case of cereal production. According to our judgement, the area cultivated by applying one of these alternative methods was extended approximately to 1850,000 hectares in Hungary during the last ten years.

Input

To choose the input factors that representing the agricultural practice in Hungary, the characteristics of crop rotations were taken into consideration. According to the IPCC Good Practice Guidance for LULUCF (2003), the input factors represent the effect of changing carbon input to the soil, as a function of crop residue yield, bare-fallow frequency, cropping intensity, or applying amendments. Therefore the four soil types representing the Hungarian croplands were divided further into three input categories.

On the base of the methodology of classification described above, the areas of the different sub-categories representing the Hungarian croplands by soil type, climate, management and input were determined. Figure 1. shows the change of the total area of cropland on high activity clay soils in Hungary by the main soil tillage systems.

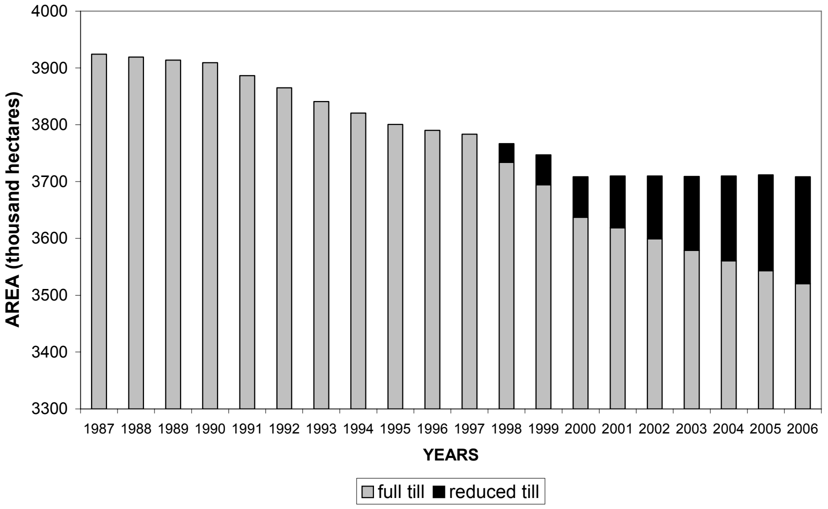


Figure 1: Total area of cropland on high activity clay soils in Hungary by the main soil tillage systems (1987-2006)

Results and Discussion

Calculation of carbon stock change in soils

According to the estimation method described in the IPCC Good Practice Guidance for LULUCF (2003), first the soil organic C stocks (SOC) were estimated for the beginning and end of the inventory time period using the relevant default reference carbon stocks (SOC_{ref}) and the default stock change factors (F_{LU}, F_{MG}, F_I). The change in soil organic C stocks in mineral soils was calculated by subtracting the C stock in the last year of an inventory time period (SOC_0) from the C stock at the beginning of the inventory time period ($SOC_{(0\ -T)}$) and dividing by 20, the time dependence of the stock change factors (D). Figure 2. shows the dynamics of the soil carbon stock of cropland areas on high activity clay soils in Hungary for the duration of 20 years.

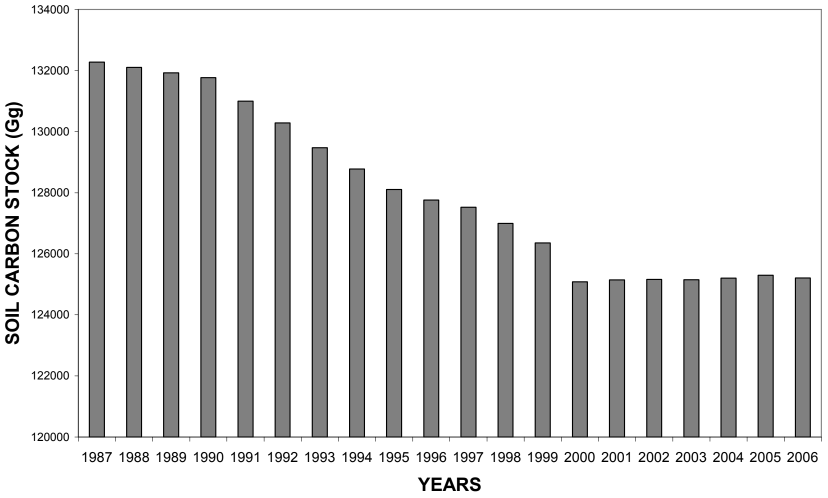


Figure 2. The change of the soil carbon stock of cropland areas on high activity clay soils in Hungary (1987-2006)

Though a significant decrease of the area of croplands was characteristic for the last four decades - roughly 800,000 hectares were transferred to another category of land use – still cropland represents the main land use category in Hungary with its approximately 50% proportion from the total territory of the country. All the ploughlands with annual crops and the orchards and vineyards with perennial woody crops are classified here. As the figures show, the decrease of the soil carbon stock is not only because of the decrease of the area of croplands, but also because of the change in the management practice.

Reduced tillage is considered to cause higher CO_2 loss from the soil by emission in general, but there are some studies that report about higher values measured in conventionally cultivated soils during a certain period after tillage operation. The impact of tillage systems on soil CO_2-emission is a complex issue as different soil types are managed in various ways. In order to gain more information in this respect, broad examination of new soil tillage methods was started in 1997 based on the research achievements gained in the past decades (FORGÁCS et al., 2005) in the Department for Soil Utilisation and Rural Development of Karcag Research Institute of the University of Debrecen, Centre of Agricultural Sciences and Engineering in close co-operation with the Department of Soil Tillage of Szent István University, Gödöllő Researches. The examinations involve in situ measurement of CO_2-emission of the soil since 2003. The main goal of this research is to reveal the processes that result in the emission of CO_2 from the soil into the atmosphere.

In order to determine the effects of the different soil tillage operations as the elements of the prospective reduced tillage systems, we designed and set a new, hopefully long-term, experiment in 2007. The experiment was set on a plot of 9.4 ha divided into four sub-plots according to the treatments. In this experiment tillage systems of direct seeding and reduced tillage based on mulching were compared to the conventional cultivation system based on ploughing. The soil type of the investigated plot is meadow chernozem solonetzic in the deeper layers, a soil type that is characteristic for the Trans-Tisza Region of Hungary. In the case of conventional tillage all the crop residues were baled and removed from the subplot, then millet was sown conventionally. In the reduced tillage treatments direct seeding was used but three different methods were applied regarding the fate of the crop residues: all residues remained (mulch), remaining mulch and application of a mulch tiller and pure direct seeding with no mulching.

The CO_2-emission values calculated for the soil tillage experiment are summarised in Fig. 3. The highest values were detected in the case of the conventionally cultivated, in other words ploughed plot, and this highest value was characteristic all along the investigated period. This was an unexpected result as reduced tillage is considered to be resulted in higher emission. Of course the shortness of the investigated period and the high amount of precipitation can not let us to conclude general conclusions, but there is no doubt that we gained remarkable results about the correlation between the soil status and the CO_2-emission from the soil. These results motivate us to continue our investigations.

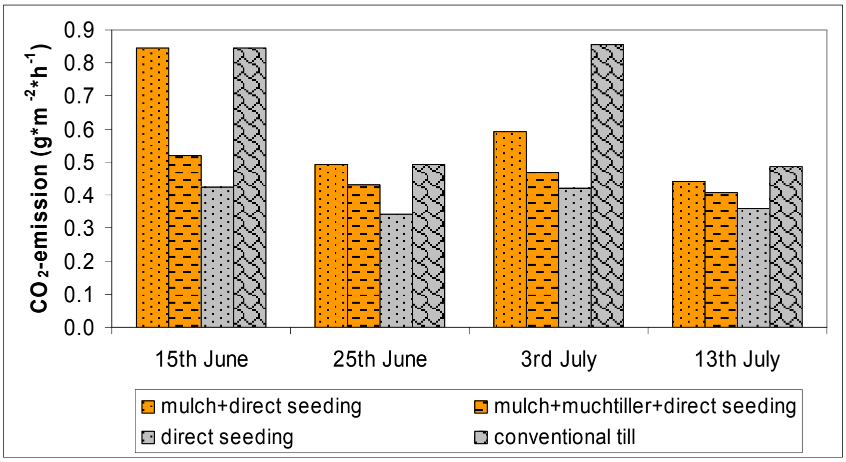


Figure 3: CO_2-emissions in the soil tillage experiment

References

Birkás M., Kalmár, T., Fenyvesi, L. and Földesi, P. (2007): Realities and beliefs in sustainable soil tillage. Cereal Research Comm. 35. 2. 257-260.

Forgács, L., Zsembeli, J., and Tuba G. (2005): Examination of a soil protective cultivation method in the Research Institute of Karcag. Realizáciou poznatkov vedy a vyskumu k trvalo udrzatel’nému pol’nohospodárstvu. Michalovce, Slovakia. 64-68.

Gyuricza, Cs., Földesi, P., Mikó, P., Ujj, A. (2005). Carbon Dioxide Emission from Arable Lands. Cereal Res. Com., 33. 1. 89-92.

IPCC (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry, UNEP (Ed. By Jim Penman, Michael Gytarsky, Taka Hiraishi, Thelma Krug, Dina Kruger, Riitta Pipatti, Leandro Buendia, Kyoko Miwa, Todd Ngara, Kiyoto Tanabe and Fabian Wagner)

Tóth, E. and Koós, S.: 2006. Carbon dioxide emission measurements in a tillage experiment on chernozem soil. Cereal Research Communications. Vol. 34. No. 1. 331-334.

Zsembeli, J. and Kovács Gy. (2007): Dynamics of CO_2-emission of the Soil in Conventional and Reduced Tillage Systems. Cereal Research Communications. Vol. 35. No. 2. 1337-1340.

Zsembeli, J., Tuba G. and Kovács Gy. (2006): Development and extension of CO_2-emission measurements for different soil surfaces. Cereal Research Communications. Vol. 34. No. 1. 359-362.

Zsembeli, J., Tuba, G. and Forgács, L. (2005): CO_2-emission of soil in an energy saving soil cultivation system. Realizáciou poznatkov vedy a vyskumu k trvalo udrzatel’nému pol’nohospodárstvu. Michalovce, Slovakia. 59-63.

Scientific session I.C Energy production and soil compaction

SUSTAINABILITY, OVERALL AND PROCESS EFFICIENCY OF ENERGY CROPS

W. Schäfer[1)]
[1)]MTT Agrifood Research Finland, Vakolantie 55, 03400 Vihti, Finland, E-mail winfried.schafer@mtt.fi

Abstract

A method to calculate efficiency of energy crop production including sun energy, direct and indirect energy for cultivation, processing, and conversion into fuel is demonstrated using rape and derived fuels as an example. Every production and conversion step is a process and calculated separately. The overall efficiency includes energy input and output of all processes. The process efficiency of rape cultivation reaches in Finland up to 1100 %. However, the overall energy efficiency of rape methyl ester (RME) is 1 to 2 ‰ only. The production of biogas from manure of dairy fed by rape meal results in a process energy efficiency of 33 to 41 %, but the overall energy efficiency of RME and biogas together is only 1.2 to 2.5 ‰. In contrast, thermal or photovoltaic solar collectors improve overall efficiency 1 to 3 orders of magnitude compared to fuel production from rape. Competition for cultivation area and the low photosynthetic efficiency limit the feasibility of fuel production from energy crops. As a measure for sustainability of renewable fuel production, the energy surplus of energy conversion from insolation to fuel per resident and square meter is proposed.

Introduction

Agricultural machinery and buildings cause up to 40% of production cost. The high costs of technical input forces to specialisation of farm production by splitting animal and crop production located at different areas or even continents, narrow crop rotations, and dependency from fossil fuels and counteracts to sustainable farming principles and green house gas mitigation. In short, the entropy of modern farming systems increases. However, a physical and technological approach and engineering proficiency may contribute to the aims of sustainable farming also in respect of energy crop issues.

The crop scientist focuses his research on high quantity and quality of yield based on a sustainable tilth. The engineer is interested in maximisation of the process efficiency. He interprets the crop scientist's approach as maximisation of photosynthesis' efficiency. Odum (1996) developed an excellent logical framework for energy accounting based on sun energy input. Although the methodology is further developed and applied worldwide (e.g. Bastianoni et al. 2007, Jiang et al. 2007, Rótolo et al. 2007, Ukidwe & Bakshi 2007), the methodology seems to be quite unknown to European decision makers in the field of environmental and agricultural sciences. One reason may be that applied thermodynamics in environmental accounting requires more scientific skills than life cycle analysis (ISO 14040) which is easily to accomplish by simple spreadsheet calculations. Objective of this paper is to support the assessment of energy crop production in terms of sustainability and energy efficiency applying basic engineering sciences methods in energy accounting. Figure 1 shows the theoretical approach.

Material and methods

The engineer quantifies the sustainability of energy crop production by means of the overall efficiency η_O that is the energy output divided by the energy input of all processes involved:

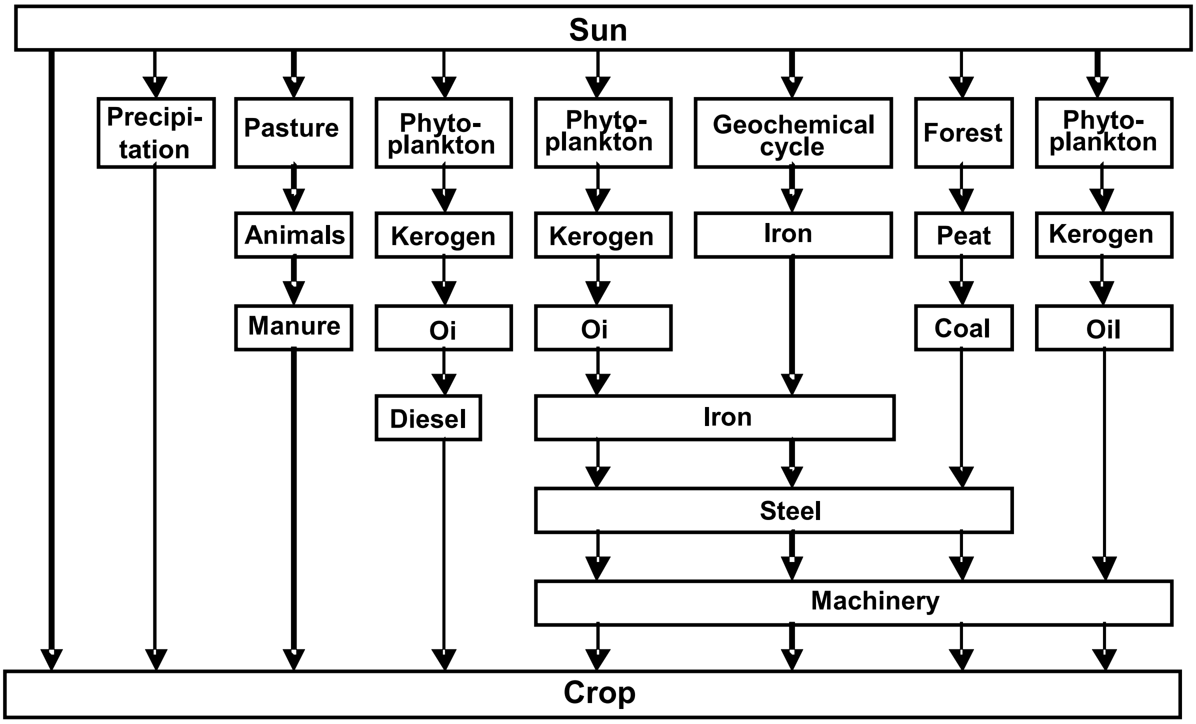


Figure 1: Simplified model of energy crop production. The model shows all the exergy flows directly or indirectly needed for the process and the partial efficiencies of the backward steps to the original solar exergy source. (Bastianoni et al. 2007, modified).

$$\eta_O = \left(\sum_{i=1}^{n}(A_i \cdot S_i \cdot \eta_i)\right) \cdot \left(\sum_{i=1}^{n}[A_i \cdot (S_i + P_i + K_i)]\right)^{-1}$$

A denotes the area, S the solar energy, P the energy input of crop cultivation, K the energy input of fuel conversion, η_i the technical efficiency of photosynthesis and i the member of crop rotation. The crop scientist concerns for η_i and to some extent for P while K and P is of engineers and partially animal production scientist's interest. Please note that the global solar-radiation intensity is limited like the cultivation area too. The equation is applicable for farm level, national level, and worldwide. However, it does not take into consideration the energy saving potential of crop fibre for heat insulation.

The calculation of the process energy efficiency includes the process energy input and the free energy (exergy) before and after processing. The engineer considers photosynthesis, cultivation, and conversion each as process. E.g., the process efficiency of buring biomass for heat production depends only on incinerator efficiency and on energy input for transport of biomass and ash. Additional treatment like pelleting, extraction of oil, anaerobic digestion, ethanol fermentation etc. raises the energy input considerably. The production of ethanol from corn renders always a negative exergy balance due to the thermodynamic laws (Patzek 2004).

Crop processing generates usually different products. Some are suitable for energy production others for fibre production, human nutrition or animal feed. This fact causes a methodological problem, called allocation. The process energy for rape crop production may be allocated to seed, straw, and roots. The process energy input for extraction, refining, and esterification of rapeseed oil has to be split between rape methyl ester (RME), meal, and glycerine, the by-product of esterification of rape oil. Depending on the allocation method, the process energy balance may diverge in a wide range.

Results and discussion

Table 1 shows a chain of processes of rape production and processing, their efficiencies and the resulting cumulated overall efficiency derived from different sources (Elsayed et al. 2003, Bugge 2000, Schäfer 1996).

Table 1: Energy input, energy output, process efficiency and overall efficiency of rape production and rape processing in Finland.

Process	***Input*** **kWh m^{-2} a^{-1}**		***Output*** **kWh m^{-2} a^{-1}**		***Process-efficiency %***	***Overall efficiency %***
crop cultivation	direct and indirect energy[a]	0.3 - 0.8	root straw seed[b]	3.3 - 6.3	*262 - 366* *262 - 366* *262 - 366*	*787 - 1100*
photo-synthesis	sun light	1000	root straw seed[b]	1.1 - 2.1 1.1 - 2.1 1.1 - 2.1	0.11 - 0.21 0.11 - 0.21 0.11 - 0.21	0.33 - 0.63
incineration	straw seed	2.2 - 4.2	*calorific heat*	1.76 - 3.78	80 - 90	0.18 - 0.38
oil and meal production	seed energy	1.1 - 2.1 0.1	oil. meal total	0.64 - 1.21 0.46 - 0.89 1.1 - 2.1	52.9 - 55.1[c] 38.7 - 40.3[d] 91.7 - 95.5[e]	0.06 - 0.12[c] 0.05 - 0.09[d] 0.11 - 0.21[e]
bio-refinery	seed energy[f]	1.1 - 2.1 0.1 - 0.2	RME meal	0.64 - 1.21 0.46 - 0.89	84.6 - 95.5[e]	0.11 - 0.21[e]
milk production	meal direct and indirect energy	0.46 - 0.89 0.2[g]	milk[h] manure heat, CH_4 total	0.09 - 0.18 0.16 - 0.31 0.21 - 0.40	14.1 - 16.5 17.1 - 19.1 22.6 - 25.2 53.9 - 60.7	0.01 - 0.02 0.02 - 0.03 0.02 - 0.04 0.05 - 0.09
anaerobic digestion	manure heat and power	0.16 - 0.31 0.03 - 0.15	biogas[i] effluent[i]	0.08 - 0.15 0.08 - 0.15	33.3 - 41.7 33.3 - 41.7	0.01 - 0.02 0.01 - 0.02
power production	biogas	0.08 - 0.15	power heat	0.03 - 0.05 0.05 - 0.10	33.3 66.7	<0.01 <0.01
thermal collector	sun energy manufacture	1000 2.3[j]	heat	600 - 800	60 - 80	59.9 - 79.8
photovoltaic collector	sun energy manufacture	1000 6 - 11[k]	power	100 - 150	10 - 15	9.9 - 14.9

[a] Direct and indirect energy input of Finnish agriculture is 0.83 kWh m^{-2} a^{-1}, of which 0.34 kWh m^{-2} a^{-1} fossil fuels, of which 0.07 to 0.14 kWh m^{-2} a^{-1} diesel/RME (LAMPINEN et al. 2006, NYHOLM et al. 2005, ELSAYED et al. 2003, BUGGE 2000, SCHÄFER et al. 1986). [b] Seed yield 160 to 310 g m^{-2}; allocation of energy output: 1/3 seed, straw, and root respectively. [c] In respect of oil. [d] In respect of meal. [e] In respect of oil/RME and meal. [f] Oil extraction 416 Wh kg^{-1} seed; esterification 476 Wh kg^{-1} seed (CAMPA®- BIODIESEL GMBH & CO. KG 2006, http://www.campa-biodiesel.de/cadeunof/cadnumw3.htm). [g] Estimated. [h] Allocation: milk 20.2%; manure 34.4%; heat 40.4%; methane 5% (HORN et al. 1994). [i] Allocation: 50% each. [j] Mass 15 kg m^{-2}; estimated energy input for production 3.9 kWh kg^{-1}; depreciation 25 years. [k] KNAPP et al. 2000.

The results show that the high process energy efficiency of the rapeseed cultivation fosters common acceptance of rape as energy crop. Even under Finnish climate conditions, exergy of rape crop exceeds up to 11-times the energy input for production and exergy of seed up to 3.7 times. Conversion of rapeseed into fuel decreases the energy surplus. Rape methyl ester (RME) delivers still 1.2-fold the energy input for cultivation and conversion. The whole rape crop (root, straw, seed) contains 3 to 6 ‰ of the overall energy input, RME 1 to 2 ‰ only. Animal production converts rape meal feed into manure, which is suitable for anaerobic digestion together with glycerine. The biogas augments the overall efficiency additionally 0.2 to 0.5 ‰. Rape cultivation requires a 4 to 7-year crop rotation. This and the low overall efficiency make it difficult in Finland to achieve energy self-sufficiency on-farm replacing diesel fuel by RME.

The technical efficiency of the photosynthesis limits the maximum energy yield and reaches up to 5 % of the insolation input in the tropics and up to 0.8 % in Finland (Lampinen & Jokinen 2006). Mainstream production renders better photosynthesis efficiencies in terms of increased biomass yield on expense of lower cultivation efficiencies because of high energy input triggered by mineral fertilisers and chemicals. Due to photosynthesis' low efficiency, even a double biomass yield improves the overall efficiency only marginally. Vice versa, 20 to 56 % lower energy input in organic crop production (Mäder et al. 2002) increases only marginally the overall efficiency.

By comparison, the efficiency of a photovoltaic collector is 165 to 248-fold better than the conversion efficiency of biomass or biogas produced from rapeseed and rape straw into electric power. The efficiency of the thermal collector exceeds heat production from burning the rape crop 157 to 443-fold. However, storage and continuous production of power and heat from sun energy is very limited. For that reason, the storage of sun energy in liquid carbon hydrates is subject of present research. Future biotechnology produces hydrogen and liquid carbon hydrates by CO_2 and H_2O (Centi et al. 2006, Gattrell et al. 2007) or thermo-chemical processes (Abu-Hamed et al. 2007, Jeong et al. 2007) powered by sun energy.

A measure for sustainability of renewable energy is the ratio between energy yield from sun energy conversion and energy consumption per capita and square meter of a nation's surface area. If we succeed, to convert insolation with an overall efficiency of e.g. 0.1% (bio-mass, solar technique etc.) into all types of energy needed, the surface area is not sufficient to cover the present energy consumption. Countries of high population density prove the most severe energy deficit, table 2.

Table 2: Sustainability of energy consumption assuming 0.1% overall conversion efficiency of insolation. ([a]Energy and Environment Data Reference Bank (EEDRB), 2003. http://iaea.org/inisnkm/nkm/aws/eedrb/data/FI-encc.html#c1, [b]Šúri M. et al. 2007, PVGIS © European Communities, 2001-2008)

Country	BG	CZ	H	PL	SK	SLO	FIN	L
Surface area[a] 1000 km^2	110.9	78.9	93.0	312.7	48.9	20.3	304.5	2.6
Population[a] 10^6 capita	7.8	10.2	10.1	38.2	5.4	2.0	5.2	0.5
Total energy consumption[a] MWh $capita^{-1}$ $year^{-1}$	33.0	28.3	31.9	27.7	43.5	45.5	68.6	116.2
Insolation[b] MWh m^{-2} a^{-1}	1.3	1.0	1.2	1.0	1.1	1.2	0.8	1.0
Sun energy yield MWh $capita^{-1}$ $year^{-1}$	18.7	8.0	11.2	8.3	10.1	12.0	49.1	5.9
Sustainability %	67.7	28.2	35.1	29.9	26.7	27.6	71.6	5.1

Conclusion

Energy crop production is captivating with many win-win situations: environmentally neutral bio-fuels replace polluting fossil fuels, farmers get better prices for energy crops, the agrochemical industry gains from intensification of energy crop production, and turn over of power industry grows due to increasing energy consumption to produce agrochemicals and to process biomass into fuel. As a following, the state tax income improves too. However, better prices for mainstream energy crops may trigger export of environmental pollution at the expense of food production because higher overall efficiency in tropical countries favours the import of organic raw material for bio fuel production.

Yet, high process efficiencies of technical processes to convert biomass into fuel justify the production of renewable energy from organic waste and residues. Thus, agriculture policy should not focus on energy crop production but on production of high quality food environment-friendly. The overall efficiency of energy production from energy crops will never be competitive with solar techniques.

Solar collectors replace fossil fuels for heat production outside agriculture already now sustainably and more efficient. Research on solar-technical processes to produce liquid carbon hydrates from methane, carbon dioxide, and water powered by solar energy without diversion into photosynthesis offers much a greater potential than research on energy crop production.

Consequently, humankind has two ways only to warrant sustainable energy supply for the future: The first challenge is to increase the overall efficiency of techniques to convert sun energy into fuel and electric power by means of improved process efficiencies. Probably cheaper and more rapidly to achieve, is the second way: energy saving.

One kernel of grain or oil seed has the potential to generate up to 50 kernels and more cultivated on fertile land. No hedge fond guarantees a similar interest rate. That means the entropy of seed is very low, compared to the thermal energy content. Thus, why humankind should burn its food?

References

Abu-Hamed T., Karni J., Epstein M. 2007. The use of boron for thermochemical storage and distribution of solar energy. Solar Energy 81: 93–101.

Bastianoni S., Facchini A., Susani L., Tiezzi, E. 2007. Emergy as a function of exergy. Energy 32: 1158–1162.

Centi G., Perathoner S. 2006. Converting CO_2 to fuel: A dream or a challenge? The 232nd ACS National Meeting, San Francisco, CA, September 10-14, 2006, http://oasys2.confex.com/acs/232nm/techprogram/P990579.htm
(12.01.2007).

Ekbladh, G.; Grönlund, E.; Ingemarson, F.; Karlsson, L.; Nilsson, S. and Strid Eriksson, I. Doherty, S. and Rydberg, T., Eds. 2002. Ecosystem properties and principles of living systems as foundation for sustainable agriculture – Critical reviews of environmental assessment tools, key findings and questions from a course process. Ecological Agriculture – 32, Centre for Sustainable Agriculture, Swedish University of Agricultural Sciences, Uppsala, 84 p.

Elsayed M., Matthews R., Mortimer N. 2003. Carbon and energy balances for a range of biofuels options. Project report number B/B6/00784/REP, Department of Trade and Industry Sustainable Energy Programme URN, 03/836, Resources Research Unit, Sheffield Hallam University, United Kingdom. Final Report for the Energy Technology Support Unit. Report No. 21/3, 27 p.
http://oasys2.confex.com/acs/232nm/techprogram/P990579.htm (12.01.2007).

Bugge J. 2000. Note: Rapeseed oil for transport 1: energy balance and CO_2 balance. The Danish Energy Agency's Model for Economic And Environmental Assessment Of Biofuels, DK-7760 Hurup Thy, http://oasys2.confex.com/acs/232nm/techprogram/P990579.htm (12.1.2007).

Gattrell M., Gupta N., Co A. 2007. Electrochemical reduction of CO2 to hydrocarbons to store renewable electrical energy and upgrade biogas. Energy Conversion and Management 48:1255–1265.

van Horn H., Wilkie A., Powers W., Nordstedt R. 1994. Components of dairy manure management systems. J. Dairy Sci. 77: 2008-2030.

Tae-Young Jeong, Gi-Cheol Cha, Ik-Keun Yoo and Dong-Jin Kim 2007. Hydrogen production from waste activated sludge by using separation membrane acid fermentation reactor and photosynthetic reactor. International Journal of Hydrogen Energy, 32: 525-530.

Jiang M.M., Chen B., Zhou, J.B. Tao F.R., Li Z., Yang Z.F., Chen G.Q. 2007. Emergy account for biomass resource exploitation by agriculture in China. Energy Policy 35: 4704–4719.

Kauppa- ja teollisuusministeriö, 2007. Energiakatsaus 2/2007, 39s.

Knapp E., Jester T. 2000. An empirical perspective on the energy payback time for photovoltaic modules. American Solar Energy Society Solar 2000 Conference, Madison, Wisconsin June 16-21, 2000, http://oasys2.confex.com/acs/232nm/techprogram/P990579.htm (12.01.2007).

Lampinen A. Jokinen E. 2006. Suomen maatilojen energiatuotantopotentiaalit. University of Jyväskylä, bio- ja ympäristötieteiden laitos. Research reports in biological and environmental sciences 84: 1-160.

Mäder P., Fließach A., Dubois D., Gunst L. Fried P., Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science 296: 1694-1697.

Odum, H.T. 1996. Environmental Accounting, Emergy and Decision Making. John Wiley, NY, 370 pp.

Patzek T. 2004. Thermodynamics of the corn-ethanol biofuel cycle. Critical Reviews in Plant Sciences 23: 519-567.

Pimentel, D., Rodrigues , Wang T., Abrams R., Goldberg K., Staecker H., Ma E., Brueckner L., Trovato L., Chow C., Govindarajulu U., Boerke S. 1994. Renewable Energy: Economic and Environmental Issues. BioScience, 44: 536-547.

Ukidwe N.U., Bakshi B.R. 2007. Industrial and ecological cumulative exergy consumption of the United States via the 1997 input–output benchmark model. Energy 32: 1560–1592.

Schäfer W., Luomi, V. Palva, T. Parmala, S. Ahokas, J. 1986. Kasviöljyt dieselmoottorin polttoaineena. VAKOLAn tutkimusselostus 42:1-37.

SFS-EN ISO 14040 Ympäristöasioiden hallinta. Elinkaariarviointi. Periaatteet ja pääpiirteet Environmental management. Life cycle assessment. Principles and framework (ISO 14040:2006) 49 s.

DUTCH (ORGANIC) AGRICULTURE, CARBON SEQUESTRATION AND ENERGY PRODUCTION

G.J. van der Burgt[1], **S. Staps**[1] **& B. Timmermans**[1]
[1]Louis Bolk Instituut, Hoofdstraat 24, NL-3972 LA Driebergen, the Netherlands,
E-mail: g.vanderburgt@louisbolk.nl

Abstract

Carbon sequestration in soils is often mentioned in the discussions about climate changes. In this paper the opportunities for carbon sequestration in Dutch agriculture are discussed at farm and national level. Farm internal carbon sources are already completely used in livestock farming. The effect under arable conditions is limited in time and very limited compared to national CO2 emission. External sources are scarce. Energy production out of crop residues and manure via biogas installations is possible but the overall impact is again very limited. The effect of this biogas pathway on soil organic matter quantity and quality is not yet known. Organic arable farmers do already have a higher soil organic matter content than conventional farmers, partly due to external carbon sources. This puts them in a leading position. The disadvantage is that it is more difficult for them to do a next step in increasing soil organic matter.

Introduction

In discussions about climate change, carbon sequestration in agricultural soils (Hepperly et al 2007) and energy production out of energy crops or crop residues (Möller et al 2008), are frequently mentioned as contributions from agriculture to minimize these changes. Within these discussions organic agriculture is sometimes mentioned showing a positive or less negative impact than conventional agriculture. The results of a comparison between organic and conventional agriculture and the results of an absolute net greenhouse gas balance of any agricultural system will strongly depend on the national, regional or even local conditions. For this reason, it is difficult to claim an overall effect.

In the following text we describe the situation in the Netherlands with three questions as guiding principles:

- To what extent could agricultural soil play a role in soil carbon sequestration in the Netherlands?
- Could agriculture become an energy producer without increasing the risk of insufficient organic matter input for maintaining soil fertility?
- Is organic farming as a system favorable above conventional farming with respect to carbon sequestration and energy production?

Method

A recent publication about soil organic matter (SOM) in four regions in the Netherlands (Hanegraaf et al 2007) states that SOM in both arable and grass areas is not declining. Data from the Central Agency for Statistics (Centraal Bureau voor de Statistiek 2007) were used for national arable and grassland areas. For estimating the decay of organic matter (OM) we used the national standard table for 'effective organic matter' (EOM) (Koopmans & van der Burgt, 2001). EOM is defined as the part of total OM which is, one year after application, not yet decomposed, thus contributing to SOM in the long term. The OM decay algorithm of Janssen (1984) in the NDICEA model (van der Burgt et al, 2006) is used to estimate OM decomposition. We assumed that an increase of 0.2% (in case of arable land, from

1.8 to 2.0% SOM) would increase overall soil fertility and could in ‘normal’ agricultural practice be realized in 10 years without causing negative side-effects (P surpluses, N leaching). For estimations of the availability of OM (manures and composts) for carbon sequestration purpose, data from CBS (Centraal Bureau voor de Statistiek 2007) and the Association of compost producers (Vereniging Afvalbedrijven 2007) were used.

For calculations of the soil carbon we assumed that 58% of SOM is carbon, that the topsoil in arable farms is 25 cm and that the soil density is 1.35 gram cm^{-3}. For organic matters applied to the soil we assumed an average C-content of 45%.

Results and discussion

Arable land

The actual average SOM content of arable land in four regions in the Netherlands with sandy soils is 1.8% (Hanegraaf et al, 2007) and is supposed to be stable during the last two decades. That means that in this area the actual average farm management is able to maintain 1,8% of soil organic matter, being 60,750 kg organic matter or 35,235 kg carbon per hectare. To increase this by 0.2%, 392 kg carbon should additionally be sequestered each year during ten years. To reach this, 392 * (1/0,45) = 870 kg EOM per hectare is needed. Additionally, extra carbon is needed to maintain the increased SOM level. After ten years this ‘extra’ has increased to 15% of the additional gift (NDICEA model calculation), so135 kg EOM.

A dosage of 870 kg EOM (1st year) up to 1005 kg (10th year) is reasonable at first sight. This can be realized, for example, by applying 8.3 (up to 9.6 in the 10th year) tons of compost with 22% OM and half of the OM being dissimilated in the first year (11 % EOM). Purchased compost at farm level is an external source of carbon; internal sources can be used too. Changes in the crop rotations can contribute to a minor degree, but cumulative it can be substantial. For example, a successful green manure crop *added* in the rotation (one in four years) might add 900 * (1/4) = 225 kg EOM per hectare and year.

Straw incorporated in the soil (once in four years) *instead of selling* brings the same amount. A cereal crop (with the straw put into the soil) *instead of a vegetable crop* (once in four years) will add 300 to 400 kg EOM. *Replacing* an artificial fertilizer application by 20 tons of cow slurry brings 600 kg EOM, so 150 kg if done once in four years, being an external carbon source for arable farms.

So far, considering the theme at field or farm level, this increase of 0.2% in ten years could indeed be accomplished with internal and/or external carbon sources. At national level the total area of arable land is about 1,000,000 hectares (Centraal Bureau voor de Statistiek 2007). At this level the situation is completely different. Compost, being an external source at farm level, is an internal source at national level. If the increase is to be realized with compost only, the need is 8.3 million tons per year. Total Dutch compost production at the time is 1,5 million tons per year (Vereniging Afvalbedrijven 2007) and this is already used in or outside agriculture for soil improvement. Other organic matter sources are not easily available.

If realized completely with internal carbon sources, which is possible but not very realistic, 3,920 kg carbon per hectare is sequestered after ten years. For 1,000,000 hectares this is 3.9 million ton carbon or 14.4 million ton CO_2, thus 1.4 million ton per year. Total CO_2-emission in the Netherlands in 2006 was 210 million tons (Milieu & Natuur Compendium 2008).The yearly sequestration would be 0.7% of total emissions, during ten years only.

Grassland

In grassland, due to a year-round production potential and a high organic matter turn-over into the soil, an average of 4.3% OM was measured (Hanegraaf et al 2007), so considerably higher than arable land. On the average, out of an agronomic point of view there is no reason to increase soil organic matter content in grassland production systems. If nevertheless desired, this can only be done by farm-external sources of carbon since most internal sources - the grass crop itself and the manure from the herd – are used already. As mentioned before, there are no substantial external sources of carbon – organic materials – available.

Energy production out of crop residues and manure

Crop residues and manure can be applied to the soil, contributing to maintain or increase SOM. It can also first be used for energy production in biogas installations and then applied to the soil, meanwhile increasing the nitrogen use efficiency of the system (Möller et al 2008, van der Burgt 2008). As far as known, the easily decomposable carbon components will be decomposed in the biogas installation as well as in the soil when directly applied. There might be minor quantitative differences in EOM between both pathways, but this is not known yet. There might also be qualitative differences in effects on soil life. This also is not known so far, nor are known the consequences for soil fertility in the long term.

We assume that in arable farming at the average 2,000 kg organic matter is available in above-ground crop residue (straw production kept out of consideration) with 45% carbon. This is 720 million kg carbon. Annual manure production in the Netherlands is 70 million tons with an assumed average C-content of 40 kg per ton, containing 2,800 million kg C. If we assume that 1 kg carbon in organic matter can produce 0.1 m^3 gas, the (unrealistic) maximum use of all crop residues and all manures would produce 280 million m^3 gas. Annual gas consumption in the Netherlands is 21,000 million m^3. This means that a (unrealistic) maximum of 1.3% equivalence of the national gas consumption could be produced by biogas installations.

Organic agriculture

Organic grassland is supposed to have the same SOM content as conventional grassland. Organic arable land has on average a higher SOM content than conventionally cultivated arable land. This higher level can not be explained by a lower decomposition rate. It can partly be explained by a higher internal input (green manures, clover grass in the rotation, cereals in the rotation, but lower yields and therefore maybe lower crop residues act contradictory) and partly by a higher external input: manures from conventional farms and purchased composts. So organic agriculture, due to its emphasis on soil fertility and SOM, is already to a certain degree using the soil for carbon sequestration. As far as this is done with internal carbon this is indeed an organic system property. As far as it is realized by input of external sources it is not a system property. For organic farmers, because of their higher starting point, it will be more difficult to increase the SOM content with internal carbon sources than for their conventional neighbors. The potential energy production out of organic crop residues compared to conventional systems is uncertain: it might be higher due to more green manures and clover grass or alfalfa in the rotation, and it might be lower due to lower crop residue yields in general.

Conclusion

In the Netherlands, at farm level, an increase in SOM content with internal or external carbon sources is possible for arable farms. The effect is limited in time (once a higher level is reached, the increase is topped off and is unnecessary out of agronomic point of view) and quantitatively very limited compared to total national CO_2 emission. For grasslands an increase of organic matter is out if the question: there is no agronomic need and all farm internal carbon sources are used already. Additional external carbon sources are scarce.

Organic farming, especially arable farmers, have a ‘plus’ that they have already put additional carbon into their soils, but this is only partly a system property and another step in increasing SOM will be difficult. Nevertheless carbon sequestration might be mentioned as a positive factor for individual farmers or organic farming as a whole. Energy production might have the same role: a very limited effect, but an interesting object for positive positioning of organic agriculture.

References

Burgt, G.J.H.M. van der, Oomen G.J.M., Habets A.S.J. & Rossing W.A.H. (2006). The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutrient Cycling in Agroecosystems 74: 275-294.

Burgt G,J,H.M. van der (2008). Nitrogen’s degrees of freedom. In: Proceedings QLIF Workshop ‘Soil nitrogen: research and extension’, Louis Bolk Instituut, Driebergen, The Netherlands, p 7-8.

Centraal Bureau voor de Statistiek (2007). http://statline.cbw.nl

Hanegraaf M.C., Geerts A., Haas M de & Weijden A.G. van der (2007). Trends in organische stof in zandgronden. NMI-rapport O 1026. NMI, Wageningen, Netherlands.

Hepperly P., Seidel R., Pimentel D., Hanson J. & Douds D.D. 2007. Organic farming enhances soil carbon and its benefits. In: Kimble, Rice, Read, Mooney, Follet, and Lal (Eds.) Soil Carbon Management, Economic, Environmental and Societal Benefits, CRC Press. p.129-153.

Janssen, B.H. (1984). A simple method for calculating decomposition and accumulation of ‘young’ soil organic matter. Plant Soil 76: 297-304

Koopmans C. & Burgt G.J.H.M. van der (2001). Mineralenbenutting in de biologische landbouw. Louis Bolk Instituut, Driebergen, Netherlands, 118 pp.

Milieu & Natuur Compendium (2008). http://www.milieuennatuurcompendium.nl

Möller K., Stinner W. & Leithold G. (2008). Effects of biogas digestion of slurry, cover crops and crop residues on nitrogen cycles and crop rotation productivity of a mixed organic farming system. Proceeding IFOAM / ISOFAR conference, 16-20 June, Modena, Italy.

Vereniging afvalbedrijven (2007). www.verenigingafvalbedrijven.nl

EFFECT OF SOIL COMPACTION ON N_2O EMISSION FROM A SANDY LOAM SOIL FERTILIZED WITH MINERAL FERTILIZER OR CATTLE SLURRY

S.Hansen
Bioforsk, Norwegian Institute for Agricultural and Environmental Research, Organic Food and Farming Division, N-6630 Tingvoll, tlf. +47 404 81 549
e-mail: Sissel.hansen@bioforsk.no

Abstract

The effect of soil compaction on N_2O emission in a sandy loam soil was studied in a long-term field trial with different fertilization and soil compaction. The fertilization treatments were: Compound fertilizer with NH_4NO_3 (NPK), cattle slurry high (CSH), cattle slurry level adjusted to organic farming practise (CSO), and an unfertilized treatment. The soil was experimentally compacted by two passes with a tractor, wheel by wheel, shortly before fertilization. Gas fluxes at the soil surface were measured by the soil cover method.

Soil compaction by tractor traffic in this moist soil increased the observed N_2O emissions per kg dry matter feed produced by 2-3 times in NPK treatment. In cattle slurry treatments the effects of soil compaction on N_2O emissions were less pronounced.

Key words: GWP, ammonium nitrate, cattle slurry,

Introduction

The ability of agriculture to limit the contribution to the atmospheric greenhouse effect depends on a successful circulation and utilisation of nutrients. Management activities such as manure application, fertilization, crop rotation, green manure, feeding strategies, tillage and soil compaction by tractor traffic, all affect the circulation of nutrients and thus the greenhouse gas emissions from agriculture. This paper presents the effect of soil compaction on accumulated N_2O emission a sandy loam soil. The treatments were selected as virtual models of fertilization in a range of dairy farms within conventional and organic practise in Norway.

Material and methods

Gas fluxes were measured during the 7th, 8th, 9th and 10th years of a long-lasting field experiment with different fertilization and soil compaction treatments. Details are described by Hansen et al. (1993) and Sitaula et al. (2000). The field experiment was located in Surnadal, Norway 25 m a.s.l., 63º 00' N, 8º 88' E, in a moist and cool climate. Normal precipitation during the growing season May to September is 64, 86, 117, 120 and 173 mm per month, and the average temperatures in the corresponding months are 9, 12, 13.5, 13.2, and 9.4°C. The soil was a well-drained sandy loam soil; the topsoil contained 2.2 % organic carbon and 0.17% organic nitrogen. The crop rotation was adapted to organic dairy farming and had a high frequency of legumes in grassland and green fodder. Crops from year 1 to 10 were: 1, green fodder; 2, barley; 3, grassland; 4, grassland; 5, grassland; 6, oats; 7, green fodder; 8, barley; 9, grassland; 10, grassland.

The experiment had a split-plot factorial design with two replicates, soil compaction on main plots and fertilization on sub plots (2.8 m x 8 m). In the compaction treatment the soil was experimentally compacted by two passes with a four tonne tractor, wheel by wheel, shortly before fertilization. The rear wheels were double-settings with a total tyre width of 140 cm (inflation pressure of 57 kPa). In front there were low pressure tyres with a total width of 100 cm. Average bulk densities (7-11 cm depth) were 1.21 g cm^{-3} in uncompacted soil and 1.30 g cm^{-3} in compacted soil. In years with grassland there were two harvests; the field was fertilized in spring and shortly after the first harvest.

The fertilization treatments reported here are NPK, CSH, CSO (Table 1), and an unfertilized treatment. CS was diluted with water up to 200% of the original volume.

Table 1: Amount of mineral nitrogen (NH_4-N + NO_3-N) and total nitrogen (Total N) applied (kg N ha^{-1} yr^{-1}). NPK = compound fertilizer with NH_4NO_3, CSH = cattle slurry high, CSO = cattle slurry level adjusted to organic farming practise.

Fertilization	NPK					CSH					CSO			
Year	7	8	9	10		7	8	9	10		7	8	9	10
NH_4-N+NO_3-N	140	83	70+50	123+88		120	26	51+30	74+52		50	15	30+20	17+18
Total N	140	83	70+50	123+88		190	62	80+48	123+88		80	34	48+32	45+30

Gas fluxes at the soil surface were measured by the soil cover chambers (thin-walled tin cans, 22.5 cm inner diameter, 23 cm high). For each treatment, there were four parallel flux measurements taken on each day of measurement. The flux was estimated by the increased concentration 3 hours after placement of the soil cover chambers. Gas fluxes were mainly measured in the first half of the growth season in the years 7, 8, 9 and 10 (Hansen et al. 1993, Sitaula et al. 2000).

The area under the flux curves (straight lines between data points) were used to estimate the accumulated N_2O emission shortly after fertilization and afterward in early summer; in year 7, 4 June to 8 July, in year 9, 8 May to 23 June and in late summer year 9; 22 July to 7 September.

Results and discussion

Fertilization with NH_4NO_3 (NPK treatment) on compacted soils with a high moisture content rapidly led to increased N_2O emissions. The average N_2O emission rates in the periods of measurement the 7th, 8th, 9th and 10th years from compacted soil were respectively 1.4, 8.3, 2.0 and 4.6 times the ones from uncompacted soil. Because this moist sandy loam is susceptible to soil compaction (Hansen et al. 1993), large effect of soil compaction on N_2O emissions from soil fertilized with NH_4NO_3 is not surprising as NO_3-N is the main source for denitrification.

In the cattle slurry treatments, the effect of soil compaction on N_2O emissions was more ambiguous than after NH_4NO_3 fertilization (Tables 2 & 3). The content of NO_3-N in the cattle slurry was low, and we did not observe such a rapid increase in N_2O emissions. However, because of denitrification during and after nitrification and break down of organic matter, higher N_2O emission from cattle slurry treatments off season is not unlikely. Soil compaction by tractor traffic is decreasing the soils infiltration capacity and a large part of N in cattle slurry treatments was probably volatilized as ammonia. Following redeposition, this ammonia is likely to contribute to further N_2O emission elsewhere.

Table 2: N_2O emission rates (μg N_2O-N m^{-2} h^{-1}) as affected by soil compaction in the years 7, 8, 9 and 10 of field experiment. Fertilization abbreviations as in Table 1.

	Uncompacted soil				Compacted soil			
Year	7	8	9	10	7	8	9	10
NPK	653	40	106	293	893	333	210	1360
CSH	440	n.d.	59	n.d.	325	n.d.	45	n.d.
CSO	309	n.d.	50	n.d.	263	n.d.	56	n.d.
Unfertilized	73	14	13	301	69	23	26	457

Table 3: Accumulated N_2O emission (kg N ha^{-1} ± standard error) in the periods after fertilization as affected by soil compaction in the years 7 and 9. Fertilization abbreviations as in Table 1.

Year	7			9			9		
Time period	Early summer			Early summer			Late summer		
NPK	5.3	±	1.6	0.9	±	0.09	1.0	±	0.28
CSH	3.6	±	0.4	0.4	±	0.01	0.8	±	0.66
CSO	2.5	±	0.4	0.9	±	0.68	0.4	±	0.3
Unfertilized	0.6	±	0.1	0.3	±	0.08	0.1	±	0.05
NPK	7.4	±	1.1	3.4	±	1.7	2.1	±	0.85
CSH	2.7	±	0.4	1.0	±	0.6	0.3	±	0.01
CSO	2.2	±	0.4	1.1	±	0.5	0.5	±	0.2
Unfertilized	0.6	±	0.1	0.7	±	0.1	0.1	±	0.03

The yields decreased as a result of soil compaction. In treatments fertilized with NH_4NO_3 (NPK) the corresponding N_2O emission per kg dry matter feed produced, was 2-3 times higher in compacted than uncompacted soil (Table 4).

Table 4: Yields of greenfodder (year 7) or ley (year 9) and the observed N_2O emission (Table 3) calculated as N_2O-N per tonne DM harvested in uncompacted and compacted soil. Fertilization abbreviations as in Table 1.

Year	Tonne DM ha^{-1}						N_2O-N tonne DM^{-1}	
	7			9			7	9
Uncompacted								
NPK	6.99	±	0.19	9.70	±	0.46	0.76	0.20
CSH	6.48	±	0.42	8.61	±	0.56	0.56	0.14
CSO	4.84	±	0.39	6.70	±	0.09	0.52	0.19
Unfertilized	3.66	±	0.24	3.46	±	0.16	0.16	0.12
Compacted								
NPK	5.12	±	0.08	8.71	±	0.13	1.45	0.63
CSH	5.16	±	0.06	7.88	±	0.02	0.52	0.16
CSO	3.52	±	0.64	5.94	±	0.43	0.63	0.27
Unfertilized	3.22	±	0.24	3.92	±	0.32	0.19	0.20

The observed N_2O emission per ha and per unit produced was higher with conventional fertilization than with fertilization adapted to organic dairy farming. This is in contrast to the findings on a field experiment in Finland (Syväsalo et.al. 2006), but in accordance with the study of two farming systems in Germany (Flessa et al. 2002).

Conclusion

Soil compaction led to a strong increase in N_2O emission in soil fertilized with NH_4NO_3. In cattle slurry treatments the effects of soil compaction were more ambiguous, but also in CSO treatment the observed N_2O emissions increased. Because of indirect N_2O-emissions, the effect of soil compaction is likely higher in cattle slurry treatments than observed.

References

Flessa, H., Ruser, R., Dörsch, P., Kamp,T., Jimenez, M.A., Munch, J.C., and Beese, F. 2002. Integrated evaluation of greenhouse gas emissions (CO_2,CH_4, N_2O) from two farming systems in southern Germany. Agric. Ecosys. Environ. 91: 175-189.

Hansen, S., Mæhlum, J.E. and Bakken, L.R. 1993. N_2O and CH_4 fluxes in soil influenced by fertilization and tractor traffic. Soil Biol. Biochem. 25: 621-630.

Sitaula, B.K., Hansen, S., Sitaula, J.I.B., and Bakken, L.R. 2000. Methane oxidation potentials and fluxes in agricultural soil: Effects of fertilization and soil compaction. Biogeochemistry 48: 323-339.

Syväsalo, E., Regina, K., Turtola, E., Lemola, R., and Esala, M. 2006. Fluxes of nitrous oxide and methane, and nitrogen leaching from organically and concentionally cultivated sandy soil in western Finland. Agric. Ecosys. Environ. 113: 342-348.

POTENTIAL OF LOW GROUND PRESSURE FOR HARVESTING MACHINERY IN A CONTROLLED TRAFFIC FARMING SYSTEM IN ORGANIC AGRICULTURE

G.D. Vermeulen[1] **& W. Sukkel**[2]
[1] Plant Research International, P.O. Box 16, 6700 AA Wageningen, The Netherlands.
[2] Applied Plant Research (PPO-agv), P.O. Box 430, 8200 AK Lelystad, The Netherlands.

Abstract

Seasonal controlled traffic farming (SCTF), i.e. CTF without using the permanent traffic lanes for harvesting and primary soil tillage, leads to improved soil structure, higher crop yields, significant reduction of the emission of nitrous oxide and increased uptake of methane. Improved timeliness of operations, easier mechanical weed control and favourable returns on investments are considered practical advantages of SCTF. Further improvements, including reduced tillage, seem possible by avoiding overcompaction of the soil in the cropping beds during harvesting. The objective of the research was to find out what ground pressures can be applied without compromising soil structure and subsequent growth of a green manure crop, i.e. without tilling the topsoil after compression. No driving over the beds (ground pressure = 0) and simulation of harvesting with equipment requiring tyre inflation pressures of respectively 40, 60 and 80 kPa were investigated. Under dry or moist (field capacity) soil conditions support of harvesting machinery on the planting bed with tyres inflated to 0.4 bar did not lead to severe compaction and subsequent yield reductions.

Introduction

Innovative management of arable soils is necessary to improve the general sustainability of farming. One option for improved soil management is the adoption of controlled traffic farming (CTF), a system with permanent traffic lanes and wide, untrafficked cropping beds. Seasonal controlled traffic farming (SCTF), i.e. CTF without using the permanent lanes for harvesting and primary soil tillage, has been adopted by several organic farmers in the Netherlands. Vermeulen & Mosquera (2008) have shown that, compared to conventional organic farming, SCTF leads to improved soil structure, higher crop yields, significant reduction of the emission of nitrous oxide and increased uptake of methane. Improved timeliness of operations, easier mechanical weed control and favourable returns on investments are considered practical advantages of SCTF.

Further improvement seems possible by avoiding overcompaction of the soil during harvesting. Potential improvements include further improvement of soil structure, reduced soil tillage, savings on energy and cost, better possibilities for soil coverage by crops in winter to preserve N and avoid water logging and soil slaking. However, CTF harvesting equipment for most crops grown in organic farming is not available and the development poses technical and economic challenges. The technical challenge is to support the high vehicle loads of current, high-capacity harvesters on narrow running gear, suited for the traffic lanes. Even when the soil is wet, machinery should not slide off the lanes. The economical challenge is to realize a sufficiently large area under CTF to ensure a high yearly usage of the specialized machinery and, therefore, reach acceptable cost per ha.

One option to possibly overcome the harvesting problem in SCTF is to support part of the machinery load on the cropping beds. In that case the ground pressure on the cropping bed should be low enough to avoid compaction of the soil under all circumstances. Experiments with low ground pressures during harvest in SCTF, ranging from 0 to 60 kPa on dry soil in 2005 and 2006 (Vermeulen & van der Wel, 2006; 2007) showed no significant negative effects on soil structure. The treatments had also no effect on the growth and dry matter yield of a green manure crop grown on the compressed soil without soil tillage other than making a seedbed. An inventory of equipment available for low ground pressures (Vermeulen & Verwijs, 2007) showed that presently developed rubber track systems allow the practical application of very low ground pressures combined with relatively high machinery loads. The objective of the experiment described in this paper was to investigate the effects of applying low ground pressures during moist harvesting conditions on the cropping beds in a SCTF system on soil structure and subsequent growth of a green manure crop without tilling the topsoil.

Materials and Methods

The experiment was conducted on a SCTF farm in a crop of Basil (*Ocimum basilicum*), harvested without compressing the soil. The soil was a loam soil with a clay content of about 22%. The treatments were: no driving over the beds (ground pressure = 0) and harvesting with equipment requiring relatively low, but attainable tyre inflation pressures of respectively 40, 60 and 80 kPa. For this purpose, a tractor (Fendt Farmer 310LSA) was loaded to the maximum allowable load (rear axle) at the specified tyre inflation pressures (Table 1). The plots were covered with wheel ruts by driving to and fro over the plots with the tractor (Figure 1). In this way the complete surface of the plots was compressed twice, simulating the passage of two large volume tyres under a harvester. The soil was irrigated 2 days before the ground pressure treatments to create moist (top)soil, simulating average harvesting conditions. The plots were 3.15 m wide and 5 m long. The number of replications was 4. The ground pressure treatments were given on 24 August 2007.

Table 1: Allowable wheel loads and actually applied loads on the tyres of the tractor used in the experiment for inflation pressures of 40, 60 and 80 kPa

Tyre	Type of load	Tyre inflation pressure (kPa)		
		40	60	80
Rear: Michelin XM27 800/65R32	Allowable at 30 km/u (kg)	2740	3790	4200
	Actually applied (kg)	2801	3790	4187
Front: Goodyear 540/65R28	Allowable at 30 km/u (kg)	1400 ¹)	1765	1980
	Actually applied (kg)	914	1206	1038

¹) Use of the tyres at 40 kPa inflation pressure not recommended by manufacturer.

Thirteen days after the simulated harvest with 0, 40, 60 and 80 kPa tyre inflation pressure, respectively, the field was sown with white mustard (*Sinapsis alba*) without ploughing the field. Tillage was restricted to one passage with a CTF seedbed combination, cutting off the roots of the Basil stubble with sweep cultivators in the front hitch, making a 5-cm-deep seed bed with a rotary harrow and sowing white mustard at a rate of 25 kg ha^{-1} (Figure 2). Therefore, the roots of the white mustard had to grow in the root bed left after the various ground pressure treatments.


Figure 1. Application of ground pressure treatments.


Figure 2. Seedbed preparation and sowing of white mustard using CTF.

The soil moisture status during compression of the soil was characterized by the average soil moisture content in the 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm depth layers and the gravimetric moisture content at -10 kPa soil water matric pressure for this soil. The soil moisture samples were taken on the zero ground pressure plots just after conducting the compression treatments. On each plot 4 cores, 30 cm long, were taken per plot, using a gouge auger, 30 mm in diameter. The soil moisture samples for the various depth layers were obtained by cutting the corresponding section from the core. For each depth layer, all samples were combined into one sample for analysis. Soil structure before and after the ground pressure treatments was characterized by total porosity and air-filled porosity at -10 kPa soil water matric pressure according to Kuipers (1961). Each plot was sampled in the 10-15 cm depth layer before and after the ground pressure treatments. Ten cores of 100 cm^3 were taken per plot in a line across the controlled traffic bed.

Crop growth after ground pressure treatments was characterized by the number of established plants per 3 m row and by the dry matter yield, 54 days after sowing. Per plot, the numbers of plants were counted 3 times on 3 m row length. The dry matter yield was determined by hand harvesting an area of 1.5 m^2 per plot.

Results and Discussion

During the compression treatments the moisture content was 25.2, 22.4, 23.0, 23.6, 23.9 and 23.6 respectively for the soil layers 0-5, 5-10, 10-15, 15-20, 20-25 and 25-30 cm, being near field capacity (-10 kPa, 23.3 % w/w; d.b.) decreased with increasing ground pressure (Table 2). Before compression treatment, no significant differences in total porosity and air-filled porosity were present, as expected.

Table 2: Total porosity (ϕ) and air-filled porosity (ϕ_{a1}) at field capacity (in % v/v) before and after the compression treatments.

Treatment		Before treatment			After treatment	
		ϕ	ϕ_{a1}		ϕ	ϕ_{a1}
0 kPa		44.3	10.1		42.5	8.2
40 kPa		44.1	10.0		41.7	7.2
60 kPa		44.6	10.7		41.5	6.9
80 kPa		43.6	8.9		40.2	5.1
lsd (p<0.05)		1.3	1.9		1.0	1.4

After treatment, total porosity and air-filled porosity decreased significantly with increasing inflation pressure. Compared with the porosities before treatment, the porosities after the zero pressure treatment were lower than those before treatment.

This cannot be correct as these plots were not compressed at all. It is suggested that the difference was caused by measurement errors due the difference in moisture content at sampling (before treatment 16.2 % w/w, dry base and after treatment 21.7 % w/w, dry base). Nevertheless, the figures indicate that the soil responded to all low ground pressure treatments.

Establishment of the white mustard was best for the 40 kPa treatment and this may have contributed to the relatively high yield for this treatment (Table 3). The dry matter yield after treatments was significantly higher for the zero and 40 kPa treatments, compared with the 60 kPa and 80 kPa treatments.

Table 3: Number of plants per 3 meter row and dry matter yield 54 day after sowing.

Tyre inflation pressure (kPa)	Number of plants per 3 m row length.	Dry matter yield (kg/ha)
0	87	962
40	104	1005
60	96	786
80	89	702
lsd (p<0.05)	11	134

Conclusions

Under dry or moist (field capacity) soil conditions in a controlled traffic farming system, support of harvesting machinery on the planting bed with tyres inflated to 0.4 bar or comparable low ground pressure running gear did not lead to yield reductions due to soil compaction.

References

Kuipers, H., 1961. Water content at pF2 as a characteristic in soil cultivation research in the Netherlands. Neth. J. Agric. Sci., 9: 27-35.

Vermeulen, G.D. & J. Mosquera, 2008. Soil, crop and emission responses to seasonal controlled traffic in organic vegetable farming on loam soil. Soil & Tillage Res. (accepted).

Vermeulen, G.D. & B.R. Verwijs, 2007. Inventarisatie van beschikbare techniek voor oogst en transport met lage bodemdruk, Plant Research International, Wageningen, Rapport 163, 48 pp (in Dutch).

Vermeulen, G.D. & C. van der Wel, 2006. Verslag van een proef met variërende bodemdruk onder droge omstandigheden. Plant Research International, Wageningen, Internal Report, 11 pp (in Dutch).

Vermeulen, G.D. & C. van der Wel, 2007. Bodemverdichting bij zeer lage bodemdruk en effect op een volggewas. Verslag van een veldproef te Langeweg in 2005. Plant Research International, Wageningen, Internal Report, 7 pp (in Dutch).

Scientific session II.A Soil Biology and Biodiversity

AN ATTEMPT TO ASSESS SOIL BIODIVERSITY IN LONG TERM FIELD EXPERIMENTS IN PRAGUE

J. Kubát, O. Mikanová, D. Cerhanová
Crop Research Institute, Drnovská 507, 161 06 Praha 6 – Ruzyně, Czech Republic, E-mail:
kubat@vurv.cz

Abstract

The effects of organic and mineral fertilisers on the soil biodiversity was tested in selected variants of a long-term field experiment i Prague – Ruzyně. Microbial biomass C, number of bacteria and basal respiration activity were evaluated as indicators of soil biodiversity. While there were significant differences among all variants in biomass C contents, there were practically no differences in bacteria counts. Basal respiration activity was enhanced by organic fertilisation but not by mineral fertilisation.

Introduction

Biodiversity has been recognised as one of the most important issues and challenges all over the world. The main studies and concerns have been focused on higher organisms however, soil biodiversity concerning soil micro-organisms and small animals (invertebrates) is not less important. Soil biota belongs among pedogenic factors and it is indispensable in ecological functions of soils, namely transformation and production functions and in the biotop function. Soil biota is also indispensable for fertility of agricultural soils and generally for soil health and soil quality.

The assessment of the soil biodiversity is rather complicated. The number of species within soil is several orders higher than that of the higher plats and animals living on the soil. Most of the soil micro-organisms are phylogenically very old and they possess large variety of metabolic pathways most of which have disappeared in higher organisms. Soil has also been considered to be the largest gene bank. The first difficulty, therefore is, the large variety of species, a lot of which has probably not been described, yet.

Second, identification of micro-organisms from soil is rather difficult, laborious and time consuming. Micro-organisms cannot be easily identified according to their morphology similarly to the higher organisms. Identification of an isolated soil micro-organism is still rather difficult procedure, in spite of the availability of new techniques.

Last but not least, there are rather difficult problems with the isolation of soil micro-organisms. There are species living in soil that can hardly be cultivated in vitro. An easy and clear evidence of this may provide the comparison of a number of bacteria determined by direct microscopic and indirect plate dilution techniques. Direct measurements usually provide ten times higher numbers than the plate dilution technique. It means that a major part of soil micro-organisms cannot be isolated and identified by ordinary techniques.

There are a large number of methods that can be used in studies of soil biodiversity. Basically, they include:

1) Determination of an incidence and biomass of the soil biota (direct microscopy, picture analyses, plate dilution techniques, biomass C and N content – e.g. fumigation/extraction, SIR).
2) Determination of activities of soil micro-organisms (e.g. respiration, N-mineralization, potential nitrification, enzyme activities, etc.).

3) Determination of diversity of the whole microbial community in soil (DNA profiles, physiological profile using Biolog system, phosholipid fatty acids, etc.).

All of them, however, provide just a scanty view that may be useful only in combination with some other soil characteristics. The importance of combining the determination of the incidence of the soil micro-organisms and their activities has been clearly demonstrated by Doelman et al. (1994). In the soil contaminated by heavy metals, the total biomass C content did not visibly changed as compared to the control not contaminated soil. However, the ratio of the resistant and sensitive bacteria increased in the contaminated soil, and what was the most alarming, they could show in further experiments, that the heavy metals resistant bacteria were much less effective in the decomposition of a number of organic pollutants than the heavy metal sensitive bacteria. In another words, vulnerability of soil biota may be changed without any visible changes in its number and basic metabolic activities.

In this paper, we have evaluated incidence and respiration activity of soil micro-organisms in selected variants in a long-term field experiment in Prague – Ruzyně.

Materials and Methods

Long-term field experiment, Field B, was described in our earlier papers (e.g. Kubát et al., 2003). We have selected four variants to evaluate the effect of organic and mineral fertilisation on soil biota and its activities:

1. Nil - variant which has not received any fertilizers since 1956
2. NPK - mineral fertilised variant, average annual N dose 100kgN.ha^{-1}
3. FYM – farmyard manure treated variant, average annual N dose 57 kgN.ha^{-1}
4. FYM+NPK – combined organic and mineral fertilisation, same doses of N as in preceding treatments.

Indicators of biodiversity were:

- biomass C content in soil
- number of bacteria growing on starch agar (plate dilution technique)
- basal respiration activity

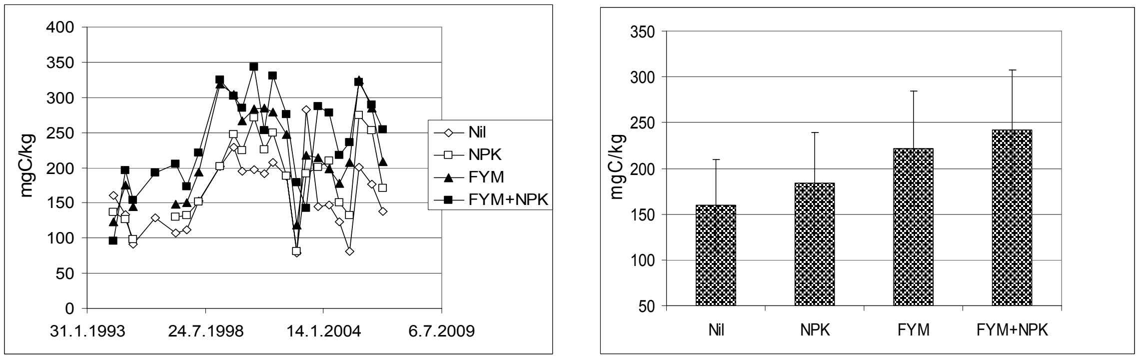
Microbial biomass C content was determined according to Vance et al. 1976, Number of bacteria was determined using plate dilution technique and starch agar, basal respiration activity was determined according to Cerhanová et al. (2006).

Results and Discussion

Biomass C content in topsoil varied considerably (from 78 to 343 mgC.kg^{-1}) during the time period, most probably depending on the cultivated crop and on the time specific weather conditions (Fig. 1a). However, it was possible to show a positive effect of both organic and mineral fertilisation on the biomass C content in topsoil when we calculated average values for the whole time period (Fig. 1b). The mineral NPK fertilisation increased the biomass C content in topsoil by about 24.5 mgC.kg^{-1} as compared to the not fertilised Nil variant. The effect of organic FYM fertilisation was almost 3 times higher (62.1 mgC.kg^{-1}) and the effect of combined FYM and NPK fertilisation was practically equal to the sum of both treatments (82.2 mgC.kg^{-1}).

The differences among average values of the biomass C content in individual variants were tested by means of t-test for dependant samples. The calculated t-test values are presented in Table 1. As the t_{crit} value for this data file was 2.831 at P=0.01, all differences between the average values were highly significant (marked by **), except for the difference between the average biomass C contents in FYM and FYM+NPK variants which was significant at P=0.05 level (marked by *). Similar calculations were used in the number of bacteria and the respiration activity data files. Results are also presented in Table 1 (NS means non significant).

Figure 1 a,b: Biomass C content in soil samples from selected plots of the long-term field experiment in Prague and its average values over the time period 1994-2006 (mgC/kg, n=22).


a) b)

Number of bacteria determined by means of plate dilution technique on starch agar are presented on Fig. 2a,b. In order to have a longer continuous data series, we used the data from the same experiment and variants collected over 1971-1982 time period. Variability of the data is still higher than that of biomass C content. There are almost no distinct differences among the selected variants in the average values over the whole tim period (Tab.1).

Table 1: Effect of organic and mineral fertilisation on the biomass C content, bacteria counts and respiration activity in soil samples from the long-term field experiment (t-test values for dependent samples).

Biomass C content			
t 0.01=2.831 t 0.05=2.080			
Variants	FYM+NPK	FYM	NPK
Nil	-5,748**	-6,237**	-2,839**
NPK	-6,887**	-6,262**	
FYM	-2,827*		
Number of bacteria			
t 0.01=2.797 t0.05=2.064			
Variants	FYM+NPK	FYM	NPK
Nil	0,450NS	0,137NS	0,690NS
NPK	-0,158NS	-0,571NS	
FYM	-0,547NS		
Basal respiration activity			
t 0.01=2.797 t0.05=2.064			
Variants	FYM+NPK	FYM	NPK
Nil	-4,417**	-4,948**	0,624NS
NPK	-5,886**	-4,319**	
FYM	-0,239NS		

The effect of organic and mineral fertilisation on the basal respiration activity of the soil samples is shown on Fig. 3 a,b. While there are practically no differences between not fertilised Nil variant and mineral fertilised NPK variant (that of the mineral fertilisation seems to be slightly negative), the differences between both FYM and combined FYM+NPK variants and not fertilised Nil variant reached about 18% of the Nil variant and they are statistically significant at P=0.01 level.

Figure 2 a,b: Number of bacteria growing on starch agar in soil samples from selected plots of the long-term field experiment in Prague and its average values over the time period 1971-1982 (CFU/g, n=25).

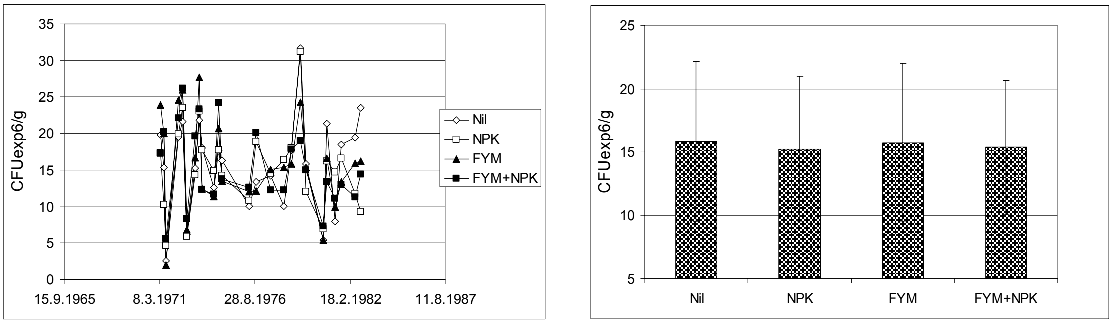
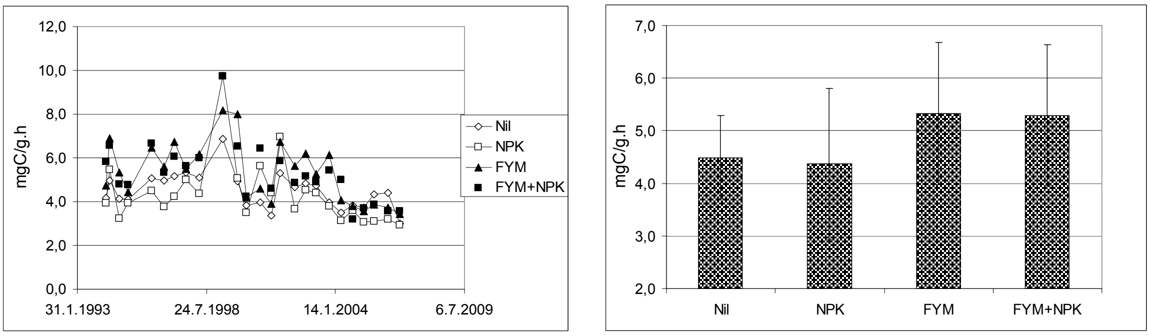

a) b)

Figure 3 a,b: Basal respiration activity of soil samples from selected plots of the long-term field experiment in Prague and its average values over the time period 1994-2006 (mgC/g.h, n=25).


a) b)

Conclusions

In spite of a high variability of the indicator of soil biodiversity, statistically significant effects of organic and mineral fertilisation have been achieved thanks to long-term field experiments and longer data time series. New methods to assess changes in soil biodiversity should be developed and calibrated in long-term field experiments.

Acknowledgment

This work was funded by the Ministry of Agriculture Czech Republic, project No: MZe0002700601.

References

Cerhanová, D., Kubát, J., Nováková, J. (2006): Respiration activity of the soil samples from the long-term field experiments in Prague. Plant Soil, Environment, 52:21-28.

Doelman, P., Jansen, E., Michels, M., Til, M. van, (1994): Effects of heavy metals in soil on microbial diversity and activity as shown by the sensitivity-resistance index, an ecologically relevant parameter. Biology and Fertility of Soils, 17:177-184.

Kubát, J., Klír, J., Pova, D. (2003): Dry matter yields, nitrogen uptake, and the efficacy of nitrogen fertilisation in long-term field experiments in Prague. Plant Soil Environ., 49:337-345

Vance, E. D., Brookes, P. C., Jenkinson, D. S. (1987): An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem., 19:703-707.

ORGANIC PEST MANAGEMENT – BENEFITS AND RISKS

E. Wyss
Research Institute of Organic Agriculture (FiBL), Ackerstrasse, CH-5070 Frick, Switzerland

Abstract

Arthropod pest management in organic agriculture has a phased approach to overcome pest problems. The first phase is the adoption of cultural practices including diverse crop rotation, enhancement of soil quality by incorporation of specific cover crops and/or the addition of soil amendments, and choice of resistant varieties that help to prevent pest outbreaks. In the second phase, functional biodiversity (e.g. incorporation of non-crop habitats such as hedgerows and wild flower strips) is implemented to encourage populations of pest antagonists. This diversification through habitat manipulation may not only lead to an improved pest-control but, also to a generally higher biodiversity. Finally, third and fourth phases of the program include deployment of direct measures such as biocontrol agents and approved insecticides, repellents, and pheromones. This phased approach dramatically reduces the impact of pest management on environmental indicators (e.g. soil organic matter, biological activity of soils, faunal and floral biodiversity, landscape, climate factors).

The comparison of the impacts of conventional and organic agriculture shows that organic agriculture performs better for the majority of the environmental indicators. In addition, no or just minor negative effects of organic farming practices, including organic pest management, are known. Moreover, it can be stated that organic agriculture enhances faunal and floral biodiversity which is part of the phased approach for pest management.

Climate change will influence agriculture and pest management. More pest species, more damages of crops and changed population dynamics are to be expected. Besides all additional risks due to effects of climate change, organically managed crop systems should be better adapted to weather extremes due the soils with high water retention capacity, enhanced soil fertility, higher percolation properties of soils and increased organic matter. In addition, organic systems have a higher biodiversity (crops, fauna, flora). Based on these facts, risks of climate change for organic pest management might be less than for conventional systems.

Phased approach for organic pest management

In the 1980s, pest management researchers in Europe began to develop holistic concepts to control pests in organic agriculture systems. Today, arthropod pest management in organic agriculture involves the adoption of scientifically-based and ecologically sound strategies as specified by international and national organic production standards. This includes a ban of synthetic insecticides and genetically modified organisms (GMOs).

Phase one of the model consists of entirely preventative methods such as site selection, crop rotation, soil management and (non-transgenic) host-plant resistance. Vegetation management is the basis for second-phase strategies that enhance natural enemy impact and exert direct effects on pest populations. These include the introduction of flowering plants or grassy strips to provide plant food to natural enemies or other forms of intercropping that may act as trap crops or interfere with pest location of host plants. Mass-reared biological control agents are used in inundation or inoculation releases in the third phase. Finally, approved insecticides of biological and mineral origin and mating disruption techniques constitute the fourth phase. Zehnder et al. (2007) use this model to give a detailed review on arthropod pest management strategies suitable for organic systems.

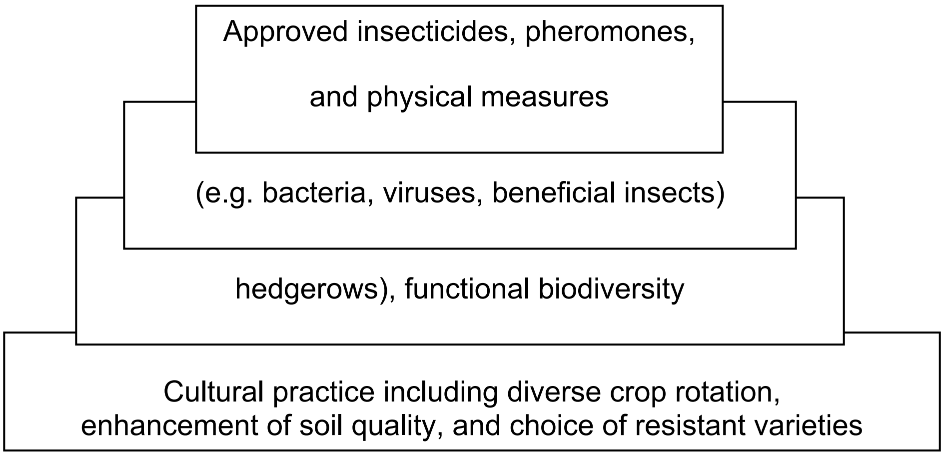


Figure 1: Phased approach for organic pest management (based on Zehnder et al. 2007).

A scientifically documented and practiced example of this phased approach is the control of the rosy apple aphid (Dysaphis plantaginea Pass.) in apple. In the first phase the organic apple grower, today, has the possibility to choose apple varieties tolerant or resistant to aphids. Some European and North American scab resistant varieties are known to be less susceptible or even resistant to the rosy apple aphid (Würth et al. 1999 and 2002; Habekuss et al. 2000). However, this range of varieties is too small to fulfil all agronomic and quality demands and therefore, susceptible varieties are still grown. Thus, on the first phase level cultural practices including selective pruning, soil management and adapted organic fertilization are important tools to lower the risk of aphid calamities.

In the second phase, the ecological equipment or habitat management is implemented in the apple orchard by sowing flowering weed strips or diverse mixtures of flowering cover plants to enhance populations of aphid antagonists (Wyss, 1995). The flowering plants provide pollen and nectar and serve as important over-wintering sites. Therefore, they are not mown or mulched before winter. Some of the sown plant species also host aphids when they are rare on apple. Hence, pollen, nectar and aphids are available to a great number of aphidophagous species throughout the vegetation period. These weed strips attract and provide shelter to a significantly higher number of aphid antagonists than in orchards without weed strips (Wyss, 1995). During spring and summer, tree inhabiting and web-building spiders benefit from a higher number of indifferent insects attracted by the weed strips. In autumn, these web-building spiders are the dominant predators and significantly reduce the number of rosy apple aphids returning from their summer host plants to the apple tree (Wyss et al. 1995). However, weed strip-management does not always provide sufficient control, particularly in years with high aphid populations.

If indirect measures of phase one and two are insufficient, biocontrol agents could be used in a third phase. Mass releases of larvae of the most promising predator, the ladybird beetle *Adalia bipunctata* L. (Coleoptera: Coccinellidae), significantly reduced the rosy apple aphid, in spring as well as in autumn (Wyss et al. 1999; Kehrli and Wyss 2001). However, the larvae were not able to reduce aphids below the economic threshold level.

Following the approach of autumn applications against the gynoparae, females and males, the effect of treatments with a processed kaolin product (Surround® WP) was assessed in experimental and on-farm orchards (Wyss and Daniel, 2004). Kaolin protects trees against insect pests because the white particle film creates a hostile and unfamiliar environment. Single and repeated kaolin treatments hindered the gynoparae and sexuales significantly from landing on apple trees and consequently less fundatrices were observed on kaolin treated trees in spring (Wyss and Daniel, 2004). If all measures mentioned before gave unsatisfactory results and if there is still an acute risk of an aphid calamity in spring, organic fruit growers may use insecticides of natural origin as a last option. The natural agent azadirachtin (extract of neem tree kernels) was proven to be very efficient against the fundatrices when applied just before apple blossom (Wyss, 1997).

This phased approach for organic pest management has shown to be responsible for a reduced impact on environment and especially on the diversity and abundance of different arthropod bioindicator groups (Wyss, 1996).

Benefits of organic agriculture for biodiversity and sustainability

Stolze et al. (2000) give a detailed assessment of organic farming's impact on the environment and use of resources compared to conventional farming. They review different environmental indicators proposed by the OECD to be essential for sustainability (OECD, 1997). In summary, organic farming performs better than conventional farming in relation to the majority of environmental indicators. Moreover, in no indicator category did organic farming show a worse performance when compared with conventional farming. Reasons for the better performance of organic agriculture compared to non-organic agriculture are multiple. On the one hand, no synthetic pesticides, no herbicides, no mineral fertilizers and less foreign feedstuff are employed but, on the other hand, broad crop rotation and organic manure are used.

Many single studies, reviews and meta-analyses comparing different farming systems have recently shown the positive effects of organic farming on biodiversity (e.g. Bengtsson et al., 2005; Fuller et al., 2005; Hole et al., 2005). These reviews showed mostly positive effects of organic farms on species diversity and abundance of plants (within-crop and crop margins), non-pest arthropods (spiders, carabids, staphylinids, and butterflies), birds, earthworms, and soil micro-organisms. In the DOC long-term trial, comparing biodynamic (D), organic (O) and conventional (C) farming practices in a plot trial, similar effects were observed as in these reviewed comparisons on farm-level (Mäder et al., 2002). Earthworms, carabids, staphilinids, and spiders were significantly more abundant in the biodynamic and organic plots than in the conventional plots. Again, an important reason for this beneficial effects of the organic production systems on biodiversity was proven to be the abdication of pesticides and herbicides (Mäder et al., 2002, Pfiffner and Mäder 1997, Pfiffner and Niggli, 1996).

The floral and faunal biodiversity fulfils important ecosystem services in organic horticulture: it (1) reduces soil erosion by a higher activity and abundance of earthworms and soil micro-organisms, (2) improves crop pollination by a higher diversity and abundance of pollinating insects, and (3) is an important component of the arthropod pest management by a more abundant and diverse pest antagonist fauna.

This higher floral and faunal biodiversity might become important in the context of climate change. We can hypothesise that the stability of more diverse agricultural systems might help mitigate the negative effects of climate change on pest populations.

Is climate change a particular risk for organic pest management?

Agriculture is not only contributing to climate change but is also affected by it (ITC 2007). Pest management will also be affected by climate change because the cold-blooded insects are dramatically dependent on temperature. Some experts believe that the effect of temperature on insects largely overwhelms the effects of other environmental factors (Bale et al. 2002). It has been estimated that with a 2ºC temperature increase insects might add one to five additional life cycles per season (Yamamura and Kiritani 1998).

Many researchers have already proven that an increase of CO_2 will increase yields but reduce the nutritional content of leaves by 10 to 20% (e.g. Williams et al. 2001). This decline of nutritional value of crops will lead to more herbivore pest damage (Bale et al., 2002). In addition, a very important natural pest control mechanism might get lost with higher temperatures especially during winter in temperate climates: with less freeze and cold weather pest insects will better survive diapause (Harrington et al. 2001). However, insects that spend important parts of their life histories in the soil may be less affected by temperature changes than those that are above ground simply because soil provides an insulating medium that will tend to buffer temperature changes more than the air (Bale et al 2002).

Climate change will also affect population dynamics of pest species and the interaction among species (e.g. Gutierrez et al. 2007, Coviella an Trumble, 1999). Therefore, changes in species composition on crop, farm and landscape level might enhance the risk of unbalanced insect communities (Andrew and Hughes, 2005). Natural enemy and host insect populations may respond differently to changes in temperature. Parasitism could be reduced if host populations emerge and pass through vulnerable life stages before parasitoids emerge. Hosts may pass though vulnerable life stages more quickly at higher temperatures, reducing the window of opportunity for parasitism. Another example of possible effect of climate change on insect pests is the following: Fungal pathogens of insects are favoured by high humidity and their incidence would be increased by climate changes that lengthen periods of high humidity and reduced by those that result in drier conditions (Petzoldt and Seaman). Both scenarios would clearly weaken the organic pest management approach by indirect measures like habitat management (functional biodiversity).

An additional problem might occur: pesticides and biocontrol agents might not work under warmer or more humid/dry climate conditions. Biocontrol agents are an important direct measure in organic pest management. The loss of any bacterial, viral (e.g. baculoviruses) or other biocontrol agent due to warmer climates would severely reduce the degree of freedom of the organic farmer to control known and new pest species.

Conclusions

In a multi-criteria analysis, organic agriculture has proven to be more sustainable than non-organic agriculture and even benefits biodiversity. This additional biodiversity plays a key role in organic agriculture: it is an important environmental indicator showing the sustainability of organic agriculture and it is part of the backbone of organic insect pest control. Especially functional biodiversity by enhancing beneficial insects by habitat management or specific measures in the crops is already an important part of organic pest control. In the future, these measures might even be a key solution to overcome new pest problems due to climate change.

Climate change will for sure enhance pest problems in crops. But, besides all additional risks due to effects of climate change, organically managed crop systems should be better adapted to weather extremes due the soils with high water retention capacity, enhanced soil fertility, higher percolation properties of soils and increased organic matter. In addition, organic systems have a higher biodiversity (crops, fauna, flora). Based on these facts, risks of climate change for organic pest management might be less than for conventional systems.

However, it will be important for farmers to be aware of crop pest trends in their region (by monitoring) and flexible in choosing both their management methods and in the crops they grow. Farmers who closely monitor pests on their farms will be in a better position to make decisions about whether it remains economical to continue to grow a particular crop or use a certain pest management techniques. It is also very important for the organic farmers to get familiar with the most modern pest prediction and pest control techniques. In addition, these techniques have to be adapted to the specific needs of organic farmers by researchers and advisers. To be able to anticipate climate change, research is needed to develop resistant or tolerant crop varieties, new techniques for functional biocontrol, computer based pest forecasting models, and new biocontrol agents.

References

Alfoeldi, T., Fliessbach, A., Geier, U., Kilcher, L., Niggli, U., Pfiffner, L., Stolze, M., Willer, H., (2002). Organic Agriculture and the Environment. In El-Hage Scialabba, N. and Hattam, C. (Eds.). Organic agriculture, environment and food security, Chapter 2. Environment and Natural Resources Series 4. Food and Agriculture Organisation of the United Nation (FAO), Rome.

Andrew, N.R., Hughes, L. (2005). Diversity and assemblage structure of phytophagous Hemiptera along a latitudinal gradient: predicting the potential impacts of climate change. Global Ecol Biogeogr. 14:249-262.

Bale, J.S. Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K., Butterfield, J., Buse, A., Coulson, J.C., Farrar, J., Good, J.E.G., Harrington, R., Hartley, S., Jones, T.H., Lindroth, R.L., Press, M.C., Symrnioudis, I., Watt, A.D., Whittaker, J.B., (2002). Herbivory in global climate change research: direct effects of rising temperatures on insect herbivores. Global Change Biology, 8:1-16.

Bengtsson, J., Ahnström, J. and Weibull, A.-C. (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology, 42, 261–269.

Coviella, C., Trumble, J. (1999). Effects of elevated atmospheric carbon dioxide on insect plant interactions. Conservation Biology 13:700-712.

Fuller, R.J., Norton, L.R., Feber, R.E., Johnson, P.J., Chamberlain, D.E., Joys, A.C., Mathews F., Stuart, R.C., Townsend, M.C., Manley, W.J., Wolfe, M.S., Macdonald, D.W and Firbank, L.G. (2005). Benefits of organic farming to biodiversity vary among taxa. Biology letters, 1, 431-434.

Gabriel, D., Roschewitz, I., Tscharntke, T., Thies, C. (2006). Beta diversity at different spatial scales: plant communities in organic and conventional agriculture. Ecological Applications, 16: 2011-2021.

Gutierrez, A.P., Ponti, L., d'Oultremont, T. Ellis, C.K. (2007). Climate change effects on poikilotherm tritrophic interactions. Climatic Change, DOI 10.1007/s10584-007-9379-4.

Habekuss, A., Proeseler, G., Schliephake, E., and Fischer, C., 2000. Resistance of apple to spider mites and aphids. In M. Geibel, M. Fischer and C. Fischer (eds.). Proceedings of the Eucarpia symposium on fruit breeding and genetics. Acta Horticulturae 538: 271-273.

Harrington, R., Fleming, R, Woiwood, I. P. (2001). Climate change impacts on insect management and conservation in temperate regions: can they be predicted? Agricultural and Forest Entomology 3: 233-240.

Hunter, M.D. (2001). Effects of elevated atmospheric carbon dioxide on insect-plant interactions. Agriculture and Forest Entomology 3: 153-159.

Hole D.G., Perkins, AJ, Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D. (2005). Does organic farming benefit biodiversity? Biological Conservation, 122: 113-130.

International Trade Centre UNCTAD/WTO (2007). Organic agriculture and climate change. Doc. No. MDS-08-152.E. 30pp.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fired, P., Niggli, U. (2002). Soil fertility and biodiversity in organic farming. Science 296: 1623-1627.

OECD (1997). Environmental indicators for agriculture. OECD, Paris.

Petzoldt, C., Seaman, A. Factsheet on Climate Change Effects on Insects and Pathogens see http://www.climateandfarming.org/clr-cc.php

Pfiffner, L., Niggli, U. (1996). Effects of bio-dynamic, organic, and conventional farming on ground beetles (Col. Carabidae) and other epigaeic arthropods in winter wheat. Biological Agriculture and Horticulture 12: 353-364.

Pfiffner, L, Mäder, P. (1997). Effects of bio-dynamic, organic, and conventional production systems on earthworm populations. Entomological Research in Organic Agriculture. Biological Agriculture and Horticulture Special edition 15:3-10.

Pimentel, D., Hepperly, P., Hanson, J. Douds, D., Seidel, R. (2005). Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience 55: 573–582.

Stolze, M.; Piorr, A.; Häring, A.M., Dabbert, S. (2000) Environmental impacts of organic farming in Europe. Organic Farming in Europe: Economics and Policy Vol. 6. Universität Hohenheim, Stuttgart-Hohenheim.

Williams, R.S. Norby, R.J., Lincoln, D.E. (2001). Effects of elevated CO_2 and temperature-grown red and sugar maple on gypsy moth performance. Global Change Biology, 6: 685-695.

Würth, M., Guiot, J., Bentz, H., Keim, R., Weibel, F. 2002. Abschlussbericht zum ITADA IIbis Projekt 2-1-4: Prüfung krankheitsresistenter neuer Apfelsorten für Tafel- und Industrieobst mit dem Ziel der Reduzierung des Einsatzes von Pflanzenbehandlungsmitteln. Institut Transfrontalier d'Application et de Développement Agronomique. p.23.

Wyss, E. (1995). The effects of weed strips on aphids and aphidophagous predators in an apple orchard. Entomologia Experimentalis et Applicata, 75: 43-49.

Wyss, E. (1996). The effects of artificial weed strips on diversity and abundance of the arthropod fauna in a Swiss experimental apple orchard. Agriculture, Ecosystems and Environment, 60: 47-59.

Wyss, E., Niggli, U., and Nentwig, W. (1995). The impact of spiders on aphid populations in a strip-managed apple orchard. Journal of Applied Entomology, 119: 473-478.

Wyss, E. (1997). Verschiedene Strategien zur Regulierung der Mehligen Apfelblattlaus *Dysaphis plantaginea* im biologischen Obstbau. Mitteilungen der Deutschen Gesellschaft für Allgemeine und Angewandte Entomologie 11: 233-236.

Wyss, E., Villiger, M., and Müller-Schärer, H. (1999). The potential of three native insect predators to control the rosy apple aphid, *Dysaphis plantaginea*. BioControl, 44: 171-182.

Wyss E. and C. Daniel (2004). Effects of autumn kaolin and pyrethrin treatments on the spring population of *Dysaphis plantaginea* in apple orchards. Journal of Applied Entomology 128: 147-149.

Wyss, E., Luka, H., Pfiffner, L., Schlatter, C., Uehlinger, G., Daniel, C. (2005). Approaches to pest management in organic agriculture: a case study in European apple orchards.Cab International: Organic-Research.com, May 2005, 33N-36N.

Yamamura, K., Kiritani, K. 1998. A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Applied Entomology and Zoology 33: 289-298.

Zehnder, G., Gurr, G.M., Kühne, S. Wade, M.R., Wratten, S.D. and Wyss, E. (2007). Arthropod pest management in organic crops. Annual Review of Entomology, 52: 57-80.

FARM MANAGEMENT PLANS IN LAND USE OPTIMIZATION AND BIODIVERSITY PROTECTION

Bořivoj Šarapatka[1], Karolína Dytrtová[2], Stanislava Čížková[2]
[1] Department of Ecology and Environmental Sciences, Palacký University,
tř. Svobody 26, 771 46 Olomouc, e-mail: borivoj.sarapatka@upol.cz
[2] Bioinstitut – Institute for Organic Agriculture and Sustainable Landscape Management, Křížkovského 8, 771 47 Olomouc; e-mail: karolina.dytrtova@bioinstitut.cz

Abstract

Active protection of nature and landscape and its integration into farm management are still not common in the Czech Republic. This paper introduces new approaches to landscape planning on the farm level which are widely used abroad, and presents the potential for their utilization under Czech conditions. The main idea of an individual approach to farms is included in the concept of conservation farm management plans. The basic framework for these plans is so-called ecological compensation areas, which represent valuable biotopes in the agricultural landscape. The presented article also evaluates the quality of grassland as part of the ecological compensation areas. The current subsidies for grassland are discussed and new proposals for payment based on increased species diversity, according to the number of indicator plant species, are also analysed.

Key words: farm management plans, optimization, landscape, biodiversity, grassland, organic farming

Introduction

In the modern information-based society of today people lose their deep sense of belonging to nature and landscape. This cannot be perceived purely from the standpoint of production or scientific exploration, but also as an important part of national identity and historic record. It is the inheritance left to us by our ancestors and we should protect a develop it. If we look around or look at various publications it is obvious that, in our actions, we are neglecting this responsibility. In recent decades the capacity of the agricultural landscape which covers the majority of land in the Czech Republic has been increasing together with increasing production (especially in more fertile areas). We can also see how, in terms of landscape and biodiversity, some plant and animal species have disappeared and many more are becoming less abundant. Moreover, continuous intensification of production has not only had an impact on the landscape and its biodiversity; problems relate to the agricultural system itself as it affects the genetic diversity of farm crops and animals. A number of various programmes aim to reduce the loss of biodiversity but also to integrate diversity into agriculture. This is especially preferred in the organic farming system and integrated agriculture – we call this functional biodiversity utilizable in self-regulation of the agroecosystem.

Material and Methods

The findings on grassland biodiversity discussed in this article are based on detailed floristic-cenological research carried out in 2001 and repeated in 2004 and 2007 in 14 organic agricultural enterprises within the Jeseníky microregion. The methods of farm plans have been verified since 2006 on 9 model organic farms throughout the Czech Republic. The chosen approach to landscape planning on the level of agricultural enterprise was created after consultation with several research institutes dealing with this issue (FiBL Frick, Switzerland; Agroscope Reckenholz-Tanikon Research Station ART, Switzerland; Leibniz Centre for Agricultural Landscape Research (ZALF) Müncheberg, Germany; OIKOS - Institut für angewandte Ökologie & Grundlagenforschung, Austria and others). Last but not least in formulating our findings were interviews with Czech organic farmers who have participated in the nature-friendly farm network project – "Organic Farmers for Nature".

Farm management plans

One of the new trends implemented in landscape planning and nature protection in Europe is the formulation of so-called considerate farm management plans. The effort to restore diverse and multifunctional agricultural landscape, improvement of water quality and protection of biodiversity while respecting its productive function initiated work on methods of Farm Management Plans. This concept has been developing in many countries (e.g. in Austria, Great Britain, Ireland, Netherlands, Germany, Sweden or Denmark), where specialists have realized that the agroenvironmental policy of the 1990s completely altered the situation and that farmers' non-productive activities must be supported. Thus, governments or the EU provide farmers with financial support for their services in the area of nature and landscape protection. Until that time nature protection mainly applied to protected areas with the predominant approach of decisions and rules imposed "from above" – resulting, in most cases, in limited farming activities. Practically no general measures applied for the open countryside. With the introduction of agroenvironmental measures to agricultural policy all farmers were given the opportunity to take part, voluntarily, in the activities to improve the environment and to support the biodiversity of agricultural land. Countries with more experience of agroenvironmental measures soon understood the advantage of individual work with farmers and began to develop methods of drawing up farm plans which help to increase the positive environmental effect of individual enterprises. Many farmers lack the knowledge required to understand the purpose of individual measures and see this only as more subsidies for their work. Therefore the farm plans and personal advisory services on farms provide an irreplaceable role in education and improve the effectiveness of investment in the landscape and the environment.

Rules and decisions imposed „from below“

The character of dialogue and personal approach to farmers or initiating discussion on the multifunctional use of landscape in a specific agricultural enterprise – these are the topics included in the new concept of farm management plans. In practical terms this concept should help to break down barriers between farmers and nature conservationists and bring them together to find common solutions.

In the form of an elaborated plan the farmer is given a detailed manual based on specialist assessment of the land and the farmer's ideas and intentions on how to improve specific plots of farm land. The potential of an integrated approach to landscape management must be highlighted as the farmer has the opportunity to get involved in more subsidy programmes at the same time, with the help of a good advisory service. The plan provides a simple summary of what to apply for and where to apply for support from various programmes relating to protection and restoration of rural areas. Besides this type of information, the plan should also provide advice in production issues – soil maintenance, optimization of crop rotation, advice on plant nutrition etc. The farmer's voluntary participation is the foundation-stone of such farm plans. It depends on the good intention to include the farmer's own views in the specific form of proposed measures. The usual procedure is for specialists to suggest several versions and, after discussion with the farmer; the best compromise is reached between the production interests of the farm and nature protection.

„Tailor-made" proposal of action

The output of the whole process is a formulated plan for implementing action which will optimize the natural and economic conditions of the farm. It is partly a time schedule in which certain activities are given priority, which of these it is appropriate to start with, and in which season etc. The second aspect is the spatial plan where the farm land is divided into various categories requiring different farming methods. Areas of special value are identified – where e.g. rare plant species have been found, and the farmer is instructed how to farm such areas. These "discovered" areas are quite significant for the farmer as they show a new quality of his/her land. Another category includes areas of certain landscape elements which deserve to be preserved and restored (e.g. hedges, balks) where pesticides should not be used or which have an anti-erosion character and thus contribute to preservation of the landscape. The third category comprises places where certain action is necessary to improve ecological conditions of the locality (grassing, revitalization of small ponds etc.) The last category forms the proposal of completely new areas and elements of the landscape which would improve the ecological stability of the landscape within the farm (planting accompanying greenery next to field tracks, founding anti-erosion line elements to be grassed or planted with suitable shrubs or trees etc.). The individual approach and educational character of farm plans are the features which can be utilized in applying agroenvironmental programmes and new grants within the Czech Republic.

The ecological compensation area system within agricultural enterprises

Discussion on so-called ecological compensation areas (ECA) (ecological balancing areas) has started in some European countries in recent years. This means a certain part of the total farm acreage of an enterprise which is established and farmed in such a way so as to create biotopes supporting wildlife. ECAs also contribute to soil and water protection. For example, in Switzerland every agricultural enterprise applying for direct subsidies and other national subsidies must show proof of a certain ECA percentage of their acreage. The ECA system is a binding part of the Swiss concept of Cross Compliance. ECAs must represent at least 3,5% of arable land with special cultures and at least 7% of other farm land of the enterprise. We have begun discussion on ECAs in CZ, and submitted our (Šarapatka, Urban, Čížková, Dytrtová) first proposal for discussion to the Ministry of the Environment. In these ECAs we have also included various types of extensively utilized meadows and pasture land within the Jeseníky microregion which we have been evaluating since 2001 while drawing up proposals for their improvement in terms of biodiversity in relation to subsidy policy.

Evaluation of permanent grassland in organic farms in the Jeseníky microregion

Our evaluation of data collected from 14 farms was based on floristic-cenological research on original grassland (vegetation was never renewed or renovation was carried out 40 or more years ago) and on newly established plots. In various types of grass-herb growth we monitored the difference in the number of species, species diversity, species balance on the plot of land and overall coverage of the herb layer. We also assessed the vitality of the plants.

The collected data shows that a great number of pastures and meadows within the Jeseníky microregion were established after ploughing by sowing common commercial mixes. However, these cannot substitute the original (regional) flora – on the contrary, there is a risk of crossbreeding with local species resulting in the gradual reduction of genetic diversity of meadow vegetation. In most cases the renewed vegetation represented communities of 5-20 species in the first years. If the plots were then farmed extensively, we could register gradual enrichment of species on them during our research.

In meadows and pastures which were intensively farmed within the 7 years of monitoring, we registered a gradual worsening of floral composition in the plant communities. Due to strong eutrophication the pasture vegetation degenerated more rapidly, resulting in monotonous uniform vegetation with a dominance of white clover *(Trifolium repens)* and dandelions *(Taraxacum* sect. *Ruderalia)* while the recorded grasses and herbs disappeared.

Only a very small part of the land in the Jeseníky microregion was occupied by semi-natural pasture and meadows, despite the fact that these play an irreplaceable role. They are the bearers of the original seed material which can be used as additional seeding in the form of hay crumbled into newly established vegetation. A large part of this meadow and pasture land did not register any degeneration in species composition during the course of the research, apart from sites where higher farming intensity was recorded. On the other hand, no improvement in the quality of grassland, in terms of biodiversity, was registered on organically farmed land. The monitored vegetation does not differ from conventional areas.

We consider improvement in species diversity to be very important, especially within the organic farming system and on a selected percentage of the total farmland acreage. The current situation does not yet correspond to this and, in relation to the planned changes in subsidy policy, it will be vital to emphasize quality in terms of biodiversity. How can this be achieved? It might be worth making at least part of the payment conditional, relating to increased species diversity and evaluate such quality according to the number of indicator plant species within the plot. The species must be easily recognizable, not only to specialists. At present, we are drawing up methodology within the framework of farm management plans and verifying the first examples on farms. This will also include a proposal for the indicator plant species for different types of vegetation. The material will be discussed with the Czech Ministries of Agriculture and the Environment and the level of payments should be calculated in cooperation with a specialist institute (the Research Institute for Agriculture. Graduation of payments according to the level of species diversity will, after the system is suitably set for this type of subsidy, provide the opportunity to return a higher percent of biologically more valuable vegetation into the countryside and include such plots in the discussed system of ecological compensation areas. The bonus for species diversity should not only apply in organic agriculture but also in the conventional system. With regard to the low intensity of grassland farming at present, increasing biodiversity on a certain percentage of farmland is a realistic possibility even for conventional farmers.

Conclusion

The methodology of farm management plans and a catalogue of ecological compensation areas suitable for Czech conditions – regarding the structure of farming and the financial instruments currently available – are gradually being verified by Bioinstitut workers in practice, in order to precisely set a suitable method of management for individual types of ECA, or possibly add new areas to the proposed catalogue. In the future this catalogue should help define ECAs in each agricultural enterprise, should include all biotopes occurring within agricultural landscape, e.g. refuges and sites suitable for wildlife, which also function as soil and water protectors. After verification, the proposed instruments will be implemented in the Czech agroenvironmental policy for the next planning period.

Acknowledgment

Elaboration of this task was made possible with the support of grants from the Ministry of Education, Youth and Sports – within its National Research Programme II (2B06101) and the Ministry of the Environment (VaV No. SP/2d3/155/08).

References

Šarapatka, B., Urban, J., Dytrtová, K., Čížková, S. (2007): Doporučení po ekologické zemědělství vedoucí k vyššímu přínosu pro krajinu. Bioinstitut, 59 p. + přílohy

Šarapatka, B., Čížková, S. (2007): Diverzita travních porostů v ekologickém zemědělství ve vztahu k dotační politice. Ekológia trávneho porastu VII, Banská Bystrica: 114 – 117.

Šarapatka, B., Niggli, U. a kol. (2008): Zemědělství a krajina: cesty k vzájemnému souladu. UP Olomouc, 271 p.

SELECTED BIOLOGICAL AND BIOCHEMICAL SOIL CHARACTERISTICS IN ORGANIC AND CONVENTIONAL FARMING

Bořivoj Šarapatka[1], Vratislav Laška[1], Jan Mikula[1], Ladislav Čáp[1], Jiří Petr[2]
[1] *Department of Ecology and Environmental Sciences, Palacký University, Olomouc, Czech Republic*
[2]*Department of Plant Production, Czech University of Life Sciences, Prague, Czech Republic*

Abstract

This paper focuses on research of selected biological and biochemical soil characteristics on an experimental site in Prague – Uhřiněves where an organic farming experiment (organic vs. conventional farming) started 14 years ago. The result of the research shows that the amount of organic matter brought into the soil was a determining factor in both the occurrence of epigeic fauna and biochemical activity. This was shown in the number of millipedes, which process the supplied vegetable material. Another indication was in higher cellulase activity in rape (field), which relates to degradation processes, as well as in ammonification and nitrification. However, not only the supply of organic matter is important, but also physical soil conditions such as aeration. Considerable disturbance of soil (e.g. when hoeing rape) resulted in the occurrence of soil biota which brought better results for the conventional variant. The research proved the complexity and integrity of agro-ecosystems in which individual actions considerably affect biological activity of soil and the occurrence of different groups of fauna, often even without any relation to a certain agricultural system.

Introduction

Intensification of agriculture within recent decades has remarkably affected biodiversity and quality of soil. Arthropods are frequently used as bioindicators for the assessment of landscape and soil quality (Paoletti, 1999; Paoletti *et al*., 1999). Soil organisms are assumed to be directly responsible for processes within the soil ecosystem, especially the decomposition of organic soil matter and the cycle of nutrients (Wardle, Giller, 1997). In organic farming some groups of invertebrates have a higher diversity, such as carabid beetles (Kromp, 1989, 1990), spiders (Feber *et a*l., 1998), and earthworms (Brown, 1999). There is a considerable difference between management of organic and conventional agriculture. Physical disturbance of soil, such as tillage is a detrimental factor for diversity of soil fauna. (Altieri, 1999).

Activity of soil enzymes, as another monitored indicator, can be one of the significant indicators of soil quality (Dick *et al*., 1996). Activity of soil enzymes is determined by numerous other factors in the agro-ecosystem, including the farming system. Besides chemical characteristics (Šarapatka, 2003), physical properties of soil are also very important. Examination of enzyme activity showed significant linear correlation with the content of organic matter in samples of compost-treated soil. (Chang *et a*l., 2007). Organic management resulted in significant increases in total organic carbon and Kjeldahl-N, soil respiration, microbial biomass, and enzyme activity compared with those found under conventional management. (Melero, 2006). Bio-dynamic soils, with the same fertilization intensity, had higher dehydrogenase activity compared to integrated farming systems. Both C_{org} and biological soil quality indicators were clearly dependent on the quantity and quality of applied types of manure, but soil microbial biomass and activity were much more affected than $C_{org.}$ (Fliessbach, 2007).

In our study we focused on research of selected biological and biochemical soil characteristics on an experimental site in Prague–Uhříněves (CZ) where various cultivars and other characteristics in organic vs. conventional farming have been monitored for 14 years (Šarapatka *et al.*, 2008).

Materials and methods

In spring and summer of 2007 we analysed conventional and organic agri-ecosystems in which we monitored epigeic fauna (beetles, harvestmens, spiders, diptera, centipedes, millipedes) and soil biota (beetles, beetle larvae, mites, springtails, centipedes, millipedes) using the pitfall trap method (5 traps to each crop and treatment).. Samples for soil biota evaluation were taken from a depth of 0 – 15 cm and an area of 1/30 m^2. These were consequently processed in modified Tullgren extractors (Tuf, Tvardík, 2005). We also studied activity of soil enzymes (acid and alkaline phosphatase, dehydrogenase, protease, urease, nitrate reductase and cellulase) using methods described in the publication (Schinner *et al.*, 1993).

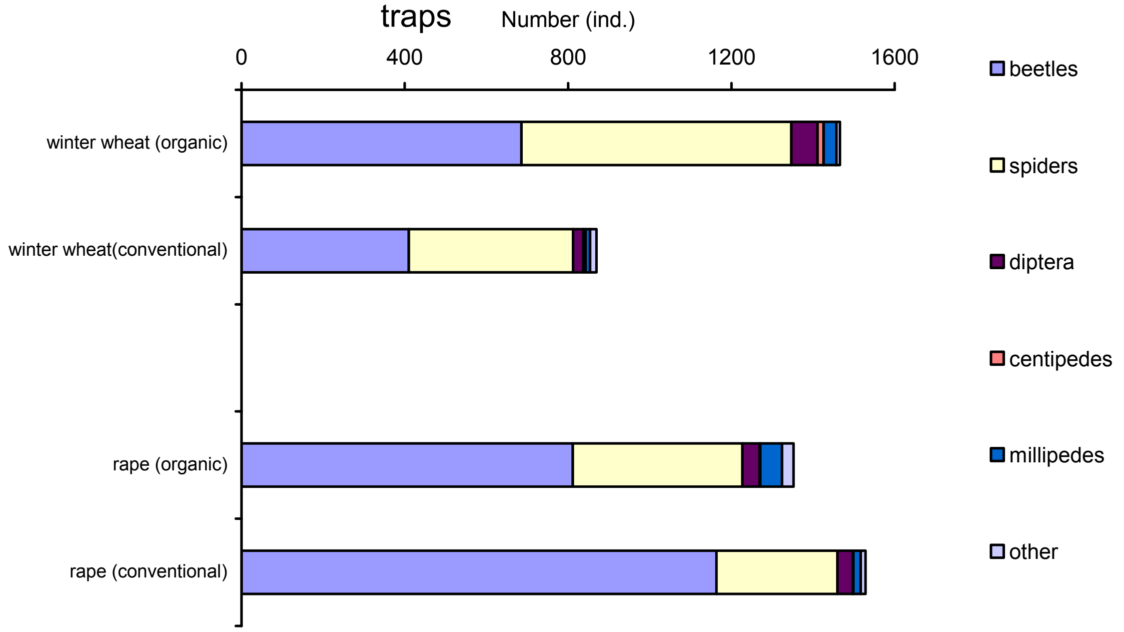
The experimental fields were situated in Prague – Uhříněves, where organic agriculture has been in operation for 14 years. The research was carried out with winter wheat and winter rape. In the conventional farming system both these crops were grown after a grain-leguminous mix, while in the organic farming system the preceding crop was two-year clover, which was mulched and ploughed in. .

Results

Soil invertebrates

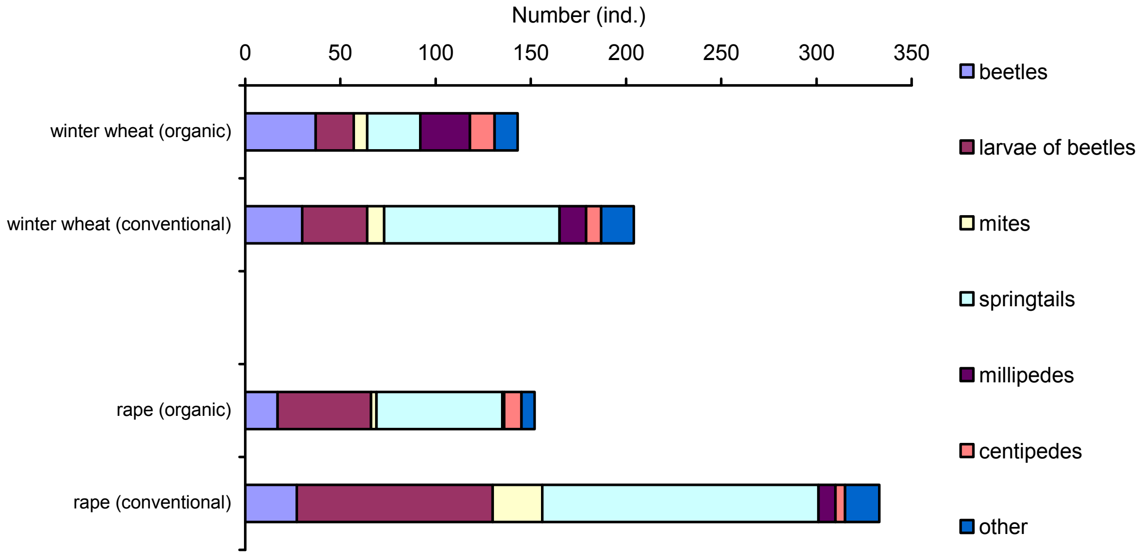
Beetles were the most abundant group in the catch from the ground traps (Fig. 1). In general, the growth of rape was more convenient regarding the occurrence of beetles, especially due to microclimate provided by the growth. A correlating fact is that in the field of rape, with taller plants and denser coverage, the dominance of beetles is most pronounced. This variation was the only one where, regarding the number of beetles, a conventional field beat the organic one. The number of spiders was similar in all cases, and generally wheat was more suitable for them, as they probably did not mind dry conditions so much. Millipedes clearly preferred organic options of both plants, which probably relates to the preceding crop rotation as it brought quite an amount of organic material into the soil and thus provided a rich supply of feed for this type of invertebrates. Diptera, being able to fly, occurred in all variants in relatively equal numbers.

Fig. 1. Total number of captured soil invertebrates in pitfall traps



In soil samples the most numerous group was that of springtails (Fig. 2). Together with beetle larvae and acarina they represent typical soil fauna, which is strongly dependent on chemical and mechanical properties of soil. Such dependence can explain their much denser occurrence in conventional fields, which are not tilled so many times a year. Centipedes, on the other hand, were more abundant in organic variations. Occurrence of beetles was quite balanced in all types of fields. Overall results of the soil sample study show that invertebrates living deeper in the soil rather prefer conventional farming.

Fig. 2. Total number of captured soil invertebrates in soil samples



Enzymes and other biological soil characteristics

Significant differences in the activity of soil enzymes were measured in the wheat crop, namely in nitrate reductase. In organic crop rotation, winter wheat was sown after two-year clover which was mulched and ploughed in. This brought into the soil a considerable amount of organic matter which was broken down by soil biota (increased numbers of millipedes and beetles in ground traps) with possibly more intensive soil respiration. In these conditions, higher activity of nitrate reductase was recorded together with low amount of mineral nitrogen in the soil. The soil probably contained more organic mass rich in N, therefore the nitrification assessment shows that communities of micro-organisms do not react to added N because of higher content of nitrogenous organic matter. In the conventional farming system the level of mineral nitrogen (both ammonium and nitrate) in winter wheat was higher, but due to a change in mineral-N management and probably greater lack of nitrogenous organic matter, communities are more sensitive in reaction to added mineral nitrogen.

The situation with winter rape was different. Although rape also follows mulched and ploughed-in clover in the crop rotation system, the agricultural methods are different (hoeing). The incorporated organic mass was intensively broken down, due to more aeration and better water conditions (compared to wheat the rape growth was more compact). The intensive break-down shows in significantly higher activity of cellulase. Mineral nitrogen content was much the same in both variants – conventional and organic, while ammonification was higher in the latter, which is the result of either a richer or more active microbe community, better disintegration of organically bound nitrogen and creation of ammonium nitrogen as a source for consequential nitrification. Nitrification itself also registered higher levels in organic rape as the community of nitrificators in this variant reacts more sensitively to the supplied ammonium nitrogen which it processes. Thus, the community gets a higher potential and requires a greater source of substrate.

Conclusion

The result of the research shows that the amount of organic matter brought into the soil was a determining factor in both the occurrence of epigeic fauna and biochemical activity, which complies with results published e.g. by Hole et al., 2005, Mäder et al., 2002. This was shown in millipedes, which process the supplied vegetable material. Another proof was in higher cellulase activity in rape (field), which relates to degradation processes, as well as in ammonification and nitrification .

The increased activity of organic agricultural systems, even if enhanced by an increased supply of organic matter into the soil, was not evident in numerous other soil enzymes such as dehydrogenase, which is connected to the general biological soil activity. In relation to soil enzyme activity, wheat in the organic variant created more anaerobic conditions which supported nitrate reductase activity (Dendooven, Anderson, 1995) and also affected ammonification and nitrification. However, not only the supply of organic matter is important, but also soil-aeration, which is more common in organic systems due to more freguent soil tillage. Considerable disturbance of soil (e.g. when hoeing rape) showed in the occurrence of soil biota (Altieri, 1999), which brought better results for the conventional variant. The research proved the complexity and integrity of agro-ecosystems in which individual actions considerably affect biological activity of soil and the occurrence of different groups of fauna, often even without any relation to a certain agricultural system (organic vs. conventional).

Acknowledgement

The authors thank the Czech Ministry of Education, Youth and Sports for supporting their research through grant No. 2B06101 from the National Research Program II, and grants VaV No. SP/2d3/155/08 and 1c/4/8/04 from the Ministry of the Environment of the Czech Republic.

References

Altieri, M.A. (1999): The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment, 74: 19 - 31.

Brown. R.W. (1999): Grass margins and earthworm activity in organic and integrated systems. Aspects of Applied Biology 54: 207 - 210.

Chang, E.H., Chung, E.S., Tsai, Y.H. (2007): Effect of different application rates of organic fertilizer on soil enzyme activity and microbial population. Soil Science and Plant Nutrition, 53 (2): 132 - 140.

Dendooven, L., Anderson, J.M. (1995): Maintenance of denitrification potential in pasture soil following anaerobic events. Soil Biollogy and Biochemistry 27 (10): 1251 - 1260.

Dick, R. P., Breakwell, D. P., Turco, R. F. (1996): Soil enzymes activities and Biodiversity measurements as integrative microbiological indicators. In: Doran, J. W., Jones, J. A. (Eds.): Methods for assessing soil quality. Soil Science Society of America, Inc. Madison, Wi: 247 – 272.

Feber, R.E., Bell, J., Johnson, P.J., Firbank, L.G., MacDonald, D.W. (1998):The effects of organic farming on surface-active spider (Sranda) assemblages in wheat in southern England, UK. Journal of Arachnology 26: 190 - 202.

Flissbach, A., Oberholzer, H.R., Gurst, L., Mäder, P. (2007): Soil organic mater and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture Ecosystems and Environment 118 (1-4): 273 – 284.

Hole, D.G., Perkins, A. J., Wilson, J. D., Alexander, I. H., Grice, P. V., Evans, A. D. (2005): Does organic farming benefit biodiversity? Biological Conservation 122: 113 – 130.

Kromp, B. (1989): Carabid beetles communities (Carabidae, Coleoptera) in biologically and conventionally farmed agroecosystems. Agriculture Ecosystems and Environment 27: 241-251.

Kromp, B. (1990): Carabid Beetles (Carabidae, Coleoptera) as bioindicators in biological and conventional farming in Austrian potato fields. Biology and Fertility of Soils 9: 182 -187.

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U. (2002): Soil fertility and biodiversity in organic farming. Science 296: 1694 – 1697.

Melero, S., Porras, J.C.R., Herencia, J.F., Madejon, E. (2006): Chemical and Biochemical properties in a silty loam soil under conventional and organic management. Soil and Tillage Research 90 (1-2): 162 - 170.

Paoletti, M.G. (1999): The role of earthworms for assessment of sustainability and as bioindicators. Agriculture, Ecosystems & Environment, 74: 137-155.

Paoletti, M.G., Hu Dunxiano, Marc, P., Huang Ninxing, Wu Wenliang, Han Churnu, He Jiahai, Cai Liewan (1999): Arthropods as bioindicators in agroecosystems of Liang Han Plain, Qianjiang City, Hubei China. Crit. Rev. Plant. Sci., 18: 457 - 465.

Šarapatka, B. (2003): Phosphatase activities (ACP, ALP) in agroecosystem soils. Acta Universitatis Agriculturae Sueciae – Agraria 396, 62 p. + app.

Šarapatka, B., Laška, V., Mikula, J., Čáp, L., Petr, J. (2008): Selected biological and biochemical characteristics of soil in a long – term organic farming experiment. Scientia Agriculturae Bohemica, Vol. 39, No 2: 212 – 217.

Schinner, F., Őhlinger, R., Kandeler, E., Margesin, R. (Eds.) (1993): Boden – biologische Arbeitsmethoden. Springer Labor, 389 p.

Tuf, I.H., Tvardík, D. (1995): Heat-extractor – an indispensable tool for soil zoological studies. In: Tajovský, K., Schlaghamerský, J., Pižl, V. (eds.): Contributions to Soil Zoology in Central Europe I. ISB AS CR, České Budějovice: 191 - 194.

Wardle, D.A., Giller, K.E. (1996): The quest for a contemporary ecological dimensi to soil biology. Soil Biology and Biochemistry 28: 1549 - 1554.

Scientific session II.B Soil pollution and water management

INFLUENCE OF PESTICIDES ON THE MICROBIAL DIVERSITY IN THE CAMBISOLS

I. Hudecova[1], **S. Javorekova**[1]
[1]Department of Microbiology, Slovak Agricultural University, Tr. A. Hlinku 2, 949 02, Nitra

Abstract

Effects of addition of pesticides, specifically were evaluated in four fields of cambisol soils (Velka Fatra, Mala Fatra, Donovaly and Dubakovo). Specifically, effects of two pesticides, herbicide Gesagard and fungicide Fundazol, on diversity, structure and activity of soil microbial communities were analysed using the Soil respiration and the Phospholipids Fatty Acid (PLFA) analysis. The similarity between the locations Velka Fatra and Mala Fatra was determined using the Principal Component Analysis (PCA) and the ANOVA method. Other fields, Donovaly and Dubakovo, were significantly different in the first component of PCA (48.32%). The data of Soil respiration showed the same relationship between these locations. Using PCA as well as Soil respiration, significant differences were established between an application of Gesagard and untreated samples. The application of Gesagard decreased the amount of all detected taxonomic groups, whereas an addition of Fundazol increased only the population of fungi. We concluded that there is a linkage between the total amount of bacteria and the microbial activity in particular fields and that the application of Gesagard affects the overall microbial population whereas the addition of Fundazol influences only the population of fungi.

Introduction

Sustainability of soil quality is essential for maintaining the biodiversity and the functioning of terrestrial ecosystems. One of the main factors which decreases the quality of soil and damages the soil structure and community of living organisms is contamination, particularly by more toxic and persistent chemicals. Recently, numerous xenobiotics, which are present in the soil due to an anthropogenic impact and natural emissions, have been identified. A xenobiotic is defined as "a chemical (or chemical mix) which is foreign for an organism and it is not normally produced or expected to be present in it, or it is chemical found in much higher concentration than usual" (Newman and Unger, 2002). Up until now, the international research has been mainly focused on the impact of pesticides on soil ecosystems (Chen et al., 2001a; Burrows and Edwards, 2002; Bellinaso et al., 2003). Various types of pesticides have been used in land management for many years, aiming to maintain the crop productivity and to obtain a higher crop yield. When the pesticides began to be used, there was no research regarding the impact of the application of these pesticides on soil ecosystem. Since discovering that some of the used pesticides were toxic to soil microbial communities, a great effort has been devoted to determining which pesticides are non-toxic to a soil ecosystem. However, the knowledge about the transformation of pesticides in soil, especially fungicides, is still largely unknown. Some of the difficulties are linked to the properties and the structure of a soil ecosystem (Kibblewhite et al., 2008). For this reason, a set of indicators should be used for the measurement of soil health, not only one of these indicators alone (Bloem et al., 2006). However, the final set of indicators which would reflect the land agriculture and the long-term sustainability of soil productivity have not yet been detected. Several characteristics have been proposed to analyse the impact of added xenobiotics, especially pesticides, on soil quality and fertility. These are physical, chemical and biological characteristics. In particular, the biological indicators are most appropriate for measuring the impact of environmental changes, changes in soil utilization as well as the contamination (Gil-Sotres et al., 2005). The main reason is that these indicators are more sensitive to changes occuring in the soil environment. Moreover, the soil organisms are important for soil processes, especially the decomposition of organic matter, forming the soil aggregates, and the nutrient cycles. Several studies suggest that Phospholipid Fatty Acid (PLFA) analysis is a powerful and responsive tool for determination of changes in soil microbial communities (Baath et al., 1992; Frostegard et al., 1993; Drenovsky et al., 2004) in consequence to soil management and contamination. A measurement of concentration of different PLFAs extracted from soil provides a biological fingerprinting of the soil microbial community. The aim of this study was to assess the diversity of soil microbial communities between different locations of cambisol soils and the effects of different treatments (glucose, herbicide Gesagard, fungicide Fundazol) on the structure and diversity of the cambisol soils. In order to be able to explain these data, the soil respiration was also measured.

Material and Methods

The soils were sampled in three reps to a depth of 0 – 10 cm from locations in grassland valleys in Slovakia belonging to the same soil type – cambisol soils. They were Greater Fatra, Lesser Fatra, Low Tatras and the Slovak Ore Mountains. Subsequently, the samples were incubated with four different treatments, glucose, Gesagard, Fundazol and a control sample, at 28 ºC for three weeks. The control samples contained only soil with added water. The effect of glucose on soil microbial community is well-known and has been observed by many scientists (Degens et al., 2001; Griffiths et al., 2001b). The other treatments (Gesagard and Fundazol) were chosen in order to determine their effect on soil microbial communities. PLFA profiles were analysed by the method of Frostegard et al. (1993). The soil samples dissolved in hexane were analysed by Agilent Technologies 6890N G.C. The G.C. equipment identifies FAMEs (particular retention time) of each sample and detects the relative concentration (total area) of individual PLFAs. Data obtained by this technique was statistically evaluated by two methods – analysis of variance (ANOVA) and principal component analysis (PCA) using a software package STATISTICA. The molar % of G^+ bacteria was counted as sum of i15:0, a15:0, i16:0, i17:0 and a17:0. The cyclopropyl and mono cy17:0, 16:1ω7, 18:1ω7 and 17:1ω9 PLFAs are specific for G^- bacteria. Actinomycetes contain PLFAs with methyl group on the tenth carbon atom from the carboxyl end of the molecule (10Me16:0, 10Me17:0, 10Me18:0) in their cell membranes. The 18:2ω6,9 phospholipid fatty acid was used for a detection of fungi in samples (Pawlett, 2002). Soil respiration was measured according to Weaver et al. (1994).

Results

Eighteen different saturated, unsaturated, methyl-branched and cyclopropane PLFAs (14:0, c14:1, i15:0, ai15:0, 3OH 14:0, i16:0, 16:1co5, Me i17:0, i17:0, ai17:0, 17:1, 17:0, 18:0, 18:2w6,9, 18:1w9c, 18:1w7t, 19:1, 19:0c), most of them identified, were used for comparing the different sites and the effects of pesticide treatment. A shift in the microbial composition was evident when the PLFA patterns of samples from different sites were compared by the Principal Component Analysis (Fig. 1). The locations Mala Fatra and Velka Fatra were similar, with a greater variation in Velka Fatra. There were significant differences (P<0.05) between locations Donovaly and Dubakovo, and remaining locations. According to the second component PCA 2, which was accounted for 23 %, the locations were grouped into two clusters. First one involved the sites Donovaly and Dubakovo and the second one contained the locations Velka Fatra and Mala Fatra.

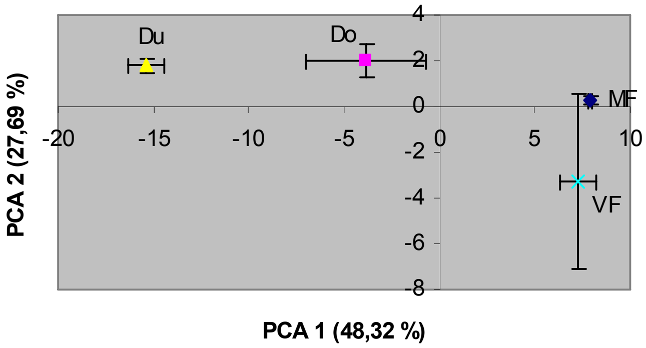


Fig. 1 Evaluation of principal component analysis using ANOVA for different fields Dubakovo (Du), Donovaly (Do), Mala Fatra (MF) and Velka Fatra (VF)

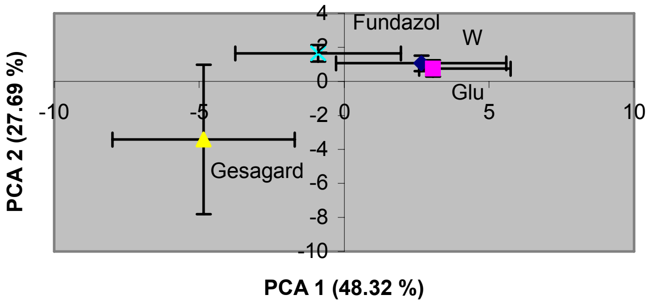


Fig. 2 Evaluation of Principal Component Analysis using ANOVA for the control sample (W) and three different treatments - Glucose (Glu), Fundazol and Gesagard

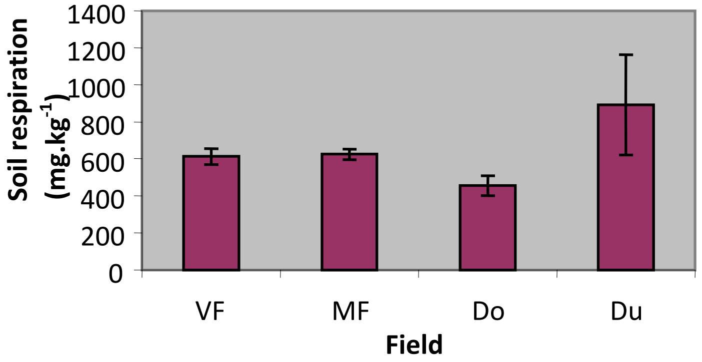


Fig. 3 Different values of soil respiration between fields

The PCA of cambisol soils with the different treatments, according to the first component, accounted for 48.32 % of variation. It showed that the PLFA composition of the soils changed after the treatment with Gesagard (Fig. 2). Other treatments had not significant effect on the soil microbial community. The data of soil respiration provided more knowledge about the differences between the fields and the treatments. The data of soil respiration measured in the fields in Velka Fatra and Mala Fatra were similar. There were significant differences between locations Donovaly and Dubakovo in a comparison to the two remaining fields (Fig. 3).

Moreover, soil respiration in the samples taken from the field in Donovaly was reduced, whereas the same parameter was of greater values in the location Dubakovo. Similarly, the soil respiration was evaluated between different treatments (Fig. 4). Although not always significantly different, the addition of the treatments resulted in an increase of the soil respiration in comparison to the control sample.

The sum of PLFA characteristics of general bacteria, G^+ bacteria, G^- bacteria, actinomycetes, fungi and ratio F/B were used as broad taxonomic microbial groupings (Table 1). Relative concentrations of these taxonomic groups were analysed using one-way ANOVA. The mol % of PLFA characteristics was similar for the control sample and the sample with added glucose. There was a trend showing a lower relative abundance of all determined groups of soil microorganisms in samples treated with herbicide Gesagard. The samples with Fundazol were significantly different (P<0.005) in a comparison to the control samples. Other groups of microorganisms did not show differences of relative abundance in the samples treated by Fundazol. The largest proportional increase in pesticide treatment was found for the taxonomic group of Fungi and the ratio of F/B in the samples with an addition of Fundazol. The largest proportional decrease was present in the samples treated with Gesagard for all taxonomic groups.

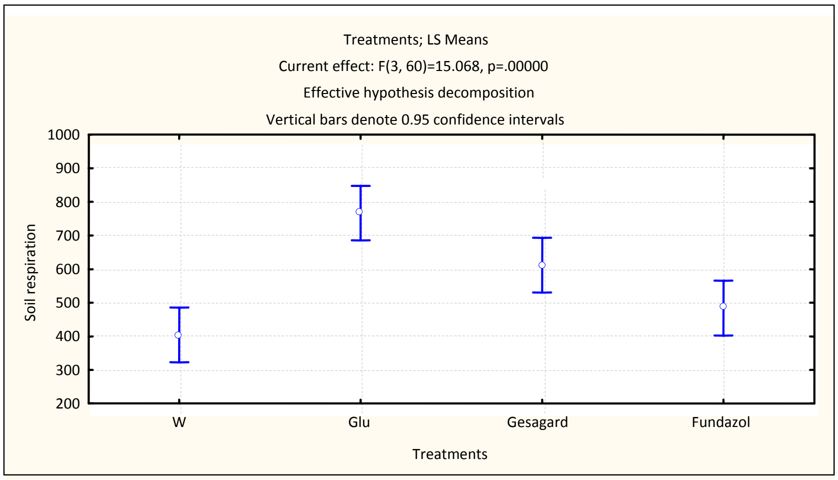


Fig. 4 Different values of soil respiration between treatments

Table 1: Sum of PLFAs used for taxonomic groups of samples with different treatments and ratios of a particular treatment to the control (untreated) sample

Treatment	G+ bacteria	G- bacteria	Actinomycetes	Bacteria (B)	Fungi (F)	F/B
Control (W)	46.15 (2.22)	9.33 (0.60)	9.52 (0.39)	67.11 (2.79)	4.14 (0.81)	0.07 (0.01)
Glucose	46.76 (1,74)	10.12 (0.52)	9.14 (0.34)	65.81 (1.96)	5.57 (0.58)	0.08 (0.01)
ratio Glu/C	1.01	1.09	0.96	0.98	1.35	1.28
Gesagard	38.92 (3.29)	7.69 (0.56)	8.28 (0.61)	57.73 (4.21)	3.95 (0.44)	0.06 (0.01)
ratio Ges/C	0.84	0.82	0.87	0.86	0.95	0.96
Fundazol	44.25 (1.66)	9.46 (0.72)	8.7 (0.51)	64.16 (1.48)	5.97 (0.42)	0.09 (0.01)
ratio Fun/C	1	1.02	0.91	0.96	1.44	1.39

Standard errors of the means (n=3) are given in brackets.

Discussion

In the first part of this conference paper, different fields of cambisol soils (Velka Fatra, Mala Fatra, Donovaly and Dubakovo) were compared. The soil microbial community of these locations has not been investigated before. This is the primary study of these locations. The PCA method showed a similarity between the locations Velka Fatra and Mala Fatra. This similarity was confirmed by a measurement of the soil respiration. According to PCA, the locations Donovaly and Dubakovo were separated. The significant differences between the locations Donovaly and Dubakovo were found using ANOVA. The amount of the total bacteria was higher in the location Donovaly, and was lower in the location Dubakovo (Table 2). This difference was probably the main factor which caused the higher activity of microorganisms in the location Donovaly.

Table 2: Sum of PLFAs used for taxonomic groups of the samples among different fields

Field	G+ bakteria	G- bacteria	Actinomycetes	Bacteria (B)	Fungi (F)	F/B
VF	49.24 (2.55)	9.33 (0.60)	8.99 (0.37)	69.16 (3.17)	4.91 (0.71)	0.07 (0.01)
MF	44.51 (0.70)	11.39 (0.28)	10.90 (0.17)	65.16 (0.30)	6.48 (0.28)	0.10 (0.00)
Do	42.55 (1.79)	8.65 (0.86)	8.03 (0.38)	65.35 (1.87)	4.33 (0.37)	0.07 (0.01)
Du	37.39 (0.68)	8.14 (0.26)	7.55 (0.16)	53.08 (0.79)	4.74 (0.17)	0.09 (0.00)

The impact of pesticides on diversity and structure of soil microbial communities was analysed. Two types of pesticides, herbicide Gesagard and fungicide Fundazol, were chosen. The main reason for the selection of these two pesticides was their potential toxicity to humans, plants and the soil structure. Gesagard (prometryne) is pre- and post- emergence herbicide, which is applied to inhibit growth of annual grasses and broadleaf weeds in a variety of crops including cotton, celery, carrots, parsley and leeks. Fundazol (benomyl) was the first truly used systematic fungicide. It is selectively toxic to microorganisms, especially to saprophytic and parasitic fungi. So far, only little research has been conducted about the influences of these pesticides on the structure and the activity of soil microbial communities. In this research, the pesticides did not have any major effect on the soil microorganisms except for the effect of Gesagard. There were significant differences between Gesagard and the control samples according to first component of Principal Component Analysis (48.32 %). Next analysis, using specific taxonomic groups of microorganisms, showed an decrease of the amount of all the evauated microorganisms (G^+,G^- bacteria, actinomycetes, total bacteria and fungi). However, the activity of microorganisms measured by soil respiration reached higher values in comparison to the control samples. The possible explanation is that some taxa inside of these taxonomic groups, such as Heliobacteria and Cyanobacteria, are susceptible to the effect of Gesagard because of the inhibition of their photosynthesis. Consequently, the reduction of these taxa might have resulted in other taxa, which are proportionally of a lower amount, becoming dominant. These taxa are able to degrade this herbicide and to utilize it as a source of energy, nitrogen and sulphur. For this reason, the intensity of soil microbial processes will increase. According to the results of PCA, an addition of Fundazol did not significantly affect the structure of soil microbial community, with an exception of the population of fungi. Generally, the addition of Fundazol reduced the amount of fungi. The possible explanation of this reduction is that the addition of fungicide kills or inhibits the activity of particular groups of fungi, especially parasitic and saprophytic fungi. This process is linked with a decrease of the function and the number of the soil microbial community. Subsequently, the other living microorganisms are able to degrade the dead cells of fungi as well as fungicide. This leads to an increase of the bacterial activity which was confirmed by the soil respiration data. The obtained data validated the conclusions of Chen et al. (2001a) and Chen et al., (2001b)

Conclusion

All the results indicated the shift of soil microbial communities between different fields and treatments. PLFA patterns showed a similarity of samples taken from locations Velka Fatra and Mala Fatra. The total amount of bacteria is linked with the microbial activity in the locations Donovaly and Dubakovo. The treatments, Gesagard as well as Fundazol, changed significantly the structure and the activity of soil microbial communities. The results of our experiments suggest that an application of Gesagard affect the overall microbial population whereas an addition of Fundazol influences only the population of fungi.

Acknowledgments

The authors would like to thank Jim A. Harris and M. Pawlett for their theoretical and practical assistance. This research was partly supported by a grant of the School of Applied Sciences, Cranfield University, and Slovak grant agency VEGA No.1/3459/06 and KEGA No. 3/6228/08

References

NEWMAN, M.C. - UNGER M.A. 2002. Fundamentals of ecotoxicology. USA: CRC Press, p. 458.

CHEN, S.K - EDWARDS, C.A - SUBLER, S. 2001a. A microcosm approach for evaluating the effects of the fungicides benomyl and captan on soil ecological processes and plant growth. In: App. Soil Biol., vol. 18, pp. 69-82

CHEN, S.K. - EDWARDS, C.A - SUBLER, S. 2001b. Effects of the fungicides benomyl, captan and chlorothalonil on soil microbial activity and nitrogen dynamics in laboratory incubations. In: Soil Biol. Bioch., vol. 33, pp. 1971-1980.

BURROWS, L. A. - EDWARDS, C.A. 2002. The use of integrated soil microcosms to predict effects of pesticides on soil ecosystems. In: Eur. J. Soil Biol., vol. 38, pp. 245-249

BELLINASO, M.L. – GREER, CH. W. – PERALBA, M.C. et al. 2003. Biodegradation of the herbicide trifluralin by bacteria isolated from soil. In: FEMS Microbiol. Ecol., vol. 43, pp. 191-194

KIBBLEWHITE, M.G. - RITZ, K. - SWIFT, M.J., 2008. Soil health in agricultural systems. In: Phil. Trans. R. Soc. Lond. B Biol. Sci., vol. 363, pp. 685-701.

BLOEM, J. – SCHOUTEN, A.J. – SÖRENSEN, S.J. et al. 2006. Monitoring and evaluating soil quality. In: *Bloem, J. – Hopkins, D. – Benedetti, A. (eds.): Microbiological methods for assesing soil quality*. Wallington: CABI, pp. 23 -49.

BAATH, E. – FROSTEGARD, A. – FRITZE, H. 1992. Soil bacterial biomass, activity, phospholipid fatty acid pattern, and pH tolerance in an area polluted with alkaline dust deposition. In: App. Environ. Microb., vol. 58, pp. 4026-4031.

DRENOVSKY, R.E. – ELLIOTT, G.N. – GRAHAM, K.J. – SCOW, K.M. 2004. Comparison of phospholipid fatty acid (PLFA) and total fatty acid methyl esters (TSFAME) for characterizing soil microbial communities. In: Soil Biol. Bioch., vol. 36, pp. 1793-1800.

FROSTEGARD, A – TUNLID, A – BAATH, A 1993. Phospholipid fatty acid composition, biomass, and activity of microbial communities from two soil types experimentally exposed to different heavy metals. In: Appl. Environ. Microb., vol. 59, pp. 3605 - 3617.

PAWLETT, M. 2002. The interaction between earthworms, liming and soil microbial community diversity and function in upland grassland. London: University of East London, 2002.

WEAVER, R.W. 1994. Methods of Soil Analysis, Part 2: Microbiological and Biochemical Properties. Madison: Soil Science Society of America.

LANDSCAPE AREA OF DRY POLDER BEŠA AND ITS USING

[1]**Kováč, L.**, [1]**Kotorová, D.**
[1]*Slovak Agric. Res. Centre – Inst. of Agroecology, Špitálska 1273, Michalovce, Slovak Rep., 07101, E-mail: kovac@scpv-ua.sk, kotorova@scpv-ua.sk*

Abstract

In years 2006–2007 research was oriented to area of dry polder Beša. Methods of ground survey, analyze, synthesis, deduction and estimation were used at solution of this problematic. At perennial swards abandonment signs were valued by advancement index as follows: 0 – starting dilapidation; 1 – advanced dilapidation; 2 – marked dilapidation based on overgrowing with self-seeded forest and shrubs. Botanical composition of perennial swards was made by method of reduce projective dominance. Aim of solution was to characterize dry polder Beša, to determine possibilities of its agricultural using, to identify individual sections and to divide of area on parts for facilitating of ground survey of this area in further time. On perennial swards abandonment signs and botanical compositions of swards were evaluated. From agriculturally using areas arable land presented 146.05 ha, mainly marginal ascent sites only partially overflowing in dependence on saturated water in polder. Perennial grassland with acreage 638.41 ha is dominant. At evaluation of botanical composition of sward favourable share of grasses of sward was determined. Low presence of legumes was ascertained. Share of legumes increased to 13 % after three years of cutting using of sward. Low legumes share in polder Beša had connected with overflowing of this area in year 2006.

Introduction

Retention reservoir Beša is very interesting area from point of view of water, landscape, ecological and agricultural. Non-regularly ecological stability of polder Beša is disturbed by its artificial overflowing in time of special flood situations. Artificial overflowing has significant effect on soil properties, on soil water regime and also on floristic changes of grasses stands in polder Beša (Kotorová et al., 2007; Kováč et al., 2007). The grasses ecosystems in dry polder Beša have the highest acreages. The aim of this research was obtained starting information for further specification of agroecosystems in dry polder Beša.

Material and Methods

In years 2006–2007 research was oriented to area of dry polder Beša, which is situated in south part of Michalovce district. Polder is dry retention reservoir with capacity 53 million m^3 and its area is 1 568 ha. Polder decrease flood wave till about 600 $m^3\ s^{-1}$.

Methods of ground survey, analyse, synthesis, deduction and estimation were used at solution of this problematic. Primary and secondary information were used, too. Source of primary information were basic documents obtained from workers of Slovak Water Enterprise – Catchment of Bodrog and Hornád rivers, enterprises subjects producing in service area, workers of Protected Landscape Area Latorica and from inhabitants of community Beša. Map documents from Soil Science and Conservation Research Institute, basic documents of Slovak Water Enterprise – Catchments of Bodrog and Hornád rivers, materials and documents of Ministry of Agriculture, Ministry Environment of Slovak Republic, Slovak Agricultural Paying Agency and others were source of secondary information.

At perennial swards (PS) abandonment signs were valued by advancement index as follows: 0 – starting dilapidation; 1 – advanced dilapidation; 2 – marked dilapidation based on overgrowing with self-seeded forest and shrubs. Botanical composition of perennial swards was made by method of reduce projective dominance (Braun-Blanquet, 1964).

Aim of solution was to characterize dry polder Beša, to determine possibilities of its agricultural using, to identify individual sections and to divide of area on parts for facilitating of ground survey of this area in further time. On perennial swards abandonment signs and botanical compositions of swards were evaluated.

Results and Discussion

In year 2006 saturation of polder with water from river Laborec significantly effected of ground survey. Start of polder saturation was noted on 31. March 2006 and 11 10^6 m^3 of water were intercepted and it was approximately 20 % from retention capacity of polder. And that ground survey was realised from polder barrage and continued in individual parts by moisture conditions of polder area. Because of gravity parameters, only minor part of water was give back to river Laborec from polder across exit object. Sites at saturation (simultaneously exit) object are localized with altitude 98.40 – 99.19 m, but in other polder parts with altitude 97.50 – 98.70 m and that lands may be used for agricultural activities till after evaporation of water level in polder. Because evaporated of water is irregular and that in time of overflowing on some sites is not possible to enter during whole year.

Table 1: Structure of land found of dry polder Beša

Structure	ha	%
Farm land	784.46	50.03
From it: arable land	146.05	18.62
perennial sward	638.41	81.38
Other area	783.54	49.97
Total acreage	1 568.00	100.00

Total area of dry polder Beša is 1 568 ha. On base of orthophotomaps in agro-system 784.46 ha are used, what is 50.03 % from total area. Other area in polder consist of ash-elm-oak meadow forests, game refuges of trees and bushes, various depression areas without agricultural using, standing water areas in different parts of polder, morasses, channels, land ways etc.

These is protected site included in „Natura 2000“ network in Beša polder, totaling 2.65 ha, with biotypes and species, which have been protected – vegetation of plants from class *Littorelletea uniflorae* and *Isoeto – Nanojuncetea*, frog *Bombina bombina* L. and precious floating plant *Marsilea guadrifolia* L.

From agriculturally using areas arable land presented 146.05 ha (18.62 %), mainly marginal ascent sites only partially overflowing in dependence on saturated water in polder.

Perennial grassland with acreage 638.41 ha (81.38 % from total polder area) are dominant. It is marshy meadows on alluvium of rivers and which are overflowing or wet. Once or several times during year character conservation of meadows on this area is conditional with flood, or high level of water. Stands consisted foxtails from phytocenological unit *Cnidion venosi*, *Alopecurion pratensis* and association *Alopecuretum pratensis*.

Individual sites presented large heterogeneity. Water in separate parts of polder retreated irregularly and aggressive of self-seeding of wood species was dissimilar, too. From argument of large polder acreage and greater distances between individual sites, polder area was divided into four parts as follows: northern, central, southern, eastern parts.

On months May and June 2007 ground survey continued with evaluation of signs of abandonment by advancement index, what manifested by bark pocket of forest and shrubs. On other sites botanical composition of sward was valued. On September 2007 using of sward in concrete year was valued.

Table 2: Perennial swards evaluation in polder Beša by individual parts in year 2007

Parameter		Part of polder			
		Northern	Central	Southern	Eastern
Area of perennial swards [ha]		165.42	124.92	218.69	129.38
Altitudes [m]		98.19 – 101.59	97.93 – 98.30	97.43 – 100.00	98.13 – 101.09
Signs of abandonment [ha]		0	0	71.90	73.61
Advancement index	0 [ha]	0	0	0.98	17.70
	1 [ha]	0	0	70.92	55.91
	2 [ha]	0	0	0	0
Botanical evaluation of sites [ha]		165.42	124.92	146.79	55.77
Botanical composition [%]	Grasses	70.5	52.7	76.8	63.8
	Legumes	4.2	5.0	2.5	0.7
	Other herbs	24.4	38.2	15.3	27.3
	Bare ground	0.9	4.1	5.4	8.2
Utilised areas [ha]		165.42	108.72	146.79	38.71
No-utilised areas [ha]		0	16.20	71.90	90.67

In northern part of polder perennial grassland present 165.42 ha. At using of swards by cutting processes of negative succession was not determined. Hay was taken from sites. In swards grasses were in majority and were on 75 % of area after cuttings. Grasses in sward from 95 till 99 % had *Alopecurus pratensis* L. From other grasses was identified *Poa compressa* L. (only 1 – 3 % presence). From legumes only *Vicia cracca* L. was presented. From other herbs very importantly were presented as follows: *Galium boreale* L., *Ranunculus repens* L., *Carex ssp.*, *Taraxacum officinale* Weber in Wiggers and *Cirsium arvense* L.Scop.

In central part of polder from total area 124.92 ha for cutting were used 108.72 ha. Only on acreage 16.2 ha was not made no agrotechnics arrangements. Botanical composition of sward was less favourable than in northern part of polder. Presence of grasses was 52.7 % and other herbs had high content – 38.2 %. At grasses dominant components was *Alopecurus pratensis* L. (70 – 80 %), further *Poa compressa* L. (10 – 15 %) and grasses from family *Juncaceae*. From *Fabaceae* in this part of polder were as follows: *Vicia cracca* L. (75 – 90 %), *Trifolium pratense* L., *Trifolium repens* L. The other herbs, as follows *Galium boreale* L., *Tithymalus lucidus* Waldst. et Kit., *Leucanthemum vulgare* lamk., *Aristolochia clematitis* L., *Lychnis flos - cuculi* L., *Carex ssp.*, *Pulicaria vulgaris* Gaertn., had significant representation.

Abandonment signs were marked in southern part of polder, where on 71.9 ha of acreage process of succession was shown and from it on 70.92 ha advanced stage of dilapidation was determined. On used sites, in comparison with other part of polder, the highest presence of grasses (76.8 %) was determined. But low presence of legumes (2.5 %, only *Vicia cracca* L.) and no presence of clover crops were determined. Grass *Alopecurus pratensis* L. was dominant (75 – 90 %) in this part of polder. From other grasses were presented only *Poa compressa* L. and family *Juncaceae*. In northern part of polder, so as in central part, the same species of herbs were dominated.

The biggest abandonment signs were ascertained in eastern part of polder. From total area 129.38 ha no-favourable tendencies of abandonment and follow succession of wood species on acreage 73.61 ha (56.7 % from area) were determined. In higher stage of succession is visible on 55.91 ha. Botanical evaluation was made on 55.77 ha. In typical float grass sward minimum presence of *Fabaceae* (only *Vicia cracca* L.) was determined. From grasses *Alopecurus pratensis* L. (90 – 98 %) and less *Juncus ssp.* were presented.

At evaluation of botanical composition of sward favourable share of grasses of sward was determined. Low presence of legumes was ascertained (in average 3.1 %) and it was yet less than found Novák (2006) and Hanzes et al. (2007). Share of legumes increased to 13 % after three years of cutting using of sward. Low legumes share in polder Beša had connected with overflowing of this area in year 2006.

Conclusion

Critical situation on water flows of the East-Slovakian Lowland and followed polder saturation with water in 2006 have effect to research of dry polder Beša. During whole vegetation water in polder was presented, and that ground survey non-enabled consequential.

From monitoring resulted, that perennial grass stands are represented with foxtail stands from association *Alopecoretum pratensis*. In 2007 ground survey continued. Demonstrations of disposing of sites in south part of polder (acreage 71.9 ha) and in east part of polder (acreage 73.61 ha) were determined. On other areas of perennial grass stands was ascertained its floristic composition. Presence of grass component was favourable in north, south and east part of polder (63.8 – 76.8 %). Leguminosae (*Fabaceae*) had low portion in stands with nearly 100 % presence of bird's tare (*Vicia cracca* L.) on 0.7 – 5.0 % of areas. Herbaceous community had the most expressive representation in central part of polder (38.2 %).

Acknowledgments

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0477-06.

References

BRAUN-BLANQUET, J. 1964. Pflanzensoziologie. Gründzuge für vegetationskunde, springerverlag. Wien New York, 1964. 864 s.

HANZES, Ľ. et al., 2007. Zmeny druhovej diverzity TTP na terasových pásových poliach v Nízkych Tatrách. In: Súčasnosť a perspektívy krmovinárskeho výskumu a vzdelávania v multifunkčnom využívaní krajiny. Zborník referátov. Nitra : SPU, 2007, s. 45-49. ISBN 978-80-8069-929-1

KOTOROVÁ, D. et al., 2007. Variabilita pôdnych vlastnosti v suchom poldri Beša. In: Transport vody, chemikálií a energie v systéme pôda – rastlina – atmosféra :

15. posterový deň s medzinárodnou účasťou. Bratislava : ÚH SAV, GFÚ SAV, 2007, s. 276-282. ISBN 978-80-89139-13-2.

KOVÁČ, L. et al., 2007. Využitie trvalých trávnych porastov v suchom poldri Beša. In: Ekológia trávneho porastu VII : Zborník príspevkov z medzinárodnej vedeckej konferencie. Banská Bystrica : SCPV – VÚTPHP, 2007, s. 310-313. ISBN 978-80-88872-69-6.

NOVÁK, J. 2006. Bonitácia využívaných trávnych porastov Západných Karpát. In: Trávne porasty – súčasť horského poľnohospodárstva a krajiny. Zborník referátov. Banská Bystrica : SCPV - VÚTPHP, 2006, s. 40-44. ISBN 80-888-72-56-1

TRANSPIRATION REGIME AND BIOMASS PRODUCTION

V.Novák[1], J. Vidovič[2]
[1]Institute of Hydrology, Slovak Academy of Sciences, Račianska 75, 831 02 Bratislava 3, Slovakia.
E-mail: novak@uh.savba.sk
[2]Bulharská 22, 91701 Trnava, Slovakia. (Previously Research Institute of Plant Production, Piešťany, Slovakia)

Abstract

This paper presents a method for estimating plant production as a function of the seasonal transpiration rate calculated retrospectively with the HYDRUS-ET software package. This approach is based on frequently published linear empirical relationships between seasonal transpiration rates of particular canopy and biomass production (yield). Novelty of this approach is the use of an empirical relationship between seasonal transpiration and yield, which leads to relatively simple method of yield evaluation with acceptable accuracy.

The cumulative frequency distribution of seasonal transpiration was chosen as the basic characteristic of the soil water regime. This approach allows one to estimate cumulative frequency curves of actual and potential yields. The difference between these two curves is the cumulative frequency distribution of yield to be optimized by the irrigation system.

The method permits a better cost-benefit analysis by comparing expected yield increases with the investment and operational expenses of the newly designed irrigation system, or of newly invoked water management practices.

Key words: soil water regime, transpiration, biomass production, mathematical modeling

Introduction

Soil water is only one of many preconditions to influence biomass production. It is known, that irrigation as one of the methods of soil water regime optimisation is contributing to the biomass production significantly. About 20 percent of irrigated soils of the world is producing more than 40 percent of plant production. Those soils are located mainly in arid or semiarid zones. A key step in design and implementation of irrigation or drainage system is to diagnose the existing (natural) soil water regime and possible influence of its optimisation on biomass production increase.

Is not easy to relate directly the soil water content to biomass production, therefore it is necessary to look for another ways of expression the relation between biomass production and soil water influence on it. Plant production can be evaluated by use of so called "crop growth models", calculating assimilation rate as a complex function of environmental parameters, which is difficult to estimate; those models are usually canopy oriented: WOFOST (van Diepen etal., 1989), MACROS (Penning de Vries et al., 1989), DAISY (Hansen et al., 1990). The soil water influence on plant production is expressed roughly there and they are not suitable to evaluate soil water regime influence on yields. Because direct and unambiguous relationships soil water content (soil water potential) – growth rate (biomass production) were not found, researchers tried to find another ways of expressing quantitatively the role of soil water in biomass production. One of proposals was to characterize the influence of soil water on plant production using transpiration as an integral part of production process. This approach is used in MACROS model too.

Results of numerous measurement in vitro conditions demonstrated the low variability ratio of assimilation and transpiration intensity under given conditions (Hsiao, 1993). From it follows linear relation between photosynthesis and biomass production rate. In reality, results of field measurements has shown linear relationship between plant production and transpiration total during vegetation period of particular plant.

A quantitative assesment of the influence of soil water in the soil root zone on biomass production can be made using well-known and widely accepted empirical relationships between biomass production (yield) and transpiration total during the growing season of a given crop (Hanks and Hill, 1980, Vidovič and Novák, 1987, Feddes et al., 1999, Kirkham, 2005). These relationships, generally thought to be approximately linear, are valid for a particular plant (canopy) at a particular site subject to standard tillage and nutrition conditions. The only transient characteristic is the transpiration rate as influenced by local meteorological conditions and soil water. The relationship between biomass production (yield) and the seasonal transpiration rate can be expressed by the linear equation.

The aim of this paper is to find the curve of exceedance of seasonal transpiration totals and corresponding yields of three important crops – maize, winter wheat and spring barley grown in conditions of South Slovakia and thus evaluate the variability of yields and their possible increase by optimizing of soil water regime.

Theory

Rate of photosynthesis, expressed by the rate of carbon dioxide consumption by plant can be expressed by the equation (Bierhuizen, Slayter, 1964)

$$P = \frac{\Delta c_{ou}}{r_{ac} + r_{sc} + r_m} \tag{1}$$

P – photosynthesis rate [kg m^{-2} s^{-1}]

r_{ac} , r_{sc}, r_m - resistance (aerodynamic) of an air boundary layer adjacent to the leaf surface, stomata resistance and mesophyll resistance to carbon dioxide transport from leaf to atmosphere [s m^{-1}]

Δc_{ou} – mass concentration difference of carbon dioxide between leaf (after carboxylation) and atmosphere [kg m^{-3}]

Transpiration rate can be expressed by the equation (van Honert, 1948)

$$E_t = \frac{\Delta c_v}{r_a + r_s} \tag{2}$$

E_t – transpiration rate [kg m^{-2} s^{-1}]

r_a , r_s - resistance (aerodynamic) of an air boundary layer adjacent to the leaf surface, stomata resistance to transport of water vapour from leaf to atmosphere [s m^{-1}]

Δc_v – mass concentration difference of water vapour between leaf and an atmosphere [kg m^{-3}]

By combination of equations (1) and (2) we can get

$$\frac{E_t}{P} = \frac{r_{ac} + r_{sc} + r_m}{r_a + r_s} \frac{\Delta c_v}{\Delta c_{ou}} \qquad (3)$$

Aerodynamic and stomata resistances are complex functions of plant properties and are changing in time. For particular plant, environment and time interval as an approximation can be assumed constant ratio of both types of resistances, as it is expressed by the first part of the right side of the equation (3) and it can be expressed as A´. Then, photosynthesis rate can be expressed as

$$P = \frac{E_t}{A'} \frac{\Delta c_{ou}}{\Delta c_v} \qquad (4)$$

The difference of carbon dioxide concentration between atmosphere and mesophyl is not changing significantly during the vegetation period, it can be expressed as a constant too

$$A = \frac{\Delta c_{ou}}{A'} \qquad (5)$$

then we can get

$$P = A \frac{E_t}{\Delta c_v} \qquad (6)$$

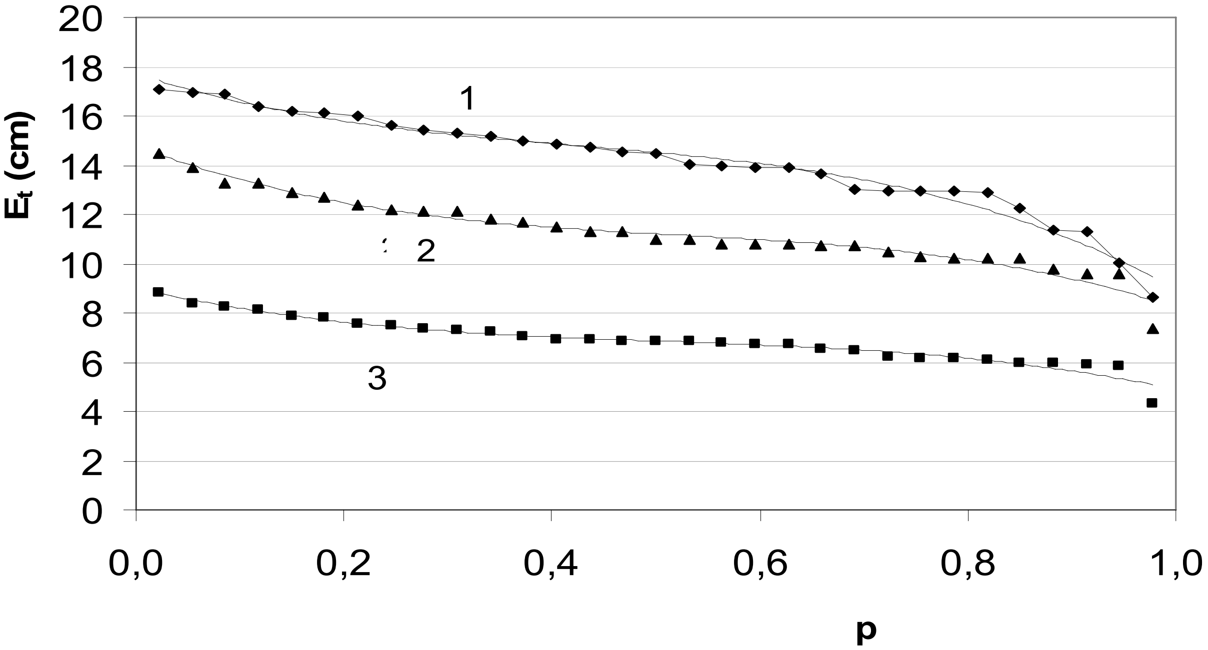
term *B* is the ratio

$$B = A / \Delta c_v \qquad (7)$$

Finally, it can be written equation for photosynthesis rate *P* as proportional to plant transpiration rate E_t

$$P = B.E_t \qquad (8)$$

Where term *B* is in physiological literature usually expressed as transpiration efficiency, its value depends on photosynthesis type (for C3 type B = 0.002 – 0003, for C4 type B = 0.004 mol CO2 / mol H2O).
This equation (8) is an expression of linear relation between photosynthesis rate and rate of plant transpiration. Approximative approach to the development of this equation lead to the robust but simplified relationship, neglecting a lot of important properties of an environment. Nevertheless, this approach is extraordinary feasible for practical purposes. Nowadays, there are relative reliably methods of transpiration estimation, mostly based on Penman – Monteith approach (Budagovskij, 1981, Novák, 1995, Allen, et al., 1998). So, the above mentioned called growth models, allowing biomass production modelling using photosynthesis evaluation, need many not easy acquired inputs and they are usually single type canopy oriented (Hansen et al., 1990).



plant; meteorological characteristics were changed only and they were measured at meteorological stations.

Simulation model HYDRUS – ET - version 1- (Šimůnek et al., 1997) was used. It is modification of well – known one dimensional model HYDRUS (version 6.1) and HYDRUS1D with interactive graphical interface. This programme is based on governing Richards equation describing transport of water in variably saturated porous media and convective – dispersion equation for transport of solute and heat as well. Richards equation involves the term to calculate, water extraction by roots. Subroutine describing rain and irrigation water interception as well as evapotranspiration and its components calculation is a part of the model HYDRUS – ET. Modified version of the Penman – Monteith and Budagovskij method for calculation of evapotranspiration was incorporated in the model used (Novák, 1995).

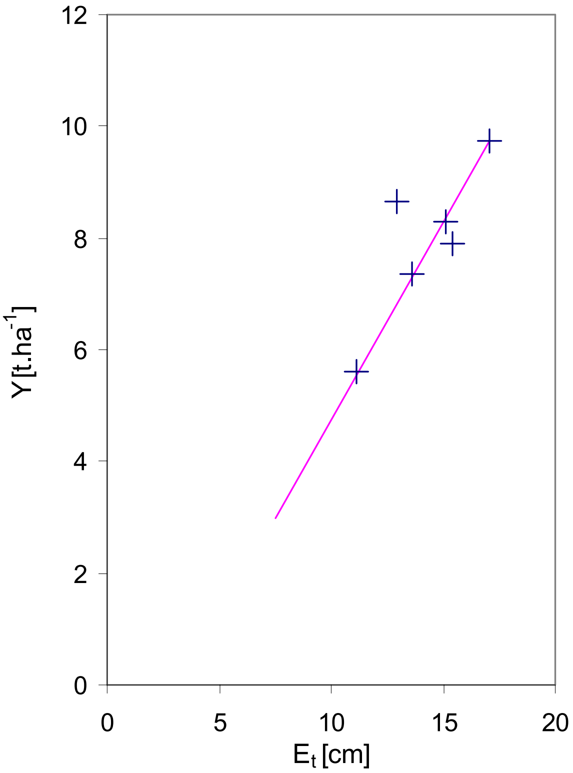


Fig.2. Dry maize grains yield *Y* and transpiration totals of maize E_t, during its vegetation period$_t$. Empirical relationship represents 5 seasons within the time interval 1971-2000 a 2003. Most pri Bratislave site, South Slovakia.

Soil

The basic characteristics of soil used in simulation procedure are in table 1.

Table 1: Charakteristics of sandy loam soil (Haplic Chernozem) at Most pri Bratislave, Southern Slovakia (Experimental field of Hydromeliorácie, s.e., Bratislava).

θ_v	$[m^3\ m^{-3}]$	0.18
θ_{la}	$[m^3\ m^{-3}]$	0.28
θ_{fc}	$[m^3\ m^{-3}]$	0.35
θ_s	$[m^3\ m^{-3}]$	0.4
K	$[m\ s^{-1}]$	$5.6.\ 10^{-7}$
α	[-]	0.0577
n	[-]	1.299

θ_v – volumetric soil water content corresponding to the wilting point $[cm^3cm^{-3}]$, θ_{fc} – soil water content corresponding to the „field capacity“$[cm^3cm^{-3}]$, θ_s – water content of the saturated soil $[cm^3cm^{-3}]$, θ_{la} - volumetric soil water content corresponding to the “limited availability” of soil water by plants $[cm^3cm^{-3}]$ K_s – hydraulic conductivity of the soil saturated with water (saturated hydraulic conductivity) $[m.s^{-1}]$, α $[cm^{-1}]$ and n [-] – van Genuchten’s equation coefficients (Genuchten, 1980).

Canopies

Three types of plants (canopies) were chosen for analysis: maize, winter wheat and spring barley. The only source of water were precipitation, no irrigation was used. Duration of growth seasons of particular plants (Tab.2) were different; different were seasonal transpiration totals too. Actual growth period of winter wheat is longer than it is noted in the table, which does not include autumn and winter period of growth. It is assumed transpiration during winter period and plant production is not significant, the most influential period is „hot“ period.

Table 2: Seasons duration of plants

Plant	**Growth period**	**Number of days**
Maize	May 5 – September 16	134
Winter wheat	April 1 – June 25	86
Spring barley	April 7 – June 25	79

Results and discussion

Three types of plants (canopies) were chosen for analysis: maize, winter wheat and spring barley. Transpiration totals E_t were calculated retrospectively for 31 seasons (Fig.1). They are presented as empirical curves of exceedance for years 1971–2000 and 2003, the last was extraordinary hot. Length of vegetation periods of winter wheat and spring barley are close, but transpiration totals are quite different (tab.3). Reasons are natural; meteorological conditions during their vegetation periods are different. Precipitation totals and air temperature are the most important factors. Winter wheat stage of ontogenesis during early part of spring vegetation period allowed quite different –higher - transpiration and growth rate.

Tab.3 presents characteristics of transpiration of the three canopies under study in season of years 1971 –2000 and 2003. Minimum transpiration totals were calculated for all the three canopies in year 1988, maximum transpiration totals were calculated for cereals in 1996, but yield of maize was the lowest (as well as transpiration total) in the season 1985. The reason of it was high precipitation total during the second part of the year 1996. It confirms quantitatively well known empirical information: particular vegetation period is of different suitability for different canopies.

Table 3: Transpiration characteristics of different canopies during their vegetation period.. Average values vere calculated from 31 years results of modeling. (E_t is seasonal average transpiration total, E_{tp} seasonal average potential transpiration total, $E_{t,d}$ daily average transpiration total, $E_{t,max}$, $E_{t,min}$ are daily averages transpiration total in season with maximum and minimum seasonal transpiration totals.

Canopy	E_t mm/year	E_{tp} mm/year	E_t / E_{tp}	$E_{t,d}$ mm/year	$E_{t,max}$ mm/day	$E_{t,min}$] mm/day
Maize	144	161	0,88	1,07	1,27	0,64
Winter wheat	113	148	0,78	1,13	1,68	0,85
Spring barley	68,9	82	0,83	0,87	1,1	0,55

Empirical curve of exceedance of dry grain yields *Y* of maize canopy (1), winter wheat (2) and spring barley (3) during the seasons in years 1971-2000 a 2003, Most pri Bratislave site is shown in Fig.3. Curves of exceedance in Fig. 3 were calculated using relationship presented in Fig. 2. This empirical relationship is relating weight of dry maize grains yield *Y* and transpiration totals of maize, during its vegetation period E_t. This empirical relationship represents 5 seasons within the time interval 1971-2000 and 2003. Such type of relationships were estimated using field data even for other two canopies (not shown here).

The optimal soil water regime for plant growth is, when soil water content is not limiting transpiration, i.e. when there is potential transpiration. Exceedance curves of the corn grain yield (Y) and the calculated potential yield (Y_p), and the difference (ΔY), for the 1971-2000 and 2003 growing seasons at Most pri Bratislave calculated from corresponding exceedance curve of potential transpiration totals E_{tp}, (Fig.4) demonstrates realtively low capacity of soil water regime otimisation for the corn grain yield increase. The average corn grain yield (Y) was estimated to be 7.64 t ha^{-1}, and the average potential yield (Y_p) 9.03 t ha^{-1}. This means that the difference was ΔY =1.4 t ha^{-1}, which represents 18% of the average yield. The question now arises whether or not it would be reasonable (cost-effective) to design and operate an irrigation or drainage system that will optimize the soil water regime such that the dry grain yield increases by some of all of the 1.4 t ha^{-1} difference.

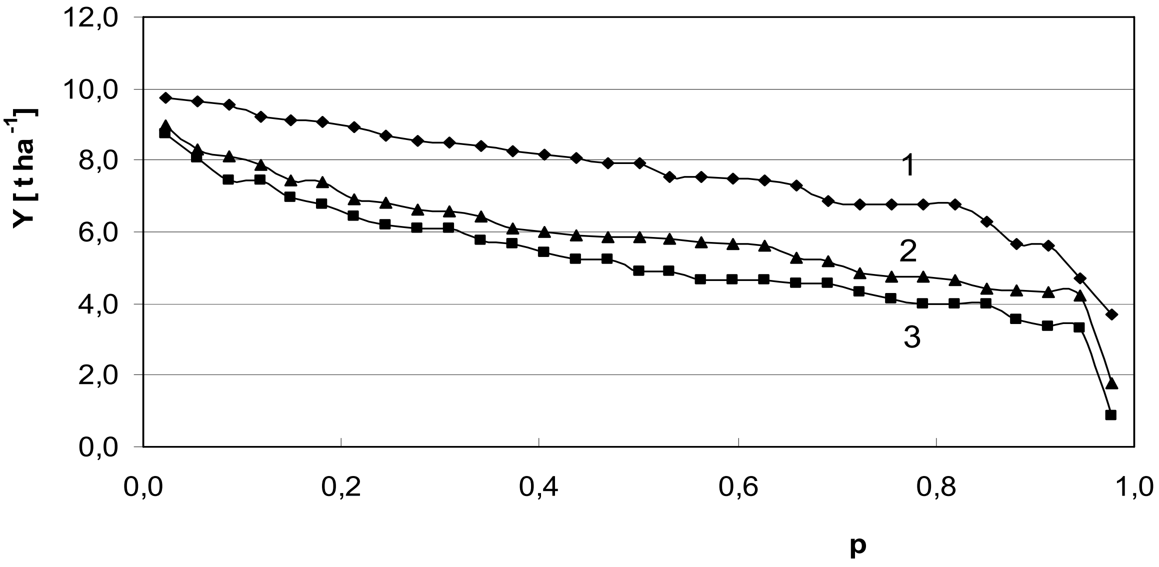


Fig.3. Curve of exceedance dry grain yields *Y* , of maize canopy (1), winter wheat(2) and spring barley (3) during the seasons in years 1971-2000 a 2003, Most pri Bratislave site.

Conclusions

1. Mathematical model HYDRUS – ET with incorporated method of evapotranspiration and its components calculation using Penman– Monteith method modified by Budagovskij and Novák, was applied to calculate seasonal transpiration totals of three canopies (maize, spring barley and winter wheat) for 31 seasons in Southern Slovakia site. Empirical curves of exceedance ot seasonal transpiration totals were designed.

2. Empirical curves of exceedance of grain yields of the three above mentioned canopies (maize, spring barley and winter wheat) were estimated, using empirical

relationship between grain yield (Y) and seasonal transpiration totals (E_t) - Fig.3. Relatively homogeneous field of grain yields (as an exception is the season 2003) demonstrates favorable conditions of South Slovakia for growth of cereals without irrigation. Irrigation practice of course can increase yields.

3. Exceedance curves of the corn grain yield (Y) and the calculated potential yield (Y_p), and the difference (□Y), for the 1971-2000 and 2003 growing seasons at Most pri Bratislave calculated from corresponding exceedance curve of potential transpiration totals E_{tp}, (Fig.4) demonstrates relatively low capacity of soil water regime optimization for the corn grain yield increase. The average corn grain yield (Y) was estimated to be 7.64 t ha^{-1}, and the average potential yield (Y_p) 9.03 t ha^{-1}. This means that the difference was ΔY =1.4 t ha^{-1}, which represents 18% of the average yield. The question now arises whether or not it would be reasonable (cost-effective) to design and operate an irrigation or drainage system that will optimize the soil water regime such that the dry grain yield increases by some of all of the 1.4 t ha^{-1} difference. Situation on the world cereals market is characterized by rapid increase of their prices. Particularly, in Slovakia the price of the maize increased more then twice during last years. It can change the situation in irrigation policy significantly and optimization of plant water regime via soil water regime is becoming very actual.

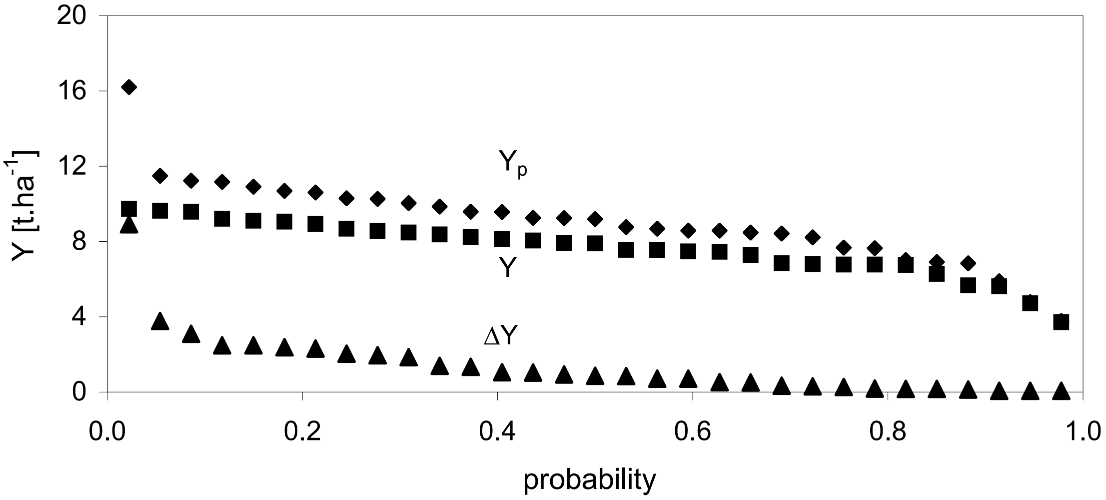


Fig. 4. Exceedance curves of the corn grain yield (Y) and the calculated potential yield (Y_p), and the difference (□Y), for the 1971-2000 and 2003 growing seasons at Most pri Bratislave, Slovakia

Acknowledgement
Author appreciate the support of Slovak Grant Agency VEGA (Grant. 2/7091/27).

Literature

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration. Irrig. Drain. Pap. No. 56, FAO, Rome, 300 p.

Bierhuizen,J.F., Slayter,R.D. 1964. An apparatus for the continuous and simultaneous measurements for photosynthesis and transpiration under controlled environmental conditions. CSIRO Austr. Div.Land Research Tech. Paper, v.24.

Budagovskij, A.I. 1981. Evaporation of soil water. In.: Physics of soil water. Nauka, Moskva.

Feddes, R.A., R.W.R. Koopmans, and J.C. van Dam. 1999. Agrohydrology. Wageningen Univ., Dept. Water Resources, 205 p.

Hanks, R.J., Hill, R.W. 1980. Modeling crop responses to irrigation in relation to soils, climate and salinity. Inter. Irrig. Inform. Center, Publ. No. 6, Bet Dagan, Israel, pp. 57.

Hansen,S., Jensen, H.E.,Nielsen, N.E.,Svensen,H.1990. DAISY: A soil Plant System Model. Danish simulation model for transformation and transport of energy and matter in the soil plant atmosphere system. The national Agency for Environmental Protection, Copenhagen, 369 pp.

Hsiao, T.C. 1973. Effect of drought and elevated CO2 on plant water use efficiency and productivity.NATO ASI Series, Vol.I 16. Interacting Stresses on Plants in a Changing Climate. (M.B. Jackson & C.R. Black, Eds.). Springer Verlag, Berlin, Heidelberg.

Kirkham, M.B. 2005. Principles of Soil and Plant Water Relations. Elsevier Academic Press, New York.

Novák, V., 1995. Evaporation of water and methods of its estimation. VEDA, Bratislava

Penning de Vries, F.W.T., Jansen, D.M., Pen Berge, H.F.M., Balkema, A. Simulation of ecophysiological processes of growth in several annual crops in several annual crops. IRRI Los Banos, Pudoc, Wageningen, pp.271.

Šimůnek, J., K. Huang., M. Šejna, Th. M. Van Genuchten, J. Majerčák, V. Novák, J. Šútor. 1997. The HYDRUS -ET software package for simulating the one - dimensional movement of water, heat and multiple solutes in variably - Saturated media. Version 1.1. Institute of Hydrology, Slovak Academy of Sciences, Bratislava.

Van Diepen, C.A., Wolf, J.,van Keulen, H., Rappoldt,C. 1989. WOFOST a simulation model of crop production. Soil Use and Management. 5, 16 – 24.

Van den Honert T.H., 1948. Water transport in plants as a catenary process. Discuss. Faraday Soc., 3,146 –153.

van Genuchten, M.Th.1980. A closed form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci.Soc. Am.J. 44, 892 – 898.

Vidovič, J., Novák, V.,1987.The relation between maize yield and canopy evapotranspiration. Rostlinní výroba, 33, 6, 663-670, (In Slovak with English summary).

COMBINED EFFECT OF DROUGHT AND HIGH ATMOSPHERIC CO_2 CONCENTRATION ON CEREALS

O. Veisz, Sz. Bencze, K. Balla, Gy. Vida and Z. Bedő
Agricultural Research Institute of the Hungarian Academy of Sciences, Brunszvik str.2, Martonvásár, Hungary 2462

Abstract

The experiments were carried out under controlled conditions in the phytotron of the Agricultural Research Institute of the Hungarian Academy of Sciences with the aim of determining the effects, interactions and correlations of drought and increased atmospheric CO_2 concentration on the biomass production and yield of various cereal species and varieties. Due to the favourable effect of increased atmospheric CO_2 concentration there was generally an improvement in the drought tolerance; the biomass and grain number of drought-stressed plants grown at doubled atmospheric CO_2 concentration were the same as those of control plants grown at normal CO_2 level with normal water supplies. A high CO_2 concentration was able to moderate to a great extent the negative effects of drought stress on quantitative yield parameters. Although the yield did not reach the control value (normal water supplies) it was higher than that achieved by drought-stressed plants grown at the normal CO_2 level, and there was an increase in thousand-grain mass and harvest index. The grain protein content became slightly higher as the result of the opposing effects of high CO_2 level and drought stress.

The differences noted between the genotypes offer the possibility of using conventional and molecular breeding methods to develop gene combinations providing better adaptability even under changed environmental conditions, leading to the development of new varieties.

Introduction

The quantity and quality of the yield of cultivated plants is the combined result of numerous factors, one of the most important of which is the yield potential of the variety, which may be achieved to varying extents depending on its adaptability to diverse climatic and agronomic conditions. The extreme weather conditions that have the greatest influence on crop production and are experienced most frequently in the Carpathian Basin are low and high temperatures and the deficiency or excess of rainfall. Water deficiency during grain ripening reduces grain filling and may accelerate seed shedding (Szigeti 2002). Water deficiency induces complex plant responses, which may lead to adaptation or to death. Drought stress defence mechanisms in different varieties are a mixture of stress avoidance and strategies designed to develop tolerance (Chaves et al. 2002).

It seems likely that the beneficial effect on photosynthesis of an increased concentration of CO_2 in the atmosphere may be exerted even in the presence of various stress factors. This is confirmed by the fact that at increased CO_2 levels there is a reduction in stomatal conductance and an improvement in water use efficiency, which can be attributed partly to a steep decline in transpiration and partly to an increase in the net rate of photosynthesis (Tuba et al. 1994).

When the effects of drought stress were examined in durum wheat varieties it was found that the plants were capable of producing surplus yields at higher atmospheric CO_2 concentrations compared with similarly drought-stressed plants grown at normal CO_2 (Kaddour and Fuller 2004). The high CO_2 level stimulated shoot formation, which would otherwise have been inhibited by the high salt content (Nicolas et al.

1993). Compared with plants grown at current CO_2 levels, those developing at higher atmospheric CO_2 concentration are capable of overcoming the yield and biomass reduction caused by heat stress, either totally or in part, depending on the characteristics of the variety. This can be partly attributed to the fact that they are able to maintain photosynthesis and stay green (Bencze 2006). Cereals also have better frost tolerance at doubled CO_2 concentration (Veisz et al. 1996a, 1997).

Materials and Methods

The effects, interactions and correlations of water withholding and increased atmospheric CO_2 concentration on the biomass production and yield of various cereal species and varieties were investigated in a series of model experiments.

The cereal species and varieties examined were as follows: winter barley: Petra, winter wheat: Libellula, Mv Regiment, Mv Mambó, winter durum: Mv Makaróni, spring wheat: Lona, spring oats: Mv Pehely. The plants were grown in two special PGV-36 climate chambers, one with normal atmospheric CO_2 concentration (360 ppm) and one with double this value (720 ppm). All other environmental parameters were the same in the two chambers. From the 10th day after heading water was withheld for a seven-day period, during which time the volumetric water content (VWC%) dropped from an average 25% to around 6%. The control water supplies ranged from 22.4–30.2%. The soil moisture content was determined with an Em50 data collector and ECH2O-type EC-5 sensors (Decagon Devices, USA).

Phenological parameters, plant height, shoot number, spike number, ratio of productive shoots, biomass production and harvest index were determined, as were the yield, thousand-grain mass and grain protein content. The results were evaluated using multifactorial analysis of variance.

Results and Discussion

Plants grown at double the normal atmospheric CO_2 level produced more organic matter, were taller, produced more spikes and had a higher yield than those grown at the ambient CO_2 concentration (Table 1 and Fig. 1).

Drought stress applied during the early phase of ripening inhibited biomass accumulation, causing forced ripening, increasing the number of sterile grains (p=10%) and reducing the final mass of the grains, the direct consequence of which was an average 40% drop in the grain yield per plant and a lower harvest index. The smaller grains had relatively higher protein content at the expense of the starch fraction (Fig. 1).

The favourable effect of the higher atmospheric CO_2 level generally caused an improvement in the drought stress tolerance of the cereal species. The biomass and grain number of drought-stressed plants grown at doubled atmospheric CO_2 concentration were the same as those of control plants grown at normal CO_2 level with normal water supplies. A high CO_2 concentration was able to moderate to a great extent the negative effects of drought stress on quantitative yield parameters.

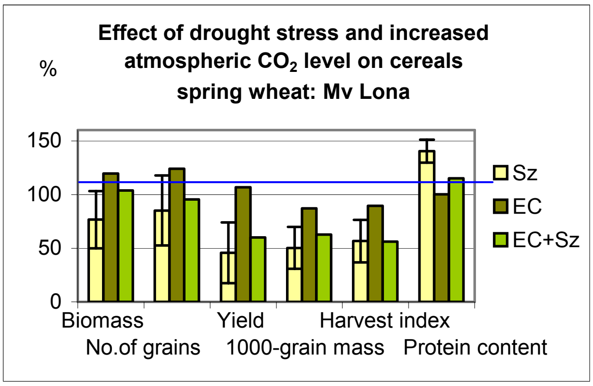
Although the yield did not reach the control value (normal water supplies) it was higher than that achieved by drought-stressed plants grown at the normal CO_2 level, and there was an increase in thousand-grain mass and harvest index. The grain protein content increased to a moderate extent as the result of the opposing effects of high CO_2 level and drought stress.

Table 1: Average effect of increased atmospheric CO_2 level and drought stress on cereal varieties

Parameters	C	D	$2\times CO_2$	$2\times CO_2+D$	$LSD_{5\%}$	$LSD_{1\%}$	$LSD_{0.1\%}$
Plant height (cm)	59.75^a	60.70^a	66.98^b	67.53^b	1.73	2.28	2.91
No. of shoots	5.49	5.49	5.63	5.80	0.42	0.55	0.71
No. of spikes	2.59^a	2.60^a	2.81^{ab}	2.88^b	0.25	0.33	0.43
Productivity (%)	50.89	50.25	53.57	54.06	4.96	6.52	8.35
Biomass (g)	7.7^a	6.7^b	8.9^c	7.9^a	0.69	0.91	1.17
No. of grains	100.6^{ab}	91.1^a	105.5^b	102.5^b	10.74	14.13	18.08
Yield (g)	2.83^a	1.76^b	3.18^c	2.30^d	0.28	0.37	0.48
Thousand-grain mass (g)	29.0^a	19.6^b	31.2^a	22.5^c	2.33	3.07	3.92
Harvest index (%)	36.2^a	25.7^b	35.5^a	27.9^c	1.68	2.21	2.82
Protein content (%)	17.04^a	21.63^b	16.23^c	19.70^d	0.16	0.21	0.28

Treatments: C= Control, D= Drought stress, $2\times CO_2$= Increased atmospheric CO_2 level, $2\times CO_2$+D= Increased atmospheric CO_2 level and drought stress

Although the positive effect of doubled CO_2 concentration was not always significant, due to the great deviation, the tendency was clear. Differences were observed between the genotypes, however. Drought stress caused above-average yield losses in spring wheat, while the drop in yield was smaller for spring barley and oats. On the other hand, the increases in biomass and yield induced by the high CO_2 level were greater in barley and wheat varieties and insignificant in the case of oats.



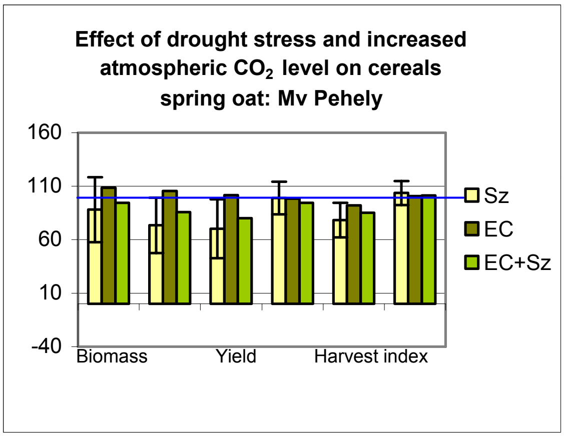


Fig. 1: Effect of drought stress and increased atmospheric CO_2 level on the mean production and grain yield quality of cereals (control = 100%)

Sz= Drought stress, EC=$2\times CO_2$= Increased atmospheric CO_2 level. Bands indicating significant differences show values obtained at the p=0.05 level of probability. Varieties tested in the experiment: spring wheat: Lona, spring oats: Mv Pehely

The measurements thus confirmed that high CO_2 concentration is able to moderate to a great extent the damaging effects of drought stress on the biomass production and yield of cereals.

Conclusions

The research was aimed at determining the effect of predicted climate changes on the biomass production and yield of cereals. It could be seen from the results that drought stress applied during the early phase of ripening inhibited biomass accumulation, causing forced ripening and leading to an average 40% drop in the grain yield per plant due to reductions in grain number and grain size. A doubling of the CO_2 concentration was able to moderate to a great extent the negative effects of drought stress on the yield, while the grain protein content increased to a moderate extent as the result of the opposing effects of high CO_2 level and drought stress.

It could be seen from the results that the diverse responses of the genotypes and changes in the environmental factors could be responsible for the contradictory results reported in the literature (Nicolas et al. 1993, Kaddour and Fuller 2004). It is clear from the experiments that it is not sufficient to examine a single variety if we are to understand the effect of climate change on cereal species.

Acknowledgments

This research was funded by the Hungarian Ministry of Education (project No. OM-00047/2005) and the National Scientific Research Fund (OTKA K063369).

References

Bencze,S. 2006. Effect of increased atmospheric CO_2 concentration and other environmental factors on winter wheat (*T. aestivum*). Ph.D. Thesis, ELTE, Budapest.

Chaves, H.M., Pereira, J.S., Maroco, J., Rodrigues, M.L., Ricardo,C.P.P., Osório,M.L., Carvalho,I., Faria,T. and Pinherio,C. 2002. How plants cope with water stress in the field. Photosynthesis and growth. Annals of Botany 89: 907-916.

Kaddour, A.A. and Fuller, M.P. 2004. The effect of elevated CO_2 and drought on the vegetative growth and development of durum wheat (Triticum durum Desf.) cultivars. Cereal Res Commun 32, 225-232.

Nicolas, M.E., Munns, R., Samarakoon, A.B. and Gifford, R.M. 1993. Elevated CO_2 improves the growth of wheat under salinity. Aust J Plant Physiol 20, 349-360.

Szigeti Z. (2002):Plants and stress. In Láng F. (2002):Plant physiology. ELTE Eötvös Kiadó, Budapest. 1005 p.

Tuba, Z., Szente, K. and Koch, J. 1994. Response of photosynthesis, stomatal conductance, water use efficiency and production to long-term elevated CO_2 in winter wheat. J Plant Physiol 144, 661-668.

Veisz, O., Harnos, N., Szunics, L. and Tischner, T. 1996 a. Overwintering of winter cereals in Hungary in the case of global warming. Euphytica 92, 249-253.

Veisz, O. 1997. Effect of abiotic and biotic environmental factors on the frost resistance of winter cereals. Acta Agron Hung 45, 247-255.

Scientific session II.C Soil conservation and policy

SOIL CONSERVATION AND POLICY MEASURES – FINDINGS FROM EIGHT CASE STUDIES ACROSS EUROPE

K. Prager[1]

[1]Humboldt-Universität zu Berlin, Faculty of Agriculture and Horticulture, Division of Resource Economics, Philippstraße 13, 10115 Berlin (Germany)

Abstract

There is a lack of knowledge about soil conservation practices in agriculture and little understanding of how farmers can be encouraged through appropriate policy measures to adopt soil conservation practices. The EU funded project “Soil Conservation and Policy Measures” (SoCo) is aiming to fill this gap. The research was guided by a framework for policy and institutional analysis, using literature and document analyses as well as a stakeholder survey and expert interviews to investigate soil conservation in eight case studies across Europe.

The paper briefly describes the case study areas and presents preliminary findings. The findings highlight i) the need to design policies that target the existing soil threats; ii) the need for good communication and cooperation both between agricultural and environmental authorities as well as between governmental and non-governmental stakeholders; iii) the necessary mix of mandatory and incentive instruments; and iv) the lack of data to monitor and evaluate the effectiveness of policies and soil conservation practices.

Introduction

While there are individual policies for water and air addressing issues of pollution and protection there is no European policy primarily concerned with soils or agricultural soils in particular. The same is true for national policies in many member states where soil conservation is rather a by-product of other agricultural and environmental policies. There is a lack of knowledge about soil conservation practices in agriculture and their links with other environmental protection objectives as well as little understanding of how farmers can be encouraged through appropriate policy measures such as the Rural Development Programme to adopt soil conservation practices. The project “Soil Conservation and Policy Measures” (SoCo) is aiming to fill this gap. The project is a part of a larger research study on sustainable agriculture and soil conservation in the European Union that has been commissioned by the European Parliament (SoCo 2008). The case studies complement an EU-wide review of policies and the regulatory environment concerning soil conservation.

Rather than addressing soil conservation issues separately from different disciplinary perspectives this project observed the interdependencies between ecological and social systems and thus applied a common framework for policy and institutional analysis in all case studies (adapted and extended from Hagedorn et al. 2002). The framework integrates the properties of soil-related transactions, soil-related actors and their characteristics, institutions (the “rules-in-use”) and governance structures. The analysis includes a variety of physical, natural, institutional, socio-economic and historical factors in order to draw conclusions why some soil conservation measures are effective while others fail. This paper places the focus on actors, policies and their effect while the project also included the analysis of farming practices and their impact on soil conservation taking into account soil types and climatic conditions. It should be noted that this paper draws on work in progress and findings are still preliminary.

Materials and methods

Eight case studies have been conducted by case study partners across Europe, namely in Germany, the Czech Republic, Bulgaria, Spain, Greece, Belgium, the UK and Denmark. The selection was guided by two main criteria: significant soil conservation issues and territorial balance (geographical coverage across the EU). In addition, a broad range of criteria relating to farming practices and farm structures, policies for soil conservation applied in the area, institutional settings, and governance structures were taken into account.

Soil degradation problems were identified following the definition of soil threats of the Thematic Strategy for Soil Protection of the European Commission (CEC 2006). Five of these threats are directly relevant in the selected case study areas, namely soil erosion, decline in organic matter, soil compaction, diffuse soil contamination (associated with agricultural use), and salinisation (Montanarella 2003).

The case studies are based on two major sources of information, literature and document analyses on one hand and stakeholder surveys and expert interviews on the other hand. Materials analysed for each case study include scientific literature relating to soil conservation policies as well as legal documents such as laws, regulations, directives, decrees, ordinances, and procedural orders. In addition, (regional) statistical information as well as policy, administrative, evaluation, and research reports, e.g., mid-term evaluations of the 2000-2006 Rural Development Programmes, were reviewed.

Quantitative data was gathered from soil science and farming practices experts. A stakeholder survey to obtain qualitative empirical data to supplement information from the literature was conducted with three different groups of actors relevant to soil conservation. The first group included farmers, farm managers and related stakeholders; the second group included administrative and governmental stakeholders involved in soil conservation policy design and implementation; and the third group included stakeholders operating outside public bureaucracies such as NGOs, farming advisors, farmers' unions and other interest groups.

Results and Discussion

Description of case study areas

The size of the case study areas ranges from 42 km² (Bulgaria) to 3300 km² (Spain). The boundaries of areas are aligned to either administrative (municipality, district) or natural units (catchment, basin). The population density varies but all areas are classed as rural areas. The area with the highest population density is in Belgium while the more scarcely populated case study areas are in Greece and Germany. Soils are heterogeneous, not only between the case study areas but also within individual areas.

Farming systems and agricultural management practices dominantly affect soil degradation and are subject to policy intervention. Approximately 1/3 to 2/3 of the total land of each case study area is used as agricultural land. The land use varies but all areas have in common that the greater share of the utilised agricultural area is used as arable land – up to 93% in the Danish case study.

The case study areas cover the major farming systems and management practices in those areas suffering from soil degradation. Farming systems include rotational cropping systems with intensive fertiliser input and heavy machinery use in the Northern and Eastern areas in Europe, where soil erosion, soil compaction, decline in organic matter, and soil contamination were identified as major soil conservation problems. Perennial cropping systems, such as almonds in Spain, induce different processes of soil degradation. The Bulgarian and the Spanish case study area feature irrigation agriculture which has an important impact on salinisation processes. Although the severity of the main soil degradation issues differs between the case study areas, soil erosion is identified among the three most relevant degradation issues in all but one of the areas (Table 1). Soil erosion is a complex problem because of its diverse causes (wind, water) and possible off-site impacts. Such off-site impacts of soil erosion, relating to eutrophication of surface waters and habitats, siltation, and infrastructure damage, might by far exceed the detrimental on-site effects of soil erosion.

Table 1: Overview of main soil degradation issues in the case study areas

Case Study Area	Soil Erosion	Decline in Organic Matter	Diffuse Soil Contamination	Soil Compaction	Salinisation
West-Flanders (BE)	4	3	5	2	0
Bjerringbro and Hvorslev (DK)	2	2	1	4	0
Axe and Parrett catchments (UK)	3	4	2-3	5	1
Rodopi (GR)	3	3	1	2	1
Guadalentín Basin (ES)	5	3-4	2-3	2-3	4
Belozem (BG)	1	3	1-2	3	5
Svratka river basin (CZ)	5	3	1	3-4	0
Uckermark (DE)	4	3	2	4	1

Note: The numbers indicate the relevance of the main soil degradation threats for the case study area, with the level being 5 = severe to 0 = not relevant.

Following erosion in relevance, soil compaction and decline in organic matter are cited as a problem for more than 6 out of the 8 case studies. Diffuse soil pollution is highlighted as problematic for the Belgian and UK case study, while salinisation is a severe degradation issue in the cases in Bulgaria and Spain.

The severity of degradation problems varies greatly among the areas as can be seen from the numbers in Table 1. It should be noted, however, that while numbers are assigned to the degradation issues, evoking the impression of quantified measurements, these assessments are mainly meant to show gradations. The severity of a degradation issue depends on various factors such as moisture content and soil types. Thus, soil compaction can be a major problem after heavy rainfall but not after dry times. Erosion may be a severe issue on highly erodible soils but hardly relevant on a less erosion-prone soil a few kilometres away.

Similar constellations are found in the Czech and German case study area with nearly identical severity of degradation issues, and the Greek region featuring similar issues and ratings. Case studies in Denmark and the UK both have soil compaction as the major soil conservation issue. The degradation types and their severity are often but not always representative for the whole country.

Farming practices that prevent soil degradation

A number of farming practices have been identified that can help prevent erosion, salinisation or other types of degradation. Examples for cropping and tillage measures are intercrops to maintain soil cover, reduced tillage to reduce erosion, and restrictions on fertiliser and manure to decrease soil contamination. Long term measures include a change of crop rotation, liming to mitigate acidification, drainage management to mitigate salinisation, retention ponds, tree strips and others. Some of these measures are already applied by farmers in the case study areas or have been applied in the past. In many cases, farmers are aware of soil degradation on their farm and in the surrounding area. In transition countries they often lack the resources (finances, machinery, specific knowledge) to tackle the problems.

Administrative system

Political institutions and types of governance provide a diverse context which affects design, implementation, impact, and adaptation of measures that influence land use and soil conservation practices in various ways. While we find similar production systems and soil conservation issues in case study areas in Denmark, the UK and Belgium, political institutions and governance structures that affect soil conservation differ considerably in these countries. This refers, for example, to tenure systems and policy implementation. Soil conservation policies may be implemented by centralised or decentralised administrative structures. The case study selection includes two federal states - Belgium and Germany - and unitary states. Among the unitary states are some where the central government has devolved more political power to lower levels, such as the UK and Spain, or remained a more centralised system such as the Czech Republic and Greece.

The Czech Republic is comparable with East Germany with respect to natural conditions and farm structures, but went through a different process of institutional, political, and administrative reform. Bulgaria, in contrast, experienced severe problems in changing the political and administrative system and has less developed implementation capacities and extension systems.

Property rights

Agrarian and social institutions represent complex norms and rules-in-use. These rules strongly influence soil degradation and conservation. An example for such institutions is practiced property rights. They regularise the choices of actors such as farmers and administrators by means of the constraints and incentives they offer. This applies, for example, to the land tenure system which partly still shows commons in Greece, mainly lease-hold in the East German, Czech and Belgian case study, or farmers predominantly cultivating their own land in Denmark, UK, Greece and Spain. In a similar way, land and soil are affected by agricultural structures which are to a certain extent also shaped by agrarian institutions. This is true for large scale farming in East Germany and Belgium as contrasted with small plots and subsistence farming in Bulgaria or Spain.

Main soil conservation policies

Findings of the case studies show that European legislation has a considerable impact on soil conservation activities: In all case studies at least two European policies such as the Nitrate Directive (EU 1991), the Good Agricultural and Environmental Condition (GAEC) standards under Cross Compliance, or Rural Development Funding, were found to be among the most important policies for soil conservation in the case study area. Individual European directives are of differing relevance in the case study areas. For example, all of West Flanders is a Nitrate Vulnerable Zone (NVZ) under the Nitrate Directive, while only a small proportion of the river basin in the Czech case study is designated as NVZ, and the Directive is not among the important policies for the UK case study area.

Incentive measures such as agri-environmental schemes support farmers who undertake soil conservation measures exceeding the cross compliance GAEC standards. In general, these schemes are well accepted and popular among farmers and are likely to be successful if prescribed measures are implemented. However, we cannot generally assume these schemes to achieve effective soil conservation as the Greek example illustrates: here, the GAEC Soil Organic matter was successful regarding the incorporation of crop residue into the soil and banning straw stubble burning with its negative effects for soils and climate while the measure to cultivate legumes was not locally adjusted and suspended because of farmers' and other stakeholders' objections.

Soil-related policies at national and regional level differ considerably across case study areas. Not all policies impacting on soils have soil conservation as a primary or secondary objective. Instead, soil conservation is often a by-product of the measure but results from implementation. Some countries have established policies that directly target their main soil degradation issue, such as Belgium's Manure Decree and Erosion Decision, while others have broader policies without targeting provisions as is the case in Bulgaria. The targeted policies tend to be more effective than the policies which have soil conservation only as a by-product. However, assessing the effectiveness of policies proves difficult in many cases due to the lack of data. Despite monitoring efforts, e.g. in the context of ex-ante, mid-term and ex-post evaluations of the Rural Development Programmes, indicators for soil are often not included or not available for the whole area. Evaluation of the policies' impact on soils is not common, which might be due to the dominance of action-oriented policies over result-oriented policies but also to the costs associated with extensive monitoring and data management.

Some countries such as the Czech Republic and Germany have specific soil protection laws that are able to secure a baseline protection but are enforced to a limited extent or provisions for Good Agricultural Practice are not well monitored. This illustrates the necessity of both, well-defined rules and the existence of an effective implementation structure, i.e. governance structure. In contrast, Denmark has no national legislation explicitly addressing soil degradation issues because the Danish government assessed the soil degradation issues and concluded that they are of minor importance or no problem at all. Another notable case is the UK case study where there is no national soil legislation but a number of incentive schemes offering payments to farmers to protect natural resources. A local partnership of governmental and non-governmental stakeholders has been formed, pursuing the improvement of soil management as one of its objectives. The Farming and Wildlife Advisory Service (FWAG) is the NGO organising the implementation of this initiative.

Local approaches such as the Municipal Erosion Plans in West Flanders where municipalities may undertake subsidised actions for erosion control based upon their erosion plan or agri-environmental schemes supporting particular soil conservation measures allow for better targeting and thus are more likely to mitigate degradation problems. Local or regional policies also allow the integration of stakeholder knowledge and feedback to a greater extent than national or European policies. A number of examples from the case studies showed that policies are more successful if they are accompanied by information and advice, e.g. provided by local agriculture offices or advisory bodies, so that farmers, landowners and land managers are aware of the problems, understand the measures and apply them adequately.

There is anecdotal evidence that implementation works better if the designing authority is also the one implementing a policy because less effort is needed for coordination. In general, vertical communication of sectoral units appears to work better than horizontal communication across departmental borders. However, policies seem more successful if a broad range of agricultural and environmental stakeholders have been consulted – or better, involved – in policy design. This has often created a common understanding of purpose and objectives of the policies and stakeholders were able to communicate this to their constituency and/or farmers as the actors making the on-ground change.

Conclusion

It is too early yet to assess whether European, national or local approaches to soil conservation are more effective. Command and control policy measures prevail in most cases, while in the UK case study there is a dominance of voluntary, incentive-based measures. In most case studies a mix of policies is applied, including command and control, incentive-based policy measures and – to a lesser extend – moral suasion initiatives and information and capacity building measures.

Emerging cross-cutting themes highlight i) the need to design policies that target the existing soil threats; ii) the need for good communication and cooperation both between agricultural and environmental authorities as well as between governmental and non-governmental stakeholders; iii) the necessary mix of mandatory and voluntary incentive-based instruments coupled with sufficient information and advice to farmers and landowners; and iv) the lack of data to monitor and evaluate the effectiveness of policies and soil conservation practices.

Acknowledgements

The project has been funded by the European Union.

References

Commission of the European Communities (CEC) (2006). Thematic Strategy for Soil Protection – COM (2006) 231 final. Available at http://ec.europa.eu/environment/soil/pdf/com_2006_0231_en.pdf.

European Commission - Environment (1991). Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) Nitrates Directive. Available at http://ec.europa.eu/environment/water/water-nitrates/directiv.html

Hagedorn, K.; Arzt, K. and Peters, U. (2002): Institutional Arrangements for Environmental Co-operatives: a Conceptual Framework. In: Hagedorn, K. (ed.): Environmental Cooperation and Institutional Change: Theories and Policies for European Agriculture. Cheltenham: Eward Elgar, pp.3-25.

Montanarella, L. (2003). The EU Thematic Strategy on Soil Protection. Available at http://eusoils.jrc.it/events/SummerSchool_2003/prog.html

SoCo (2008). Website of the SoCo Project. Sustainable Agriculture and Soil Conservation. Available at http://soco.jrc.ec.europa.eu/

POLICY MEASURES ENCOURAGING SOIL CONSERVATION IN AGRICULTURE – A CASE STUDY FROM BRANDENBURG (GERMANY)

N. Hagemann[1], N. Heyn[2], K. Prager[1] & J. Schuler[2]
[1]Humboldt-Universität zu Berlin, Faculty of Agriculture and Horticulture, Philippstraße 13, 10115 Berlin (Germany), [2]Leibniz-Centre for Agricultural Landscape Research, Eberswalder Straße 84, 15374 Müncheberg (Germany)

Abstract

This paper is based on the results of a case study in Brandenburg (Germany) that has been conducted as part of the of the EU funded project "Soil Conservation and Policy Measures" (SoCo).

The paper identifies the most important agricultural soil conservation measures in the case study area as well as needs and possible gaps in the policy framework and points out some solutions on how farmers can be encouraged to apply technical measures that contribute to soil conservation.

Introduction

Agriculture plays an important role in the maintenance of natural resources and cultural landscapes and is a prerequisite for other human activities in rural landscapes across Europe. However, inappropriate agricultural practices and land use can have adverse impacts on natural resources.

The project "Soil Conservation and Policy Measures" (SoCo) is part of a larger research project on agricultural soil conservation in the European Union. Using a theoretical framework of policy and institutional analysis (adapted and extended from Hagedorn et al. 2002), the study was designed to improve knowledge on soil conservation practices in the agricultural sector and to analyse how farmers can be encouraged through policy measures such as the Rural Development Programme to adopt soil conservation practices.

Based on the analysis of a variety of physical, natural, institutional, socio-economic and historical factors, the study draws conclusions why some soil conservation measures are effective while others fail.

Materials and methods

The Uckermark region was selected as a case study area because of its high potential for soil degradation caused by high intensity agriculture. A further selection criterion of the study region is related to its structural transformation in conjunction with the German reunification in 1990. This transformation was characterised by a restructuring of farm sizes, changes in the farm organisation from large cooperative farms to other legal organisations (e.g. smaller family run farms), an increasing share of organic farming, changes of farming practices, soil conservation policy measures and rules, as well as improved technical measures and increasing yields. In this aspect, the case study region is typical for all five East German Federal States.

The results of the case study are based on semi-structured interviews that have been conducted with farmers as well as stakeholders with expertise in soil conservation practices and policies. A literature review revealed further information for the analysis of soil conservation and policy measures.

Data were gathered by means of qualitative interviews with farmers, administrative authorities implementing soil conservation policies, agricultural and environmental interest groups and other soil-related stakeholders. In total, four different questionnaires have been used in the case study area Uckermark as guidelines for the interviews: One questionnaire for the soil experts, one for farmers, one for administrative as well as governmental stakeholders and the fourth for civil society actors. Quantitative data on soil conditions, degradation types, and related farming practices that cause or prevent soil degradation complement the qualitative data.

Results and Discussion

Soil degradation problems in the case study region

The main soil degradation problems in the case study area are water erosion, soil compaction and decline in organic matter. Soil experts pointed out that water erosion is strongly associated with row crops, namely sugar beets, maize and potatoes. Farmers and soil experts reported that inadequate soil cover is a major cause leading to water erosion and soil losses. Intensive field traffic of heavy machinery causes changes in soil structure and leads to compaction and productivity losses. The decline in organic matter mainly results from the release of large amounts of plant nutrients to plant uptake or leaching. Soil organic matter levels usually decrease where low residue crops, such as potatoes and sugar beets, are grown. Large amounts of nutrients are extracted with the harvest while little material is left on the field, e.g. silage maize.

Farming practices that prevent soil degradation

The implementation of conservation tillage increased during the last ten years, since farmers are aware of these problems on their farms and try to reduce costs for labour and machinery. Several technical measures that are needed for the protection of agricultural soils in the case study region are not supported by current policy measures. In former agri-environmental schemes practices like intercrops were funded, but they were closed, while in other German states this measure is part of the agri-environmental scheme (for example in Saxony and Lower Saxony).

Relevant measures to address soil degradation

The identified soil conservation policy measures can be classified as command and control measures as well as incentive-based measures. Most of the policy measures have their origin at the European level and have to be implemented by the member states. The member states have leeway for the implementation but they make use of it to a varying extent. As a result regional or local soil degradation problems are not sufficiently targeted because of the heterogeneous soil characteristics.

For the case study area there is only one policy measure that directly targets soil conservation; the German Federal Soil Protection Act (Federal Ministry for the Environment, Consumer Protection, Nature Conservation and Nuclear Safety 1999). However agricultural soil conservation plays a secondary role, because the measure has primarily been designed for closed dumpsites and industrial plants. In addition, there are several policy measures in the area of environmental and agricultural policy that address soil conservation as a by-product.

The most important policy measures for soil conservation are the Direct Payment Obligations Act (European Commission 2003), the Nitrate Directive (European Commission 1991) and the agri-environmental scheme in the framework of the Brandenburg Rural Development Programme (Ministry of Rural Development, Environment and Consumer Protection 2007). These policy measures include some measures that impact directly or indirectly on soil conservation and they are well accepted by farmers. The Direct Payment Obligations Act and the Nitrate Directive are important because they are connected with the direct payments and therefore farmers are willing to comply with these regulations. Agri-environmental schemes are popular amongst farmers because they receive additional funding for applying certain soil conservation measures. Especially in regions like the Uckermark where the soil fertility is quite low the programmes such as grassland extension are well accepted.

Although the above mentioned policies are effective according to their uptake, their efficiency towards the application of technical soil conservation measures is limited. Many measures could better contribute to soil conservation if they were defined in more detail. For example, the Direct Payments Obligation Act could be better targeted to soil degradation problems if more precise technical measures were included. The same holds true for the German Federal Soil Protection Act, where only the Code of Good Farming Practices is referred to as a basis for compliance. For the Nitrate Directive some provisions are well defined such as the limitation for the amount of fertiliser that can be applied.

Concerning the composition of the policy measures a mixture of mandatory as well as incentive-based instruments is seen as beneficial to soil conservation: many stakeholders said that there need to be mandatory regulations that assure a minimum standard that all farmers have to fulfil, but they should be completed by incentive-based programmes that directly address local soil degradation problems. Additionally local problems need to be taken into account because the soils in Brandenburg are quite heterogeneous. Therefore the mandatory regulations need to be more flexible when it comes to implementing the measure at the regional level. To target regional or local soil degradation more efficiently the agri-environmental schemes as well as the Contractual Nature Conservation[1] are relevant instruments, but therefore they have to be provided with more money. These two measures have in common the broad range of actors included in the policy design and the implementation process. This offers the opportunity to include local knowledge and to make the measures more efficient.

For the efficiency of the policy measures the implementation is another crucial point. Administrative actors reported that at state level the governmental actors did not further implement federal legislation because they did not want to go beyond the already existing legislation. Almost all actors stated that the advisory services play a vital role in the implementation process, illustrating that information distribution is an essential factor for the successful implementation of policy measures. Farmers are to some extent aware of the degradation problems on their fields, but there is a need to distribute information to prevent these degradation problems as well as the instruments that target these problems. One stakeholder said: “On-site experiences are more effective in the long run than pressure by policies”.

Throughout the study it became apparent that rather than introducing new policy measures, the existing ones need to be implemented more effectively. New regulations would make it costly for the administration that already lack the capacities – financial as well as personal - and the bureaucratic burden would increase.

Conclusion

For an effective soil conservation policy mandatory as well as incentive based policy measures have to be applied. Because of the diversity of soil degradation problems in the case study region such as erosion, compaction and decline in organic matter, the policy measures need more flexibility for individual adaption at the local level. To enhance the uptake of farming practices that contribute to soil conservation more

---

[1] The Contractual Nature Conservation is a policy measure developed by some states to enhance nature protection. It consists of individual contracts between farmers and the administration.

technical measures need to be included in the policy measures. Another important point that contributes to soil conservation is the information distribution either by administrations or advisory bodies.

Acknowledgement

The project has been funded by the European Union.

Literature

European Commission 2003. Council Regulation (EC) No 1782/2003 of September 2003 establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No 2019/93, (EC) No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC) 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and (EC) No 2529/2001. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:270:0001:0069:EN:PDF.

European Commission 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). Available at http://ec.europa.eu/environment/water/water-nitrates/directiv.html.

Federal Ministry for the Environment, Consumer Protection, Nature Conservation and Nuclear Safety 1999. Federal Soil Protection and Contaminated Sites Ordinance Available at http://www.bmu.de/files/pdfs/allgemein/application/pdf/bbodschv_uk.pdf

Hagedorn, K.; Arzt, K. and Peters, U. (2002). Institutional Arrangements for Environmental Co-operatives: a Conceptual Framework. In: Hagedorn, K. (ed.), Environmental Cooperation and Institutional Change: Theories and Policies for European Agriculture. Cheltenham: Eward Elgar, pp.3-25.

Ministry of Rural Development, Environment and Consumer Protection 2007. Entwicklungsplan für den ländlichen Raum Brandenburgs und Berlins 2007 – 2013 as of 13.7.2007 (Rural Development Plan). Available at http://www.mluv.brandenburg.de/cms/media.php/2317/swot.pdf (19/10/08).

SALINISATION IN THE CASE OF BELOZEM VILLAGE, BULGARIA. MATCHING TECHNICAL AND POLICY MEASURES

Penov, I. Manolov,. A. Alexiev. &Y. Kavardziev
Agricultural Univesity- Plovdiv, Dep. Agricultural Economics, 12 Mendeleev str., 4000 Plovdiv,
Bulgaria, e-mail ipenov@au-plovdiv.bg

Abstract

Soil salinisation is one of the major soil degradation problems for Southern European countries and the global worming is expected to increase the threat of secondary salinisation. This paper investigates salinisation in the case of Belozem village, Bulgaria, where the technical solutions introduced in the past, are not supported by the current institutional settings. Based on data collected by means of interviews with local actors, and analysis of the existing policy, the paper tries to match the currently possible technical solutions to policy measures in place. The paper finds that most of the policy measures currently existed in the area have rather an indirect impact on soil preservation. The most imperative technical and institutional solutions are related to organization of the irrigation-drainage system maintenance. Due to the currently low level of social capital in the area, as a sort-term solution is recommended the local municipality and Irrigation company to organise the maintenance activity, and as a long-term one, the farmers to get involved in the process.

Introduction

Unlike most of the other soil degradation problems, preventing soils from salinisation processes, in most cases, requires not only technical measures but also active cooperation and voluntary participation of the local actors. There are more than 35,000 hectares of salt-affected soils in Bulgaria, but this number does not include the areas with a high risk of salinisation..

Belozem is located in South Bulgaria, the eastern part of the Thracian plain, 30 kilometres east of the town of Plovdiv. The village has 4200 ha of land, of which 40% are affected by salinisation process. The main soil types in the area are Luvisols, Solonetz, Vertisols and Gleysols. The first information regarding salinisation processes in Belozem dates back to the 15th century when the flooded rice production was introduced in the area. Because of improper choice of location for the rice fields and use of tail waters (waters released from rice cells) for irrigation, salinisation started to increase gradually. During the 19th century, the forests surrounding the village were cut down and the meadows ploughed up. This destroyed the natural soil drainage. In 1928, there was an earthquake in the area, which caused the land surface to sink down, bringing it closer to the underground waters. During the sixties and seventies, the State initiated an extensive programme for the reconstruction of the existing irrigation system, the development of a drainage system and chemical melioration. As a result, soil salinisation was reduced significantly and a large part of the land surrounding the village was reclaimed. Following the agrarian reform and land restitution of the 1990s, the irrigation system in the area is somehow maintained, while the drainage system is neglected. The new institutional settings do not support the previously implemented technical measures. This poses a real threat for the level of salinisation to reverse back to the situation that existed before the sixties.

The report aims to provide guidance how the salinisation can be “managed” under the new institutional settings. In order to reach our goal: (1) the actors’ perceptions are investigated; (2) the crop structure and cultivation practices are evaluated; and (3) the policy measures are analysed and matched with the possible technical solutions.

Material and Methods

In order to investigate the soil conservation problems in Belozem, semi-structured interviews with the actors involved have been conducted. Four different questionnaires have been used: for soil experts; for farmers; for administrative actors; and for actors outside the State bureaucracy. The questionnaires included two parts. The first part, which is common for all actors, the interviewees were asked to identify and evaluate the soil degradation problems in the area. In the second part, specific questions for each group of actors were included, reflecting their expertise. There is one soil expert in the area with a long experience in salinisation problems. Therefore he was not only interviewed but also invited to join the team. There are five large-scale farmers in the village and interviews were conducted with all of them. The smaller scale farmers were chosen randomly and we continued to conduct interviews until we stopped receiving new information about the issues. Interviews were taken also from all important actors from the local administration. We found three organisations outside the state administration working in the area of Belozem. Although soil conservation issues are not among their main priorities, they were also included into the sample because they are involved in solving rural development issues. The total sample includes 31 interviews: 1 soil expert; 18 farmers; 9 actors from the state administration, and 3 actors outside of the administration. All interviews were conducted face-to-face, the majority with semi-structured questionnaires. However, for a few interviews an open-ended questionnaire was used.

Results and Discussion

In order to investigate the actors ’ perceptions they were asked whether they had observed certain symptoms of soil degradation in the area and to rate the severity of problems from 1-no problem to 5- a severe problem. Most of the reported by the farmers symptoms of soil degradation were related to salinisation and compaction. Eleven out of eighteen farmers reported that they found changes in plant growth caused by salinisation in the area, 15 respondents reported that they have seen salt crusts in the village fields. Only nine detected these visual symptoms of soil deterioration on their cultivated land. The farmers rated salinisation as the most severe soil problem in the area. The mean rating regarding the severity of this problem is 4,11 for the area outside the farm and 3,50 on the farm (coefficients of variation 20,25 and 31,38 respectively). Farmers’ perception for the other soil degradation problems such as soil erosion, decline in organic matter or off-site damages is not so clear and the answers are not homogenous. In most cases, farmers were better in observing the symptoms but not able to determine the severity of the problem.

The soil expert assessed salinity as a main soil degradation problem in the village of Belozem (rank 5). The second important problem is compaction (rank 3), followed by decline of organic matter, a negative carbon balance and water retention capacity (rank 3). A teacher from the local agricultural school gave priority to salinisation as the main soil degradation problem (rank 4) followed by the compaction and retention capacity of soil (rank 3).

The director of the local office of the Ministry of Agriculture and Food (MAF) and the ecologist of Rakovski municipality (Belozem belongs to this municipality) both assess salinisation as the most important soil problem for the region (rank 4-5). The experts from the local office of the Ministry of Environment and Water (MEW) and the regional agricultural advisory services in Plovdiv provided their assessment about the soil degradation problems in the Plovdiv region. According to the expert from the local MEW office soil degradation problems exist in the region but their severity is not high (1-2). However, the specialist from the regional agricultural services evaluated the severity of the problems higher (2-3). He also stated that for Belozem salinisation traditionally is a severe problem.

The main crops grown by the interviewed farmers are field crops (1734,60 ha): wheat, rice, maize, sunflower, barley, triticale, alfalfa, and maize-silage. Vegetables are grown on 298,4 ha and include tomatoes, peas, watermelon, cabbage, pepper, and potatoes. About 75% of the land farmers cultivate is non-saline while the remaining 25% are ameliorated Solonetz and weakly salt-affected soils. Depending on salt-tolerance, plants can be divided into 4 groups (sensitive, moderately sensitive, moderately tolerant and tolerant). The winter cereals are generally tolerant to saline soils. Barley and triticale are classified as tolerant, while wheat and rice are moderately tolerant; sunflower, maize and alfalfa are moderately sensitive crops. Most crops are highly sensitive to salinity stress during the germination and seedling stages. However, after these stages many crops can tolerate higher salinity levels (Kavardziev, 1985; Cardon et al, 2007).

Because of characteristics of the most spread soils in the region Luvisols and Solonetz (heavy soils with poor physical and chemical properties, with tendency to compaction and heavy water-air regime), more tillage practices are necessary. Deep ploughing (up to 30 cm) is a basic farming cultivation practice for all crops grown in Belozem area. It restricts the influence of salt concentration on soil fertility, improves the soil drainage, and contributes to dislocation and vertical salts' distribution. The next tillage practice applied to most crops is disk harrowing. This practice is performed 2-3 times, before sowing, depending on the soil conditions. After sowing of winter cereals, many farmers roll on the soil surface with rollers to increase capillary upward movement of water, which ensures enough moisture for seed germination. This practice is not suitable for Solonetz and Alkali Solonchaks soils, because keeping the soil surface in a crumbly condition decreases the risk of soil swelling, compaction and creation of anaerobic conditions. In order to destroy weeds and decrease evaporation of soil moisture, farmers hoe one or two times when maize and sunflower are grown. This is a good practice for decreasing upward moving of salts from lower soil horizons. Most of farmers use unspecialised machinery for conducting soil tillage practices, but on larger farms modern machinery is used, which can perform several soil tillage operations at the same time. These machines allow deeper soil cultivation, which improves the salts leaching.

The farmers in the village predominantly apply nitrogen fertilisers (ammonium nitrate and urea). Mainly the bigger field crop producers and almost all vegetable producers employ phosphorus fertilisers (triple super phosphate) and very little potassium. The application rates of nitrogen are adequate for wheat, barley, triticale and rice crops and vary between 100 and 120 kg N/ha. Among all field crops, only rice is well provided with phosphorus. Overall, reduced application of fertilisers has a negligible effect on soil salinisation, but it leads to a depletion of the soil nutritional reserves, lower the yields, revenues and incentives to invest in agriculture.

All winter field crops, silage maize and in parts alfalfa are grown without irrigation. Winter cereals are rarely irrigated in Bulgaria because there is sufficient precipitation during their vegetation period. However, good yields from alfalfa and maize (grain and silage) can be obtained with only 2–3 irrigations during the vegetation period. Most vegetables are irrigated from wells, but unfortunately, quality and salt content is not controlled. This may cause secondary soil salinisation. The irrigation system (especially the secondary canals) is partly destroyed and/or not well maintained.

The main sources for irrigation water are Maritza River and Piasachnik Water Reservoir. The water quality and chemical composition of both sources are suitable for irrigation and also can be used for salts leaching without special salinity control. It belongs to water quality class C2 - medium salinity hazard (EC is 263 µS/cm for Maritza water and 376 µS/cm – Piasachnik Reservoir).

Improvement of crop rotation (structure) is comparatively easy from the technical point of view and this requires the cultivation of crops, which are more tolerant to salinisation. Flooded rice is also a suitable crop, at least for the Belozem case. Constructed and located in appropriate places, rice fields can support the salt leaching processes. Including crops covering the soil surface in the rotation, especially during hot summers, will reduce the danger of secondary soil salinisation. The application of subsoiling will improve the surface soil drainage, reduce the risk of salinisation, and decrease the soil compaction. Incorporation of crop residues in the soil will mitigate three important soil degradation issues of the region, i.e. salinity, reduction of organic matter and compaction. However, the experts' opinion is that the structure of the crops is suitable for the situation and can be only marginally improved.

Both the irrigation system and the main canals of the drainage system are already in place but after 1990 both were poorly maintained. Especially for the secondary canals, the problem is severe. Further development of the drainage system is not imperative and may not even be necessary. However, maintenance activities such as cleaning and unblocking the drainage canals are essential. This type of maintenance does not pose any technical problems, it merely requires organisation and financial support.

Chemical melioration was carried out in the village in the past. Results from long-term experiments established in the local research station showed a long-lasting positive effect on soil fertility. The chemical melioration requires cooperation to a less degree compared to drainage system maintenance. It can be conducted in cooperation as well as by individual farmers.

Tree strips can be planted on the most severely affected by salinisation land or along the drainage canals. There is a successful experiment at the edge of the village, where a small forest was planted about 20 years ago. This forest has several tree species Honeylocust (Gleditsia triacanthos), Black Locust (*Robinia pseudoacacia*) and Tamarisk (Tamarix ramosissima). One possible technical problem of this measure is the availability of seedlings of resistant tree species.

There are several policy measures implemented in the area. The per hectare payments programme introduced in 2007 has three main elements: (1) per hectare payment to all farmers; (2) per hectare payments to farmers in areas with handicaps; and (3) environmental per hectare payments. In order to receive these payments a farmer needs to be registered in the local office of MAF, and to submit an application form to the Agricultural Payment Agency. After introduction of this policy, more farmers registered their land in the local branches of the MAF and they declared the plots they cultivate, Therefore, the authorities have information on who holds the use rights. All farmers considered the general per hectare payments program as successful. The main factors for success are: (1) simple process of application: (2) clear and comparatively low cost application procedure; (3) clear rules; (4) low cost monitoring and sanctioning procedures.

Financial support for purchasing farm equipment was available under the SAPARD programme and it is available now under the Programme for Development of Rural Regions in Bulgaria 2007-2013. Providing financial support for purchasing equipment is very important for Belozem village and for Bulgarian agriculture. Most of the interviewed small and medium size farmers use outdated farm equipment, purchased after the liquidation of local cooperative, or put together with parts from various other machines. Small farmers complained that only large farmers had access to SAPARD money and this programme has not contributed to their development at all. All classified this policy as unsuccessful or with very limited success. The main factors for the partial failure of this scheme are: (1) complex process of application; (2) unclear and comparatively high cost application procedure; (3) unclear evaluation procedure; (4) high cost monitoring and sanctioning procedures.

In the beginning of 1990s a Water User Association was established in the neighbour town of Rakovski. Currently, this association experiences problem and some larger farmers in the area initiated a process to establish a new water user association. On one hand, the large farmers have resources and organisational capacity to successfully set up the new association. On the other hand, if these large farmers take a key position in the association they may be tempted to manage the infrastructure in their own interest, neglecting the interests of the small farmers. In Belozem village there are several large farmers, but neither of the interviewed expressed interest in the establishment of an association.

The water and soil monitoring procedures are well developed in a number of legal documents. The local office of MEW, located in Plovdiv, conducts soil and water monitoring in Belozem on four constant points. The Water Law requires all existing wells to be registered in the Regional Basin Office. Some of the wells were registered, but we suspect that a good number of them are still unregistered. Well registration is imperative especially for Belozem village because of several reasons. First, the monitoring of underground water level is important for the preservation of the underground water resources. Second, the monitoring of the salinity level of water that farmers use for irrigation is important for preventing secondary soil salinisation. Small farmers cannot seriously affect the level of underground water resources, but they can contribute to the soil salinisation problem.

Conclusions

Currently there are several technical measures that can be applied in the case of Belozem: (1) maintaining and possibly further development of the drainage system; (2) chemical melioration; (3) improvement in crop rotation and cultivation practices; (4) planting tree strips. The first measure is the most important for preventing the processes of secondary salinisation. Without its implementation, the other measures will have a short-lived effect. There is only a slight opportunity to improve the existing crop structure and rotation, but the cultivation practices can be improved if certain investments are made in farm equipment. Chemical melioration is recommended only in plots affected by secondary salinisation. Tree strips could also be planted along the drainage canals in order to improve the natural soil drainage.

In Bulgaria there is a well elaborated system of strategies, concepts, and legislation regarding the soil preservation. However, not much has happened at local level so far. Soil conservation is not the main goal of the policy measures implemented in the area but rather it is a by-product resulting from cross compliance requirements. The per hectare payment programme, help clarifying the use rights and increases the farmers accountability. In addition, this measure will stabilize the farm income and hence farmers will have stronger incentives to introduce soil technical conservation measures. The measures for farms' modernisation can help farmers to purchase new equipments and to improve the cultivation practices and crop structure. However, currently only few farmers from the village have participated in these programmes Farmers, find the application procedure difficult and not transparent. To correct for this problem agricultural advisory services could be expanded to municipality level. The policy for establishment a water user association that has the capacity to maintain the drainage and irrigation system was unsuccessful in the village. Therefore, a temporary solution could be that both the municipality and the Irrigation Company to invest in this activity.

The finding in this report suggests lessons for land conservation policy that can go beyond the case study region. First, they suggest that the technical solutions need to be supported by appropriate institutional settings. Second, the legislation regarding soil conservation might require time and supportive actions in order to promote establishment of suitable institutions on local level. The legislation might not work if the cooperation between farmers, State organisations, and NGO's is not sufficiently developed and/or the rules are not adapted to the local conditions. Third, the policy measure might not have the desired impact if the farmers find the application procedures difficult, not transparent, and are discouraged to apply. Fourth, the economic environment influences the prospects for soil conservation. Instability of the farm income and agricultural product prices might decrease the farmers' incentives to invest in soil conservation practices. Therefore, creating a stable economic environment is a precondition for institutional development.

Acknowledgments

This paper has been developed in the frame of Sustainable Agriculture and Soil Conservation Project (EU-project).

References:

Cardon, G., Davis, J. and Waskom, R. (2007): Salt-Affected Soils, no. 0.503, Colorado State University, Extension. Available at: http://www.ext.colostate.edu/PUBS/CROPS/00503.html

Kavardziev Y., "Saline soils", 1985, In: Penkov M., Dzunenski B., Kavardziev Y., "Melioration of soils with unfavourable conditions", Zemizdat, Sofia, 117 - 247 p (In Bulgarian).

SOIL ENVIRONMENTAL FUNCTIONS - THEIR SOCIETAL IMPORTANCE AND VALUE

Radoslav Bujnovský[1], Jozef Vilček[2]
[1] Soil Science and Conservation Research Institute, Gagarinova 10, 827 13 Bratislava, Slovak Republic
[2] Regional branch of Soil Science and Conservation Research Institute, Raymanova 1, 080 01 Prešov, Slovak Republic

Abstract

Similarly as ecosystem soil provides many services and goods that in soil science are named as soil functions. Besides biomass production, that is possible economically evaluate, the soil provides other ecological functions that are priceless for the society. Sustainability of societal development requires maintenance of soil quality and soil functions - especially the ecological ones. Principles and results of economic valuation of selected soil ecological functions are presented. Preliminary average values of selected ecological functions of agricultural soils in Slovakia are based on previous index evaluation of these functions and defined assumptions and represent 5000 € per hectare for water retention, 4000 € per hectare for filtration of organic pollutants (in fact including inorganic pollutants) and 3800 € per hectare for transformation of organic pollutants, respectively. Valuation of soil and its ecological functions seems as possible way for improvement of soil protection especially in modification of soil price at its permanent sealing but financial values should not to be used as a ground for forming ethical values, which are imminently connected with human approach towards soil and its degradation, and which are essentially needed by global society.

Key words: soil, soil functions, economic valuation

Introduction

Soil as environmental component plays important role as at biomass production and functioning of ecosystems as well as human life quality and thus primarily influences the development of society. This fact can is mentioned in papers and documents since last decade of previous century (e.g. Blum, 1990; Council of Europe, 1992; European Commission, 2006).

Similarly as ecosystem soil provides many services and goods (de Groot et al., 2002) that in soil science are named as soil functions. Besides biomass production, that is possible economically evaluate, the soil provides other ecological functions that are priceless for the society. Recently elaborated proposal of EU Frame Directive on soil protection (European Commission, 2006) considers the following ecological, socio-economic and cultural soil functions:

- biomass production, including in agriculture and forestry
- storing, filtering and transforming nutrients, substances and water
- biodiversity pool, such as habitats, species and genes
- physical and cultural environment for humans and human activities
- source of raw materials
- acting as carbon pool
- archive of geological and archeological heritage.

Sustainability of societal development requires maintenance of soil quality and soil functions - especially the ecological ones. Besides definition of basic principles for evaluation of selected soil functions it is necessary to search also ways for economic valuation (pricing) that can be considered with regard to modification of agricultural soil taxation.

Materials and Methods

The paper is oriented on evaluation the importance of soil functions for the society and benefits from selected environmental functions of agricultural soils. The economic valuation is based on general evaluation of soil functions through accessible or basic set of indicators often called “minimum data set” of indicators (e.g. Doran, Parkin, 1994; Larson, Pierce, 1994) that can embrace as soil as well as site parameters. Individual ecological soil functions are placed into hierarchical system of soil function values. Subsequently suitable frame method of economic valuation is chosen. Economic valuation of selected environmental soil functions is based on previous index evaluation of agricultural soils (Bujnovský et al., 2008), ranked into 5 classes, where existing or derived data on soil parameters that are accessible from databases of Soil information system of Soil Science and Conservation Research Institute Bratislava. The assumptions used as start-point for economic valuation are introduced in Table 2 in next part of paper.

Results and Discussion

Soil use in relation to development of human society and soil functions in simplified form illustrates Table 1.

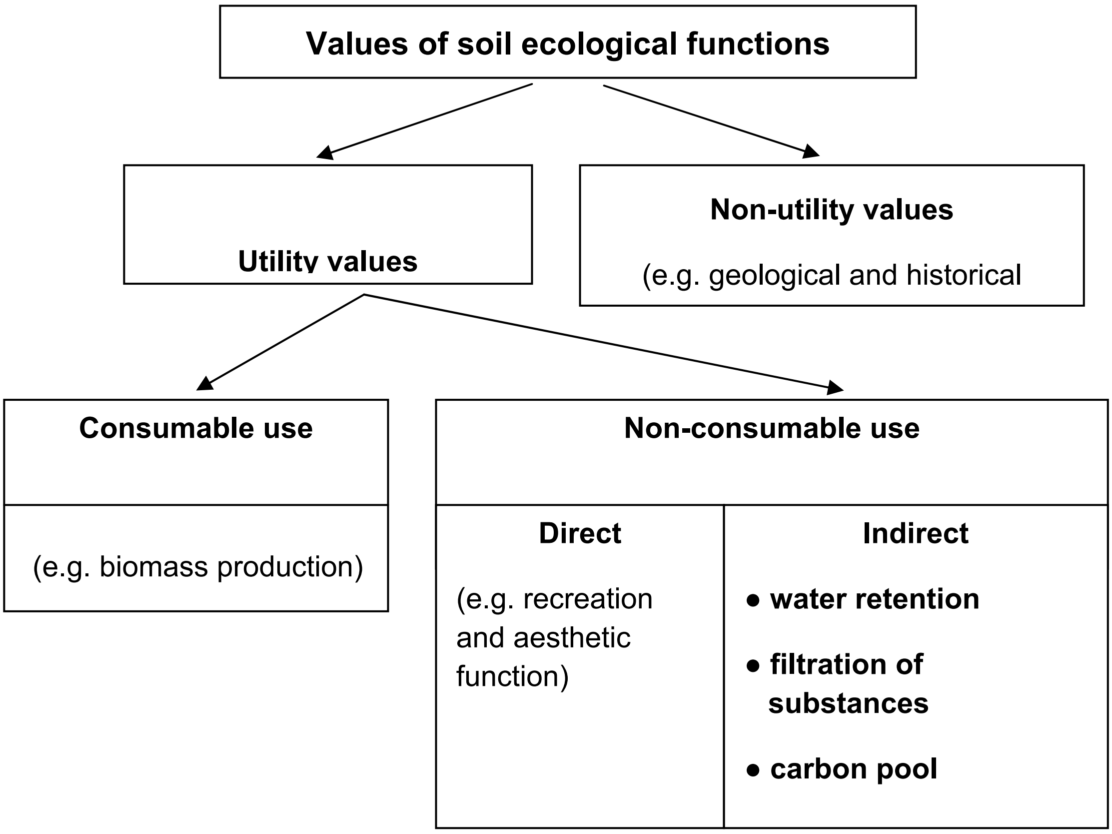
Table 1: Societal interests linked with soil use and societal values as starting point for sustainable societal development

Societal values relevant to soil	Societal interests relevant to soil use
Ecological values corresponding with water retention, substances filtration and transformation, buffering soil changes (pH), biodiversity pool	Maintenance of soil quality and other affected environmental constituents
Social values corresponding with biomass production and partly with other ecological functions	Provision sufficient amount of safe food as contribution to the creation of good health state of population Maintenance of potential possibility for alternative soil and landscape use
Socio-economic values corresponding with soil function as space for economic activities of human (source of raw materials, space for infrastructure and residential development) and partly with biomass production	Development of economically oriented activities with aim to promote regional development, development of employment, living and economical standard of people

It is necessary to mention that in given system usually dominate economically oriented societal interests despite of fact that society claim for many ecological and social values of soil and landscape. Preference to economic interests together with reluctance to search compromise solutions is often manifesting in soil degradation.

Living conditions and subsequently quality of human life directly or indirectly depends on the accessibility environmental goods and services that usually have non-monetary value (de Groot et al., 2002). As introduce Scott et al. (1998), services represent properties of ecological, soil functions from that human derives the benefits. While production function (biomass production) brings utility values, many soil ecological functions can be ranked into regulation functions of environment (e.g.. Daily, 1997; de Groot et al., 2002; Hawkins, 2003) - see Fig. 1.

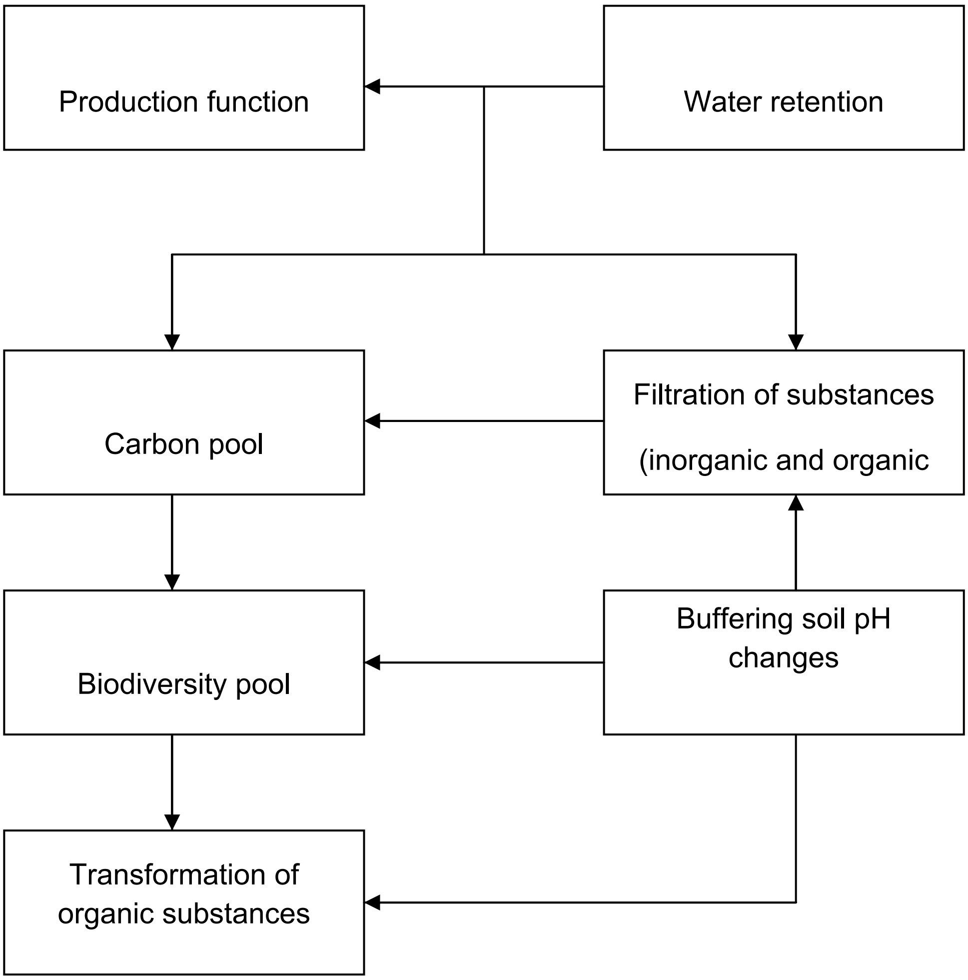
Figure 1. Ranking of services resulting from soil ecological functions into value categories



Economic valuation of selected soil functions - in analogy to ecosystem services (e.g. deGroot et al., 2002; Faber et al., 2002; Daily, 1997; Hawkins, 2003; Hackett, 2006) – represents indirect market economic valuation of selected regulation soil services (expressed by ecological functions) can be based on estimation of *i)* saved or avoided costs due to provision of given soil function or *ii)* replacement costs relating with returning of damaged soil into original state or quality. So the values of most soil ecological functions are classified as use values of indirect non-consumptive use.

In harmony with above introduced ranking of soil ecological functions, the selection of valuated functions respects also their mutual relationship and hierarchy (see Fig. 2).

Figure 2. Hierarchy of production function and ecological soil functions with regard to their valuation



Economic valuation of selected soil functions is based on assumptions introduced in Tab. 2. Preliminary average value of selected ecological functions of agricultural soils in Slovakia represents 5000 € per hectare for water retention, 4000 € per hectare for filtration of organic pollutants (including practically inorganic pollutants) and 3800 € per hectare for transformation of organic pollutants, respectively.

Buday et al. (2006) estimated the replacement costs resulting from positive externality of agricultural landscape (protection against floods, prevention against water erosion, absorption of SO_2 and NO_2 and disarming of organic wastes) at 440 to 560 € per hectare. Linkeš et al. (1996) introduce the non-production soil functions of Slovakia at 780 € per hectare. Presented estimation of values of ecological soil functions significantly exceeds existing estimations.

Table 2: Frame for economic valuation of selected soil ecological functions

Soil function	**Benefit or remediation saved costs**
Water accumulation retention water capacity in soil (up to 1 m)	Soil is regarded as reservoir Average costs of artificial basin are considered to be 2 € per 1 m^3.
Filtration and immobilisation of organic pollutants sorption of organic pollutants on SOM and clay expressed through evaluation of significant soil parameters (Cox, SOM quality Q4/6, topsoil depth) with regard to average sum of rainfall	Soil is regarded as water treatment plan and price of waste water collection approximately 0.75 € per 1 m^3 is taken as price for the soils category with very high capacity for substances filtration. Of course this economic valuation indirectly embraces also filtration of inorganic pollutants - - so there is assumed to divide the initial above introduced price by half to maintain different spatial distribution of soil capacity to provide filtration of two types of pollutants.
Transformation of organic pollutants biotic and abiotic transformation of organic pollutants expressed through evaluation of selected parameters (SOM quality – Q4/6, Cox, clay content, pH) with regard to average annual air temperature	It is assumed that very high ability of soil to transform the organic pollutants can be identical to costs for soil decontamination (over 1000 µg.kg^{-1} PAU). Average PAU content in Soils of Slovakia is around 200 µg.kg^{-1} PAU. The assumed costs for decontamination are 30 USD per tonne and 0.1 m soil layer is assumed.

Valuation of soil and its ecological functions seems as possible way for improvement of soil protection especially in modification of soil price at its permanent sealing. In spite of that, in harmony with Sciama (2007) financial values should not to be used as a ground for forming ethical values, which are imminently connected with human approach towards soil and its degradation, and which are essentially needed by global society.

Conclusions

Economic valuation of soil ecological functions offers the broader view on real importance and subsequently the value of the soil for the society. Estimated economic value of selected soil ecological functions is considered as contribution to the improvement of soil protection especially in modification of soil price at its permanent sealing.

Acknowledgments

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0124-06 and RTD project „Multifunctional soil use“ supported by Ministry of Agriculture No. 2006 UO 27/090 03 03/090 03 19 as well as APVV projects No. 0124-06.

References

Blum,W.E.H. (1990): The challenge of soil protection in Europe. Environ. Conserv. 17, 72-74.

Buday,Š., Chrastinová,Z., Gubová,M., Fáziková,M., Kusá,Z., Petrášová,V. et al. (2006): Rural development and changes of food verticals in the context of Slovakia integration into EU. VÚEPP, Bratislava, 231 pp. (in Slovak)

Bujnovský,R. et al. (2008): Evaluation and pricing of soil and its functions. (manuscript) - in Slovak.

Council of Europe (1992): Recommendation No. R (92) 8 of the Committee of ministers to member states on soil protection. Council of Europe, Brussels, 4 pp.

Daily,G.C. (ed.) (1997): Nature’s services: Societal dependence on natural ecosystems. Island Press, Washington, D.C., 394 pp., ISBN 1-55963-475-8.

de Groot,R.S., Wilson,M.A., Boumans,R.M.J. (2002): A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41, 393-408.

Doran,J.W., Parkin,T.B. (1994): Defining and assessing soil qiality. In: Doran,J.W., Coleman,D.C., Bezdicek,D.F., Stewart,B.A. (eds.), Defining soil quality for a sustainable environment. SSSA Spec. Pub. No. 35, 1994, 3-21, ISBN 0-89118-807-X.

European Commission (2006): Proposal for a directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC. COM(2006) 232 final. European Commission, Brussels, 30 pp.

Faber,S.C., Constanza,R., Wilson,M.A. (2002): Economic and ecological concepts for valuing ecosystem services. Ecological Economics 41, 375-392.

Hackett,S.C. (2006): Environmental and natural resources economics. Theory, policy, and the sustainable society. M.E. Sharpe, Inc., London, 524 pp. ISBN: 0-7656-1472-3.

Hawkins,K. (2003): Economic valuation of ecosystem services. University of Minnesota, 42 pp.

Larson,W.E., Pierce,F.J. (1994): The dynamics of soil quality as a measure of sustainable management. In: Doran,J.W., Coleman,D.C., Bezdicek,D.F., Stewart,B.A. (eds.), Defining Soil Quality for a Sustainable Environment. SSSA Spec. Publ. No. 35, 37-51, ISBN 0-89118-807-X.

Linkeš,V., Bielek,P., Juráni,B., Bujnovský,R. (1996): Benefits from non-production functions of the soil and its agricultural use. (Study report) VÚPÚ, Bratislava, 1996, 16 s. (in Slovak)

Sciama,Y. (2007): Towards a planet-wide ethic. A talk with Dominique Bourg. Research EU No. 52, 16-17.

Scott,M.J., Bilyard,G.R., Link, S.O., Ulibarri,C.A., Westerdahl,H.E.: Valuation of ecological resources and functions. Environmental Management 22, 1998, 49-68.

Posters

RESEARCH ON ENERGY WILLOW *(SALIX SP.)* PRODUCTION IN HUNGARY

Cs. Gyuricza[1], P. Mikó[1], L. Nagy[1], L. Alexa[2], & J. Zsembeli[3]
[1] Szent István University, 2103 Gödöllő, Páter Károly u. 1. Hungary
[2] Profikomp Ltd. 2100 Gödöllő, Dózya Gy. út. 28. Hungary
[3] Karcag Res. Inst. of Univ. of Debrecen, 5300 Karcag, Kisújszállási út 166. Hungary

Abstract

Cultivating woody energy crops on arable land opens up new possibilities for agriculture in Hungary. In Gödöllő, through experiments with different willow species, a technique adapted to cultivation site was elaborated. In our research, we examined the impact of various willow species and different forms of nutrients (compost, artificial fertilizer, and control without nutrient) on the development of plants as well as on soil condition characteristics. In the present study our results for heavy metal content are introduced based on measurements taken from the soil and the plants. Our research results indicate that the heavy metal content of plants is influenced by the form of the nutrient the soil was treated with; however, at the same time, for certain heavy metals our results varied. Nevertheless, results obtained for the dry substance were always below the critical pollution threshold limit.

Introduction

About half of the territory in Hungary, approx. 4.5 million hectares, is utilized for arable crop production. It is estimated that on several hundred thousand hectares the profitability of cultivating traditional crops cannot be guaranteed with current support systems (*Barczi et al.* 2006). These areas are often covered by water and are prone to flooding by inland water; furthermore they are sand or sandy loam, low cultivation site assessment grade soils with extreme water and nutrient management properties. Since these cultivation areas can often also be found in socially and economically disadvantaged regions, agriculture is going to play an essential role in the future. Thus, removing the land from cultivation or switching to other cultivation methods (e.g. from arable land to grassland or forest) cannot be considered as viable solutions (*Dobó et al.* 2006). Planting arboreal energy crop plantations can contribute to retention of the rural population and become a profitable agricultural sector in the future. Broadly speaking, all agricultural areas in Hungary can be utilized for cultivating fast-growing tree species (*Gyuricza* 2007). As these tree species can generally tolerate unfavourable growing conditions, they can also be planted on fields prone to flooding by inland water and flood plains, where other crops cannot be grown. Certain plant species (e.g. salix species) can be safely cultivated on especially dry, drought-prone areas. About 60% of the arable land in Hungary is prone to erosion or deflation, so planting short-cutting-rotation plantations on these areas could provide excellent soil protection as the soil will be covered almost all year round (*Farkas et al.* 2005).

Material and Methods

The woody energy plant experiment was set up in the Szent István University Demonstration Farm for Plant Cultivation on April 12, 2007. The area is situated in the Gödöllő Hills micro-region, 323 m above sea level. The experiment was carried out in two-factor random block arrangement repeated three times. Five different willow species or clones (*Sven, Inger, Tordis, Tora, and Csala*) were used. For each species three different nutrient supply levels were set: 1; surface cover with compost

(50 t/ha), 2; nitrogen fertilizer applied in the spring (50 kg/ha), 3; control treatment with no added nutrient. The compost and the artificial fertilizer were transferred to the soil in the rows at the beginning of May. The technique applied was twin-row with 70 cm row width with 2.5 m between the twin rows in order to leave space for machinery. In the present study the results for heavy metal content are introduced. To determine heavy metal content, samples were taken from plants as well as the soil for each treatment. Soil samples were collected from the top 10 cm of the soil.

Results and Discussion

No significant differences were found in heavy metal content between the various willow species, so data were averaged, and as a result only the differences between the different nutrient supply levels were compared. From the point of view of environmental pollution, cadmium is the most dangerous element, not only for humans and animals but also for plants (*Debreczeni and Sárdi* 1999). In the top layer of the soil, cadmium content did not exceed 0.2 mg.kg^{-1} measured in dry matter, which is not more than 20% of the pollution threshold limit. At the same time, the amount taken up by plants was 250-270% more than that measured in the soil, which, in the case of energy crops, does not pose food administration risk. According to data in the literature, in horticultural and arable crops, it does not exceed the 0.3 mg.kg^{-1} dry matter content.

Chromium is fairly often found in the soil, most of it is absorbed in the top 10 cm layer. Based on our experiment, in the case of the compost-treated soil chromium content was significantly larger than in the artificially fertilized or control plots. However, even this larger chromium content was far below the pollution threshold limit (75 mg.kg^{-1}). In various plant parts, measured chromium concentration was exceptionally low. This indicates that the metal cannot easily be transferred to the shoots of the willow. Based on data in the literature, nearly 98% of the chromium taken up by plants is accumulated in the roots.

References

Barczi, A. – Joó, K. – Pető, Á. – Bucsi, T.: 2006. Survey of the buried paleosoil under the Lyukas-mound in Hungary. Eurasian Soil Science, 39, Suppl. 1., 133-140.

Debreczeni B. – Sárdi K.: 1999. A tápelemek és a víz szerepe a növények életében. In: Tápanyag-gazdálkodás (Ed. Füleky G.), 30-90.

Dobó, E. – Fekete-Farkas, M. – Kumar Singh, M. – Szűcs I.: 2006. Ecological-economic analysis of climate change on food system and agricultural vulnerability: a brief overview. Cereal Research Communications, 34:1. 777-781.

Farkas, C. - Randriamampianina, R. – Majercka, J.: 2005. Modelling impacts of different climate change scenarios on soil water regime of a mollisol. Cereal Research Communication, 34: 1. 185-188.

Gyuricza, Cs.: 2007. Cultivating woody energy crops for energetic purposes. Biowaste, 2:4. 25-32.

NEMATODE COMMUNITY STRUCTURE AND SOIL CHARACTERISTICS IN ORGANICALLY AND CONVENTIONALLY MANAGED LEEK ON SANDY SOILS

D. Buchan[1], **S. De Neve**[1] **& M. Moens**
[1]Dept. of Soil Management, Fac. of Bioscience Engineering, Ghent Univ., Coupure Links 653, Ghent, Belgium, 9000. E-mail: david.buchan@ugent.be
[2]Unit Plant Sciences, ILVO, Burg. Van Gansberghelaan 96 bus 1, Merelbeke, Belgium, 9820.

Abstract

Chemical and biological soil parameters were compared between organically and conventionally cultivated leeks on sandy soils in Flanders, Belgium. Organic carbon and nematode abundance were significantly greater in organic fields, bulk density and soil pH significantly lower, but indices of nematode community structure did not reflect these differences. A residual effect of organic enrichment in organic fields was suggested by a generally greater channel index, indicating a more fungal-mediated decomposition pathway. Differences in soil texture remained present despite a sampling aimed at consistency of soil type.

Introduction

Both long term trials and surveys have shown organic management results in more abundant and diverse soil biota (Mäder *et al.*, 2002; van Diepeningen *et al.*, 2006). However differences due to soil texture and crop type are rarely taken into account in comparisons. Seasonal temperature fluctuations further influence soil biota (Mulder *et al.*, 2003), as do fertilisation and tillage (Neher, 1999). Among soil biota, nematodes have been recognised as useful indicators of soil conditions, being ubiquitous, abundant and present at several trophic levels in the soil food web (Bongers, 1990). Their extraction is standardized and individuals can readily be identified and allocated to functional and trophic groups (Bongers, 1990; Ferris *et al.*, 2001). Leek (*Allium porrum*) is a common over-wintering crop of intensive field vegetable production in the sandy loam/loamy sand soils of Flanders (Belgium) and is seldom fertilised during winter/early spring. The aim of this survey was to compare organically and conventionally managed fields supporting the same crop grown on soils of the same soil region, at a time of year when biological activity is expected to be low and unaffected by recent tillage and fertilisation activities.

Material and Methods

Six organically and 7 conventionally managed leek fields were selected from the sandy loam/loamy sand soil region of Flanders, Belgium. All fields were sampled shortly before harvest at the beginning of April 2008. Three independent composite samples were obtained from each field from 10x10 m plots in which 40 cores (0-20 cm depth) were randomly collected. Separate undisturbed samples were collected to determine bulk density. Moisture content was determined for all samples and results are expressed in terms of dry soil. Microbial biomass was determined using the fumigation-extraction method, organic carbon content by Walkley & Black dichromate oxidation. Mineral nitrogen (NO_3^--N + NH_4^+-N) was extracted from fresh soil with KCl and measured colorimetrically with a continuous flow auto-analyzer (Chemlab System 4, SKALAR, The Netherlands). Soil pH was measured in KCl. Texture was determined using the Hydrometer method on a single composite for each field. After hand-mixing a 200.0 g fresh subsample was taken for the extraction of nematodes using the zonal centrifuge method. Nematodes were counted and their abundance expressed per 100 ml dry soil. Mass slides were prepared and a minimum of 100 nematodes identified at x400 magnification to family or genus level where appropriate. Identified nematodes were allocated to functional guilds according to Yeates *et al.* (1993) and Bongers (1990). Indicators of community structure (Maturity for all nematodes (MI), plant parasites only (PPI) and c-p 2-5 only (MI 2-5), Enrichment (EI), Structure (SI), Basal (BI) and Channel (CI) indices) were calculated as described by Ferris *et al.* (2001). The means of organic and conventional fields were compared with either Welch's modified two-sample t-test or the Wilcoxon rank-sum test (where assumptions of normality could not be fulfilled) using S-PLUS.

Results and Discussion

The means and standard errors of organically versus conventionally managed soils are presented in Table 1. Bulk density was significantly lower in organically managed fields (p = 0.0086), reflecting the higher soil organic carbon of organic soils (see below). The significantly higher pH of conventional soils (p = 0.0009) may be due to calcareous material observed during sampling (e.g. from past liming practices). Organic carbon was significantly higher in organic soils (p = 0.0006), reflecting the increased addition of organic amendments in organic agriculture. Other studies have found only small or no differences in organic carbon (Mäder *et al.*, 2002, van Diepeningen *et al.*, 2006). The abundance of nematodes was also significantly higher in organic fields (p = 0.0067) and was correlated with organic carbon (r = 0.565). The lack of any significant differences in the levels of mineral N indicates that there were no residual effects of previous fertilisation. Microbial biomass tended to be higher in organic fields but differences were not significant, perhaps due to very low values compared to other studies where significant differences were observed (Mäder *et al.*, 2002; Mulder *et al.*, 2003). None of the maturity indices differed significantly, mainly due to high variability, although other authors also note little significant differences in nematode community indices (Neher, 1999; van Diepeningen *et al.*, 2006). Contrary to expectations, the EI and SI of conventional fields were generally greater. The greater basal index of organic fields was mainly due to high numbers of bacterivorous Cephalobidae, while the generally greater CI, while not significant, reflects more fungivorous nematodes and a more fungal-mediated decomposition channel. Although at the time of sampling organic enrichment was no longer detectable in the EI, a more persistent effect could be observed from the CI, perhaps associated with more recalcitrant organic matter or later stages of decomposition. However the average clay content was significantly lower in the organic fields (p = 0.0190), and soil texture has a strong influence on the soil nematode community (Neher, 1999). In conclusion, organic leek fields differed from conventional counterparts in having more organic carbon and total nematodes, but the composition of the nematode community did not reflect important differences in management. Repeated sampling at times of greater biological activity might reveal more differences between the effects of mineral fertilisation and organic matter addition on the nematode community. Despite sampling design for consistency, differences in soil texture, pH and bulk density could not be ruled out from having an influence on the nematode community.

References

Bongers 1990. The maturity index: an ecological measure of environmental disturbance based on nematode species composition. Oecologia 83: 14-19.

Ferris H., Bongers T. & de Goede R. G. M. 2001. A framework for soil food web diagnostics: extension of the nematode faunal analysis concept. Applied Soil Ecology 18: 13-29.

Mäder P., Flieβbach A., Dubois D., Gunst L., Fried P. & Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science 296: 1694-1697.

Mulder Ch., De Zwart D., Van Wijnen H. J., Schouten A. J. & Breure A. M. 2003. Observational and simulated evidence of ecological shifts within the soil nematode community of agroecosystems under conventional and organic farming. Functional Ecology 17: 516-525.

Neher D. 1999. Nematode communities in organically and conventionally managed agricultural soils. Journal of Nematology 31: 142-154.

Van Diepeningen A., de Vos O. J., Korthals G. W. & van Bruggen A. H. C. 2006. Effects of organic versus conventional management on chemical and biological parameters in agricultural soils. Applied Soil Ecology 31: 120-135.

Yeates G. W., Bongers T., de Goede R. G. M., Freckman D. W. & Georgieva S. S. 1993. Feeding habits in soil nematode families and genera - an outline for soil ecologists. J. Nema. 25: 315-331.

Table 1: Means and standard errors for measured soil parameters grouped according to management type. Significant p-values are indicated by * ($p < 0.05$) , ** ($p < 0.01$), *** ($p < 0.001$).

Parameter	Organic	Conventional	P-value
Bulk density (Mg m^{-3})	1.268 ± 0.025	1.367 ± 0.025	0.0086 **
Moisture content (g g^{-1})	0.212 ± 0.005	0.222 ± 0.010	0.2022
Clay content (%)	6.00 ± 0.92	9.23 ± 0.94	0.0190 *
Organic Carbon (%)	1.86 ± 0.11	1.16 ± 0.14	0.0006 ***
Nitrate-N (µg N g^{-1})	1.32 ± 0.20	1.29 ± 0.30	0.9303
Ammonium-N (µg N g^{-1})	0.53 ± 0.07	0.66 ± 0.12	0.3568
pH (KCl)	5.58 ± 0.11	6.30 ± 0.16	0.0009 ***
Microbial C (µg g^{-1})	37.10 ± 3.27	31.86 ± 3.85	0.3067
Nematodes (100 ml^{-1})	781 ± 56	570 ± 75	0.0067 **
PPI	2.22 ± 0.01	2.15 ± 0.08	0.4387
MI	1.73 ± 0.16	1.83 ± 0.17	0.6762
MI 2-5	2.12 ± 0.02	2.54 ± 0.16	0.0739
EI	69.58 ± 10.72	79.26 ± 6.57	0.3094
SI	19.96 ± 3.36	55.16 ± 11.10	0.0591
BI	27.16 ± 8.85	16.12 ± 5.31	0.3094
CI	31.95 ± 19.82	4.99 ± 2.96	0.2677

ETHYLENE BIOSYNTHESIS IN PEA CULTIVATED *IN VITRO*

L. Váňová[1], M. Kummerová[1], O. Votrubová[2] & Š. Zezulka[1]
[1] Department of Plant Physiology and Anatomy, Institute of Experimental Biology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic
[2] Department of Plant Physiology, Faculty of Science, Charles University in Prague, Viničná 5, 128 44 Prague, Czech Republic

Abstract

This study examined the effect of increasing concentration (0.1, 1 and 5 $mg.l^{-1}$) of Fluoranthene (FLT), an important polycyclic aromatic hydrocarbon, on plant growth, ethylene content and accompanying changes in anatomical structure of roots and stems of pea (*Pisum sativum* L.) after 21 days *in vitro* cultivation. Plant growth was negatively influenced by higher concentration of FLT (1 and 5 $mg.l^{-1}$). The ethylene content is increasing proportionally with FLT concentration in the environment and higher ethylene content is responsible for presence of aerenchyma in cortex of roots and shoots.

Introduction

With increasing environmental pollution and anthropological disturbances to ecosystems, the study of abiotic stress response in plants has become more important in agriculture, forest management, and ecosystem restoration strategies.

Polycyclic aromatic hydrocarbons (PAHs) represent important group of hazardous organic contaminants. Their presence in the environment has been shown to lead to the decrease of both quality and quantity of yields. The mechanism of vegetation uptake of organic pollutants is governed by the chemical and physical properties of pollutant, environmental conditions and the plant species. Pollutants may enter the plants by partitioning from contaminated soil to the roots and from the atmosphere by wet and dry depositions to above-ground parts. They are rapidly sorbed to the surface compartment (e.g. the waxy cuticle layer on leaves) and then diffuse slowly into the inner compartments (cellular lipophilic components).

Gaseous phytohormone ethylene is known to promote cell death in defined tissues during plant development and in response to some stressors. Programmed cell death (PCD) is part of the survival strategy of plants to stress. PCD leads to formation or enlargement of air spaces (aerenchyma) that facilitate gas exchange and improve supply with O_2 and CO_2. Other response of plants to the stress is PCD of epidermal cells above adventitious root primordia at the stem nodes. Both aerenchyma formation and epidermal PCD are controlled by ethylene (Steffens and Sauter, 2005).

Material and Methods

Apical segments of pea (*Pisum sativum* L.) were cultivated on Murashige-Skoog (MS; Murashige and Skoog, 1961) cultivation medium with either growth regulator 0.1 $mg.l^{-1}$ of indole-3-acetic acid (IAA) or a combination of 0.1 $mg.l^{-1}$ IAA and 0.1 $mg.l^{-1}$ of N^6-benzyladenine (BA) and 0.1, 1 or 5 $mg.l^{-1}$ of fluoranthene (FLT). Cultivation was done under defined conditions (photopheriod 16/8, PAR 40 $\mu mol.m^{-2}.s^{-1}$, temperature 25±1°C). Growth, ethylene production and changes in anatomical structure were evaluated after 21 days of cultivation of pea plants. Ethylene production was analyzed in the flame-ionization detector gas chromatograph (GC-FID) (50 m capillary column Al_2O_3 „S“ 15 µm, ID 0.53 mm). Temperatures of the packing, column and detector for the assessment of gas hydrocarbons were 230°C, 40°C and 200°C, respectively (Fišerová et al., 2001). The results were processed with software STATISTICA 6 (StatSoft, Inc.®). Plant material embedded in parafine was cut using microtome (Pazourková, 1986). Cuttings (thickness 10 μm) were coloured by safranin and aniline blue.

Results and Discussion

The biomass production is a reliable external indicator of the internal affection of plant metabolism. Changes in fresh weight of callus and shoots of plants enable to evaluate the extent of their influence in relation to the concentration of FLT and the time of exposure. An increased production of biomass was recorded in plants treated by the lowest FLT concentration (0.1 mg.l^{-1}). Higher concentration of FLT (1 and 5 mg.l^{-1}) reduced the weight of shoot and callus of pea plants (Fig. 1A). Increased ethylene production is a result of the occurrence of stressors in the environment. The effect of cytokinins on the elevation of ethylene production, as recorded by Kumar et al. (1987), was indicated also by an increased production of ethylene in plants cultivated *in vitro* on a medium with IAA+BA combination (Fig. 1B).

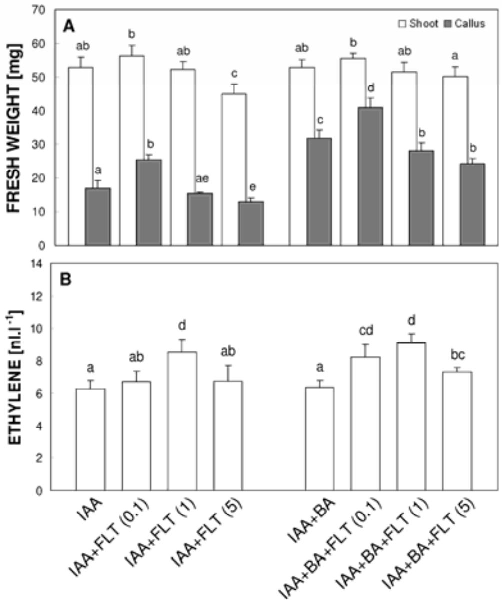


Fig. 1 Fresh weight (A) and ethylene content (B) in 21-day-old pea *(Data points are means of 6 replicates. Different letters show statistically significant difference between values)*

Lysigenous air space formation starts with PCD of defined cells located in the mid-cortex of the root. As PCD progresses large cavities are formed but the outer- and innermost cell layers of the cortex remain intact. PCD is preceded by cell acidification followed by loss of plasma membrane integrity, processes which are indicative of execution of PCD (Steffens and Sauter, 2005). These all lead to the formation of longitudinal channels where oxygen can diffuse from shoots to roots.

Conclusions

Growth of pea plants was negatively influenced by higher concentrations of fluoranthene. The plant content in ethylene is increasing proportionally with concentration of fluoranthene in the environment. The higher ethylene content in plants is connected with number of intercellular spaces (aerenchyma).

Acknowledgement

This work was financed by Ministry of Education, Youth and Sports of the Czech Republic (FRVŠ 476/G4/2008).

References

Fišerová H., Hradilík J., Procházka S., Klemš M., Ráčilová A. (1996). *Rostlinná výroba* 42, 245-248.
Kumar P.P., Reid D.M., Thorpe T.A. (1987). *Physiologia Plantarum* 69, 244-252.
Murashige T., Skoog F. (1962). *Physiologia Plantarum* 15, 473-497.
Pazourková Z. (1986). Univerzita Karlova, Praha.
Steffens B., Sauter M. (2005). *Plant Physiology* 139, 713-721.

BIODIVERSITY OF PULSE CROPS IN IRAN

S. Najib Nia
Ferdowsi University of Mashhad, Iran

Abstract

Due to nutritional and agronomic criteria of pulse crops, they play an important role in cropping systems of many developing countries. Pulse crops have a long history of cultivation in Iran and some of them such as Lentil (*Lense culinaris*) and Chickpea (*Cicer arietinum*) are domesticated in this country. An attempt was made to evaluate diversity of these crops in Iran from 1983-2003. Results showed that diversity of irrigated crops was higher than rainfed. However, the value of diversity in general was low.

Introduction

Pulse crops have been considered as the main source of protein for developing countries and therefore play an important role in food habitat of the people in these countries (Bagheri, Nezami and Soltani, 2000). These plants are also important components of crop rotation in dry areas of the world. In recent years due to problems associated with intensive agriculture, the role of legumes in sustainability of cropping systems has been accelerating. Although some of these plants including Chickpea and Lentil have been originated in Iran, diversity of pulse crops in general is not high in the country. This is also true for the crop biodiversity as a whole (Koocheki, 2006) because from 38 crop species cultivated in the country 20 species contribute to 88 percent of total cultivated area. The aim of this study was to evaluate the present status of biodiversity of pulse crops in Iran.

Material and method

Pulse crops including Bean (*Phaseolus vulgaris*), Chickpea (*Cicer arietinum*) and Lentil (*Lense culinaris*) were included in this survey. Data were collected from statistical sources of the Ministry of Agriculture and the local data basis. Shannon index was calculated based on the cultivated area. In other words in the Shannon formula (34, 39):

$$(1) \qquad H= -\sum((n_i/N) * \ln(n_i/N))$$

n_i/N is the ratio of cultivated area for each crop to the total cultivated area of pulse (Smale et al , 2003). Similarity index for different provinces was calculated by cluster analysis with MINITAB Ver. 13.1 software.

Results and discussion

In Table 1, Shannon diversity index from 1983 to 2003 for pulse crops is shown. From this Table, it is apparent that the diversity index under rainfed condition showed an increasing trend whereas this was not the case for irrigated condition. However this index was somehow inconsistent for the total of irrigated plus rainfed crop. Higher diversity for irrigated crop seems to be associated with expansion of irrigated land for these crops particularly dry bean in recent years.

Table 1: Pulse diversity means in Iran from 1983 to 2003.

Year	Shannon diversity index		
	Rainfed	irrigation	Rainfed+irrigation
1983	0.52	1.27	0.96
1984	0.50	1.26	0.95
1985	0.59	1.21	0.97
1986	0.54	1.26	0.98
1987	0.63	1.22	1.13
1988	0.80	1.31	1.18
1989	0.70	1.30	1.10
1990	0.58	1.29	1.03
1991	0.72	1.17	1.02
1992	0.66	1.11	1.03
1993	0.63	1.16	0.97
1994	0.68	1.24	1.02
1995	0.65	1.25	0.96
1996	0.58	1.18	0.83
1997	0.72	1.11	0.99
1998	0.70	1.08	1.03
1999	0.69	1.07	1.00
2000	0.65	1.17	0.96
2001	0.64	1.17	0.92
2002	0.64	1.09	0.95
2003	0.62	1.04	0.99

Conclusion

In conclusion it appears that diversity of pulse crops is generally low (0.50 to 1.31) and high diversity under irrigated condition compared with rainfed crop is mainly due to non irrigated production of bean.

References

Bagheri, A. A. Nezami and M. Soltani. 2000. Improvement of Cool Season Pulse Crops for Stress Tolerance. Education, Extension and Researches Organization Press of Ministry of Agriculture of Iran, NO. 445.

Koochehi, A. 2006. Agrobiodiversity of field crops in Iran. Iranian Academy of Science special publication.

Smale, E., J. Meng, P. Brennan and R Hu. 2003. Determinants of spatial diversity in modern wheat: examples from Australia and China. Agricultural Economics, 28: 13-26.

DIFFERENT SOIL TYPE AND TILLAGE INFLUENCE ON SELECTED HERBICIDES BREAKDOWN

Ing.Štefan TÓTH, PhD, Ing. Martin DANILOVIČ, PhD.
Slovak Centre of Agricultural Researche, Institute of Agroecology, Spitalska 1273, 071 01
Michalovce, Slovakia, toth@scpv-ua.sk

Abstract

The study compares *acetochlor* (GC/MS), *dicamba* (HPLC/DAD), *metribuzin* (GC/ECD), *S-metolachlor* (GC/ECD) and *terbuthylazine* (GC/ECD) fate from topsoil (5-30 cm) and subsoil (50-60 cm) samples according to three tillage systems on Gleyic Fluvisol and Eutric Fluvisol under the environmental conditions of Central Europe during 2005. The work presents the results of exact field investigation of no-till technology, reduced agrotechnique and conventional tillage. The long-term large scale stationary field trial is established by a block method, soil samples were taken from each four times being repeated the basic variant. Our solution and results confirm the phenomenon of herbicide residue content in soil strong dependence on the used tillage system enhanced or delayed by soil conditions and actually determined by weathering as environmental factor, as well as herbicide residue differentiation by herbicide own environmental fate parameters. The tillage system can be used as a tool of herbicide efficiency being increasing or decreasing, but incorrect interaction of the used tillage system and a chosen herbicide brings side effect therefore it can be the way of environmental risk. For the recent changes in soil treathment technology, governmental regulation, scrutiny and areas studies of herbicides applicability it is desirable to work up alternatives of the tillage system impact.

Keywords: tillage system, soil type, herbicide, residue

Introduction

Considering the herbicides fate at different tillage practices there are many previous works, great number of both original scientific and review works (e.g. Locke et al, 2006). However the type of the tillage system being used can profound changes in the soil environment and thus it is confirmed as important factor of the soil applied herbicides behaviour, the general applications cannot always be formulated because of the diversity of farming practices and local conditions where the research was conducted. However much effort was devoted to herbicides behaviour study, unfortunately there is a lack of herbicide fate studies covering Central European continental conditions or any study concerning different soil tillage treatment impact.

This study compares *terbuthylazine, dicamba, metribuzin, S-metolachlor* and *acetochlor* fate from topsoil and subsoil point of view according to three tillage systems on two soil types. The work presents the results of exact field investigation, the results of field trial carried out during 2005.

Material and methods

This study was carried out in Eastern Slovakian Lowland. The influence of different agrotechnics on above mentioned five herbicides was observed in the field stationary trial established in two localities, two soil types respectively. The followed factors of the trial and its levels are listed in the table 1.

Table 1: Followed factors of the field stationary trial and its levels and other specifications respectively

Factor	Factor level
Soil type - locality	**Gleyic Fluvisol** (GF) – localized at Milhostov
	Eutric Fluvisol (EF) – localized at Vysoká nad Uhom
Agrotechnic	**No–till technology** (NT) - direct sowing by special drill machines Great Plains and Kinnze 2000
	Reduced agrotechnique (RA) - shallow soil cultivation, pressowing harrowing, sowing by drill machines Great Plains and Kinnze 2000
	Conventional tillage (CT) - stubble breaking + deep ploughing, presowing harrowing, sowing by drill machines Great Plains and Kinnze 2000
Herbicide (crop)	at Gleyic Fluvisol: **terbuthylazine** (maize), **dicamba** (spring barley), **metribuzin** (soya bean), **S-metolachlor** (broad bean), **acetochlor** (sunflower)
	at Eutric Fluvisol: **terbuthylazine** (maize), **dicamba** (spring barley), **metribuzin** (soya bean), **S-metolachlor** (pea), **acetochlor** (sunflower)
Soil layer	**topsoil** (top.): 0,05 – 0,30 m
	subsoil (sub.): 0,50 – 0,60 m

The same long-term large-scale field stationary trial was established by the block method in both the localities – soil types, respectively. There were 10 blocks equal to 10 parts of entire crop rotation on each locality, our solution includes only half part (5 blocks - crops per locality, soil type). Acreage of each block is 1.5 ha (excluding shelter belst), each block is aimed for 3 above mentioned different agrotechniques observation according to their crop within 4 subblocks equal to 4 spacely distributed repetitions. Acreage of each our basic variant was 56 m^2 (8 x 7 m). We have solved the residues of five above mentioned herbicides, each herbicide was applied to soil surface without any incorporation or on the different stage of the crop stands according to registered doses in water rate of 300 $l.ha^{-1}$. Dates of applications: *acetochlor* 10.5. GF, 9.5 EF, *dicamba* 8.6. GF, 15.6. EF, *metribuzin* 10.5. both GF and EF, *S-metolachlor* 14.4. at both GF and EF, *terbuthylazine* 10.5. GF, 9.5. EF. Observed herbicides and their further specifications are presented in the table 2.

The soil samples were taken (28.09.2005) from each basic variant and the residual analysis was made for *acetochlor* (GC/MS - analytic method for residues/detector, quantification limit 0,016 $mg.kg^{-1}$), *dicamba DMA* (HPLC/DAD – quant.limit 0,01 $mg.kg^{-1}$), *S-metolachlor* (GC/ECD, quant.limit 0,01 $mg.kg^{-1}$, detection limit 0,008 $mg.kg^{-1}$), *terbuthylazine* (GC/ECD – 0,005 $mg.kg^{-1}$, det.limit 0,002 $mg.kg^{-1}$) and *metribuzin* (GC/ECD with the same limits as *terbuthylazine*). The obtained exact results were worked out by descriptive statistical indexes (average, standard error of deviation).

Table 2: Herbicidal variants and selected parameters of active compounds

Trademark / active compound (% of trademark)	Dose [kg, resp. l.ha^{-1}]	Vapour pressure [mPa]	Solubility in water at 20°C [mg.l^{-1}]	Soil degradation DT_{50} [days]	Leaching potential index [GUS]	Organic carbon sorption constant [mg.g^{-1}]
Trophy *acetochlor (76,8)*	2,5	400	223	14 (13)	1,94	203
Dual Gold 960 EC *S-metolachlor (96,0)*	1,4	3,7	480	22 (21)	0,76	2261
Sencor 70 WP *metribuzin (70,0)*	1	0,121	1165	19 (40)	2,57	37,9
Click 500 *terbuthylazine (50,0)*	3	0,15	8,5	46 (45)	2,74	220
Banvel 480 S *dicamba (48,0)*	0,125	1,67	5500	14 (12)	3,31	13

The mentioned parameters of selected active compounds (besides dose) are accepted from Pesticide Properties Database (University of Hertfordshire & Footprint, 2007). For the Soil degradation DT_{50} there are next data in bracket, according The Pesticides Manual summarized by Tomlin (2003).

Results and Discussion

According to the measured herbicide residues content (table 3) there were significant differences among the solved soil types, the tillage systems, the soil layers as well as herbicides themself. However *acetochlor* and *S-metolachlor* negative all findings being meant no possiblity of statistical valuation, their remained causality can be objected. The valuation of *dicamba, metribuzin* and *terbuthylazine* is more difficult.

In the preface it is necessary to note an environmental impact. On both localities untill the fifth day after application of *acetochlor, metribuzin, S-metolachlor* and *terbuthylazine* there was no day with rain over 3,6 mm. Concerning the application of *dicamba* the great amount of precipitations 36,8 mm (9.6.) and 12,4 mm (10.6.) occured immediately a day after, that caused a deluge and subsequently run-off at heavy clay Gleyic Fluvisol. Similarly 39,5 mm (9.6.), respectively next 8,8 mm (10.6.) of precipitations fallen without any deluge effect at sandy loam medium Eutric Fluvisol where the *dicamba* application was made in a week after the storm rainfall event when conditions were optimal.

Consequently with the mentioned environmental event the fate of *dicamba* was influenced by deluge at GF. We measured less *dicamba* residues at heavy clay soil in comparison to sandy loam medium soil, in contradictiory with *metribuzin* and *terbuthylazine* residues. There were measured more *metribuzin* and *terbuthylazine* residues at Gleyic Fluvisol in comparison to Eutric Fluvisol. The higher *metribuzin* and *terbuthylazine* content at clay heavy soil corresponds to the herbicide own higher organic carbon sorption constant in one breath with higher sorption capacity of GF as EF. There is higher sorption capacity at clay heavy soil than at sandy loam medium soil, as well as stronger *terbuthylazine* than *metribuzin* sorption potential.

In general the *dicamba, metribuzin* and *terbuthylazine* residues content was on regularly higher level at topsoil in comparison to followed subsoil layer, however in the case of *metribuzin* and *terbuthylazine* there were no differences at EF followed soil layers. The higher *terbuthylazine* than *metribuzin* residues content at GF subsoil corresponding to leaching potential of herbicide. The less *dicamba* residues content at GF, including both followed topsoil and subsoil layer, then at EF ones can be partially the result of the run-off effect caused by deluge. Among solved herbicides *dicamba* there are more leachingable, that agrees with its the highest subsoil residue values at EF.

The valuation of *dicamba, metribuzin* and *terbuthylazine* residues according to the tillage system brings no uniformal effect of the used agrotechnique single impact or interaction impact of the agrotechnique on followed soil types. Concerning the tillage systems impact it is remarkable the fact that at the soil sampling we exlude the upper topsoil (0-5 cm) that include crop residues on soil surface.

In the case of *dicamba* there was the highest residue amount at conventionall tillage, less at no-till technology and the least at reduced agrotechnique in general. This general trend was concretely also valid for EF, but concerning GF at the same valuation it is changed position of the conventional tillage with no-till technology. The status of *dicamba* residues according to the tillage systems, at Gleyic Fluvisol including followed soil layers, is probably just secondary one being influenced by occurred deluge event.

In the case of *metribuzin* and *terbuthylazine* residues valuation according to the tillage systems it is notable that at the EF it was only one measurable content, i.e. *terbuthylazine* at no-tilled topsoil. That fact is completely conformable with higher organic carbon sorption constant of *terbuthylazine* in comparison to *metribuzine´s* one and by the same way with the highest organic matter content on topsoil expectable just at no-till technology.

The status of *metribuzin* and *terbuthylazine* residues content at GF topsoil and subsoil according to the followed tillage systems is similar to each other, and probably is affected by above mentioned deluge event occurred approximately a month after these herbicides application. The less residues of *metribuzin* than *terbuthylazine* and their conrete allotment is being corresponded to shorter *metribuzine* soil degradation halftime and in contrary with *terbuthylazine* higher organic carbon sorption constant as well as higher leaching potential due to mainly longer halftime.

Table 4: The herbicides residues content in soil (mg.kg^{-1}) according to soil type and variants of tillage system and soil layer

Soil type	Agrotechnique	Soil layer	Herbicidal active compound				
			acetochlor	dicamba	metribuzin	S-metolachlor	terbuthylazine
GF	CT	top. (SD)	< 0,016 (-)	0,250 (0,050)	0,003 (0,002)	< 0,008 (-)	0,010 (0,008)
		sub. (SD)	< 0,016 (-)	0,070 (0,045)	< 0,002 (-)	< 0,008 (-)	0,005 (0,000)
	RA	top. (SD)	< 0,016 (-)	0,160 (0,140)	0,003 (0,002)	< 0,008 (-)	0,023 (0,008)
		sub. (SD)	< 0,016 (-)	< 0,010 (-)	< 0,002 (-)	< 0,008 (-)	0,010 (0,007)
	NT	top. (SD)	< 0,016 (-)	0,645 (0,596)	< 0,002 (-)	< 0,008 (-)	0,006 (0,003)
		sub. (SD)	< 0,016 (-)	< 0,010 (-)	< 0,002 (-)	< 0,008 (-)	0,007 (0,006)
EF	CT	top. (SD)	< 0,016 (-)	0,950 (0,650)	< 0,002 (-)	< 0,008 (-)	< 0,002 (-)
		sub. (SD)	< 0,016 (-)	0,200 (0,195)	< 0,002 (-)	< 0,008 (-)	< 0,002 (-)
	RA	top. (SD)	< 0,016 (-)	0,300 (0,295)	< 0,002 (-)	< 0,008 (-)	< 0,002 (-)
		sub. (SD)	< 0,016 (-)	0,025 (0,245)	< 0,002 (-)	< 0,008 (-)	< 0,002 (-)
	NT	top. (SD)	< 0,016 (-)	0,300 (0,010)	< 0,002 (-)	< 0,008 (-)	0,008 (0,002)
		sub. (SD)	< 0,016 (-)	0,035 (0,030)	< 0,002 (-)	< 0,008 (-)	< 0,002 (-)

SD – standard deviation

Concerning *acetochlor* and *S-metolachlor* negative finding causality we suggest some objectives. All *acetochlor* residual analyses were made by GC/MS using at relatively high level of detection limit of 0,016 mg.kg^{-1}. Our further suggestion concerning *acetochlor* with no detected residues is connected mainly with high vapour pressure of such herbicide. Thus the incorporation of *acetochlor* might be a favourable method of application to reduce escape losses by vapouring. Similar causality can be valid for non measurable values of *S-metolachlor* residues, each of them were below the used GC/ECD detection limit of 0,01 mg.kg^{-1}, and quantification limit 0,008 mg.kg^{-1} respectively. Furthermore *S-metolachlor* was applied in soil about a month earlier than *acetochlor, terbuthylazine* and *metribuzin* and approximately two months earlier than *dicamba*.

According to the measured residues of the solved *dicamba*, *metribuzin* and *terbuthylazine* the strong influence of the followed soil types with the different both the chemical and physical properties was evident and the apparent impact of above mentioned deluge event at Gleyic Fluvisol. Our results confirm the higher *metribuzine* and *terbuthylazine* residues level of the soil with higher clay mineral and organic carbon content. In the case of *dicamba* it is possible, the ascertained residue status can be strongly effected by deluge event, probably because being secondary. According to many authors the sorbed herbicide is kept since escape by leaching or run-off and protected from the microbial degradation - the main source of soil breakdown. The aged *metribuzin* and *terbuthylazine*, both applied a month before *dicamba* at GF and the deluge event, were probably kept since escape, and in contrary with the highest *dicamba* content at EF can be distorted. The less or no *metribuzin* and *terbuthylazine* at EF can be also the result of higher microorganisms activity partially as well as smaller sorption capacity, respectively. The most visible result of the trial is obtained from the soil horizons valuation. The relation of *dicamba*, *metribuzin* and *terbuthylazine* residues agrees with the herbicides mobility potential. There was confirmed no uniformal effect of the solved tillage systems impact on *dicamba, metribuzin* and *terbuthylazine* residues.

Conclusions

Our solution and results confirm the phenomenon of herbicide residue content at soil strong dependency on the used tillage system enhanced or delayed by soil conditions and actually determined by weathering as environmental factor, as well as herbicide residues soil content differentiation by herbicide´s own environmental fate parameters. The studied agronomically manageable factor, tillage system, can be used as a tool of herbicide efficiency of increasing or decreasing, but incorrect interaction of the used tillage system and chosen herbicide brings side effect thereby it can be the way of environment all pollution. For the recent changes in soil treatment technology, governmental regulation, scrutiny and areas studies of herbicides applicability it is desirable to work up alternatives of the tillage system impact.

Acknowledgement

The work presents results of APVV project *27-035504 „Parametric risc assessment of herbicides using under agroenvironmental conditions of Slovakia“*

References

LOCKE MA, ZABLOTOWICZ RM, WEAVER MA (2006): Herbicide fate under conservation tillage, cover crop,and edge-of-field management practises. In: Handbook of Sustainable Weed Management, Haworth Press, Inc., Binghamton, NY, pp. 373-391.

TOMLIN CDS (2003): The pesticide Manual. BCPC, Hampshire, UK, 13th edition, 1344 p., ISBN 1 901396134

UNIVERSITY OF HERTFORDSHIRE & FOOTPRINT (2007) Pesticide Properties Database. Creating tools for pesticide risk assessment and management in Europe, updated in 9.11.2007. UK, http://www.herts.ac.uk/aeru/footprint/en/

QUANTIFICATION OF RHIZOSPHERE MICROORGANISMS FOR BIOINDICATION OF SOIL QUALITY

L. Ködöböcz[1], K. Gruiz[2] & A. Murányi[1]
[1]Res. Inst. Soil Sciences & Agrochemical Chemistry of Hungarian Academy of Sciences. H-1027
Budapest, Herman Ottó 15, Hungary. E-mail: kodobocz@hotmail.com
[2]Budapest Univ. Technology & Economics, Dept. Agricultural Chemical Technology

Abstract

The goal of the experiment was to analyse the relationship between soil quality and quantity of rhizosphere microorganisms.

An integrated phytoremediation experiment including physical, chemical and biological treatments was established on a mine waste. The total element content of plant and soil samples and number of heterotrophic bacteria and microscopic fungi was determined. Two tailed correlation analysis between soil physical and chemical and microbiological properties was studied. Changes in physical and chemical characteristics of mine waste had a positive effect on quantity of rhizosphere microorganisms. Our results indicated that there is a relationship between soil-plant parameters and CFU number of rhizosphere microbes. We have concluded, that rhizosphere microorganisms as mediators in plant soil interactions indirectly could indicate the effect of different soil melioration and remediation technologies.

Introduction

Soil microbiota especially rhizosphere microorganisms play an important role in soil-plant interactions. The rhizosphere is the zone of soil influenced by roots through the release of substrates that affect microbial activity. Microbial activity in the rhizosphere affects rooting patterns and the supply of available nutrients to plants (Barea et al., 2005). Interactions between soil physical, chemical and biological properties are determine the functioning and diversity of soil microbial populations (Azevedo et al., 2005). Throught the quantification of biological parameters of the rhizosphere we can indicate soil functioning and quality of agricultural systems and remediated lands as well.

Materials and methods

Sampling site is located on the territory of an abandoned Pb/Zn mine. A multy-level mine waste phytoremediation experiment with chemical and biological treatments was set up with three different combinations: 1. mine waste; 2. mine waste with fly ash; 3. mine waste with fly as and lime. Soil samples were taken from rhizosphere at three replicates both from control and treated plots in 0-20 cm depth. The total element content of plant and soil samples was determined by ICP spectrometry. The number of CFU (colony forming units) x g^{-1} dry sample was determined using plate count method on Nutrient (for heterotrophs) and Rose Bengal Agar (for microscopic fungi). For two-tailed correlation analysis between soil physical and chemical and microbiological properties SPSS program were used.

Results and discussion

Soil properties and plant microbiota. Number of heterotrophic microorganisms had a strong negative correlation with soil conductivity ($p<0.01$) and a positive correlation with soil pH (KCl), C, humus, K_2O and P_2O_5 content. Also a positive correlation ($p<0.05$) was found with soil B and Ca content (Table 1). There was a negative correlation ($p<0.01$) between number of microscopic fungi and soil pH (KCl), B, Ca, Mg and Mn content. The positive effect of fly ash and lime supplements on plant dry weight and rhizosphere microbiota particularly related with changes in soil (mine waste) pH. The strong correlation between soil pH and rhizosphere microbial parameters also confirms this assumption. Soil remediation throught the improvement of physical and chemical characteristics of the degraded soils stimulate the life of the microorganisms existing in the soil (Hernandez-Fernandez et al., 2007).

Table 1. Correlation between number of rhizosphere microorganisms and main soil physical and chemical factors

	EC	pH (KCl)	C	Humus	Ca	Mg	Mn	K_2O	P_2O_5
Hetero-trophs	-0.541^{**} 0.000	0.533^{**} 0.001	0.588^{**} 0.000	0.587^{**} 0.000	0.357^{*} 0.028	-	-	0.663^{**} 0.000	0.539^{**} 0.000
Micro-fungi	-	-0.466^{**} 0.003	-	-	-0.552^{**} 0.000	-0.574^{**} 0.000	-0.539^{**} 0.000	-	-

**- Correlation significant at the 0.01 level

* -Correlation significant at the 0.05 level

Rhizosphere colonization. Colonization of plant rhizosphere was estimated through the numbers of colony forming unites of heterotrophs bacteria and microscopic fungi. The CFU number of native microbial population of mine waste was about 10^6 g $^{-1}$. After microbial inoculation the CFU number of mine waste had rise but the differences were not significant comparing to the control plot. As a result of complex chemical and biological treatments the number of heterotrophic microbes had rise up to $5x10^8$ and the differences were significant comparing to the untreated mine waste. A relationship between plant shoot dry weight and CFU number of rhizosphere microbes was established.

Conclusions

Rhizosphere microorganisms proved to be appropriate biological indicators to characterize of soil quality.

Acknowledgements

Finacial support of NKFP (3-020-05) and GVOP-33.1.1.-2004-05-0257/3.0 projects are highly acknowledged.

References

Azevedo et al.: 2005. Pedobiologia. 49: 565-576.
Barea et al.: 2005. Journal of Experimental Botany. 56: 1761-1778.
Hernandez-Fernandez et al.: 2007. Biologia. 62 (5): 542-546.

EFFECT OF CROP STANDS ON THE LOCAL EARTHWORM POPULATION

S.Sivaruban[1] and S.Sivachandiran[2]
[1]Department of Agronomy, Faculty of Agriculture, University of Jaffna, Ramananathan Road, Thirnelveli, Jaffna, Sri Lanka,
[2]Department of Agronomy, Faculty of Agriculture, University of Jaffna, Ramananathan Road, Thirnelveli, Jaffna, Sri Lanka sivas@jfn.ac.lk or ssivamathy@yahoo.com

Abstract

An experiment was conducted to select the suitable crops to be used in crop rotation based on the earthworm population. Different crop stands in a calcic reddish yellow latersol over a period of 6 months (August 2007/February 2008) at Agriculture Research Station, Thirunelvely, Jaffna, Sri Lanka. Six different crops stands such as green gram, maize, fodder grass, okra, sun hemp and bare land with weeds were tested in complete randomized design with three replicates. All the crops were cultivated under pure organic management. 30 earthworms were introduced to each plot. Random soil sampling was done in one month interval and number of earthworms was counted. The average density of mature earthworm ranging from 11.1 to 88.8 individuals (ind) m^{-2}. The average density of earthworm juveniles range from 107.4 to 1081.4 juvenile's' m^{-2}. Highest number of earthworms was obtained in sun hemp plot followed by green gram, fodder. The least earth worm count was recorded in the soil allowed under natural vegetation. The results indicated that to enhance the earth worm activity in the soil sun hemp, legume crop such as green gram and fodder crop can be incorporated in the crop rotation calendar in organic farming. Any how long term research is needed to find more comprehensive results.

Introduction

Farming activities are classified in to two groups according to use of farm input as conventional farming and organic farming. In conventional farming is a form of agriculture which largely use of synthetic fertilizers and pesticides and plant growth regulators. Synthetic fertilizers have high concentration of plant nutrient. It leached from water and causing water pollutions. Some synthetic pesticide and herbicide have toxic substances and it accumulated through food chain, harmful to human health and affects the bio diversity in ecosystem.

Organic farming is a form of agriculture which avoids or largely excludes the use of synthetic fertilizers, pesticides and plant growth regulators. As far as possible, organic farmers rely on crop rotation, crop residues and animal manures to maintain soil productivity and supply of plant nutrients, and to control weeds, insects and other pests.

Objectives of the study

1. To find the suitable crop combinations to use in crop rotation in organic farming
2. Conservation of biodiversity and ecosystem.

Materials and methods

A field experiment was carried out in the research station, Thirunelvely, Jaffna, Srilanka during August 2007 to February 2008 to find the suitable crop combination for earthworm population with different crops. In this experiment, six treatment combinations with three 3 replicates were used and were carried out in complete randomized design (CRD). Two equal boxes were prepared. Boxes were consisting following treatments T1-Green gram, T2-Maize, T3-Control (natural vegetation), T4-Sunhemp, T5-Fodder (Guinea) and T6-Okra.

T1R1	T2R1	T3R1	T4R1	T5R1	T6R1	Box 1
T2R2	T3R2	T4R2	T5R2	T6R2	T1R2	
T3R3	T4R3	T5R3	T6R3	T1R3	T2R3	
T5R1	T6R1	T3R1	T4R1	T2R1	T1R1	Box 2
T1R2	T5R2	T6R2	T3R2	T4R2	T2R2	
T2R3	T1R3	T5R3	T6R3	T3R3	T4R3	

Table 1: Field design

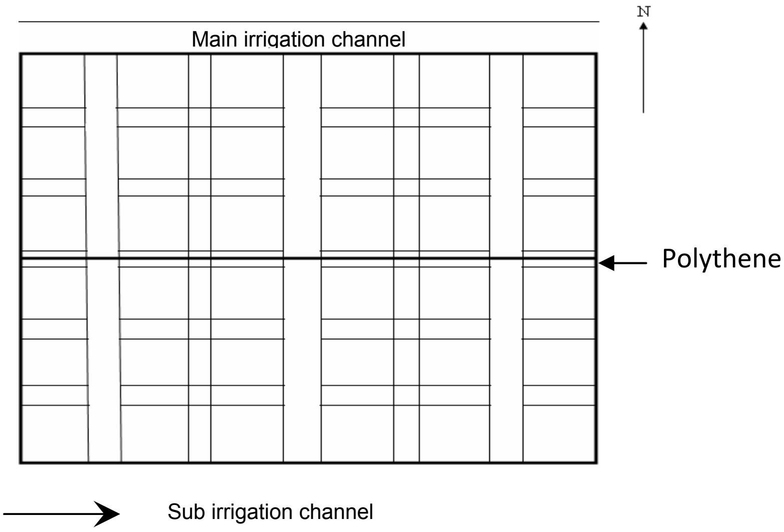


Figure 1: Field Layout

Then Blocking was done perpendicular to the gradient. Each block was further divided into six plots of 1.8 m x 1.8 m size to accommodate the treatment. Two separate boxes were prepared. Then it was separated as 6 columns and 3 rows. So each box has 18 plots such as 6 treatments with 3 replicate. Totally 36 plots were prepared. Pit was dug at 50 cm depth surrounding the field and in between boxes. 100 Cm girth polythene was place vertically in pit. Then pit was filled with soil. 50 Cm polythene was allowed above soil the surface. Then it was place vertically by using wood and end of the polythene was jointed with sticky polythene tape.

After the land preparation one bucket of cattle and goat manure mixer (5kg) and one Palmyrah leaf box of leaf mould (12kg) were applied and mixed well with soil. Initially 30 earthworms were introduced to each plot. Only local earthworms were used in this experiment. Natural organic matter, mechanical and botanical pest and disease control were used our experiment.

Earthworm numbers were recorded through soil sampling at one month interval (one soil sample/month). Soil samples were took randomly in plots. The results were analyzed in by SAS package.

Results and discussion

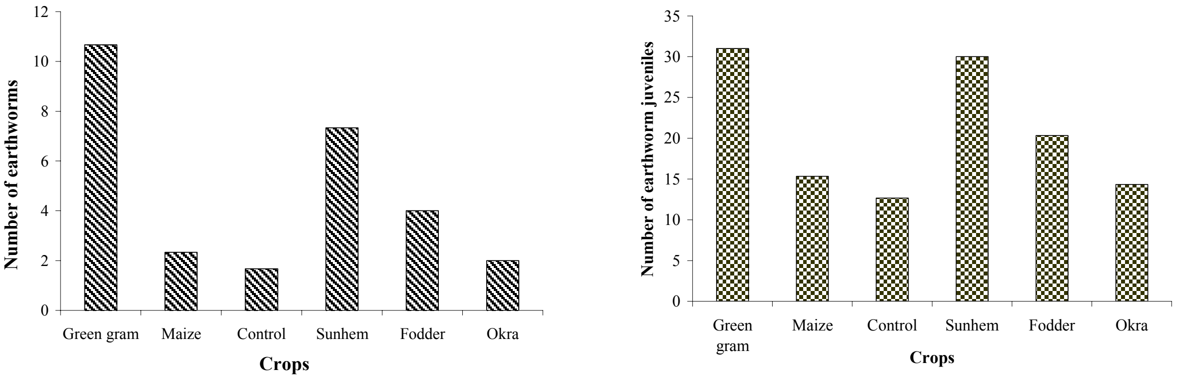


Figure 1: Number of mature earthworm and earthworm juveniles in Soil sample I

Figure 1 shows the changes of earthworm population with different crop stands. Higher number of mature earthworms was found in Sun hemp (T_4) and Green gram plots (T_1) compared to other crops and they are statically significant at $\alpha = 0.05$. Land fully covered with vegetation and leaves in green gram and sun hemp. So plots had been maintained with moisture for long period and got more amounts of organic matters. Both sun hemp and green gram fix atmospheric nitrogen. Nitrogen is important factor for protein synthesis.

In case of maize, Okra and guinea (fodder), less number of mature earthworms and juveniles were observed. It may be due to that defoliation of leaves was less in these crops (Okra) at vegetative stage and dead leaves fixed with stem (Maize and Guinea). So addition the organic matter to plot was prevented.

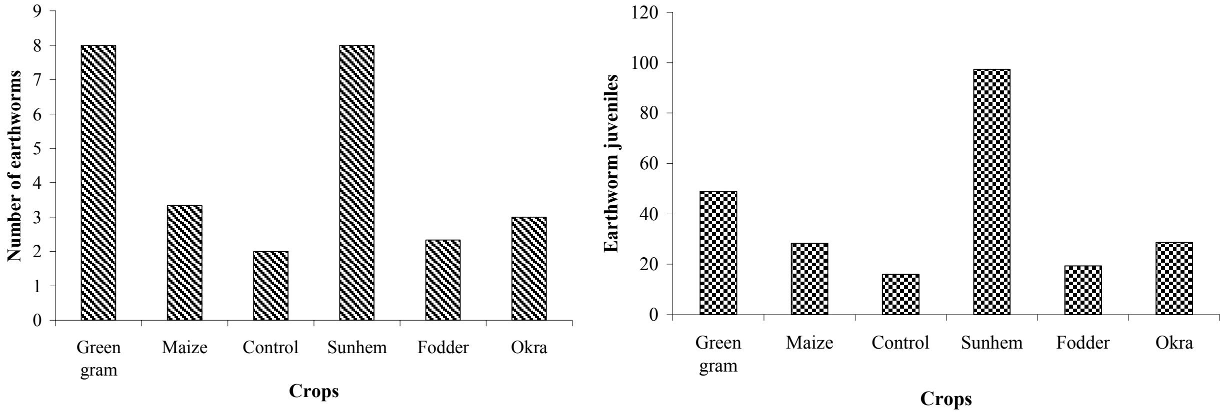


Figure 2: Number of mature earthworm and earthworm juveniles in Soil sample

Figure 2 shows the changes of mature and juveniles earthworm with different crops in later stages. Higher number of earthworm juveniles was counted in Sun hemp and

Green gram plots compared to other crops. Average number of earthworms in soil under Sun hemp (T_4) was significant. Table 1 gives the ranges of earthworm presented in each crop stand.

Table 1: Range of earthworm number and different crop stands

Crop stands	Mature Earthworm Range(m^2)	Earthworm Juvenile Range(m^2)
Green gram (die back)	88.8 to 118.5	344.4 to 544.4
Maize	22.2 to 37.1	129.6 to 314.8
Natural vegetation	14.8 to 22.2	140.7 to 255.5
Sun hemp	51.9 to 88.8	333.3 to 1081.4
Fodder	18.5 to 44.4	129.6 to 225.9
Okra	18.5 to 33.3	144.4 to 318.5
Clean land	11.1	107.4

Conclusion

- Earthworm population was significantly different with crop stands at $\alpha = 0.05$.
- The average density of mature earthworm ranging from 11.1 to 88.8 individuals (ind) m^{-2}.
- The average density of earthworm juveniles range from 107.4 to 1081.4 juvenile's' m^{-2}.
- High number of earthworms was found in the soil samples covered by sun hemp, ranging mature earthworms 51.9 to 88.8 individuals (ind) m^{-2} and range of earthworm juveniles 333.3 to 1081.4 juveniles m^{-2}.
- When the organic matter level was increased in the soil earthworm population also increased.
- The nitrogen fixing crops favoured the earthworm activities and regeneration compare to other crops.
- Sun hemp and green gram can be included in the crop combination when planning the crop rotation in organic farming.

References

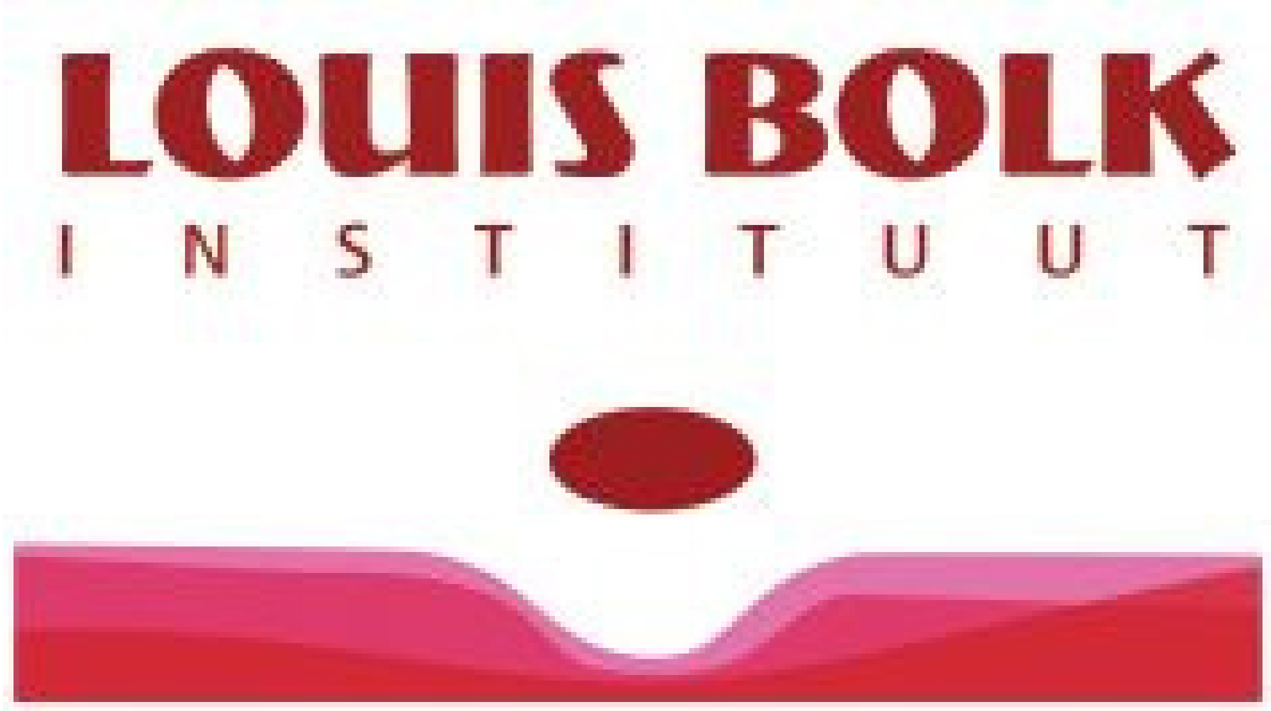
Bhatnagar, R.K. and Palta, R.K. 1996. Earthworm: Vermiculture and vermicomposting, Kalyani publishers, Ludhiana, p 106.

Bohlen, P.J. 2002. Earthworms. Encyclopedia of soil science, 42: 370-375.

Gupta,p.k.,2003, Vermicomposting for sustainable agriculture, Agrobios(India),75:115-117.

Kladivko, E.J.,1993, Earthworms and crop management. Agronomy 279. Purdue Univ.Extension Service.
<http://www.agcom.purdue.edu/AgCom/Pubs/AY/AY-279.html>

Sponzors




Ematech
technológie

EKOTREND MYJAVA
PRODUKT ČISTEJ PRÍRODY

LEGUSEM

STREDNÁ
ZÁHRADNÍCKA
ŠKOLA
PIEŠŤANY
PIEŠŤANY

NATURAL DOMIN & KUSICKÝ

AGROKARPATY s.r.o. PLAVNICA

SEMA HŠ, s.r.o
SLÁDKOVIČOVO

u Juhása
1848

Stredná odborná škola obchodu a služieb Piešťany

SARTORIUS SERVIS, s.r.o.

sartorius