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ABSTRACT OF PhD THESIS

Application of a newly developed agri-environmental indicator system in field plant production practice

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1. RESEARCH AIMS

This work was intended to provide methodological support for the development of a modern environmental information system. Using this system the farmers can successfully identify the environmental impacts of their work, allowing them

1.1. to analyse the relation of environmental sources and the land use
1.2. to keep an up-to-date record on field plan production and environmental management
1.3. to comply with agrarian support system related obligations for supplying data demanded by national and EU authorities.

In order to establish the environmental information system my research work is centred around four main aims:

1. **Quantitative determination of environmental impacts**

   In this phase a standardized monitoring system based on traditional field data as well as remote sensing data has been developed, which provides an easy and fast means for identification and quantification of environmental impacts in field plant production. Data collection was performed in the "Puszta" region of Tedej Inc., at Hajdúnánás-Tedej.

2. **Mapping of data obtained by the monitoring**

   This phase involved integration of data gathered by different methods into a uniform GIS environment, to allow of their comparison with each other and their modelling depending on each other.

3. Evaluation of quantified environmental impacts

Aiming at a detached impact assessment, we developed an indicator system, which provides information on the status of the soil and on the environmental impact of the agricultural activity to the farmer and at the same time helps the authorities in monitoring the efficacy of the regional support based on environmental protection.

4. Testing of the indicator system in the practice of field plant production.

Field testing of the developed indicator- and environmental information system was performed in the same area as the data collection.

2. BASIS OF RESEARCH

The 2078/92 EU enactment accepted in 1992 as a part of the reform of the Common Agricultural Policy brought about a change for the agriculture of the EU and of the whole Europe. This enactment re-evaluated the role of agrarian sector as a food producer and established a new, multifunctional farm model. According to the new agricultural policy, agriculture in return for the governmental support, has to accomplish environmental and societal functions.

Thus, in connection with the new policy, the support system also has been changed. Quantity-based support will only be available to those farms, where the satisfactory quality and quantity is obtainable without drastic intervention, and is attainable using extensive methods.

The support available for farms larger than 20 hectares will gradually decrease. The disengaged sources will serve as support for agri-environmental protection and rural development. These changes will lead to the increase of importance of smaller farms and rural development in the common agricultural policy.

For Hungarian farms these support opportunities will only be available if they understand their makings, thus are able to find the support forms most adequate for their situation. For successful application and obtaining support, however, the farmers have to know the productivity and natural values of their property as well as the environmental impact of the production process.

On the other hand, for the decision-maker it will be crucial for the supervision of support to obtain modern, exact data.

My work addresses these practical issues. For quantification and monitoring of environmental impacts an agri-environmental indicator system has been developed, while data collection problems are addressed by development an EU-conform environmental information system based on GIS and remote sensing technologies.

3. METHODS OF RESEARCH

3.1. Presentation of the sample area

The area where the study was conducted was an approximately 1500 hectares large intensively cultivated farm land. It is located at the border of the Hortobágy region and the Hajdúság loess region, thus its soil in the west is solonec-soloncak, while in the east chernozem. Besides the intensively cultivated areas, in the lower areas there are patches of degraded plant associations characteristic to lick soils of the Hortobágy, which are important for nature protection causes and serving as refugees for a number of farm associated plant- and animal species.

3.2. Setting up the environmental information system

The basis of the environmental information system is the soil information system created in GIS environment in 2000. This system was completed with the digital relief model of the area, with the aerial photos taken by (FÖMI) Institute of Geodesy, Cartography and Remote Sensing, with the scaled plan of the estate, with the vegetation maps drawn in the years 2001-2004 and with a hyperspectral image taken in August, 2002, with a 80-channelled DAIS (Digital Airborne Imaging Spectrometer) 7915. All raster and vector data stocks were digitalized and georeferenced according to the EOV (Uniform National Projection system).

Digitalization and geoprocessing was performed using the ArcView 3.2 and the Erdas Imagine 8.0, respectively. Thus all data stocks were integrated into the same projection system, thus it was possible to visualize and manipulate them together.

The next step was attaching base line data to the map database. First the field register book data continuously recorded by the corporation were included into the database. Input data connected with the different work processes performed on the individual fields of the study area were recorded in Microsoft Excel 2000. A dBase IV data table was created out of this digital data stock, which can be manipulated by ArcView 3.2 as attributive data, thus the data could be connected to map elements, e.g. to tables, allowing of the geospatial modelling of production data.

As a result, connected data on material and energy input of the work processes of cultivation, nutrition, plant protection and water management in a given year can also be inquired together with visualization of the tables on the map.

3.3. Collection of data regarding the status of resources

The extent of resource exploitation was determined using the soil information system and the field register book. In order to complete these data, I performed examinations regarding the salinity status of the soil and prepared the vegetation and the biotope network map of the natural and semi-natural areas of the region. I used the amount of water handed out for irrigation to quantify water consumption.

The fuel used up was assessed according to the 1. and 1/A appendix of the 60/1992 (IV.1.) Government Regulation, including among other issues the methods to calculate the fuel and lubricant consumption of different agricultural engines in different work processes.

Analysis of the hyperspectral photo was based on examinations of the soil salinity status and vegetation maps supplemented with the land use categories based on the field register book

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3.4. Development of the agri-environmental indicator system

Due to the orientation of the new EU support system towards nature-protection and environmental management, I used the following viewpoints during development of the indicator system.

The indicator system should express

- the expectations of the society and of the decision-makers,
- the multifunctionality of the production,
- the present status of the environment and the sensitivity of the system to environmental impacts,
- expected impacts and the reactivity of the system,
- and the possible production, ecological and economic advantages accessible by changes in the management system.

According to these issues the developed indicator system includes the expectations towards the farmer in the field of

- nature-protection,
- production technology,
- governmental decrees and
- informatics.

Consequently, based on the available data I established the following indicator groups.

Table 3.1. : Environmental elements, systems and the connected indicator groups

Environmental elements	Issues
Soil	Soil loss due to erosion
	➢ erosion
	➢ deflation
	Condition loss due to accelerated decomposition of organic materials
	Decrease of biodiversity
	soil compaction
	Saline accumulation – secondary salinization
	Contamination
	Nutrient accumulation
Water	Water use
	Deterioration of water quality
Air	Changes in air quality
Ecosystems, biodiversity	Habitat networks (homogeneity of biotopes)
	➢ Structure
	➢ Dimensions of biotopes
	➢ Connections between different habitats
	Species composition
	➢ Number of species
	➢ Diversity
	➢ Population trends
	➢ Flagship species
	Genetic diversity
	➢ Semi-natural agro-ecosystems
	➢ Agro-ecosystems
Landscape	Diversity and natural character
	Homogeneity
	Cultural character

The indicator systems within groups are presented in the appendix.

4. MAIN ESTABLISHMENTS OF THE WORK

Due to its distinctive natural environment, the "Puszta" area of the Tedej Inc. is exceedingly suitable to demonstrate how these advantages can be exploited utilizing the present support programs initiated by nature- and agri-environmental protection pursuits.

As it is situated at the border of two geographical regions, its soil structure exhibits extreme heterogeneity, which definitely limits the cultivation modalities, but, on the other hand, provides excellent opportunities for the corporation to obtain, with proper conduct, the increasingly available support sources based on the Common Agricultural and Rural Policy.

Present support systems, besides production-based support actions, support primarily those activities, where the production is conducted in terms of environmental deference, i.e. resources are exploited in a manner, and to the extent conforming to the natural specialities of the area.

The aim is to plan a production system where the difference between the needs required from and the natural specialities of the area is small, the proportion of artificial resources remains well below that of the natural resources, which do not diminish during production, or at least remains in balance.

The first step towards this production system is to develop and build an environmental information system using which the farmer can estimate the natural specialities of the production area, and can also successfully identify the environmental impact of the activity.

The monitoring system utilizing both traditional field data collection, GIS and remote sensing technologies presented here is suitable for building a database necessary for such an information system in the scope of field plant production.

Keeping a consistent record of cultivation data provide detailed information on the resources needed for the production, on the material and energy input and on cultivation work performed in the area. The analysis of the status of the natural resources is based on soil parameters (salinity, compaction, modelling of tillage works on each table), relief data (erosion, contamination spread, compromised areas) and botanical data (biodiversity, status of the ecosystems).

Integration of data collected with different methods into a homogeneous GIS environment allows of their comparison with and their modelling depending on each other. Thus, they conform to the requisite of an environmental information system, i.e. comparison and counter-dependent re-evaluation of the elementary data should provide additional, wider sense information.

A good example is the conclusion drawn from analysis of field and hyperspectral data. We found that soil salinity status is gradually deteriorating along irrigation canals and inland inundation areas, which indicates inadequate irrigation and water management practice.

Contrastingly, the relatively high species diversity of and especially presence of sensitive, protected species in the inclusion areas covered with semi-natural vegetation and their stability shows a well-balanced nutrient management as well as a reasonable and moderate pesticide use.

Accordingly, a properly built environmental information system is suitable for impact evaluation and for measurement of the environmental efficiency.

To ensure objectivity, however, it is necessary to develop a perspicuous and reliable indicator system, which provides unequivocal information on the state of area in question for the farmer, for the political decision-maker as well as for the authorities bestowing support and monitoring its efficacy.

Elementary data for the indicator system presented in this work can be collected completely in case of soil, ecosystems and landscape, and partially in case of air and water. The extent and distribution of pesticide, manure and chemical fertilizer use can be quantified according to field register book data and spatially visualized using the GIS system. The extent of water and fuel consumption can be analysed similarly, and fuel consumption can be used to calculate flue gas load.

Physical load of the soil can be calculated from soil cultivation data and their spatial visualization together with the soil status. Using the resulting soil information system, such a cultivation practice can be planed, which conforms to the local conditions of the production site.

It was possible to gather information on the salinity status of whole area (1500 hectares) by sampling a significantly smaller (cca. 1 hectare) teaching area using the remotely sensed photo. These results, in view of the development plan, can be used in predicting possible yield losses and in planning sowing structure (sowing salt tolerant plants, withdraw highly salt affected areas from cultivation, developing water biotopes in areas affected by surplus water).

Data obtained with mapping of semi-natural vegetation compared with hyperspectral data allows of setting up spectral libraries for individual associations, which facilitates data collection on stability and natural status of different associations.

Furthermore, re-evaluating data and exploring correlations provide a means to develop a land use zone system in the area.

Integrating tillage data into a GIS enables the developed system to connect to land evaluating system of DeMETER and to MEPAR coordinated by FÖMI, supplying them with the potential to evaluate the environmental and ecological impact of production.

Thematic processing of cultivation, soil and nature-protection data and connecting them to cultivation units (fields) enables the system to facilitate the preparation of the operation plan necessary for obtaining a support for Sensitive Nature Areas.

The monitoring and indicator system allows of performing the assessment of the environmental status required for introduction of environmental management systems.

5. NOVEL SCIENTIFIC ACHIEVEMENTS OF THE WORK

1) I proved that development of a sufficiently structured and detailed digital environmental information system can efficiently be used in the development of indicator systems for assessment of environmental load.
2) I showed that thematic and systematically recorded cultivation data serve as elementary background data for quantification and evaluation of environmental indicators in the scope of field plant production.
3) For the soil as an environmental element and for the ecosystem and the landscape as environmental systems, I developed an indicator system applicable specifically in agriculture in order to objectively evaluate the environmental impact of farming.
4) I proved that remote sensing technology, based on an existing environmental information system, is suitable for assessment of soil salinity status of the studied area.
5) I established that remote sensing technology, based on an existing environmental information system, is suitable for assessment of the ecological status of semi-natural biotopes and for monitoring of diversity of landscape and land use.

6. FUNCTIONAL UTILITY OF ACHIEVEMENTS

1) With the delineation of the structure of an environmental information system I outlined a possibility for the development of a reliable data supplying system utilizable in monitoring of environmental management support actions.
2) I determined the composition of data sources and the quality of the data processing required by the developed indicator systems.
3) The hyperspectral data collected and integrated into the system allows of identification of grass associations based on spectral data.
4) I established critical spectral ranges calibrated with field and laboratory measurements for assessment of spatial distribution of soil salinization.
5) I developed an indicator-based method to reduce harmful emission and decrease in use of fossil energy.

7. APPENDIX

7.1 table **State of soils: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Soil compaction **Dust** **Soil loss** ➢ **Erosion** ➢ **Wind erosion** **Exchange of Carbon** **Loss of organic matter**	Trafic on the field	Weighting factors referring to certain tillage works multiply with the utilized area	Field register book
Salinisation	Salt accumulation	Extend and proportion of salt affected areas	hyper spectral images, environmental information system
Contamination	active ingredient content of pesticides	mg/l	Field register book
	Active ingredients /ha	mg/ha	Field register book
Nutrient load	N load	kg/ha	Field register book
	P load	kg/ha	Field register book

7.2 table **State of water: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Water use	Water used for irrigation	m^3/ha	Field register book, hyper spectral images, Environmental information system
Water quality ➢ **nutrient load**	1. N and P load	Kg/ha	
	2. boundary vegetation	Type, width	
➢ **pesticide load**	1. active ingredient load	mg/ha	
	2. boundary vegetation	Type, width	
	3. non sprayed field margins	Type, width	

7.3 table **State of air: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Contamination	CO load	m^3/ha	Field register book, Environmental information system
	PAH load	m^3/ha	
	NO_x load	m^3/ha	

7.3 table **State of habitat coherence: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Spatial complexity	1. boundaries between patches	Boundary diversity	
	2. number of boundary types		
	3. proportion of cropped to uncropped land – including marginal features	Habitat classification	• aerial photographs • land use maps, • biogeographical maps
	4. length of linear habitats (hedgerows, tree rows, reed, grass margins)		
Habitat quality	1. Extend of habitats associated with agricultural land management	Extend of semi-natural habitats	
	2. natural habitats situated inside of the agricultural fields	Extend of habitats	• habitat classification according to the Monitoring System for National Habitat Biodiversity • database of Environmentally Sensitive Areas
Habitat connectivity	1. linkages between valuable natural/semi-natural habitat types	• presence of ecological corridors • length • quality	
	2. . linkages between valuable natural/semi-natural habitat types with special focus on NATURA 2000 sites		• aerial photographs • land use maps, • biogeographical maps • CORINE database
	3. habitat diversity	Diversity indices	Sites elected in NATURA 2000 progams

7.4. table **State of species diversity: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Population trends	1. proportion of declining to stable and increasing plant species	Density	According to the vegetation mapping and national species atlases
Species richness	2. number of species		
Indicator species	3. presence of particular flagship species	Proportion of flagship species to the total number of species	
	4. ratio of specialist to wide spread species		
	5. presence of invasive species	Proportion of invasive species to the total number of species	

7.4. table **State of genetic diversity:** : **Issues, indicators, components and linkages**

Issue	**Indicator**	**Component**	**Reference**
Actual genetic diversity in semi-natural agro-ecosystems	1. Genepool diversity within populations of farm related plant species in semi-natural agro-ecosystems	Shannon diversity index	According to the vegetation mapping and national species atlases
	2. hedgerow length	ha/total farm area	According to the vegetation mapping and national species atlases
Genetic diversity in farm species	3. Genetic diversity in farm crop species	Ratio number of field grown varieties	Field register book
	4. trends in changes within number of field grown varieties	Positive or negative trends	Field register book
	5. extend of Environmentally Sensitive Areas (ESA)	Areas with valuable genetic diversity/ total farm land	According to the vegetation mapping and national species atlases
		Areas with less valuable genetic diversity/ total farm land	According to the vegetation mapping and national species atlases
	6. number of crop species under regulation for plant genetic resources conservation	Number of species, varieties	Field register book
	7. proportion of traditional crop species	Number of species, varieties	Field register book

7.5 table **State of genetic diversity: Issues, indicators, components and linkages**

Issue	Indicator	Component	Reference
Natural coherence	1. Adequateness of land use according to bio-physical conditions	• Land use type; • Soil types • Geomorphology • Hydrology • Climate	CORINE database Soil maps ESA databases
	2. proportion of semi-natural habitat types of total farm area		CORINE database ESA databases
	3. number of natural habitats bordering a fields		
	4. linkages between related landscape elements	Number of different and use types	
	5. share of characteristics habitat type(natural or cultural)	size proportion to cultivated land	Aerial photograph databases
Natural diversity	1. openness versus closeness	Share of farm land, forests and grassland	Environmental information system
	2. total number of species associated with agricultural land use / farm unit		
	3. habitat diversity		
	4. land use diversity	Number of types and their shares	
	5. plant biodiversity	Proportion of historical land use	
	6. presence of water surfaces	Proportion to total farm land	
	7. relief	Diversity in geomorphology	
Natural character of land use	Intensity of land use	• Share of irrigated/non-irrigated land	Field register book Biomass indices Vegetation and yield map
		• Yield of cereals	
		• Share of cereals in the farm	
		• Share of cultivated land	
		• Share of grassland	

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