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Applied PhD School for "Precision Crop Production Methods"

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Sub-program: Technical backgrounds of site-specific precision plant production
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DOCTORAL (PhD) THESIS

THE PRECISION AGRICULTURE AIDED BY
REMOTELY SENSED DATA

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1. Introduction

The method of Remote Sensing predominates in various areas: from the medical sciences to meteorology through mechanical engineering applications. In a narrow sense, the author considers the aerial photographs and satellite images as remotely sensed data, which the content of the map can be updated with from time to time.

The main objectives of the dissertation:

1. Selection of a uniform geometrical system where map, GNSS positioning, satellite image, aerial photo and agricultural technics could be managed.
2. Testing the accuracy of satellite positioning (ACT and DGPS max. receivers) on the field.
3. Demonstrability of in-field variability with space images. Classification and segregation.
4. Analyzing the connection between artifical fertilizer programme and satellite images, optional interconversion between them.
5. Utilization of aerial photos.

2. Materials and method

GNSS (Global Navigation Satellite System) measures
The author carries out accuracy tests of ACT and CSI Wireless DGPS Max satellite positioning systems.

Figure 1: The two instruments (left), On the field (right)

The investigation of positioning modules was carried out on the experimental field of the University of West Hungary in Mosonmagyaróvár.
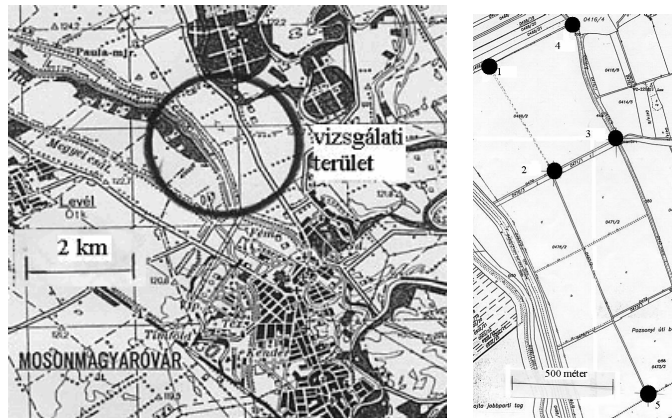

Figure 2: The site of GNSS measures

The points are marked with stones and pegs in the middle and at the corner of the field, as well as farther on. The distance between the nearest points is 350 metres, and between the farthest points it is 1900 metres. The ACT instrument was set to receive the EGNOS satellite signals.

Display: latitude φ, longitude λ, the number of satellites, HDOP. The DGPS max intsrument is suitable for the reception of GPS satellite signals and OmniSTAR differential correction signals. Accuracy: φ latitude and λ longitude display 5 characters after decimal point, in degree (°). It means about 1.1 metre accuracy.

Examination period: 30 August 2004 – 3 September, and 3 December.

Satellite images

The author investigates other ways in the utilization of space images made through NÖVMON crop monitoring. Are they appropriate to gain information about in-field variability? Can it help precision agriculture?
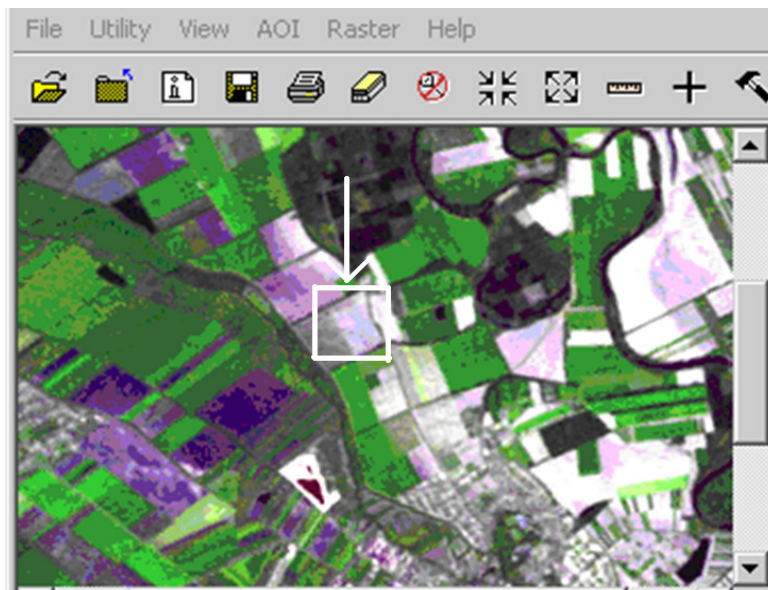
Figure 3: The experimental field and its surroundings. Copyright ESA 2001, published by EURIMAGE, FÖMI archives data, Copyright FÖMI (Institute of Geodesy, Cartography and Remote Sensing) 2001

The area of the field is 15.3 hectares (ha). Pioneer experiments about site-specific nutrient replenishment are in process at the Institute of Biosystems Engineering under the control of Professor Miklos Nemenyi and Karoly Kacz. The thesis is assisted by the dissertation of Peter Akos Mesterhazi. The dissertation concludes the experiments carried out in 2001, 2002, 2003. In November 2001 a soil sampling was taken on the experimental field, and by reason of later nutrient replenishment 63 management units were established.

Table 1: Management units and fertilizer portions (N, K_2O, P_2O_5 [kg/ha]), extract

Management units	2002 spring		2002 autumn		2003	
	N	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
1	133	95	45	59	24	91
2	117	95	0	59	0	91
3	117	95	45	49	67	91
4	117	85	45	39	24	91
5	117	85	45	29	67	91
6	117	85	45	29	67	91
7	117	85	77	19	79	91
8	133	75	45	29	24	91
9	133	70	0	23	0	74
10	117	70	45	19	67	91

The heterogeneity of the field does not appear on space images, however, if pixel rates are classified into groups, separate spots are visible which can have connection with field heterogeneity and the distribution of fertilizer portions. Classification was prepared by ERDAS image processing programme. According to the experience gained through classification, categories 4-6-8 are preferable for a field, different pixel groups could be highlighted.
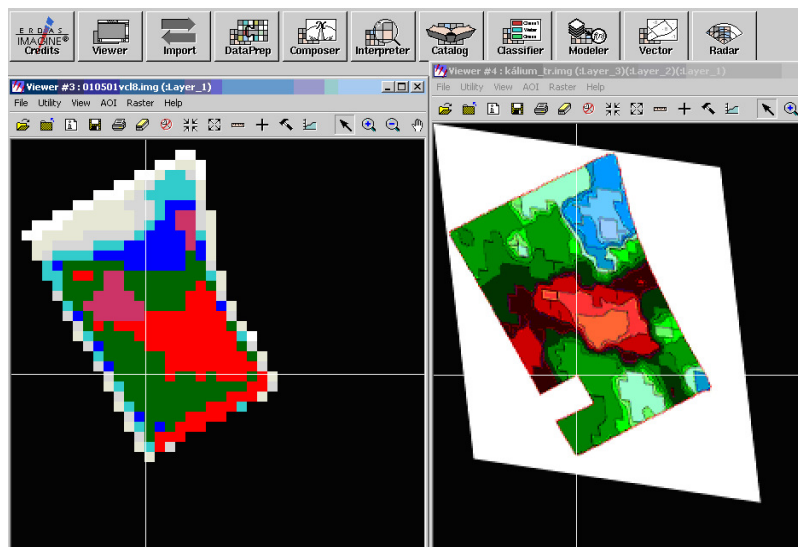

Figure 4: Correlation search visually between satellite image (on the left) and fertilizer plan (on the right)

Interconversion

Is there a connection between separate spots on space images and fertilizer programme spots? How much do nutrient replenishment data and space image data complement each other? It can be interpreted that the two tables are each a surface and what distance there is between these surfaces and how they join. The calculation is described with the following formula: $g(x) \cong A f(x) + B$

Search for A and B value where in x_i pixel points the $g(x_i) \cong A f(x_i) + B$ appromixation is the best! The task is to solve with least square method, that is the variation of deviation to be minimum.

Error:= error (A,B)= $\sum (g_i - (Af_i + B))^2$

Equations for the minimum extreme value:

$$\frac{\partial error}{\partial A} = 2((\sum f_i{}^2)A + (\sum f_i)B - \sum f_i g_i) = 0$$

$$\frac{\partial error}{\partial B} = 2((\sum f_i)A + nB - \sum g_i) = 0$$

Calculation of A and B

$$A = \frac{n\sum (f_i g_i) - (\sum f_i)(\sum g_i)}{n(\sum f_i{}^2) - (\sum f_i)^2} \qquad B = \frac{1}{n}\sum g_i - \frac{1}{n}(\sum f_i)A$$

The author carried out tests not only in fertilizer programmes but also certain soil data.

Evaluation of orthophotos

It is expected with the completion and maintenance of Land Parcel Identification System, LPIS-HU that orthophotos will be taken with 3-year update period. These can be used – consider in-field variability examination – for what it was originally intended: identifying land parcels and separating bearing surface. On one hand it could be used for interpretation purposes with analytic methods, on the other hand for planning, obtaining geometrical data, with 0.5 metre accuracy, in EOV (Uniform Land Projection – Hungary) system.

3. Results

GNSS measures

Table 2: ACT results

point number	Numb. Of meas.	φ average of latitudes	φ RMS error	λ average of longitudes	λ RMS error
1	6	47,906953	±0,000010	17,248208	±0,000008
2	4	47,902295	±0,000006	17,252255	±0,000203
3	6	47,903835	±0,000026	17,256448	±0,000077
4	6	47,908958	±0,000013	17,253512	±0,000008
5	6	47,892225	±0,000011	17,258892	±0,000079
aver.			±0,000013		±0,000075
metre			±1,43 m		±5,60 m

In general direction the deviation: ± 5.8 metres.
The average should be treated with reservation because a serious error (beyond measure accuracy) occurs in it, and it must be ignored when

processing. Errors occurred during the experiment are interesting therefore remained.

Table 3: DGPS max measurements

point number	Numb. Of meas.	Φ average of latitudes	φ RMS error	λ average of longitudes	λ RMS error
1	6	47,906943	0,000008	17,248207	0,000008
2	4	47,902298	0,000017	17,252358	0,000009
3	6	47,903803	0,000020	17,256500	0,000009
4	6	47,908952	0,000008	17,253520	0,000010
5	6	47,892213	0,000008	17,258935	0,000024
Aver.			0,000012		0,000012
metre			±1,3 m		±0,9 m

In general direction the average deviation: ± 1.6 metres.
During measurements the DGPS max was in a position capable of receiving differential signals.
The author calculated the average of geographical coordinates in EOV system and compared them to the EOV coordinates of points.

Table 4: Deviation of EOV coordinates

Point	ACT land survey system	DGPS MAX land survey system
1	1,9	0,96
2	7,9	2,1
3	5,7	0,6
4	2,8	1,5
5	4,7	0,8
Average	4,65	1,21

It can be stated that the accuracy of static positioning on the field with 1.1 meter accuracy receivers declined, moreover measurement occurred as well which could not be evaluated.

Satellite images

The author gathered satellite images and management units into a single system. Pixel size: 50x50 metres. The management units were collected in tables, and the pixel values of satellite image bands were exported, tabuleted. The tables were converted into Excel programme.
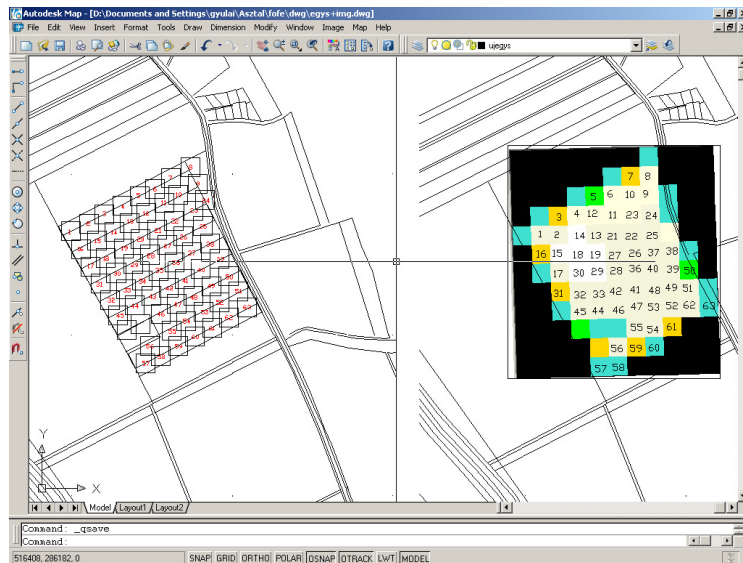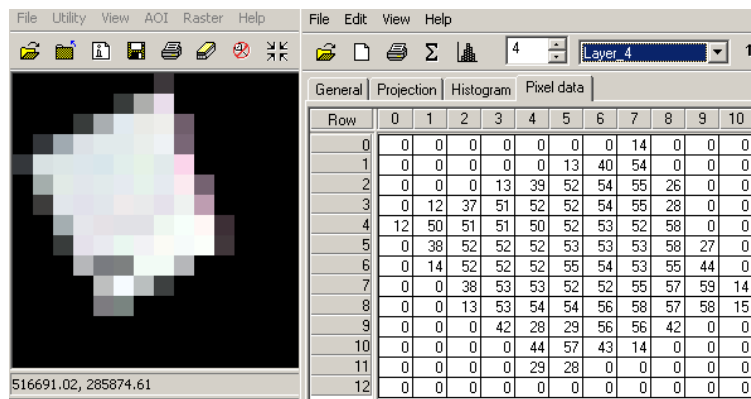

Figure 5: Original and comparable management units

Figure 6: Satellite image and fourth band prepared for export. The value of black background pixels: 0.
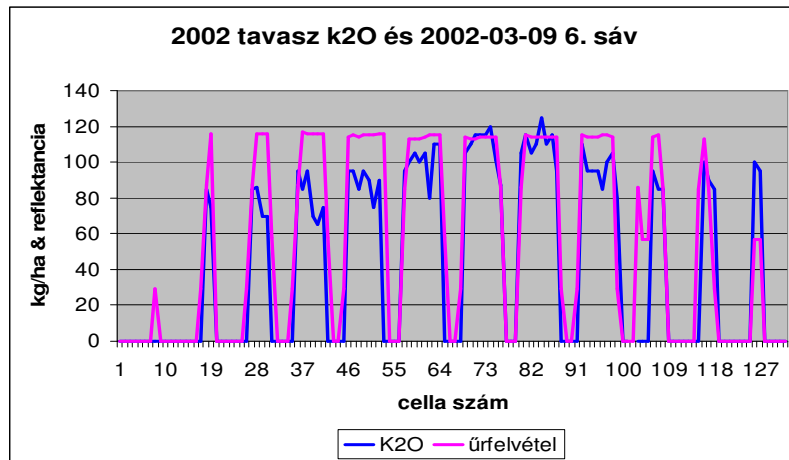
8

Figure 7: Potassium fertilizer and satellite image dated 09.03.2002. No. 6. band synchronism. Correlation: 0.8945.

Correlations between satellite image bands and suggested portion for 2002 spring K_2O fertilizer:

    Band 1   0,8956
    Band 2   0,8998
    Band 3   0,9027
    Band 4   0,8974
    Band 5   0,9028
    Band 6   0,8945
    Band 7   0,9082

Correlation average: 0,9001, standard deviation: 0,0048 < 1 %

The correlations around 0.9 show that the data structure is right, data are kept together, zero pixel values and non-zero pixel values are arranged. These raise more investigation: is there a connection between fertilizer programme and satellite images? Probably one data can be calculated from the other?

Mathematical testing, interconversion: error= $\sum(g_i-(A*f_i +B))^2$ Result:

09.03.2009 satellite image band 6 versus K2O

A=1,0069 joining near one, B= 7,9102

Error= 82375 → average deviation= 25

N is calculated:

09.03.2009 satellite image band 6 and Nitrogen portion

A=0,8298 joining near one,

B= -1,6579 distance between them

Error= 96826 → average deviation= 27

The error significantly exceeds table values (between 20-120), the average deviation is 44-48 %, thus the interconversion is not possible, relation could not be defined between satellite image and fertilizer portions.

Synchronism testing
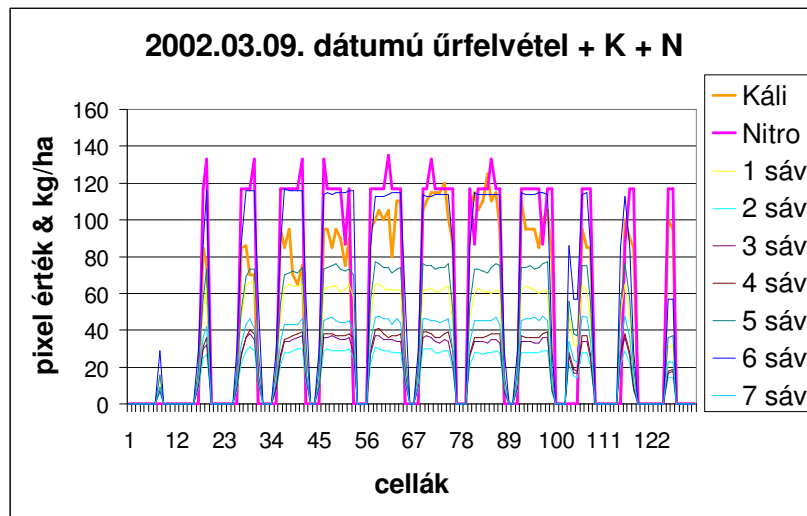Is the site-specific interference reflected on satellite images?

Figure 8: Position before first management, synchronism of 09.03.2002. datum sat. image bands versus Potassium, Nitrogen
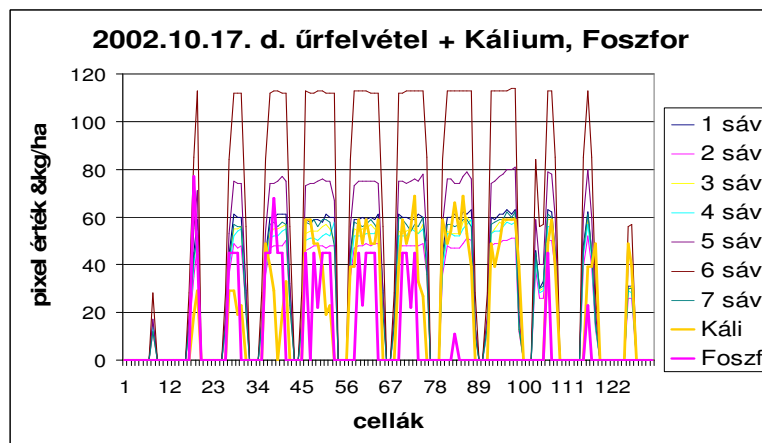

Figure 9: Comparing position after 2002 spring management, 17.10.2002. datum sat image to 2002 autumn management vs Potassium and Phosphorus portions

It can be defined from Figure 8 that
- N portion is nearest to band 6 (thermal infra)
- the highest reflection comes from band 6, the weakest from band 2, the others are in the middle
- reflection on most parts of the field is balanced
- Potassium curve does not join band 6 so much as Nitrogen

In Figure 9 reflection curves are balanced but differ from fertilizer portions.

Management is not clear significantly from synchronism testing.

Investigation of soil test

From the 17 types of soil sampling (which was the basic data of fertilizer programme) the Arany-fixity and Potassium content were examined.
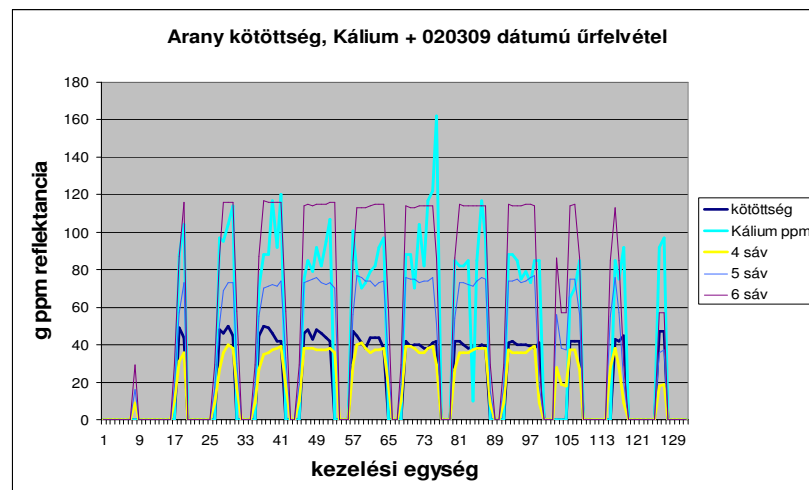

Figure 10: Satellite image dated 09.03.2002 bands 4, 5, 6, synchronism of Arany-fixity and K_2O_5 ppm

Band 4 and Arany-fixity are close enough, however, not so close as seen from Nitrogen portion and band 6 of the same satellite image, which had interconversion test as well. According to previous experience, neither in this case can interconversion be expected.

Classification

After spontaneous classification the author interpeted satellite images made on 4 variouss dates, searching for the answer whether soil changing

tendency could be detected. Time scale and number of class scale analysis were completed by the author.

Sequence of dates:

1. 1 May 2001: uncovered field after corn (maize) seeding

2. 9 March 2002: uncovered field after corn harvest and taking soil sampling

3. 17 October 2002: uncovered field after spring fertilizer programme, before autumn programme, after corn harvest

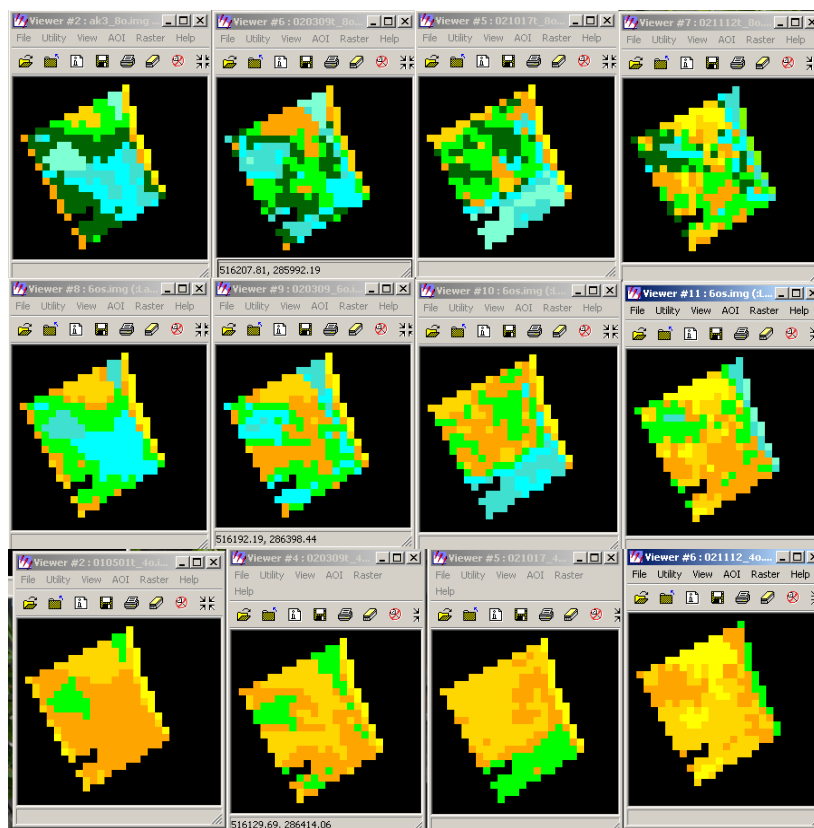4. 12 November 2002: after spring and autumn programme

Figure 11: Classified satellite image, category 8, 6, 4 top-down

On the edge of the field different pixel value sites are found but in time the field becomes more homogeneous.

The 8 category arrangement (above) shows that the first is inhomogeneous in biggest spots, then it gradually becomes mosaic. The

southeastern band of the field is remarkable, it indicates separate homogeneity on every image.

The second and third line shows the 6 and 4 category arrangement. The bigger sharp spots before the fertilizer programme (first two pictures) are apparent, the two after the programme become mosaic, rearranged.

To sum up: with interpretation progressing from multi-category (8) to fewer category (6-4) the sharp big inhomogeneity spot is determined for date 1. The table becoming more homogeneous in time is not excluded.

Aerial photos

The image made in 2000 helped in field setting. Satellite image was cut so that the biggest area would remain, and the disturbing edge pixels should not be involved in the cutting. However, they were contained in some parts, as it can be seen from classification. On the 30-metre resolution satellite image the bushes and roads do not appear, while on the aerial photo these are detached. After the author separated them with a cutting frame, obtaining the coordinates of the frame and on this basis designed the field cutting with a software.
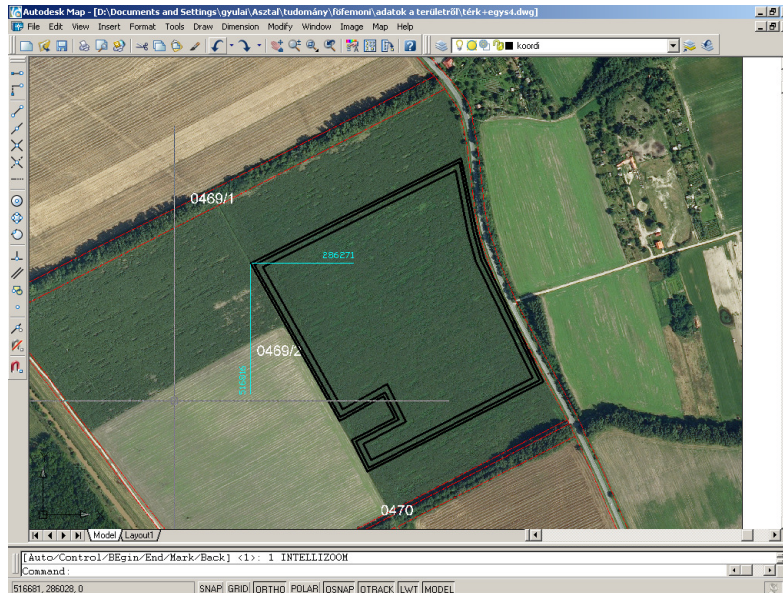

Figure 12: Cutting frame design

4. New scientific results (theses)

1. The fertilizer portion (kg/ha) for the agricultural field and the space image pixel value could be formed into a single system. Therefore their connection is to be examined with mathematical and interpretation method.
2. The uniform data structure according to 1. is right: it shows correlation near 0.9.
3. Connection 1. examined with the least square method is not an interconversion. Connection investigated with synchronism has no numerical information content.
4. Classification at 4-8 class level method on interpretation level is suitable for the time scale analysis of field inhomogeneity changing.

5. Conclusion

The dissertation deals with an area of the research work at Mosonmagyaróvár Faculty of the University of West Hungary which is in process for some years.
Supported by soil data taken in November 2001, MTA TAKI (Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, RISSAC) completed a fertilizer programme which was fulfilled in spring-autumn 2002 and 2003. The author took part in the realization of the programme with Peter Akos Mesterhazi and professors controlling the work.

The objectives and their realization are summarized in the following:
1. Selection of a uniform geometrical system where map, GNSS positioning, space image, aerial photo and agricultural technics could be managed.
The map of the Land Register Office, the satellite images received from FÖMI and the aerophotos purchased from FÖMI were given in EOV system. The author inserted management units and counted GNSS measurements into EOV, in this way the unionisation succeeded.

2. Testing the accuracy of satellite positioning (ACT and DGPS max. receivers) on the field
ACT and RDS max DGPS measurements taken on the field indicated that 1.6 meter accuracy could be achieved with 1.1 meter point display

instruments, but measurements occurred as well which could not be evaluated.

3. Demonstrability of in-field variability with space images. Classification and segregation.
First it is practical to cut the field from its surroundings. On 15 hectares field level the cutting and 4-6-8 classification had visible results, it could be interpreted with the map visualisation of site-specific fertilizer programme.

4. Analyzing the connection between artifical fertilizer programme and space images, optional interconversion between them.
The author managed the fertilizer programme, soil data and space images in chart form. Interconversion of fertilizer portion and space images was examined with least square method. Coclusion: the interconversion could not be used with practical accuracy. The experience was the same with soil data taken in November 2001.

5. Utilization of aerial photos
The orthophoto was found suitable for numerical accuracy and interpretation and can be used for analysis. It also proved perfectly suitable for 0.5 meter accuracy definition of coordinates, editing, e.g. table cutting design.

6. Publications in connection with the dissertation

Lectures, conference issues
Neményi M. - Mesterházi P. Á. - Gyulai I. (2001): A kemikáliák helyspecifikus kijuttatásának műszaki feltételrendszere az agrárgazdaságban, Győr, Széchenyi István Főiskola, Tudományos Napok

Gyulai I. - Neményi M. - Kacz K. - Mestererházi P.Á. (2002): GIS alkalmazások, XXIX. Óvári Tudományos Napok, előadás és CD kiadv.

Gyulai I. (1997): GIS studies for environmental engineers, előadás PROCEED program keretében, Győr-Deventer, kézirat

Gyulai I. (2000): Környezetelemzés távérzékeléssel, előadás, kiadvány, a Magyar Tudomány Napja, Környezettudományi tanácskozás, Győr, Széchenyi István Főiskola

Gyulai I. (2008): Távérzékelés: a fenntartható erőforrás eszköze, VI. Környezet tudományi Tanácskozás, Széchenyi István Egyetem, Győr, 2008. nov. 7.

Gyulai I. - Zajovics Gy. (2002): Szennyezőforrások felderítése, nyilvántartása, Környezettudományi Tanácskozás, Széchenyi István Egyetem, Győr

Gyulai I. (2008): Precíziós kitűzések, MTESZ előadás, Győr, 2008. október 28., kézirat

Gyulai I. (1981): A geodézia új irányai, digitális térkép, MTESZ előadás, Győr, kézirat

Periodical
Gyulai István - Horváth Richárd - Dr. Oláh Ferenc (2005): Elektronikus térkép, információ a városi közlekedésben, Városi Közlekedés folyóirat, 2005/1

Lectured notes
Gyulai I. - Bulla M. (2002): Távérzékelés, egyetemi jegyzet, SZIF-Universitas Kft.

Bulla M. - Domokos E. - Gyulai I. - Harkányiné Székely Zs. - Konrád R. - Kovács B. - Kovács E. - Lénárt L. - Madarász T. - Mucsi L. - Németh N. - Szabó I. - Szűcs P. - Tóth A. - Winkler G. (2007): Környezeti informatika, HEFOP elektronikus jegyzet, Veszprém

Bulla M. - Gyulai I. - Ónodi G. - Payer J. - Radnainé Gy. Zs - Pestiné Rácz Éva - Rédey Á. - Zseni Anikó (2007): Környezetállapot-értékelés, monitorozás, Magyarország környezeti állapota, HEFOP elektronikus jegyzet, Veszprém

Alexay Z. - Bulla M. - Buruzs A. - Gyulai I. - Nagy G. - Koren E. - Papp Z. - Szalay D. - Szalay Z. - Tóth P. - Zseni A. - Pestiné Rácz Éva (2006): Környezetvédelem, elektronikus jegyzet, Humánerőforrás-fejlesztési Operatív Program, (HEFOP), Veszprém