Ph.D. dissertation thesis

Environmental impact assessment based on soil indicators

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Debrecen, 2014

1. BACKGROUND AND AIMS OF THE DISSERTATION

In the last 50 year the Common Agricultural Policy (CAP) became the most productive Community achievement in European Union. In 1992 it was introduced for all Member States as an "accompanying measure" to the Common Agricultural Policy (CAP) reform called McSharry-reform. In 1997 thank to Agenda 2000, agricultural subsidies are connected to environmental and rural development payments. In June of 2003 farmers could receive direct payments provided that they maintain their land in good agricultural condition and comply with the standards on public health, animal and plant health, the environment and animal welfare (cross-compliance) contained in the Regulation (Jámbor és Harvey, 2010)..

So Agri-Environmental Programs have key role in how to motivate farmers to implement sustainable farming practice by environmental related agricultural payments. These have number of benefits. However, their ecological effects are less known and not clear their operative efficiency (*Jámbor és Harvey, 2010*). So the ascertainment of real environmental damages and the exploration of potential hazards are required to get adequate political emphases on nature protection with parallel specific provisions in a not environmental orientated social and economic system. This is confirmed by official statement of European Commission that highlighted the role of environmental indicators in communication (*Smeets és Weterings, 1999*).

Agriculture is in direct relation with environment so it has strong effect on it and in parallel the state of nature basically determines the characteristic and efficiency of agricultural activities. There always been environmental changing effects of agricultural activities. However, intensity and impact areas of process resulted environmental changes have wide range spatial and time variability (*Kreybig, 1946*).

Agricultural sector is pointed as polluter while even though it's damaging effects, it could contribute to protect the environment (*Horváth, 1999*). To detect these effects the use of indices and indicators are required.

OECD (Organisation for economical CO-operation and Development) has set up the pressure-state-response (PSR – Pressure – State – Response) model which emphases anthropogenic originated environmental pollutions and answers to structure its work on environmental policy and reporting. The modified version of PSR framework is being used worldwide as a reporting tool. In 1994 OECD set up DPSIR model (Driving forces-Pressure-State-Impact-Response) which helps to analyse and highlight anthropogenic originated environmental cause-and-effect relationships.

Numbers of literatures are available how to use indicators in business sector in an environmentally closed system. In the frame of environmental impact assessment elaborated environmental indicator systems are used by companies. However, agriculture is an environmentally opened system. Due to these conditions specific analyses are required. Complexity of environmental analyses makes it almost impossible to realize a measured data based and entirely exact environmental impact assessment. Consequently the most of natural processes are approached by modelling methods. To protect Hungary's natural talent, soil tillage has key role in the field of agricultural developments, environmental protection and environmental oriented crop production. As soil is one of the most important production factor, it basically determines the quality and the economic conditions of it. Different soil tillage systems, methods and agricultural techniques have different impacts on soil parameters and on soil water balance. In addition, we have to take it into account that energy and water saving technologies are adequate only for economical and environmental oriented, sustainable farming practice.

In the frame of my thesis crop production will be analysed, from the point of view of DPSIR framework by my research adopted and developed agri-environmental indicators.

My researches contribute to get more detailed information about research area, subject main agri-environmental problems. In addition it could be basis for the area's development movements in the field of water management, agriculture and environmental developments for the next EU programming period.

The aim of my work details:

General aim of my dissertation is the evaluation of crop production technology based on some agri-environmental indicators, to get information about soil – soil moisture content – biomass production system and give solution on how to decrease and eliminate agri-environmental pollutions and contaminants.

- Evaluation of environmental impacts of crop production on
    - soil state,
    - soil water balance,
    - biomass production by its cause and effect relations.
- Environmental impact assessment based on agri-environmental indicators in different spatial levels:
    - lysimeter experiment,
    - half-laboratory experiment,
    - soil tillage experiment.
- There will be environmental pollution analyses by concrete crop production technologies.
- Crop production technology resulted agri-environment state will be estimated by
    - soil state parameters,
    - soil water balance,
    - biomass production aspects, correlations in different years.
- Evaluation of crop production as agri-environmental driving force at landscape level in different years by GIS methods.
- An own research implemented DPSIR frame indicator system will be compiled which will be tested by practice in decision support process.

Give recommendation on how to improve agri-environmental subsidies in next EU budget period.

2.RESEARCH METHODS

My agri-evironmental indicator based researches were made in Debrecen and in Karcag area. My studies extend to laboratory measurement and landscape evaluation.

Treatments of daily impacts related experiment

To gain more detailed information on the impacts of different soil surface on environmet in-situ measurements were done in a lysimeter experiment at the Lysimeter State of Karcag Research Institute of the University of Debrecen, CASE. The experiment was carried out between 26th and 27th August 2009. 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 this experiment in situ measurements were carried out to separate environmental effects of bare and grass covered soil surfaces (driving forces). State indicators were the following: soil- and air temperature, soil moisture and soil CO_2 emission.

Treatments of different soil cultivation based experiment

To get more detailed information on the effect of different soil cultivation processes in-situ measurements were carried out at Institute of Water and Environmental Management, University of Debrecen. The soil is sandy loam. All treatment had four reputations and one control. Four different soil surface types were created as driving forces and their effects on the environmental state. Soil loosening treatments were loosening, ploughing in 20 cm and in 40 depths.

Closed soil surfaces and not closed soil surfaces were made. In addition the impacts of soil compaction were measured as well.

There were treatments on different nitrogen level impacts on environmental state. Ranges were 0 N, 50 N, 100 N and 150 N.

State indicators were the following: soil- and air temperature, soil moisture and soil CO_2 emission.

Treatment of soil tillage experiment

In the Department for Soil Utilisation and Rural Development of Karcag Research Institute of the University of Debrecen, Centre for Agricultural Sciences and Engineering in close co-operation with the Department of Water- and Environmental Management broad examination of new soil tillage methods was started in 1997 based on the research achievements gained in the past decades. In 2007 a reduced cultivation system and a conventional tillage system were used in that experiment (H-1) of 15 ha divided into four plots:

Conventional tillage	34 m x 480 m	1.63 ha,
Conventional tillage	33 m x 480 m	1.58 ha
Reduced tillage	114 m x 480 m	5.47 ha,
Reduced tillage	114 m x 480 m	5.47 ha

Agri-environmental impacts of crop production technologies were analysed as driving force indicators and pressure indicators. 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 (I-2) 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. In 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.

Conventional tillage	73.3 x 480 m
Direct seeding	72.2 x 480 m
Mulch+ Direct seeding	65 x 480 m
Mulch+Mulchtiller+ Direct seeding	33 x 480 m

Measurements and used equipments

To determine soil respiration infrared based method was used which means that different gas molecule absorbs on different wavelength (Burai, 2005).

One fraction of the experiment is to investigate the CO_2-emission from the soil and the soil state determined by the tillage operations, hence by measuring the CO_2-emission the effect of various tillage operations as the elements of different soil cultivation systems on the microbiological activity of the soil can be judged by soil-plant system. The CO_2 gas emitted from the soil mainly originates from root respiration, microbiological activity and decomposition of organic matters. So measurements were carried out after harvesting to exclude root respiration processes. However, effects of the different soil tillage operations were detectable.

An Oldham MX 21 PLUS infrared gas analyser was used to measure the CO_2-concentration of the air above the soil surface before and after a 30 minute-long incubation period in Debrecen. For the spatial delimitation of the measuring area PVC cylinders (Zsembeli, 2005) were applied. These were inserted to the soil in 10 cm depth.

In order to quantify this, in situ CO_2-emission of the soil was measured by means of an ANAGAS 98 infrared gas analyser in Karcag. For the spatial delimitation of the measuring area the original cylinders (Zsembeli et al., 2005) were substituted with a newly developed frame+bowl set. The metal frame is inserted into the soil (sharpened bottom edge) down to 5.5 cm and the trough around the frame is filled with water. The volume of the plastic bowls is approximately 2,800cm^3, the diameter of the metal frames is 20 cm. From measured concentration (ppm) values, CO_2 emission ($g*m^{-2}*h^{-1}$) was calculated by Flux formula.

<u>Measurement of main abiotic indicators</u>

Main soil physical and chemical parameters were measured at Institute of Water and Environmental Management, University of Debrecen. The air and soil temperature were detected by TESTO 925 digital thermometer. Soil moisture content was measured in 150 mm depth by TRIME-FM portable moisture measurement instrument.

Meteorology data were supplied by WEATHERLINK VANTAGE PRO2 system in Debrecen.

At Karcag soil moisture is measured by TTN-M (40 cm depth), soil thermal (5 cm and 10 depths) and air thermal is measured by digital thermometer. In addition there is a meteorology station at Karcag Research Institute.

<u>Geodetic survey</u>

There was a geodetic survey at B-5 parcel of Karcag Research Institute to get information about the surface of an inland water spot and spatial correlations in July 2010. It has the GRID structure of the mesh 10 meters x 10 meters.

There is a Geodetic Control Point (GCP) at the building of Karcag Research Institute which is registered by Institute of Geodesy, Cartography and Remote Sensing (FÖMI). To get a more precision survey, a shp was created which contained a 10 meters x 10 meters GRID structure by ArcGIS 9.2 and was copied to Trimble Uno GPS.

Landscape indicator based measurements

Direct physical indexes are terrain, hydrogeology, soil parameters, land use (Kollányi, 2004) which are involved into my GIS analyses. Digital Evaluation Model (DEM) based on 34 topographic map by contour line and point digitalization. Contour lines were reclassed, aspect and slope categories were analysed too in ArcGIS 10.1. software.

In IDRISI Selva Software 11 different slope categories and flow direction were analysed in Karcag area.

In Karcag area there are 7 soil water monitoring devices were set up in 1950's. So long term time series could be. Analyses were implemented by Microsoft Office Excel and Surfer 9.

Related to Karcag area LANDSAT ETM+ images were downloaded between 2003 and 2010. Ma analyses required images without black lines and without clouds. After this selection I could measure two drought (2003 and 2007), two precipitated (2006, 2010) and an average year (2009). LANDSAT7 ETM+ images were cut into the right size in IDRISI Selva by a window based on Karcag area. This window was made in Arc GIS 10.1 by the map of Karcag inland watershed area. Based on Band3 and Band 4 Normalized Vegetation Indexes (NDVI) were calculated to get information on biomass production state of Karcag area in different years. In addition I measured the correlation between biomass production, land use and soil conditions. Soil conditions were defined by Agrotopo map database. The following codes were used: code nr. 1. (soil type), code nr. 3. (soil physical type), code nr. 7 (soil organic content t ha^{-1}).

Land use categories were determined by Corine CLC vector database 2000 and 2006. This database was downloaded from the homepage of European Environmental Agency (EEA).

A first these indicators were tested at H-1 parcel. So I could determine NDVI values range to crop yields. Then I made landscape level evaluations.

Landscape level soil carbon stock change based on IPCC method

The amount of carbon stored in and emitted or removed from permanent cropland basically depends on the crop type, the management practices, the soil variables and the climate variables. The calculation method we used is based on the default factors given in IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry

(LULUCF 2003). According to this method, the existing carbon stock (from the native soil type and the climate characteristics) and the land use factor (from the land use type, management and input features) must be determined.

The soil type was categorised as High Activity Clay Mineral Soil on the base of AGROTOPO data base. In addition soil organic content determination based on Agrotopo database as well in Karcag area. In the case of H-1 parcel, soil organic content was determined for both soil tillage systems by laboratory measurements.

Soil types harmonised with the land use types of Corine CLC 2006 database to determine the rate of arable land on different soil types in Karcag area. This harmonisation process was made by IDRISI Selva software.

The climatic classing, the determination of the climate zone was done on the base of climate maps made by the Hungarian Meteorological Service. As the mean annual temperature of the investigated area is above 10°C and the annual precipitation is less than the evapotranspiration, the factor of the category Warm Temperate Dry was applied.

To choose the input factor that representing the agricultural practice of the region, 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 Low Input category for conventional tillage, while Medium Input category for reduced tillage were applied for the calculations.

According to the estimation method described in the IPCC Good Practice Guidance for LULUCF (2003) – based on AGROTOPO map data base harmonisation – first the soil organic C stocks (SOC_{ref} in t ha^{-1}) were estimated with default stock change factors (F_{LU}, F_{MG}, F_{I}) for the beginning. Then I made practical oriented recommendation on how to increase soil carbon stock till the end of inventory time (20 years).

Compilation of research oriented DPSIR indicator system

On the bases of OECD and European Environmental Agency published DPSIR framework, I implement to my researches an own DPSIR agri-environmental indicator system. This indicator system bases on concrete measurements and analyses. Detailed structure of it will be described in the frame of my results because it builds on my previous outcomes and results.

3. MAIN OBSERVATION OF DISSERTATION

Agriculture is in direct interaction with environment as part of natural system. So it has strong effects on nature. However, the characteristic and efficiency of agricultural activities are entirely determined by elements and state of nature. Agricultural plant production has plenty of environmental pollution and at the same time, it could contribute to agriculture environmental protection.

Agri-environmental schemes has key role in agriculture related environmental activities by the motivation of farmers to implement sustainable and good agricultural practice. To detect these effects, use of indicators and indices are required. In 1994 OECD set up DPSIR model (Driving forces-Pressure-State-Impact-Response) which helps to analyse and highlight anthropogenic originated environmental cause-and-effect relationships.

In my thesis I estimated the environmental effects of plant production – as Driving force of DPSIR – by subjected agri-environmental relationships.

My agriculture-environment indicator oriented researches were carried out in Debrecen and in Karcag region. My research work covers lab measurements, field experiment analyses in Karcag, GIS evaluation works and predictions based on IPCC method in Karcag area.

Based on DPSIR model, I compiled a new agri-environmental indicator system adapted to my researches.

My researches were carried out from laboratory measurements till landscape level at Debrecen and at Karcag.

Based on DPSIR model, I compiled a new agri-environmental indicator system adapted to my researches.

Group of Agricultural-environmental Driving forces contain the evaluation of climate conditions, time series meteorology database, soil conditions, conventional and reduced tillage systems and tillage based elements of plant production systems. Uses of agricultural machinery, characteristics of nutrient management, pest control system were estimated to confirm agricultural-environmental benefits of reduced tillage.

Group of Agricultural-environmental pollutions involve macro- and microeconomics regulations, land use changes, lack of professional skills and decrease of wildlife. Moreover, the following indicators were evaluated: air pollution and soil degradation processes by agricultural machinery, inland water and ponds, changeable soil water regime, year effects on yield (drought, high precipitation, average year).

Agricultural-environmental state indicators such as nha, power kWh, number of till, diesel usage kg ha^{-1} were used to get information about positive or negative effects.
The state of soil-water system was characterised by the evaluation of soil state parameters, soil resistivity, soil surface and inland water quality. Furthermore, the cause and effect relationship was measured of CO_2 emission of the soil, soil temperature and soil moisture in different tillage systems.
Both uses of yield and NDVI indicators were suitable to characteristic the state of different places in varies years. Agri-environmental state indicators of Karcag area were the following: terrain conditions, area and ratio of different land uses based on Corine database, NDVI indicators with correlation to land use and soil conditions (by Agrotopo database). NDVI values were calculated by 3rd and 4th channel of LANDSAT images. Moreover, based on IPCC method and soil organic content, soil carbon stocks were calculated on arable lands of Karcag area. In addition I made an agri-environmental friendly prediction on how to change land use to achieve higher soil carbon stock in 20 years time by agricultural-environmental effect indicators.
I've made recommendations on how to solve problems of inland water, reduce drought damages by tillage and use of mulch technology. Importance of using manure and green manure were highlighted.
To compensate agri-environmental risks and reduce environmental impacts, allowances could be applied in the frame of Agri-Environmental Program and Natura 2000.
Agricultural-Environmental Response indicators were used to make recommendations on next EU budget period. These were the following: promoting professional consultant activity, organising regularly professional days for farmers to achieve a more efficient communication between research institutes and farmers. In my opinion it is very important to inform farmers about sector specific application opportunities and how to do a good application. Getting subventions in the frame of Agri-Environmental Program, contributes to implement the agri-environmental oriented and good farming practice in wide range.
I made the following observations:
It was exhibited that daily impact of bare soil surface on environment is so much more extreme. So it's very important to avoid this surface type to keep the moisture content of the soil and lower temperature to achieve better soil microbiological activity during drought summer days.

On the bases of cultivation experiment, it is essential to use mulch technology and close soil surface in drought periods.

In addition it was confirmed that in the case of conventional tillage the limitation factor was soil temperature and in the case of loosening the soil moisture content was the limitation factor. Consequently to achieve good soil transpiration conditions we should take it into account that the aim is the less disturbance of the soil. The reasons are agrotechnical methods indirectly increase CO_2 emission of the soil. Indirect processes like soil degradation (deflation, erosion), land drainage are resources of carbon mobilisation.

Based on field level crop production analyses, reduced tillage has number of advantages such as better energy consumption, lower mechanical inputs thus dwindle CO and CO_2 emission. Our results generated from the CO_2 emission measurements can contribute to the reveal of environmental pollution of CO_2 emission of the soil, hence agriculture could be developed pursuing an environmental friendly way in the future by the use of alternative tillage systems.

On arable lands, which based on conventional tillage, it is recommended to do nutrient supplement by plants demand and soil analyses. Instead of using only N or NKP fertilizers, macro and micro elements could contribute to higher yields with appropriate quality. However, alternative solutions such as manure, green manures and/or mulch technology contribute to management practices which build up soil C by increasing the input of organic matter to soil and/or decrease soil organic matter decomposition rates.

When soil surface is covered by plant residues (mulch) erosion is avoid and organic matters are kept into the soil. As organic matters have significant affect on soil structure, buffer capacity, water retention ability, biological activity and nutrient equilibrium it is recommended to use this technology widely in practice.

Since the biomass production and yields were similar on reduced tillage plots (H-1), so energy saving management consumption result more cost saving than yield loss. In addition there were higher harvested yield than in conventional tillage system.

Only those pesticides were used which are allowed by Agri-Environmental Program. However it could be more environmental oriented practice by the application of integrated pest management.

Based on my analyses, NDVI as vegetation index is suitable for biomass mapping and separating plants inside a parcel. In addition NDVI values have correlation with soil heterogeneity. Mixed pixels should leave out of consideration. On reduced tillage plots higher biomass productivity was detected. However yields were similar to other plots. So the amount of biomass quantity not changed in parallel with yield level in the comparison of tillage systems. Consequently the use of mulch was exhibited by biomass mapping. Both biomass vegetation index and yield level monitoring are suitable for state agri-environmental indicators.

On the bases of different level measurements, the soil CO_2 emission is appropriate agri-environmental state indicator to detect differences of soil disturbances, soil tillage systems and changing agricultural practice. Close correlation was demonstrated between soil cultivation intensity and soil respiration. To gain more detailed information an automated soil CO_2 flux monitoring system is necessary.

DEM of Karcag area based results qualified for surface state oriented descriptions.

Studying the effect of different soil utilisation/cultivation methods on the carbon stocks based on both IPCC method and Agrotopo map database are competent to use their results as state indicators. It is recommended at Karcag area the conversion of a part of arable land with conventional tillage into energy saving conservation systems affects carbon stocks. Carbon stocks in soils can be significant and changes in stocks can occur in conjunction with most management practices, including crop type and rotation, tillage, drainage, residue management and organic amendments. The annual increase of the carbon stock can be up to 0.55 t ha^{-1} if the conversion to reduced tillage practice is combined with a higher input of organic matters e.g. annual cropping with cereals where all crop residues are returned to the field. Or if residues are removed then supplemental organic matter (e.g. manure, green manure) is added. However, green manure practice is not so popular because of drought summers resulted risks on water supplement of crops in dry tillage systems. I gave a recommendation for (experimental) planting green manure e.g. winter rye/winter wheat with vetch (Lathyrus L.) or Lathyrus sativus. The differences are considerable, hence all farmers who still follow conventional soil tillage should think over whether the sustainability of crop production would not requires the conversion into a soil protective, energy- and soil carbon stock saving management practice.

Lowland area's characteristic soil type is solonec soil. Parts of these are arable land. It could be an environmental solution to change their land use to grassland. European Union supports environmental oriented sustaining of these lands by allowances, subventions. In addition these are long term solutions to increase C stock of the soil in

Karcag area. Based on my recommendation on 29 352.06 ha, in 20 years time, 35 330.42 t soil C stock rising is realizable.

In the case of landscape level NDVI evaluation, most of the NDVI values depended on soil heterogeneity, year effect and indirectly it was affected by quantity and distribution of precipitation.

For the next EU planning period, in the frame of next Agri-Environmental Program the communication will have key role between research institute and farmers, consultant and farmers. For the success of Agri-Environmantal Program, it is required to draw the attention of farmers on the details and conditions of Agri-Environmental Program and other agricultural related application opportunities and the way of successful realization. In addition tax benefits, more subsidies, and joint implementation projects could help to motivate farmers and agricultural firms to adopting new practices.

I verified the eligibility of DPSIR based agri-environmental indicator system which is implemented, detailed and developed by my researches. In Karcag area I gave a recommendation on its practical extension and adaptation.

4. NEW SCIENTIFIC RESULTS OF DISSERTATION

1. Analysed soil tillage systems were evaluated based on agri-environmental indicators in Karcag area. I contributed to the numerical characterization of environmental state, detection of environmental impact processes, and to discover cause and effect relations of different soil tillage systems.
2. Adapted to my researches a DPSIR framework based, agri-environmental indicator system was developed in different spatial level, which is suitable for agri-environmental impact assessment evaluation in Karcag area and areas with similar environmental conditions.
3. Based on geodetic survey of inland water spot, micro surface morphology and the leaching of nutrient were detected by inland water samples. I contributed to numerical characterization of inland water environmental impacts.
4. Correlation of yields and biomass production was determined based on LANDSAT ETM+ images by NDVI incices. I contributed to the process of how to get information about the correlation between biomass production and yields
5. Corine land use database, Agrotopo map database and LANDSAT ETM+ images collectively were integrated and used during the

spatial surface characterization and agri-environmental oriented impact assessment at Karcag area by my research adapted DPSIR indicators in different years. Theses evaluation are useful for decision support processes by environmental oriented program planning and monitoring activities.

6. Based on both IPCC method and Agrotopo map database, soil reference carbon stock was estimated at Karcag area. Consequently it is recommended at Karcag area the conversion of one part of arable land with conventional tillage into energy saving conservation systems affects carbon stocks. In addition application of mulch technology and (or) supplemental organic matter are necessary as well. On poor areas with solonec soil I gave a recommendation to change land use to improved grassland and get subventions in the frame of SAPS and Agri-Environmental Program by European Union.

5. PRACTICLE UTILIZATION OF RESULTS

1. I contributed to the numerical characterization of environmental state, detection of environmental impact processes, and to discover cause and effect relations of different soil tillage systems. This recommendation involves energy and cost saving management consumptions with alternative solutions such as using more manure, adopting green manures and/or mulch technology, less ploughing in right depth and integrated pest control practice.
2. Adapted to my researches a DPSIR framework based, agri-environmental indicator system was developed in different spatial level, which is suitable for agri-environmental impact assessment evaluation in the field of agri-environmental oriented decision support planning and monitoring activies.
3. Correlation of yields and biomass production was determined which promote yield mapping improvements and the preparation of environmental oriented developments.
4. Corine land use database, Agrotopo map database and LANDSAT ETM+ images collectively were integrated and used during the spatial surface characterization and agri-environmental oriented impact assessment at Karcag area. My results contribute to decision preparation and decision support processes in the field of environmental oriented program planning and monitoring activities.

5. Based on both IPCC method and Agrotopo map database, soil reference carbon stock was estimated at Karcag area I gave solution on how to improve soil carbon stock in practical way. The conversion of one part of arable land with conventional tillage into energy saving conservation systems affects carbon stocks. In addition application of mulch technology and (or) supplemental organic matter (e.g. manure, green manure) are required. On poor areas with solonec soil I gave a recommendation to change land use to improved grassland and get subventions by European Union.

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7.PUBLICATIONS RELATED TO THE DISSERTATION

Register number: DEENKÉTK/291/2014.
Item number:
Subject: Ph.D. List of Publications

Candidate: Nikolett Szőllősi
Neptun ID: H7CJ33
Doctoral School: Kerpely Kálmán Doctoral School of Corp Production, Horticulture and Regional Sciences
Mtmt ID: 10027380

List of publications related to the dissertation

Hungarian book(s) (1)

1. Juhász C., **Szőllősi N.**: Környezetmenedzsment. Észak-alföldi Régióért Kht., Debrecen, 188 p., 2008. ISBN: 9789639874060

Foreign language Hungarian book(s) (1)

2. Juhász, C., **Szőllősi, N.**: Environmental management. Debreceni Egyetem, Debrecen, 138 p., 2009.

Hungarian book chapter(s) (1)

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4. **Szőllősi N.**, Juhász C., Kovács G., Zsembeli J.: A növényborítás hatása a talaj CO2 emissziójának napi dinamikájára.
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The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

19 September, 2014

H- 4032 Debrecen, Egyetem tér 1. ¤ E-mail publikaciok@lib.unideb.hu