Possibilities of Geoinformation Technologies in Mapping and Management of Soils in Croatia

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SUMMARY

The paper mentions some major issues considering the application of geo-information technologies in mapping and management of soils in Croatia. Results taken from two independent projects are described. In one, use of DGPS receivers and remote sensing in soil mapping is described and in other, use of GIS tools and SGDB for decision making.

GPS has proven to be efficient and powerful tool for mapping soils and navigation in the field. The accuracy of positioning (95% probability radius) ranged from 5 m for DGPS with averaging to 19.1 m for single fix DGPS and 144 m for single fix uncorrected GPS method. Landsat TM image was used to map organic matter content (%) ranging from 0 to 15% with precision of ±4.6%. GIS software was used to derive interpretation maps such as suitability for crop production, vineyards and suggest measures for the improvements and protection of soil.

To objectively evaluate use of different methods of positioning, 95% probability error radius should be used. Use of the remote sensing and GIS tools is also a promising improvement. A GIS Soil Information System - soil map linked with the database of soil properties is an objective tool to come to decisions on land use. The conventional mapping units (Soil mapping units) can be replaced with the raster-based maps of single soil properties of fine grain of detail (30x30m) by using remote sensing and terrain data. The applications of these systems can bring management of soils in Croatia to a finer and more objective level – precision management.

KEY WORDS

geoinformation technologies, Geographical Information System (GIS), Global Positioning System (GPS), raster-based GIS, soil mapping

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Geoinformacijske tehnologija u kartiranju i gospodarenju tlima u Hrvatskoj

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SAŽETAK

U članku se spominju neki glavni aspekti uporabe geoinformacijskih tehnologija u kartiranju i gospodarenju tlima u Hrvatskoj. Prikazani su rezultati dva nezavisna projekta. U jednom je opisana uporaba DGPS prijemnika te daljinskih istraživanja u kartiranju tala, a u drugom uporaba GIS alata te Geografske baze podataka o tlu za potrebe donošenja gospodarskih planova. GPS se potvrdio kao uspješan i moćan alat za kartiranje tala te terensku navigaciju. Točnost pozicioniranja (95% polumjer vjerojatnosti) kretao se od 5 m za DGPS metodu sa usrednjavanjem do 19.1 m za dinamičnu DGPS metodu te 144 m za grubu GPS metodu bez korekcije. Landsat TM snimka je rabljena za kartiranje sadržaja organske tvari (%) u rasponu od 0 do 15 % sa preciznošću od ±4.6%. GIS program je rabljen za izradu interpretacijskih karata kao što su pogodnost za ratarstvo, vinogradarstvo te kao pomoć pri odabiru mjera za unapređenje i zaštitu tala.

Preporučljivo je rabiti 95% polumjer vjerojatnosti pogreške za objektivnu procjenu različitih metoda pozicioniranja. Uporaba daljinskih istraživanja te GIS alata je također obećavajuće unapređenje. GIS Sustav informacija o tlu - digitalna karta povezana s bazom podataka o tlu je objektivan alat za donošenje odluka o uporabi zemljišta. Tradicionalne kartografske jedinice tla mogu se zamijeniti s raster-temeljenim kartama pojedinačnih parametara o tlu fine prostorne rezolucije (30x30m) uporabom satelitskih snimaka te podataka o reljefu. Primjena ovakvih sustava može podići gospodarenje tlima u Hrvatskoj na objektivniju i precizniju razinu – precizno gospodarenje.

KLJUČNE RIJEČI

geoinformacijske tehnologije, Geografsko Informacijski Sustav (GIS), Globalni Sustav za Pozicioniranje (GPS), raster-temeljeni GIS, kartiranje tala

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INTRODUCTION

Geoinformation technologies

Geoinformation technologies are a new group of tools, methods, instruments and systems developed in recent decade to improve acquisition, processing, display and use of geoinformation. Examples of such tools are GPS (Global Positioning System) receivers, GIS (Geographical Information System) tools, algorithms for spatial data modelling, remote sensing techniques, geostatistical tools etc. Starting from the end of the 80's (Soil Science Society of America, 1987), these tools are more and more directly applied in mapping and management of soils. They cannot replace knowledge and expertise of an experienced surveyor and land user, but may be able to improve it by making them more analytical and objective, see Burrough (1993) and Wilding and Petersen (1990). Emphasise is being put more and more on equipment rather than personnel (Ibanez, et al., 1993). One of these tools is especially GPS technology that is today well developed and widely used in many environmental applications.

However a number of issues concerning the use of advanced tools are still unclear or undefined. This paper presents some summary results considering the application of Geoinformation technologies in mapping and management of soils in Croatia with intention to propose possible improvements.

GPS and Soil mapping and management

GPS is routinely being used for soil survey purposes from beginning of 90's. In the last few years number of application is increasing. There are two main groups of application of GPS in mapping and management of soils:

- Navigation: finding previously selected sites in the field;
- Mapping: of soil profiles, auger samples and soil related features;

The application of GPS in land management is today related to development of new branch – precision agriculture or precision farming (Committee on Assessing Crop Yield, 1997). Very often, accuracy or precision of specific GPS method is unknown or misinterpreted. It seems likely that integration of GPS into soil management could make application much more powerful and efficient. There are also a number of other practical questions that appeared such as: which method to use regarding the scale of application? What are technical limitations of use of GPS on field? How does canopy influences the accuracy of positioning?

Up to today, number of researchers has tested the use of GPS in mapping and managing the soil and similar resources. Long, et al. (1991) compared GPS with traditional methods of navigation (compass plus topo-map – distance-azimuth readings, aerial photos). The conclusion of this work was that GPS shows higher accuracy, cost-effectiveness and efficiency. A medium or low cost GPS receiver can be used to map sites to accuracy within 5 m (differential GPS or DGPS) and soil boundaries to within 30.5 m (100 feet – US national mapping standard). Finally, Long, et al. (1991) concluded: "ground positioning with the GPS was faster, less difficult, and more accurate than conventional positioning".

The type of receiver and GPS method that will be applied in soil mapping or management depends primarily on the accuracy wanted and funds available (see Figure 1). Hand-held receivers have been tested for the use in soil survey by Ardo and Pilesjo (1992). As a measure of accuracy, distance from known to GPS-derived position the error vector is routinely used. For each GPS method (raw GPS data, different number of sequential fixes, differential GPS etc.), mean distance its standard deviation, 90th, 95th, and 99th percentiles etc. can be calculated. Which of these statistical parameters should be used as a mapping criterion?

Accuracy of a GPS method is usually improved through averaging or differential correction (so called "DGPS"). August, et al. (1994) have evaluated especially accuracy and precision of GPS for environmental applications in general. They showed that using the averaging function, the 95% radius of a raw GPS method can be decreased to up to 40 to 70 m (average from 300 replicates). Ardo and Pilesjo (1992) experienced similar results while testing the Magelan hand-held receiver. For DGPS the 95% probability radius was quite lower – from 10 m for a single fix measurement to less than 6 m (average from 300 replicates).

Arnaud and Flori (1998) proved that 95% probability or confidence radius can be improved using only averaging without differential correction to about 30 m. This should be taken as a maximum accuracy that can be achieved with a raw GPS signal in some feasible time. The value of error vector in normal GPS method was mostly controlled by Selective Availability, so the 95% probability radius for single-fix GPS was about 100 m. In year 2000, the selective availability was turned off by US Government, so described accuracy mentioned here can not be taken into account any more.

Remote sensing and Soil mapping

From the beginning of development of remote sensing techniques, soil surveyors were looking for a way to map soils directly from images saving in that way the resources. Already Thompson, et al. (1983) found Landsat bands 4, 5 and 7 to be responding to the within-field soil variability even with increasing ground cover. However, these bands can directly

Figure 1. Some popular available GPS receivers for mapping and management of soils today on the market: (a) Hand-held GPS receiver (b) High precision GPS in backpack (c) Precision agriculture GPS receiver-display system for agricultural mechanisation

reflect only the soil cover or vegetation status and than indirectly the soil status. Remote sensing has not proved to be sufficiently useful for directly delineating different kinds of soils but may be valuable for providing information on e.g. soil moisture status or erosion. So the single LANDSAT or SPOT bands are not advisable to be used in environmental correlation. However, compound indices such as NDVI (Normal Difference Vegetation Index) which generally reflects biomass status, correlates well with the distribution of the organic matter or epipedon thickness what also has a physical logic, see work by McKenzie, et al. (1999) and Hengl (2000). Apparent from directly using the radar images, this is the main source of information for mapping vegetation status but also human influence and biomass production. Recently Odeh and McBratney (2000) got positive results when predicting the clay content with the help of coarse 1x1 km AVHRR data. A significant correlation between filtered NDVI values and CEC (Cation Exchange Capacity), EC (Electric conductivity) and pH was also established. Further on, it became interesting to integrate use of DEM (Digital Elevation Model) and radiometric data i.e. AVHRR data that is complemented with a DEM parameters: curvature, slope, aspect and the potential drainage density layers Dobos, et al. (2000). Results from this case study in Hungary showed that the use of multi-spectral and multi-temporal databases together with the Digital elevation and terrain descriptor data improved the mapping performance significantly.

GIS tools and soil geoinformation in Croatia

The Department of Soil science in Zagreb is using the GIS software actively for soil mapping and decision-making purposes ever since 1994. The first GIS developed was 1:300K digital SoiI Information System of whole Croatia. This GIS was based on work done during the national inventory of soils (semi-detailed soil survey) done in 1970's and 80's, project called: "The basic Soil map of Croatia", see Bogunovic, et al. (1998a). The original survey covered about 55,713 km^2 of land with more thousands of full profile descriptions with selective lab data analysis (1-5 per 10 km^2 in average) and was aimed at medium scale 1:50K. Due to technical limitations of that time, the map had to be generalised to effective scale of 1:300K. However, this GIS database was developed by using only 303 representative soil profiles and 65 taxonomic units linked to 4500 polygons.

A need for geoinformation on natural resources in Croatia is crucial for the development of the especially critical agriculture but also forestry, land conservation and others. Croatia being first a land in transition and second severely damaged in the war for independence, requires large amount information to be built up and brought to modern international standards. This will then be a good basis for the development and reclamation studies. At the moment, the Department of soil science in Zagreb is doing a general Land use evaluation on a county level (county by county) based on their SGDB - Soil Geographical Databases (Bogunovic, et al., 1998b). Till now, digital SGDB using most of the original soil profiles have been built up already for four counties at effective scale of 1:100K.

Modern Soil management - mapping units or grid cells?

In traditional mapping of soils, the objects to be mapped are usually represented with specific discrete objects or entities: Soil Mapping Units (SMU). This system is conventionally used also to plan the management of soil i.e. land, see work by Rossiter (1999), Zinck and Valenzuela (1990). Demands for quantitative soil information at finer resolutions are growing. At landscape or regional levels, resolutions from 20 m – 1 km and for precision agriculture usually of less than 20 m are needed, as mentioned by McBratney, et al. (2000).

In a raster-based GIS that is by Canepa (1998) starting to be dominant in the environmental applications, the same cartographic rules used for manual or automated plotting where the discrete model of space is used cannot be applied without modification. When working with the raster-based GIS, issue of grid or field resolution becomes a major cartographic issue.

The grid resolution in a raster-based GIS corresponds to the scale factor in the vector-based GIS. As suggested by Valenzuela and Baumgardner (1990), detail of a raster map should range from minimum legible delineation (0.1 or 0.25 mm) to 3 mm on map. Chaplot, et al. (2000) suggests that the field resolution for DEM, hydrological and erosion modelling purposes should not be coarser than 50 m. However, the finer resolutions require much powerful software and hardware for processing. Which resolution to select that is still feasible? Table 1 shows how is an increase of the detail related to technical requirements of a raster-based map.

Considering the application of the parametric raster-based SIS (Soil Information System) in, for example, Land evaluation or management planning it can be done per each pixel by using raster map calculation - parametric environmental management. A simplified scheme of such a GIS map calculation can be seen in Figure 2. In this case, ground pixel (e.g. 25x25 m) becomes a unit of management and soil properties are considered more quantitatively. It is still open how could such a system be integrated with the software that is based on doing simple entity-based operations such as querying in the ArcView or ALES packages.

METHODS

The paper gives some summary results taken from two independent projects: a) an MSc research work in Baranja done from September 1999 till February 2000 by Hengl (2000) and b) the Land evaluation project for the needs of the Karlovac county as described by Bogunovic, et al. (2000). The first research work was focused on the use of DGPS receivers and remote sensing in soil mapping is described and the other on the use of GIS tools and SGDB for decision-making. In the following sections, specific procedures and methods used are explained in more detail.

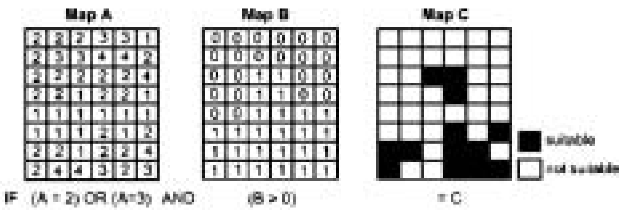

Figure 2. Map calculation scheme with maps of single soil properties in Land Evaluation procedures.

Research area Baranja

Data input and processing

Most of the data was inputted through scanning and then digitising i.e. maps were scanned, georeferenced and then digitised on the screen in ILWIS GIS package (Westen and Farifteh, 1997). Four main data sources and maps were used (Table 2).

Map sheets were scanned with AGFA A3 Duoscan scanner at a spatial resolution of 166 pixels per inch, so that 1 pix is equal to 0.16 mm on map or 8 m on the ground. The images were imported into ILWIS, separately georeferenced using grid intersections in local coordinates shown on the map.

The NDVI index was calculated from TM LANDSAT image from August 1992. It was assumed that NDVI map of the area when the NDVI is in it's maximum will best correlate with soil properties (especially organic matter content and thickness of the A horizon). The original TM 6-bands-image was first georeferenced and then resampled to 30 x 30 m ground resolution. The NDVI was then calculated as – (TM4-TM3)/(TM4+TM3) ratio.

Most of GIS operations was done using ILWIS 2.3 package (PCI-ILWIS ®) under MS Windows. Statistical analysis was done in Minitab12 statistical package (1998, Minitab Inc). All processing was done under PC 266 MHz, using 64 MB of RAM.

Table 1. Factors important for selection of the most suitable field resolution of GIS

Field resolution (m)	5 x 5	25 x 25	100 x 100	1 x 1 km
Related map scale factor:	25 000	125 000	500 000	> 1M
Minimum legible area (MLA) = 0.2 mm				
Management unit area (ha)	0.0025	0.0625	1	100
Management type	Detail studies	Precision agriculture	General land use planning	
Related positioning system	$1,000 DGPS	$300 GPS	$100 GPS	
RS compatibility	Still not compatible (aerial photography)	SPOT, LANDSAT		NOAA
Related positioning system	Quantitative soil properties (lab measurement)	Qualitative soil properties (classes)	Vegetation indexes, Climatic data	Average climatic data

Table 2. Original data used for the research, their scale, year of collection and form.

TYPE	SCALE (resolution)	YEAR (data collection)	FORM
Soil map Shows the soil type class according to Croatian detailed soil classification and structure of mapping unit, slope class, drainage class, parent material, texture etc.;	50 000	1975/76	4 A2 size maps sheets
Soil survey reports With the physical and chemical lab data for ~ 100 georeferenced profiles;	50 000	1975/76	document
Satellite image Landsat TM corrected but not georeferenced;	30 x 30 m	1992, August	25 MB raster image
Topographic map With roads, settlement, general land use/cover, contour lines;	50 000	1981/83	10 A3 size maps sheets

Table 3. Original data used for the research, their scale, year of collection and form.

TYPE	SCALE (resolution)	YEAR (data collection)	FORM
Soil map Shows the soil type class according to Croatian detailed soil classification and structure of mapping unit, slope class, drainage class, parent material, texture etc.;	1:50.000	1972-1987.	16 A2 map sheets
Soil survey report With the physical and chemical lab data for cca. 400 georeferenced profiles;	-	1972-1987.	16 separate documents
Topographic map	1:50.000 1:25.000	1950-1960. 1978-1982.	16 A2 size maps sheets 48 A2 size maps sheets
Land use and Land development plans Made for the use of the Karlovac county			Report
Map of the drainage system	1:5.000	1988.	3 A-0 size maps sheets
Infrastructure Administrative units, settlement etc.	1:25.000	1999	already input vector maps

GPS measurements

For GPS measurements, Garmin's (GARMIN co.) system of two independent receivers has been used (GPS 100 SRVY II). The system belongs to the middle-cost receiver group with market value of approximately 1500 USD. One receiver weighs about 300 g and has a time of initialisation of 2 minutes. During the fieldwork in Baranja, twenty-nine points, soil mini-pit locations were located using three methods:

1. AERO method – points are located on the aerial photos (1:20 K) on the field and then on-screen digitised on the ortho-photo;
2. GPS method – 'raw' or Single-fix GPS reading on the field;
3. DGPS method – averaged DGPS (N = 180, 1 s interval) done by post-processing.

The comparison of different methods of positioning was done using mean-square error vectors, as well as scatter-plots of the individual deviations, taking the DGPS value as a reference:

$$d(DGPS-GPS)=\sqrt{(X_{GPS}-X_{DGPS})^2+(Y_{GPS}-Y_{DGPS})^2}$$

$$d(DGPS-AERO)=\sqrt{(X_{AERO}-X_{DGPS})^2+(Y_{AERO}-Y_{DGPS})^2}$$

After the fieldwork, data from FIELD and BASE were downloaded to PC and post-processed using Garmin's PC100S2 Version 2.02 software. Result of post-processing is an ASCII file that can be then imported into some table calculator and then analysed. It should be taken into account that the results shown here are from the time when the Selective availability was still turned on so nowadays one can expect much better location accuracy.

Research area Karlovac county

Data input and processing

Soil science department in Zagreb has developed in 2000 a complete SIS of the Karlovac County and then made an evaluation of the land resources for general agricultural groups by using the FAO methodology (1976) and for physical planing by using the methodology by Kovačević (1993). Main data sources/maps used in this project can be seen in Table 3.

The digitalisation of the GIS layers: soil boundaries, profiles, settlement, rivers, water bodies and forests was done by using a A3 tablet digitiser (Calcomp) under the Auto CAD13 program package. Processing and further generalization of of all above mentioned

Table 4. Statistical summary for results on GPS testing. N indicates number of repetitions.

Error vector	N	Average (m)	S_x standard deviation (m)	Minimum (m)	Maximum (m)	95% prob. radius
DGPS(n=300)-TRUE*	20	2.5	2.0	0	6.0	5.0
DGPS(single-fix)-TRUE	100	8.5	5.2	0.7	23.9	19.1
GPS(single-fix)-DGPS	25	44.1	48.3	9	167	144
AERO-DGPS	26	48.7	57.9	6	213	191.4

*Taken from August, et al. (1994).

digitalized data in accordance with criteria of elaboration of maps at the scale of 1:50K, was done by using Arc Info and Arc View program package. The data of soil properties referring to soil mapping units (soil units, drainage, slope, parent material, rockiness, stoniness, root-able depth, way of wetting, etc.) were linked to few thousand polygons, and data referred to soil profiles (soil units, mechanical composition, physical and chemical soil properties etc.) were linked to 257 soil profiles, which is a standard way to organise a Soil geographic database as mentioned by Zinck and Valenzuela (1990). For this part were used Acces and Arc View program package. Based on the common properties of the soil-mapping units, they were evaluated for multipurpose use in agriculture and physical planning and needed measures for soil improvements suggested, such as addition of carbonates, hydro-melioration or soil protection (Husnjak, et al., 1998). Here the key issue used to asses suitability and capability are the soil type classes, based on the Yugoslav soil classification system as described in Skoric, et al. (1985), and their composition inside the mapping units.

RESULTS

Use of GPS in mapping soil profiles

What are practical limitations of the use of DGPS?

The accuracy predefined in the manual can be only achieved in open spaces. In the case of dense canopy (e.g. 100 years old oak forest), the signal is weak, values can deviate more than 100 m from true location and very often it is not even possible to do a measurement. During the processing of the data, 3 points (10%) had to be excluded from statistical analysis because they didn't satisfy post-processing requirements and had an error of probably more than 5 m. This is generally the main limitations of post-processing DGPS method – points are located but with unknown accuracy. Most often problems with post-processing were insufficient coverage (no pseudo-range pairs) and too high Geometric dilution of precision (GDOP) (>8).

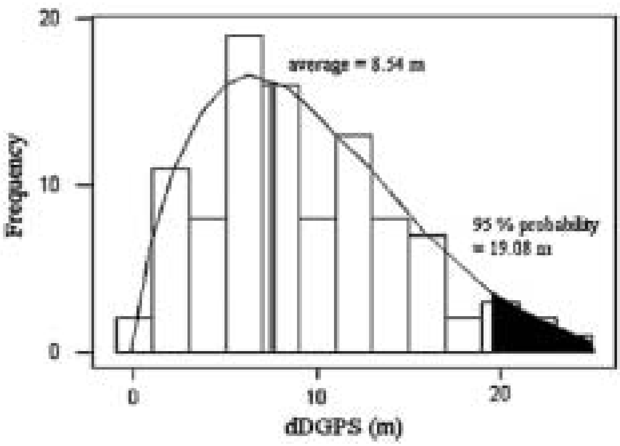

Figure 3. Distribution of error radius for single-fix DGPS method and parameters used to evaluate accuracy of positioning – average error and 95% probability radius.

How to evaluate the accuracy of a GPS method?

It is still unclear in literature how to asses actual accuracy of GPS and which type of the probability distribution or formula to calculate error vector should be used? After graphical examination of the histogram of error values, it was concluded that error vector for each of positioning methods has a log-normal distribution (Figure 3). So, to calculate average value and 95% probability radius, the data was first log-transformed – log(d+10). The 95% radius was then calculated as $\bar{x}+1.645\cdot s_x$ - one way 95% normal probability (Table 4). This statistical parameter was taken as an equivalent to the MLA and should be considered as main the criterion to evaluate accuracy of a specific positioning method. Figure 4 shows how the values fluctuate around the average value inside the 95% probability radius.

Mapping soil organic mater using NDVI

The following example shows how the remote sensing can be used to map soil property directly. Organic matter content in topsoil (OM in %) has been analysed in 93 points (Figure 5). This data was then correlated with the NDVI value map extracted from the Landsat TM image from summer 1992. The resulting regression model can be seen in Figure 5

Using the equation OM = 1.69924 + 15.0956 NDVI2 it is possible not only to estimate value of OM in not visited locations but also to asses the uncertainty of regression model in Figure 6. In this case, the error of regression estimation was 2.34%. So the precision of the model can be considered to be ±4.6%. It is expected that the precision would improve if other soil environmental variables were included in the regression modelling.

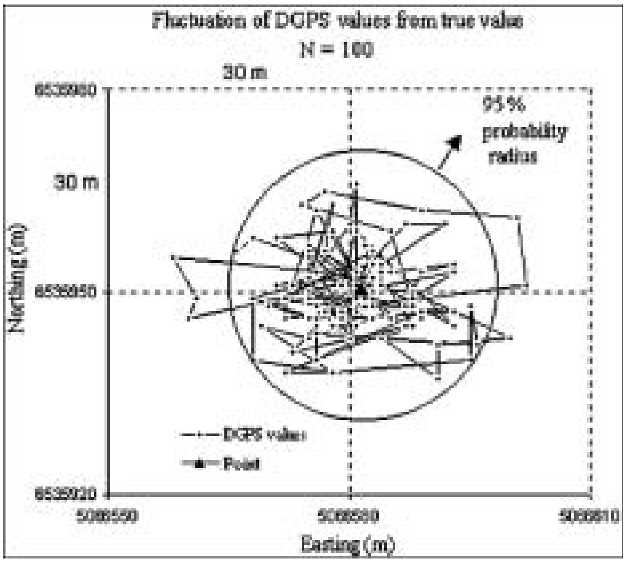

Figure 4. Fluctuation of single DGPS fixes from the averaged/true position.

Using Soil Information System to evaluate suitability

These results show how is a GIS used to produce suitability maps for specific land use purposes. Based on a soil map linked with the a database of soil properties, specific thematic maps are derived for Karlovac county such as:

- Suitability map for vegetable farming – example for agricultural development (Figure 7);
- Land capability map – example for physical planing;
- Map with requirements for liming – example for land conservation;

The soil and management related data were linked with specific SMU's (using command "join" in ArcView) from the Soil map. The main results were the land evaluation for multipurpose land-use and capability maps for specific agricultural production systems, but also the specific agro-technical measures important for improvement of the soils.

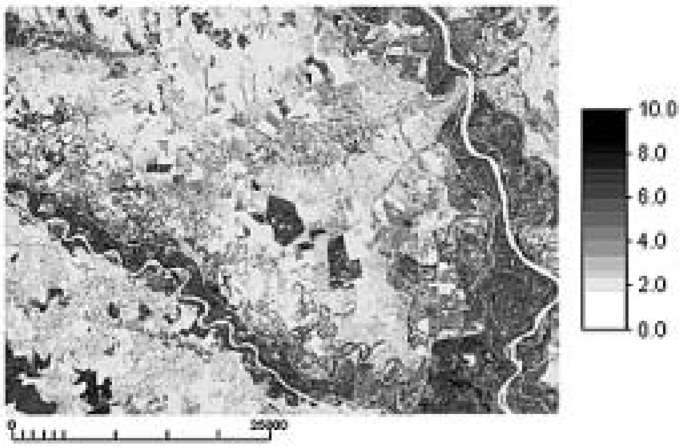

Figure 6. OM (%) calculated from the NDVI map for Baranja. ($OM = 1.6992 + 15.0956\ NDVI^{2)}$)

DISCUSSION AND CONCLUSIONS

The GPS technology and precision agriculture

The GPS mapping can be effectively implemented in soil mapping and in environmental applications in general. It is important to emphasise that selection of GPS method has to be based on cartographical needs of user. When compared to location of points on 1:20 K scale ortho-corrected aerial photos, positioning using raw single-GPS reading can give equal or even better (with averaging) results. Where average error of only few meters is needed, static DGPS methods should be used. To objectively evaluate use of different methods of positioning, following moments should be especially considered:

- What is the working scale of application?
- What is 95% probability radius of specific positioning method (or MLA)?
- How reliable are the values and how can they be validated?
- Which method is most cost-effective?

In a recent statement by USA President Clinton, he announced that the US Government has stopped the

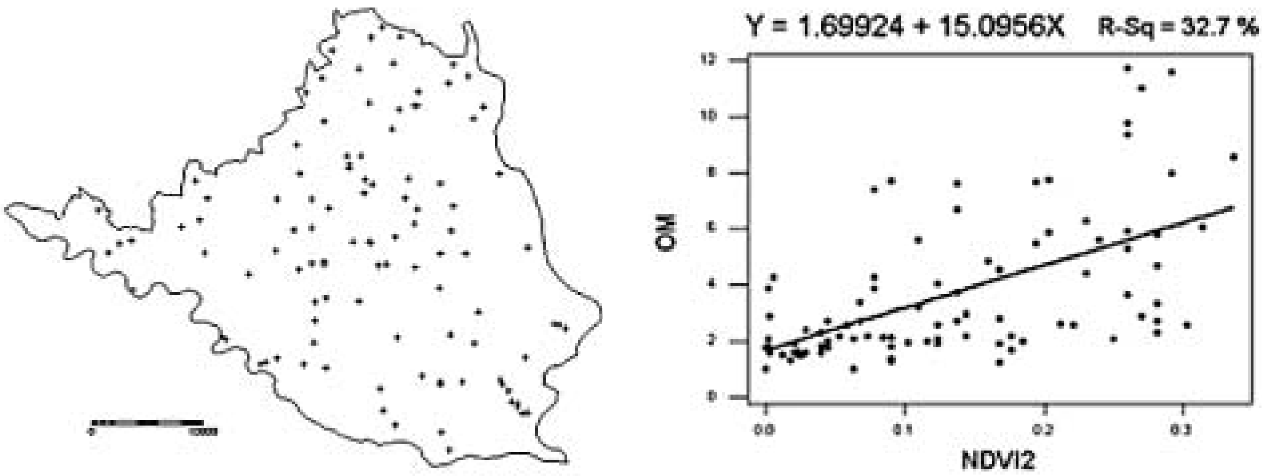

Figure 5. Research area Baranja: points used for regression fitting (map) and calculated model (right).

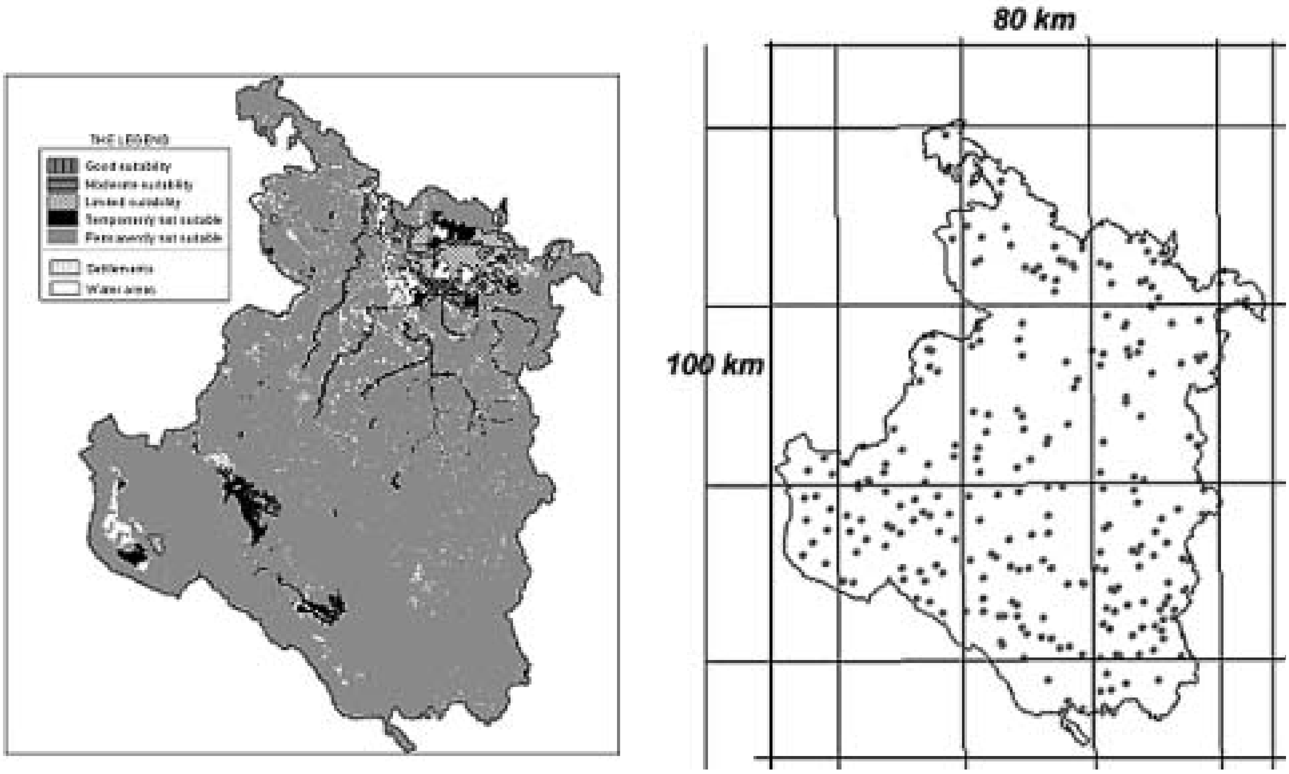

Figure 7. Soil Information System is used to calculate e.g. suitability map for vegetable farming (left) based on the number of tables of soil properties of mapping units or from the pit samples (right).

intentional degradation of the GPS signals. According to a study conducted by the University of Texas, these errors are reduced to approximately a 30-meter radius for a single-fix GPS! This revolutionary change is expected to improve application of GPS in a number of professions drastically.

Today, there are three main groups of users can be separated in the sense of application: users that need high accuracy for its application (scales higher then 1:25K), users that need only general idea where they are (location accuracy worse then 50 m) and users in-between. Required accuracy for the most of applications in soil mapping and management today such as navigation in field and in vehicles, precision agriculture, soil mapping and implementation of management etc., falls in the range in-between few meters (1:10K) and few tens of meters (1:100K), with the cell sizes of the raster-GIS in-between 10 and 50 meters.

GIS tools and decision making

To be able to achieve a sustainable development and make proper decisions on the use of land resources, it is of utmost importance to work with reliable and high quality geoinformation. The decision making based on geoinformation use to be highly complex and required large amount of time and resources. Today, thanks to development of GIS tools, it is possible to develop low or high cost information systems that are sound basis for an objective decision making. The GIS of Karlovac county described here enables users, i.e. decision makers to quickly asses needed information and do queries by using simple GIS browser such as ArcView. Such a system is not only a set of digital maps but also open for further updating and upgrading of geoinformation what is usually much lower investment then the initial building of a GIS.

Increasing the effective scale of exisiting soil information in Croatia

The existing 1:300K for whole Croatia and separate county's SISs are today being used in bigger national land use planning activities. However, most of the mapping units are associations often of two or more contrasting soils and delineations are usually to big than they should be according to the standards as mentioned by Forbes, et al. (1981). It was evaluated that the SIS is too general and not useful for detailed land use planning, taxation, or land reform i.e. at more regional level. On the other hand, much more can be made of the basic soil data. There is actually a large amount of soil and soil related data that could be incorporated to produce something more detailed and accurate. A large amount of original soil data exist that could be improved with the fine grain remote sensing products and soil-landscape models (downscaling).

There are 20 counties in Croatia and if the methodology proves to be successful, the parametric raster-based SIS's could be built for each county and then merged to cover the whole country. In that sense, the existing 1:300K SGDB could be improved in detail and brought to the 1:100K effective scale or even less i.e. field resolution of 20 m and then maybe even used directly in precision agriculture.

Other interesting issues such as: How to apply maps of single soil properties in LUP and environmental studies? Are the maps of single soil properties with fine grain of detail more beneficial to soil information users (Land use planning, crop-growth modeling, conservation, environmental impact assessment etc.) than the conventional soil map? Are the raster maps of single soil properties per specific depths and with defined accuracy more beneficial to soil users than map of soil types? Will be addressed in future research activities.

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