Theses of university doctoral (PhD) dissertation

EVALUATION OF THE CHANGES OF AGRICULTURAL LAND USE ON AREAS WITH DIFFERENT ENDOWMENTS USING GEOGRAPHICAL INFORMATION SYSTEM TOOLS

Kálmán Kovács

Consultant:
Prof. Dr. János Nagy, Doctor of the Hungarian Academy of Sciences

UNIVERSITY OF DEBRECEN
Kerpely Kálmán Doctoral School

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1. PRELIMINARIES AND OBJECTIVES OF THE DOCTORAL DISSERTATION

The biggest challenge of our age is the conflict that has been evolved between the ever-growing need for energy and other natural resources by the technology-led development and the continuously decreasing stocks (fossil energies, mineral raw material), as well as the deterioration of their quality (air, soil, sweet water). Therefore, surveying the resources and developing their rational management are of particular importance. In my dissertation, I deal with the usage of fertile soil as one of the most important natural resources. One of the objectives of my research is to use specific examples to prove that geographical information systems can be used to plan landscape management and they even make it possible to explore new connections.

Geographic Information System (GIS) is a modern instrument which, however, only works well if it approaches its served field of research or branch of science with proper respect. Since its essence is modelling and measurement, it is necessary to become acquainted with the most important professional bases, features and tricks of the field we intend to model and measure in order to make decision or compile decision preparing materials. Therefore, in my thesis I intended to provide pictures about all of my research fields (landscape utilisation-planning in spillway reservoirs, maize sowing seed development comparative analyses and land use during motorway construction) and about how the existing or evolvable geographic information systems adapt themselves to the solution processes and what added value they represent.

I have been working at the Department of Mathematics (currently of Differential Equations) of the Budapest University of Technology and Economics (BME) for more than two decades; parts of my research activities carried out there (Fourier series approximations) are directly applicable for the performance of geographic information system and remote sensing tasks. Beside my university work, the experience gained during my public career guided me to the practical tasks related to land use (landscape management-planning in flood areas, motorway network developments, plant growth and yield estimation in different sample areas) the elaboration of which is described in detail in my thesis. I used satellite pictures in every analysis, the efficiency of which I became convinced of in the last decade as President of the Hungarian Space Board.

I kept my professional attachment to information technology in the course of my public activities as well, thus I was able to participate in the elaboration of important materials like the National Information Technology Strategy and I could facilitate the launching of laws (electronic broadcasting – 2003, freedom of electronic information – 2005) and programs (eHungary – 2002, PublicNet – 2003) supporting the development of information society in Hungary, which make it possible to apply information technology instruments in an increasingly wide range. My thesis includes the utilisation and introduction of multiple European geographic information systems. The fact that a part of my public activities opened the door for me to participate in European projects and to cooperate in the elaboration of the related domestic programs helped me get acquainted with these systems. We live in the era of network knowledge. In the course of my work I always lean on the cooperation with different professional fields, because I am convinced that – and the same is true for e.g. the future prospects of agricultural management - only responses offering multifunctional, complex solutions (*Nagy*, 2006) are competitive among the challenges of our age. These responses require multidisciplinary approaches (*Kovács*, 2009b). I tried to give voice and space to this view in my thesis.

My research objectives:

Study of Fourier series approximation Modern geographic information system applications considerably rely on the most important data collecting procedure of our time: remote sensing. Not by accident, because in the last decade a particularly large development is experienced in this field. Information content of data sources has been increased, capacity of computers has been improved, and therefore it is possible to use images with higher geometric and radiometric resolutions (*Lillesand* et al., 2004). Because of the increasing demand for remote sensing data, number of image processing has been increased in the order of magnitude within several years, which enforces larger scale automatic processing. One of my research areas is Fourier series approximation which has a significant role in image processing – mainly in the field of filtering and enhancement (*Závoti,* 1999). The aim of my research on the field of Fourier series approximations was to use spectrum analysis or another procedure analogous to it for as wide a scope of functions as possible for future image processing. My objective was to improve convergence conditions and by this to strengthen the mathematic grounding and reliability of image processing.

Land use investigation on three professional fields. Modern land use requires a complex – social, economic, environmental – approach and also efficiency and sustainability to be kept in mind. All these require collective management of the knowledge related to the field and also the analysis of its interactions. Multifunctional agriculture gains ground more and more extensively in Hungary as well (*Dobos* et al., 2000); it is environment and landscape management complying with the requirements of sustainability and embedded in the so called eco-social market economy (*Ángyán* et al., 1999). The objective of my research is to verify: geographic information systems are suitable and efficient instruments for the fulfillment of the complex demand of land use analysis, planning and monitoring and also for the recognition and confirmation of new relations on the fields of landscape management, cultivation and linear infrastructure.

Landscape management-planning in spillway reservoirs. Semi-natural landscape management is the strategic development path of the Hungarian rural areas. The improved Vásárhelyi-plan has as its objective to build spillway reservoirs alongside the Tisza River and to elaborate new landscape management in these areas (*Váradi*, 2002). My research subject is the analysis of the new landscape management planned to the area of the spillway reservoirs in 'Nagykunság' and in the area of Szamos and Kraszna Rivers. Basically, the method of landscape management means a management which conforms to the natural endowments and which is formed by many factors: e.g. natural endowments of the land use, climatic and soil conditions, inundation levels and conditions of water regime (*Alföldi,* 1999), proprietary and utilisation background. In the course of the planning of landscape management taking place in the area of spillway reservoirs the objective is mainly not the formation of wetland habitats and the conservation of their condition, but the development of a distinguished landscape management system conforming to the terrain position of the flood area. My research objective is to verify: territorial data obtained from available geographic information systems and from remote sensing provide adequate information for the planning of the new landscape management system to be elaborated within the spillway reservoirs. My additional objective was to create such a planning aid by means of which it is possible to overview and compare the possible different landscape management versions easily.

Plant growth and yield estimation in different sample areas. The recent decades brought fundamental change in agricultural land use: The implementation of only one cultivation technology (*Rátonyi* et al., 2005) – which conforms to the soil conditions, water balance and important production factors – can give a satisfactory response to the new environmental and economic challenges. In these days fast and accurate information services have become the basic requirements of secure agricultural production. It is justified in more and more fields that by processing data obtained via remote sensing such information can be gained which can be utilised in both technological and decision-preparing processes in the course of the cultivation of the given plant. (*Víg* et al., 2008). My research objective is to investigate and justify the applicability of the estimation of plant development and growth by means of the processing of satellite images on a new field: maize-seed production (*Ványiné* et al., 2009). My research also covered whether it is possible to provide assistance by means of satellite images for the designation of the most suitable crop lands from the point of view of certain significantly different hybrids.

Land use during motorway construction. The combined effects of the regional challenge of globalisation and our EU accession made it obvious that two comparative advantages are presenting themselves for Hungary for the integration into global economy: one of them is the field of services and products with significant added value based on our knowledge and qualifications; the other is international transportation and logistics based on our geopolitical situation and traffic infrastructure (*Michelberger*, 2005). The latter entails significant land use. Land use of motorways is basically decided in the phase of network planning, but it becomes definite by the time of the finalisation of the track. Modern traffic network planning is a task requiring the joint application of numerous professional fields. Expectations – beside functionality and economic efficiency – tend to cover the analysis of the effects on natural and human environment and the consideration of the long-range objectives of regional development and arable land management (*Kovács,* 2009a). My analysed area is the section of motorway M7 between Lake Balaton and Nagykanizsa. My research objective is the comparison of the applicability of different GIS-purpose data acquisitions – particularly remote sensing data – for the determination of the land use of motorway construction and for the revelation of the difference between planned and actual utilisation.

Hereby, I would like to acknowledge those who I could work together with in the recent years; working with whom I could acquire many new knowledge and experience and who helped me to successfully carry out the research activities.

2. RESEARCH METHODS

2.1. FUNCTION APPROXIMATIONS WITH FOURIER SERIES

Applicability and – the closely connected – quality limits of the Fourier series image processing which has an important role within the most important data acquisition procedure of geographic information systems (remote sensing), are mainly resulted from the fact that the image function and the functions describing disturbances are sometimes unable to fulfill the strict conditions of Fourier series approximation (*Álló* et al., 1989). Additional problem is that we are unable to determine how large an error it is and what sort of change it causes in the image if we apply the procedure in spite of the fact that the conditions are not exactly met (*Székely*, 1994). My objective was to improve the convergence criteria of the Fourier series approximations strengthening the mathematical grounding and reliability of image processing.

Function series and function classes involved by the research

Function series applied for function approximation in the course of my research are classic Fourier series, generalised – referring to an optional orthonormal system – Fourier series, Hermite-Fourier series and Freud series (*Kovács*, 1995). The functions to be approximated belong to the function classes of continuous periodic and almost periodic functions. Periodic functions are the most applied instruments of technical procedure descriptions. With the improvement of our measurements more and more physical, natural phenomena are proved to be describable with functions that are not periodic though, but show very little differences. The nature of "almost periodicity" can be specified according to many aspects. Therefore, relatively many – different – definitions are used in mathematics, which describe either identical or different function classes. L-almost periodicity used in the course of my research is one of the widest descriptions (*Kovács*, 1993).

2.2. PLANNING OF LANDSCAPE MANAGEMENT IN THE AREA OF SPILLWAY RESERVOIRS

The *Nagykunság reservoir area* belongs to the Tiszafüred-Kunhegyes-plain small region within the Central Tisza Region and Nagykunság small region group. The *Szamos-Kraszna reservoir area* belongs to Szatmár-plain small region within the Upper-Tisza Region; it is situated in its north-western region.

The sample areas are moderately warm-dry climate areas. The annual sunshine duration varies between 1950 and 2000 hours, and the areas of Nagykunság get the majority of the sunshine. On an average, the sun shines 780-800 hours during the summer period and 170-190 hours in winter. The annual average temperature is 9.6-9.7 ^{o}C in the Szamos-Kraszna area and 9.8-10.2 ^{o}C in the Nagykunság reservoir area. Fluctuation of temperature is high in both areas. The Nagykunság reservoir area is an area without independent water-course; it has only internal water canals, which partly lead towards Tisza and towards Hortobágy-Berettyó. It is an extremely dry, poorly draining, strongly water-deficient area. Lf=0.5 l/s.km^2; Lt=3%; Vh=150 mm/year. Precipitation is few with large uncertainty; therefore irrigated cultivation is particularly justified. The Szamos-Kraszna reservoir area is a moderately dry area with a minimal water-deficiency (Lf=3 l/s.km^2; Lt=15%; Vh=20 mm/year). It is favourable for arable crop and horticultural plants with higher water demand and lower heat demand.

Utilised data sources and their processing method

The most important geographic information system data and data systems used as initial data for planning the land use of the reservoir areas were the following: digital relief map of the area (*Winkler*, 2003), as well as its previous and current land use data. The physical characterisation of the soils of reservoirs took place based on the Kreybig approach. For fixing the image and transforming it into the Unified National Projection System (EOV) MagicPro 8.0 software has been applied. For the creation of the digital relief model ArcView Spatial Analyst module has been used. The creation of the digital relief map of the reservoir was set out from paper maps. It was based on the GIS adaptation and reambulation of the Kreybig Soil Map Series and the Digital Kreybig Soil Information System (DKSIS) developed by the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC)

For the determination of the past land use of the analysed areas the paper maps of the I. and II. military surveying were used; current land use was determined based on the images of the Corine Land Cover database (*Mihály*, 2007) and "Légiprojekt 2000" and also on cadastral data.

2.3. COMPARATIVE ANALYSES OF DEVELOPMENT AND GROWTH

Maize-seed production takes place in the area of Hajdúszoboszló, on the most advantageous fields of Hungary, by means of a high standard cultivation technology.

Utilised data sources and their processing method

Data acquired through on-site investigation: In the years 2004-2007 regular on-site assessment took place on the maize-seed production sites of Syngenta Seeds Ltd. Phenological observations took place on 68 agricultural plots twice a week on average. Determination of *climatic data* took place by means of local measurement and data provided by the Hungarian Meteorological Service. Climatic conditions – considering average values – have been favourable during the observed period.

	Favourable values	**2004**	**2005**	**2006**	**2007**
Effective heat sum (GDD) (°C)	1250-1750	1377	1388	1442	1660
Average temperature of the growth season (°C)	16.8-19.0	17,5	17,3	17,6	18,7
Precipitation of the growth season (mm)	270-410	378	**455**	348	394
Precipitation of the winter period (mm)	230-310	**224**	**186**	237	**151**
Annual quantity of precipitation (mm)	500-720	602	641	585	545
Heat sum-precipitation ratio (°C/mm)	1.9-3.1	2.3	2.2	2.5	3.0
Average vapour content of July (%)	-	70.2	82.3	73.1	66.6

Table 1: Climatic characteristics of Hajdúszoboszló *(blue numbers: unfavourable data)*

However, monthly distribution of precipitation showed a mostly unfavourable fluctuation. In 2007, between April and July there was hardly half of the precipitation than in other years.

Month	**Favourable precipitation amount (mm)**	**Fallen precipitation (mm)**			
		2004	**2005**	**2006**	**2007**
IV.	44-60	**40**	**69**	51	**1**
V	44-70	**24**	**73**	63	66
VI.	45-75	68	64	**84**	**12**
VII.	50-80	**150**	68	61	65
VIII.	50-80	65	**118**	**82**	**160**
IX.	40-56	**30**	**63**	**6**	**90**

Table 2: Monthly changes in the amount of precipitation *(blue numbers: unfavourable data)*

Remote sensing images (geometrically transformed 7 channel Landsat 5TM images) were put at our disposal by the Institute of Geodesy, Cartography and Remote Sensing. In case of quantitative analyses, given radiation amounts and indexes calculated from them mean information about certain "objects"; therefore radiometric correction is necessary before processing. For atmospheric and radiometric correction the COST model was applied. (*Chavez,* 1996). Beside the radiance values of the sensor the zenith angle and the Sun-Earth distance have also been used for this (Table 3). During the correction process the distorting effect of the relief has not been considered, because there was no significant difference in the height values of the investigated areas.

Date	Sun height	Distance	Date	Sun height	Distance
03/05/2004	55.2183306	1.0081037636	11/05/2006	56.9955304	1.0098622808
20/06/2004	61.1035966	1.0162423988	26/06/2006	60.8968669	1.0165293535
22/07/2004	56.2897385	1.0160135663	12/07/2006	59.1431592	1.0165657206
23/08/2004	49.0642815	1.0111828892	22/08/2006	50.4528317	1.0115552713
31/05/2004	59.9419450	1.0138853062	21/05/2007	58.8469306	1.0119992654
16/06/2004	60.6372514	1.0158609439	22/06/2007	61.1916058	1.0162809092
25/07/2004	57.5349300	1.0157273528	15/07/2007	59.3908567	1.0165340190
10/08/2004	54.0123307	1.0136905800	16/08/2007	52.1910118	1.0127893758

Table 3: Data of the applied Landsat 5TM images (Source: US Geological Survey)

Method of evaluation

For assessing the condition of the floral vegetation we used the Normalized Difference Vegetation Index (NDVI), which is calculated from the reflectance values of close infrared and red channels (*Rouse* et al., 1974). Analysis of NDVI is a proven, reliable method for the assessment of net biomass. Occasional instability of NDVI values – on a surface covered with poor vegetation – is caused by the variance of the colour and moisture content of the soil and by the most important climatic variables (precipitation, temperature, evapotranspiration, sunlight, relative humidity).

Within the interval between -1 and +1 NDVI value of areas with abundant, healthy vegetation is between 0.2 and 0.8, but the field recordings and samplings are necessary for the evaluation of the values. GIS processing and analysis took place within an ArcGIS ArcInfo 9.1 and Erdas Imagine Professional 8.7 software environment. We analysed the connection between GDD and NDVI divided to years and the connection between NDVI and yield results divided to years and observation dates by means of regression analysis. The strength of the connections can be evaluated based on the correlation coefficient (R) and the coefficient of determination (R^2), while their genuineness can be evaluated based on the significance value belonging to the ratio of the variance of the estimation and the remainder values (F test statistics). The statistical analyses took place on a 5 percent significance level by means of the SPSS 13.0 software package.

2.4. ANALYSIS OF THE LAND USE OF MOTORWAY DEVELOPMENT

Motorway M7 is a public road element of the V. Helsinki corridor running from Ukraine to the Adriatic Sea. The investigated area is the section between Balatonkeresztúr and Nagykanizsa of Motorway M7 (between 173.35 and 206.20 km) which contacts with the Small-Balaton and other area segments belonging to Natura 2000 areas and on a significant part with the area of preserved water bases.

Data utilised for the measurement of area use and their processing method

Parts of the starting data were paper-based plan and tender documentations and construction (also execution) plans, which were provided by the National Infrastructure Development closed Ltd. with research purposes.

The used documents:

1./ M7 Balatonszárszó-National boundary section – Building Permit Drawings – Environmental impact study – Specification IV. (170+765 – 187+485), August 2001

2./ M7 Balatonszárszó-National boundary section – Building Permit Drawings – Supplementary environmental impact study – Specification IV. (170+765 – 187+485), September 2001

3./ M7 Balatonszárszó-National boundary section – Building Permit Drawings – Environmental impact study –Specification V-VI.(187+485–218+227), August 2001

4./ M7 Balatonkeresztúr-Nagykanizsa (170+700–206+200km) Offer call documentation referred in the tender call sent with the subject of the preparation of the modified building permit drawings and construction plans and proper execution of the construction permit – Volume 1 – Guidelines for appliers, February 2006

5./ Above document – Volume 4.a. –The items of the quantitative report, February 2006

6./ M7 (170.7–206.2km) Balatonkeresztúr-Nagykanizsa – Departure from the construction permit - Modification of the environmental protection permit, 07.08.2007

7./ M7 Balatonkeresztúr-Nagykanizsa (170+700 – 206+200 km) and Balatonkeresztúr – Sávoly (170+700–182+000) – Construction plan – Delimitation plan, August 2005

8./ M7 Balatonkeresztúr-Nagykanizsa (170+700 – 206+200) – Sávoly – Zalakomár (182+000 – 193+300) – Construction plan – Delimitation plan, August 2005

9./ M7 Balatonkeresztúr-Nagykanizsa (170.7–206.2km) –M7 Zalakomár - Nagykanizsa (193.3 – 206.2 km) – Execution plan – Delimitation plan, February 2006

The other parts of the starting data were medium- and high-resolution satellite images and high-resolution orthophotos, which were put at our disposal by FÖMI:

Satellite image: IRS-P6 LISS-III

Orbit altitude: ~817 km, Inclination: 98.7 degrees, Resolution: 20x20 meter, Number of zones: 4; B1: 0.52–0.59 µm, B2: 0.62–0.68 µm, B3: 0.77–0.86 µm,B4 1.55–1.70 µm.

Satellite image: IKONOS

Orbit altitude: ~681km, Inclination: 98.1 degrees, Resolution: Multi 4m, Pan 1m, Zones: 4+1; B1: 0.445–0.516µm, B2: 0.506–0.595µm, B3: 0.632–0.698µm, B4: 0.757–0.853µm, P: 0.526 – 0.929 µm, Date: 11.06.2008 and 18.06.2008

High altitude image: "Ortofotó-2008"

Flying altitude: 5800-6200m, Camera: Vexcel UltraCamX, FocalLenght:100.5 mm

Ground Sample Distance: 50 cm, Date: from 01/06/2008

As the first step of the analysis the determination of the values concerning area use took place by using the detailed reports and summarized data of documents 1-6.

In the second step I determined the planned degree of area use from the "Delimitation plans" (documents 7-9) of the construction plans; first I archived the given pages and then I transformed them into the ArcViewGIS software and EOV.

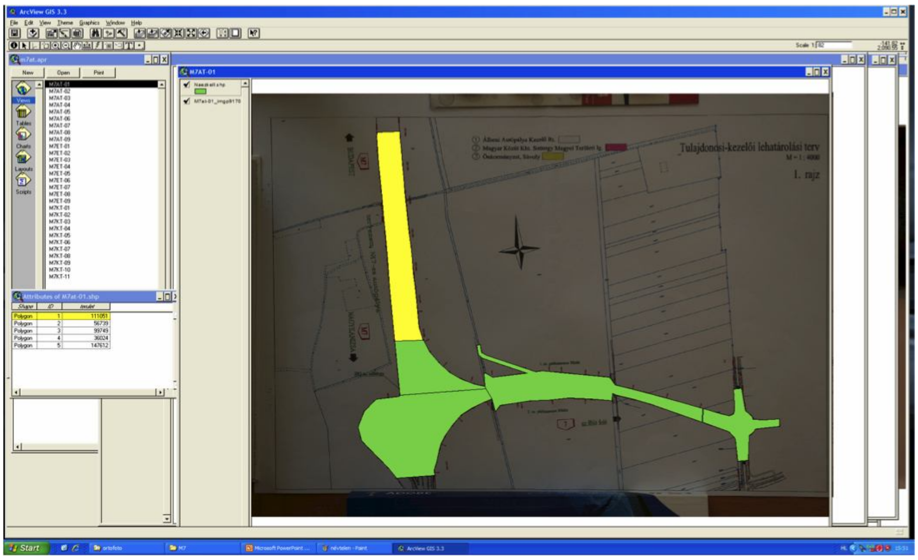

Figure 1: Measuring of area use on the "Delimitation plans"

As the third step of the analysis the determination of the actual area use took place by means of remote sensing images. Since IKONOS images were available only from the 173.350 km of the motorway, I carried out the analyses from this segment of the construction. I determined the boundaries of the actually used areas by visual sensation and I measured them with ArcViewGIS software.

3. RESEARCH RESULTS

3.1. FUNCTION APPROXIMATIONS WITH FOURIER SERIES

Below, I would like to introduce the results which I achieved in the course of my research on the field of Fourier series, Hermite-Fourier series and generally orthogonal series approximations of continuous and almost periodic functions.

Uniform approximation of continuous functions with Fourier series

Uljanov has already asked the question back in 1964, whether in the case of an optional, continuous, periodic function is there such a $\nu : N \leftrightarrow N$ permutation, that the Fourier series of f rearranged with ν permutation uniformly approaches f, namely ${}_{\nu}S_n(f) \rightarrow f$ (*Kovács*, 1991). In the following theses – under significantly lightened conditions – I prove uniform convergence concerning the Fourier series of a continuous function according to orthonormal function systems. The mathematic notions occurring in the theses and the details can be found in the references (*Kovács*, 1991).

Theorem 1

Let $\Phi = (\varphi_n),(n \in N)$ be an orthonormal function system on an I interval, satisfying the following properties: Φ is uniformly bounded, normally summable, and „quasi matrix system" on I. Then for any $f \in C(I) \cap L_2(I)$ function there exist a $\nu : N \leftrightarrow N$ permutation and a numeric sequence $\{K_i\}, K_i \rightarrow \infty, i \rightarrow \infty$ such that the K_i- partial sequence of the partial sum sequence formed after the ν determined rearrangement of the Φ determined Fourier series belonging to f converges to f on I uniformly.

Uniform approximation of continuous functions with additional function series

As further generalisation, I extended my theses to series expansions by Legendre polynomials (*Kovács*, 1991), Hermite-Fourier series, and Freud series (*Kovács*, 1995), proving uniformly convergent approximation for continuous functions similarly to the way described above, in the correspondent norm.

Theorem 2

Let $f(x) \in C(R) \cap L_\infty^*(R) \cap L_2^*(R)$ with Hermite-Fourier series. Then there exist a permutation $\nu : N \leftrightarrow N$ and a numeric sequence $\{K_i\}, K_i \to \infty, i \to \infty$ such that, the K_i-subsequence of the partial sums of the ν-rearranged Hermite-Fourier series tends to f uniformly in *-norm.

Theorem 3

Let $1 < \alpha \leq 3$ be fixed, and $f(x) \in C(R) \cap L_\infty^*(R) \cap L_2^*(R)$ with Fourier-Freud series expansion. Then there exist a permutation $\nu : N \leftrightarrow N$ and a numeric sequence $\{K_i\}, K_i \to \infty, i \to \infty$ (both of them depend on f and α) such that the K_i-subsequence of the partial sums of the ν-rearranged Fourier-Freud series tends to f uniformly in *-norm. (If $\alpha > 3$ then the convergence is locally uniform.)

Fourier series approximation of almost periodic functions

As an extension of the theses concerning periodic functions Révész (*Révész*, 1990) proved, that for any f uniformly almost periodic function there exist a permutation $\nu : N \leftrightarrow N$ and a numeric sequence $\{K_i\}, K_i \to \infty, i \to \infty$ such that the K_i-subsequence of the partial sums of the ν-rearranged Fourier series tends to f uniformly.

I carried out my analyses in a more general scope, within the L-almost periodic function class defined by (and later named after) B. M. Levitan (*Kovács*, 1993). I managed to verify the following approximation thesis on this wider set:

Theorem 4

Let f be a bounded, finite-dimensional L-almost periodic function with its Fourier series. Then there exist an ordering a $\nu : N \leftrightarrow N$ and a numeric sequence $\{K_i\}, K_i \to \infty, i \to \infty$ (both of them depend on f) such that the K_i-subsequence of the partial sums of the ν-rearranged Fourier series tends to f locally uniformly.

Let me remark, that if the function is uniformly almost periodic then the convergence will be uniform as well.

3.2. PLANNING LAND MANAGEMENT ON THE AREA OF SPILLWAY RESERVOIRS

Accentuation and levels of utilisation

The planned reservoir in Nagykunság lies between 84 and 94 mBf (meters above Baltic Sea level) and it has relatively high level differences. The surface of the planned Szamos-Kraszna reservoir is flat, the main proportion of its area is at 108.5-111.5 mBf. The surface is well accentuated. The so-called hydromorphic soil series have developed in the area that is one can find the same type of soils at nearly the same spatial levels. The spatial utilisation levels of reservoirs have been defined on the basis of DTMs, soils, flooding levels, possessive relations, biological corridors etc.

Spatial utilisation level	**Feature of levels**	**Area of the utilisation level (ha)**	
		Szamos-Kraszna reservoir	**Nagykunság reservoir**
I.	Low flood area	1785	635
II.	High flood area	1790	1153
III.	floodless level	697	758
IV.	area of existing and shelter forests	422	620
V.	existing water bodies	212	653
VI.	other utilisation	209	223
Total		*5115*	*4042*

Table 4: Area of utilisation levels in the reservoirs

Project matrix for the development of utilisation alternatives

Primary and secondary suggested utilisation alternatives were defined for each level. I included these alternatives into an area utilisation project matrix. The plan suggestions concerning the whole area of the reservoir or a bigger part of the area can be developed by the combinations of area levels and methods of land use.

Utilisation level	**Recommended land use method**					
	Wetland habitats	**Grass**	**Plough land**	**Garden, orchard**	**Forest**	**Other**
I.	xxx					
II.		xxx			xxx	
III.		xx	xxx	xxx	xxx	
IV.					xxx	
V.	xxx					
VI.						X

Table 5. **Project matrix**: recommended land use methods per land use level
(xxx-primary-, xx-secondary land use form; x-no specific land use form)

Figure 2 and Table 6 shows a possible recommended area utilisation alternative for the landscape use of the Nagykunság reservoir, whereas that of the Szamos-Kraszna reservoir is shown in Figure 3 and Table 7. We tried to renew the mosaic character and the environmental friendly crop production which conforms to the original landscape functions, as well as to reduce the risk of field crop production.

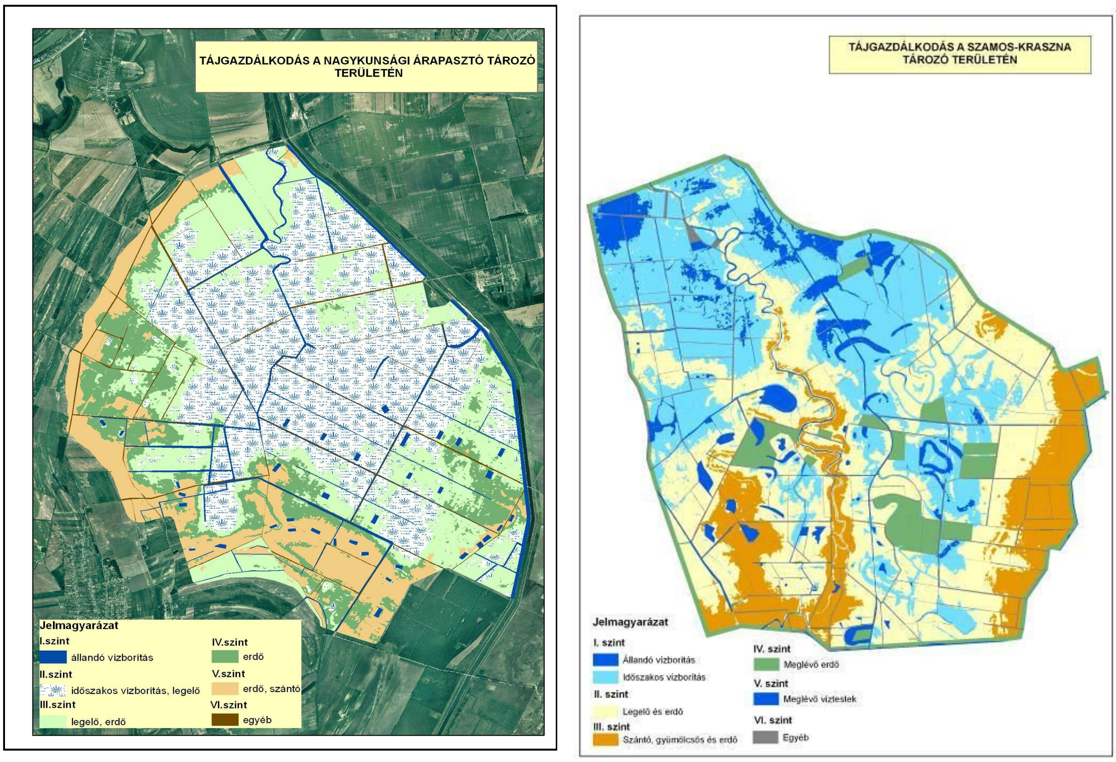

Figure 2: Recommended landscape management in the area of the Nagykunság (on the left) and Szamos-Kraszna reservoirs (on the right)

Land use	**Current area (ha)**	**Recommended area (ha)**
Plough land	3287	653
Meadow, pasture	79	758
Forest	430	620
Wet area, stream	126	1788
Other	120	223
Total	***4042***	***4042***

Table 6: Current and recommended land use in the Nagykunság reservoir (to the left)

Land use	**Current area (ha)**	**Recommended area (ha)**
Plough land + orchard	3595 + 7	697*
Meadow, pasture	813	1790**
Forest	232	422***
Wet area, stream	-	1997
Other	468	209
Total	***5115***	***5115***

Table 7: Current and recommended land use in the Szamos-Kraszna reservoir

**and forest (level 3), **and forest (level 2), ***existing forests (level 4)*

3.3. COMPARATIVE EXAMINATIONS OF DEVELOPMENT AND INCREASE

High standard production technology is applied during maize sowing seed production; therefore, the development of a crop is in close connection with the temperature values of the growing period. Consequently, we did not examine the change of NDVI values on the basis of a given day in a year – which is a common practice, according to the specialised literature – but as a function of growing degree days (GDD), starting with the date of sowing.

Evaluation of the correlation between NDVI and GDD

The examination was going on until the maximum NDVI value. The positive correlation can also be observed by graphic trend analysis (Figure 3). We proved the significance of correlations by regression analysis for all four years (Table 8).

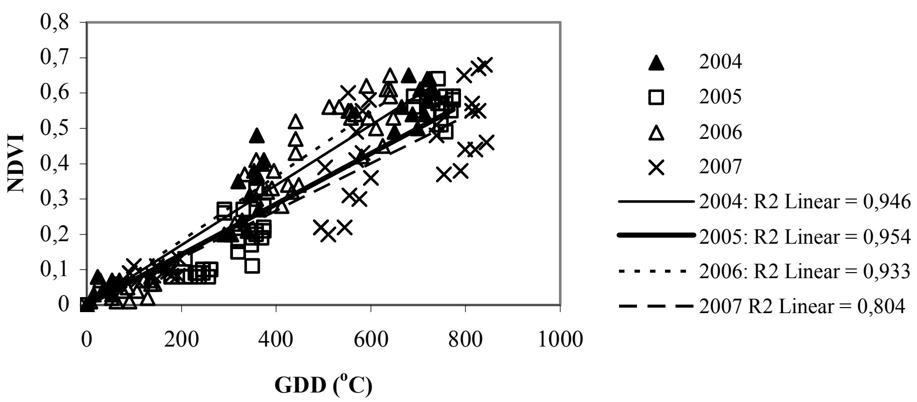

Figure 3: Correlation between growing degree days (GDD) and NDVI

The highest correlation coefficient was obtained in 2005 (R=0.977), whereas the lowest one was obtained in 2007 (R=0.897). In 2005, NDVI depended 95.4% on GDD (R^2=0.954). Valid regressions are always marked with (*) in all following tables. The F-statistics provided the highest value in 2005 (F=1078), therefore, the correlation between GDD and NDVI was the most expressed one in this year.

Examined year	**R**	**R^2**	**F**	**Sig.**
2004	0.973	0.946	648.007	0.000 (*)
2005	0.977	0.954	1078.400	0.000 (*)
2006	0.966	0.933	630.197	0.000 (*)
2007	0.897	0.804	163.792	0.000 (*)

Table 8: Results of the regression analysis between GDD and NDVI
(R =correlation coefficient, R2 = determination coefficient, F = F- statistics, Sig. = Significance)

Evaluation of the correlation between NDVI and yield (t ha⁻¹)

Based on the graphic trend analysis, the correlation between NDVI and yield was the most expressed in the 4th date of observation in 2004, whereas it was the 3rd and 4th date in 2005 and the 3rd one in 2006 (Figure 4). Same results are obtained by the regression analysis.

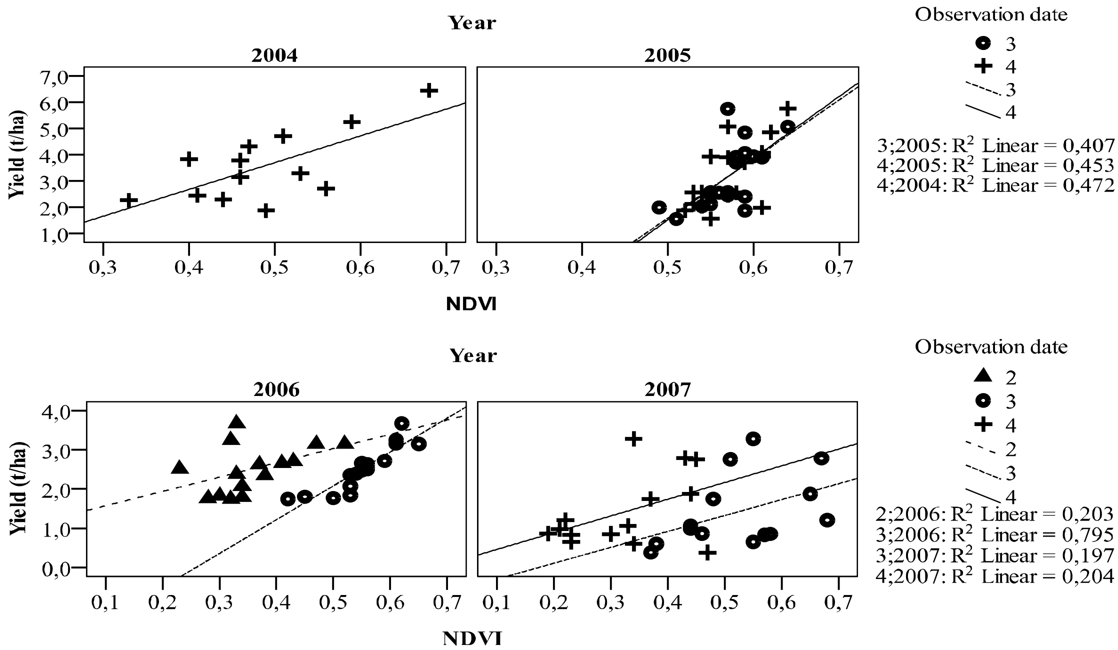

Figure 4: Correlation between NDVI and yield (2004-2007)

We carried out the regression analysis for all dates of observation in each year. The analysis of 2004 is presented in Table 9 as an example.

Date of observation	R	R^2	SEE	F	Sig.
1	0.199	0.039	-	0.451	0.516
2	0.287	0.082	-	0.985	0.342
3	0.330	0.109	-	1.344	0.271
4	0.687	0.472	1.01	9.827	0.009 (*)
4th date of observation		**B**	**SE**	**T**	**Sig.**
Regression constant		-1.390	1.606	-0.866	0.405
Regression coefficient		10.178	3.247	3.135	0.009

Table 9: Results of the regression analysis between NDVI and yield (t ha^{-1}) (2004)
R = correlation coefficient, R2 = determination coefficient, SEE = standard error of estimation, F = F-statistics, B = non-standardised coefficient, SE = standard error, T = t-statistics, Sig. = Significance, (*) = The variance of estimated and residual values differs on a 5% level of significance.

The significance value belonging to the F-statistics (0.009) is lower than the selected level of significance (0.05) only on the 4th date; therefore, the correlations observed on the other dates were not proved. In the 4th date, NDVI depended 47.2% (R^2=0.472) on yield. The regression coefficient significantly differs from zero, whereas the regression constant does not, therefore, the regression equation is Y = 10.178 * X, where Y = estimated yield, X = NDVI value. Based on the standard error of estimation (SEE), yield can be estimated at 1.01 t ha^{-1} accuracy.

The standard deviation of yield was the lowest in 2006 (0.226), whereas the highest value was that of 2007 (0.632), that is the sowing seed maize populations were the most homogeneous in 2006 and they were the most heterogeneous in 2007. Due to the examination, the lower the standard deviation of the yield is, the stronger the correlation between NDVI and yield is. Using the calculated values, we determined the estimated yields of sowing seed production areas. We classified the yield maps using ArcGIS 9.2 Spatial Analyst module (Figure 5).

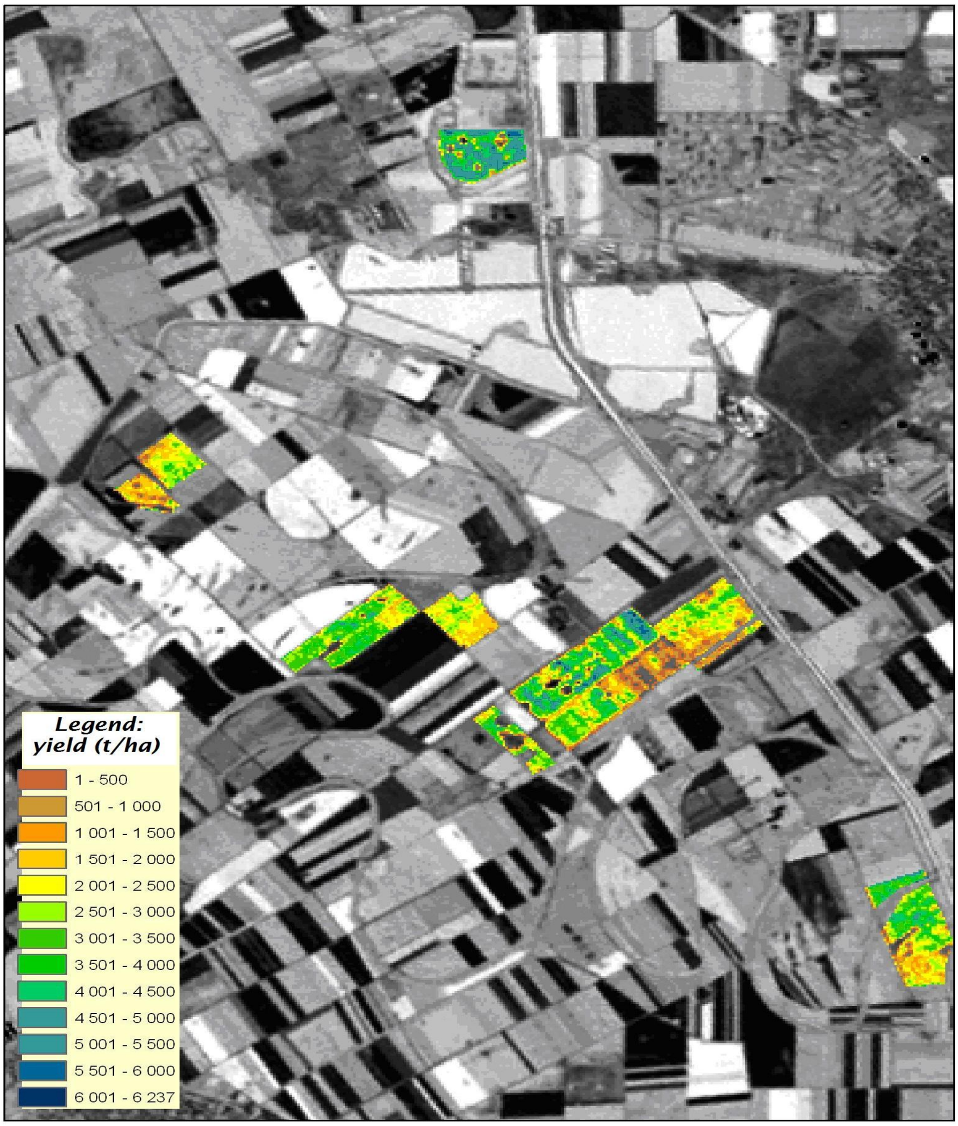

Figure 5: Estimated yields of sowing seed production areas (Hajdúszoboszló, 2005)

Evaluation of the differences between maize hybrid production processes

We performed the examination of the differences between hybrid production processes for the period between 2004 and 2006. We selected two hybrid production processes that had high element numbers in all three years. It is an important condition that the two selected hybrid production processes were significantly different from the phenotype point of view.

The average yield of the maize sowing seed production process 1 was 4.9 t ha^{-1}, its average NDVI was 0.60, whereas the ratio of yield (t ha^{-1}) and average NDVI was 8.08. The ratio of the average yield of the hybrid production process 2 and the average NDVI was 4.09, its average yield was 2.2 t ha^{-1} and the average NDVI was 0.54. Based on Levene's test, identity was found in the yield and the variance of the NDVI of the two hybrid production processes, whereas the independent two sample t-statistics proved difference in their mean values. Based on t-statistics, the yield of maize sowing seed production 1 was higher than that of hybrid production 2 by 2.64 t ha^{-1}, whereas its NDVI value was higher by 0.05. The correlations between NDVI and yield were strong. The variance of the estimated and residual values significantly differed in the case of both maize sowing seed production processes (Sig. = 0.039 and 0.013), therefore, regressions are valid. Yield depends 60.7 % (R^2 = 0.607) on NDVI (hybrid production 1), on a 0.63 t ha^{-1} (SEE=0.63) error level. Yield depends 74.0 % (R^2 = 0.740) on NDVI and yield can be predicted on the basis of NDVI with a 0.33 t ha^{-1} (SEE=0.33) error(hybrid production 2).

As a result of the examination, I managed to use NDVI measurements to distinguish hybrids that significantly differ in their phenotypes.

Hybrid production	**R**	**R^2**	**SEE**	**F**	**Sig.**
1	0.779	0.607	0.63	7.721	0.039 (*)
2	0.860	0.740	0.33	14.206	0.013 (*)
hybrid production 1		**B**	**SE**	**T**	**Sig.**
Regression constant		-2.351	2.638	-0.891	0.414
Regression coefficient		12.344	4.442	2.779	0.039
hybrid production 2		**B**	**SE**	**T**	**Sig.**
Regression constant		-2.504	1.278	-1.960	0.107
Regression coefficient		8.947	2.374	3.769	0.013

Table 10: Correlation between NDVI and yield (t ha^{-1}) in hybrid production

R = correlation coefficient, R2 = determination coefficient, SEE = standard error of estimation, F = F-statistics, B = non-standardised coefficient, SE = standard error, T = t-statistics, Sig. = Significance, (*) The variance of estimated and residual values differs on a 5% level of significance.

3.4. EXAMINING THE LAND USE OF MOTORWAY CONSTRUCTION

Determination of the planned land use from the data of project documentation

Despite the detailed technical project documentation, the total value of the planned land use of motorway construction cannot be determined on the basis of numerical data. The main reason for this is the fact that the current land use categories of technical documentation cannot be used to determine the total spatial usage. Nevertheless, the average size of usable road surface (road-bed, exit ramps) is 2.5 ha per kilometer. I calculated 4.114.754 m^2 of planned land use from the delimitation plans, which means 12.53 ha km^{-1} on average if we take a 32.85 km long section of the motorway as a basis.

Determination of actual land use from remote sensed data

The three remote sensing measurements (Ortofotó-2008, IKONOS, IRS-P6) provided nearly identical total values (independently of their accuracy) (Table 11). The average of the three measurements is 5070102 m^2, which is 15.43 ha km^{-1} land use. All three measurements had final results exceeding the planned one by 20%. This surplus (2.9 ha km^{-1} on average) is 2900 ha (29 km^2) if we consider the 1000 km long motorway which was built in the last 15 years. The total average usage (15.43 ha km^{-1}) is 15000 ha (150 km^2), which is 0.17 % of the country's area.

	Planned land use	**Ortofotó-2008**	**IKONOS**	**IRS-P6**	**Measured average**
Total land use (m^2)	4114754	5079143	5082836	5048329	5070103
Average land use (ha km^{-1})	12.53	15.46	15.47	15.37	15.43

Table 11: Land use of Motorway M7 between 173.350 km and 206.200 km

Comparison of remote sensed data

The similarity of accuracies of the three remote sensing methods observed during the determination of the total value of land use is only illusory. The null hypothesis of the normality of the three series of measurements (22 takes each) was proved with a χ^2-test of $f = r - 3$ degree of freedom on a 5% level of significance. I carried out the analysis of the applicability of remote sensing methods mainly during measurements referring to the deviation from the planned values. The sample mean of the measurements of the remote sensing methods are similar, but the experimental standard deviation and the range are significantly higher in the case of IRS-P6 than the other two. T-test proved the

H_0 hypothesis referring to the similarity of the expected values concerning all three relations (IRSP6–Ortofotó, IRSP6–IKONOS, Ortofotó–IKONOS) on a 5% level.

Section limits		**Length**	**Difference between remote sensed and planned land use**		
			Ortofotó	**IKONOS**	**IRS-P6**
from	to	km	m^2	m^2	m^2
173 350	174 500	1 150	9 983	8 760	30 550
174 500	175 360	860	31 152	29 064	59 187
175 360	176 940	1 580	79 960	77 813	75 121
176 940	178 450	1 510	21 027	26 632	10 999
178 450	180 000	1 550	111 961	108 512	137 130
180 000	182 000	2 000	989	3 210	-10 516
182 000	183 020	1 020	32 699	34 533	46 952
183 020	184 500	1 480	21 562	22 710	31 041
184 500	185 730	1 230	11 256	13 864	25 995
185 730	187 190	1 460	15 030	18 416	-11 019
187 190	188 600	1 410	70 101	63 731	-2 895
188 600	190 000	1 400	27 488	28 375	-20 817
190 000	191 160	1 160	46 572	48 926	14 562
191 160	193 300	2 140	20 790	17 191	-43 972
193 300	192 200	1 350	43 279	47 790	66 302
192 200	196 100	1 450	33 772	33 440	73 019
196 100	197 050	950	84 175	82 758	88 370
197 050	198 570	1 520	38 423	35 038	55 693
198 570	200 850	2 280	44 526	54 892	87 228
200 850	202 200	1 350	45 127	47 437	61 242
202 200	204 520	2 320	111 163	100 696	131 269
204 520	206 200	1 680	63 366	64 306	28 146
Difference total (m^2)		**32 850**	**964 400**	**968 093**	**933 586**
Average of difference (m^2)			**43 836**	**44 004**	**42 436**
Std. dev. of difference (m^2)			**31 084**	**29 018**	**46 839**
Sample range (m^2)			**110 972**	**105 302**	**181 102**

Table 12: Difference between measured and planned land use (Motorway M7)

I used F-test to examine the similarity of standard deviations which also characterise the accuracy of measurements. The null hypothesis referring to the similarity between Ortofotó and IKONOS measurements was proved on a 5% level of significance. If we compare IRS-P6 measurements with Ortofotó and IKONOS measurements, we have to reject the H_0 hypothesis on a 5% level of significance and we have to accept the alternative hypotheses $H_2 : \sigma_{IRS-P6} > \sigma_{Orto}$, and $H_2 : \sigma_{IRS-P6} > \sigma_{IKONOS}$. The accuracy of IRS-P6 measurements is significantly worse than that of the other two measurements.

	Ortofotó -IKONOS	**IRS-P6 - Ortofotó**	**IRS-P6 - IKONOS**
$\sqrt{F_{0,90;21;21}} = 1.34$	1.07 → $\sigma_1 = \sigma_2$	1.51 → $\sigma_1 > \sigma_2$	1.61 → $\sigma_1 > \sigma_2$
$\sqrt{F_{0,95;21;21}} = 1.46$	1.07 → $\sigma_1 = \sigma_2$	1.51 → $\sigma_1 > \sigma_2$	1.61 → $\sigma_1 > \sigma_2$

Table 13: Examination of the accuracy of measurements

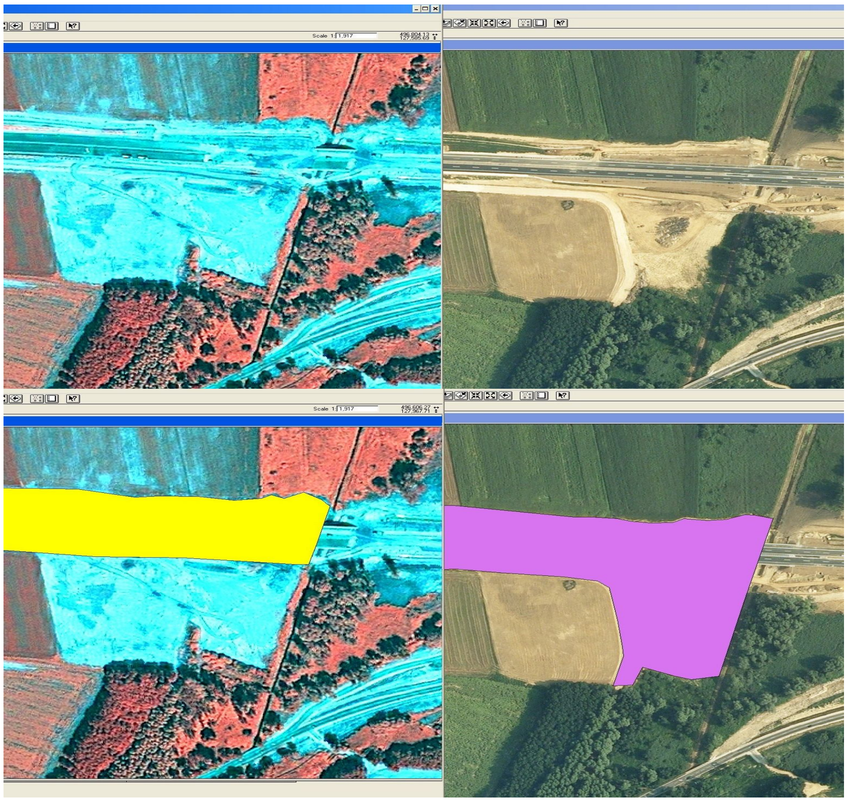

Figure 6: Differences in measuring the land use of Motorway M7 during the evaluation of the remote sensing images by IKONOS (left) and Ortofotó-2008 (right)

Mean error of Ortofotó-2008 and IKONOS measurements

I performed balancing calculations (*Detrekői*, 1991) to analyse the mean error of measurements. I established that the two measurements can be considered to have normal distribution, they are independent, they are similarly accurate and free from regular errors, because $\left|\sum_{i=1}^{k} d_i\right| \leq 0.25\sum_{i=1}^{k}\left|d_i\right|$, (where d_i is the difference between the measurements) is realised (in our case: 3690 < 0,25*72647). Therefore:

- mean error of one difference: $m_d = \sqrt{\frac{\sum d_i^2}{k}} = 4257$ m^2 ,
- mean error of one measurement: $m_L = \sqrt{\frac{\sum d_i^2}{2k}} = 3010$ m^2 ,
- mean error of the arithmetic mean of the two measurements: $\overline{m}_L = \frac{1}{2}\sqrt{\frac{\sum d_i^2}{k}} =$ 2128 m^2.

The mean error of one measurement is 3010 m^2 that is 1.3% on average.

4. THE NEW SCIENTIFIC RESULTS OF THE THESIS

Theses 1

Due to the development of satellite and remote sensing technologies during the last years and the rapidly increasing demand for remote sensed data, the magnitude of using image processing increased during the last few years and it also calls for the opportunity of automatic processing. I proved the following theses referring to the Fourier series approximations that play a rather important role in digital (spectral) image processing.

a) I proved for any Fourier series generalised by a normally summable, uniformly bounded $\Phi = (\varphi_n), (n \in N)$ orthonormal function system, which is "quasi matrix system" on interval *I*, the following theorem:

For any arbitrary $f \in C(I) \cap L_2(I)$ there exist a permutation $\nu : N \leftrightarrow N$ and a numerical sequence $\{K_i\}, K_i \to \infty, i \to \infty$ such that, the K_i-subsequence of the partial sums of the ν-rearranged Fourier-series of f by Φ, converges to f uniformly on *I*.

I proved similar theorems for Hermite-Fourier and Fourier-Freud series.

b) I proved that the Fourier series can be used for uniformly convergent production of the L-almost periodic functions:

Let f be a bounded, finite-dimensional L-almost periodic function with its Fourier series. Then there exist an ordering a $\nu : N \leftrightarrow N$ and a numeric sequence $\{K_i\}, K_i \to \infty, i \to \infty$ (both of them depend on f) such that the K_i-subsequence of the partial sums of the ν-rearranged Fourier series tends to f locally uniformly.

Theses 2

During the planning of the landscape management carried out in the area of spillway reservoirs, the aim is to develop a natural landscape management system which conforms to the spatial levels of the reservoir area. During the examinations referring to the land use of the Szamos-Kraszna and the Nagykunság spillway reservoirs, I proved that the territorial data acquired from GIS data systems and those that were identified on the basis of satellite images, along with their presentation in maps can be used to plan landscape management. The developed project matrix is an effective tool for this task, as we can associate primary and secondary spatial usage-land use alternatives to each spatial utilization level. The recommendations referring to the landscape management of the whole reservoir or its parts can be selected from the combinations of these alternatives, based on the actual aspect of optimalisation or by other considerations.

Theses 3

Today, quick and accurate information services are basic requirements of safe production. I presented and statistically proved the applicability of satellite images in maize sowing seed production in the following areas:

a/ proving the strong correlation between NDVI and GDD,

b/ determination of the optimal time interval which can be used in the NDVI-based yield estimation.

c/ proving the fact that crop year and genotype have a significant effect on NDVI values.

Theses 4

My examinations concerning Motorway M7 proved that building one section of the motorway means 14-18 ha land use per kilometer on average and that there is a significant (15-25% on average) difference between the planned and actual use. I proved that relatively low cost medium resolution (20x20m) satellite images are suitable to detect differences of this type.

Theses 5

Based on the comparison of measurement series performed on high resolution (1m) satellite images and high resolution (0.5m) orthophotos (Ortofotó-2008), I proved that high resolution satellite images (IKONOS) are suitable for the detection and displaying of estate-level differences between the actual and planned land use of motorway construction with the accuracy of orthophotos, which would cost a lot more.

5. PRACTICAL USEFULNESS OF RESULTS

Modern landscape management calls for a complex – social, economic, environmental – approach and the consideration of effectiveness and sustainability. All these aspects need the joint handling of an enormous amount of knowledge related to this field and the evaluation of their correlations, therefore, only GIS data and data systems can "serve" this need. In my thesis, I strived to present the fact that geographical information systems are more and more frequently used in Hungary and they are especially suitable and effective in land use evaluation, planning and monitoring. Therefore, a wide range of new connections can be found and proved in the area of landscape management, crop production or even land use connected to the development activities of track infrastructure.

Due to the development of satellite and remote sensing technologies during the last years and the rapidly increasing demand for remote sensed data, the magnitude of using image processing increased during the last few years and it also calls for the opportunity of automatic processing. In my Thesis, I proved that generalised Fourier-series (that play a rather important role in digital image processing) can be used in uniformly convergent production in a wider range of functions, in the L-almost periodic function group. Similarly, I also acknowledged that the even approximation of continuous functions can also be improved by further orthogonal function sequences and a special summing procedure. Although the confirmation of the theses is constructive, there were no previous research done concerning their applicability in image analytical procedures, due to the calculations and amount of time needed by these procedures. The dynamic increase of computer performance would make it justifiable to perform another research in hope of more widespread applicability.

During the landscape management in the area of spillway reservoirs, it was not an aim to develop mainly wetland habitats and maintain and preserve their conditions, but to develop a natural landscape management system which conforms to the flood area (if necessary, the reservoir area, but preferably also the part of headland not covered by the reservoir). The territorial data acquired from GIS data systems and those that were collated during the examinations, along with their presentation in maps can be a good starting point for the planning of landscape management. An effective tool for this is the elaborated project matrix that associates primary and secondary spatial usage (land use) alternatives to each spatial utilisation level. The recommendations referring to the landscape management of the whole reservoir or its parts can be selected from the combinations of these alternatives, based on the actual aspect of optimalisation or by other considerations. The matrix shows the alternatives one can choose to recommend future land use. Also, we can check how wide opportunities we have during the negotiation process of making the recommendation accepted. The project matrix developed on the basis of GIS data is a practical tool in the planning procedure of the landscape management of reservoirs.

At the same time, I consider it important to examine the expected effect of the new management form on employment, as well as the newest approach of sustainability (cradle to cradle – C2C) and the usage alternatives of the complex thinking of harmonic development. Therefore, our recommendation concerning the new type of landscape management would be able to consider both the criteria of "multifunctional agriculture" and the economic, environmental and social conditions of the region.

My examinations concerning Motorway M7 proved that building one section of the motorway means 14-18 ha land use per kilometer on average and that there is a significant (15-25% on average) difference between the planned and actual use. I proved that relatively low cost medium resolution (20x20m) satellite images are suitable to show differences of this type.

A significant part of motorway network development (e.g. the transversal network – M8 and M9 motorways) is still ahead of us. The expected amount of direct land use due to this process provides enough reasons to recommend the following: plans concerning land use would have to be prepared in digital form and the winner of the project should report on the actual land use, presenting it on digital maps during the whole period of construction and every quarter in the following year. My examinations proved that medium resolution (20x20m) satellite images are suitable for this task. One check-up measurement a year – with the accuracy which is prescribed for the company doing the construction – would be justifiable even on the Contractor's side to supervise the construction.

During my examinations, I observed that motorway construction – similarly to other track infrastructure (e.g. railroad) – necessarily affects land use (especially the agricultural one) in the given region by crossing estates and contiguous agricultural plots. Since the middle of the nineties, nearly 1000 km motorway has been built. It would be worth analysing the changes done in the surroundings of motorways and also those that are still in process (estates, cultivation, yield, cost bearing capacity, etc.) in order to be able to take them into consideration when designing further construction and designating the track of a future motorway.

The applicability of the estimation of crop development and growth by processing satellite images was proved in a new area: maize sowing seed production. Furthermore, I managed to distinguish the development of significantly differing hybrids also with the help of satellite images; therefore, we can provide valuable help in designating the most appropriate area from the aspect of their production. All these could be achieved by using the much stronger correlation of NDVI-GDD instead of the usual NDVI-calendar day one. Based on the examinations, it can be stated that if there are several satellite images available and we can also conclude precipitation and soil moisture data from the images, then we could provide an even more accurate estimation related to the development of the crops, in the case of examining a more complex parameter.

Today, quick and accurate information services are basic requirements of safe production. By processing remote sensed data, we can obtain information that can be used in the entire crop production sector, both in the case of technological issues and also during the preparation of decisions. By gathering and analysing this information, the data user (producer, consultant, decision maker) can effectively track the phenomena that are important from the aspect of management and those that are characteristic of the production site. The technology of industrial processing takes steady quality of goods for granted. A well developed and installed monitoring system (containing the optimal designation of production areas, yield estimation, quick determination of negative processes in the development and growth of crops, etc.) is required for programmable production.

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Proofread article in Hungarian journals written in foreign language:

Dobos A. – Kovács K*. – Víg R. – Nagy J.: 2009. The effects of climate change on the growth and crop of maize (Zea mays L.). Időjárás, to appear (2010).

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