

UDK 528.8:004.6:528.88:551.4:631.111.2:634.8
Izvorni znanstveni članak

Methodology of Development of Purpose Maps in GIS Environment – Resource Management

Mladen JURISIĆ – Osijek¹, Stanislav FRANGEŠ – Zagreb²,
Ivan PLAŠČAK – Osijek¹, Ante ŠILJEG – Zadar³

ABSTRACT. The purpose of this research was to determine the methodology of land capability evaluation with regard to an array of objective limiting factors when growing, for example, perennial crops. The methodology of relief parameterization was used in the method for calculating geomorphological parameters, and pedometric mapping methods were used to calculate pedological variables. Inventory of the actual condition of land cover was made based on sketches and maps that were gathered during field research. These sketches were then geo-referenced and overlapped with LANDSAT satellite images to determine the actual situation. The best locations for a particular type of perennial plantation were selected by using logic and spatial queries. Best locations (in this example for vineyards) were identified as an area overlap (areas with, according to the spatial plan, either valuable, especially valuable or other arable soils, southern relief exposition with the total annual incident light $>1,208 \text{ KWh/m}^2$, and the location where the relief slope is not higher than 12% and lower than 2%, or where elevation exceeds 110 m and soil acidity does not exceed 5.6 pH). The query resulted in a simple map. The map shows areas which are either suitable for viticulture (1) or not suitable for viticulture (0). Similar approach could be used also for thematic maps of different purposes, for example, urbanization maps, or mapping valuable sources of water, gas, thermal wells and other resources of special importance for the country. According to the results obtained in our example of finding the methodology for development of thematic maps in GIS environment, the total of 17,782 ha in the County area is suitable for viticulture. The best way of developing spatial plans for particular crops would be to develop maps of negative scores for all crops, and then to standardize these values to find the best possible crop for each location. Thematic GIS layers can be used as the foundation for loans, advice on what crop to choose, making decisions on land re-allocation and land use, reconstruction i.e. modified land use.

Keywords: geo-information systems (GIS), methodology, thematic maps, resource management, spatial plan, purpose map, EU pre-accession funds.

¹ Prof. dr. sc. Mladen Jurišić, Faculty of Agriculture, University J. J. Strossmayer, Trg Sv. Trojstva 3, HR-31000 Osijek, Croatia, e-mail: mladen.juriscic@pfos.hr.

Ivan Plaščak, dipl. ing., Faculty of Agriculture, University J. J. Strossmayer, Trg Sv. Trojstva 3, HR-31000 Osijek, Croatia, e-mail: ivan.plascak@pfos.hr,

² Prof. dr. sc. Stanislav Frangeš, Faculty of Geodesy, University of Zagreb, Kačićeva 26, HR-10000 Zagreb, Croatia, e-mail: stanislav.franges@geof.hr.

³ Ante Šiljeg, prof., Department of Geography, University of Zadar, Franje Tuđmana 24i, HR-23000 Zadar, Croatia, e-mail: asiljeg@unizd.hr.

1. Introduction

To improve efficiency and competitiveness of an industry, i.e. efficiency of resource management in a country, governments of these countries (especially EU member states) adopt the so-called operative programmes to stimulate loans to such industries. The goal of such programmes is to increase efficiency of different aspects of management. For example, it is of great importance for the Republic of Croatia to make an inventory of resources, that is, to improve their use and efficiency. Through various projects (supported by the EU and its programmes related to the use of pre-accession funds), the Croatian Government stimulates an increasing number of small and large entrepreneurs, even family farms, to increase their plantations and to become serious producers with a higher share in the market economy.

To allocate funds from such sources in the best possible way, the following is required: to educate economic operators (land owners and company owners, especially those related to resource management) on the possibilities and to carefully choose among the received loan applications. Among other, it is necessary to have a good knowledge of production potentials of a particular location (land owned by the requesting party) so that as much funds as possible is invested into areas with the highest production potential related to targeted production.

Accelerated development of geo-information technologies has taken place also in our country (application in various fields, especially in natural resource management). Inventory of large areas can be made very quickly either by using satellite images or by positioning by means of GPS device or digital aero-photogrammetry (Jurišić et al. 1999 and Jurišić et al. 2005; Husnjak and Bogunović 2002a and 2002b).

Thematic maps of different purposes in Croatian agriculture have been already in the process of making, although not to a sufficient extent. Among organized systems of implemented geo-information technologies, a digital land registry, LPIS (part of the AIACS systems), better known as ARKOD, should be mentioned here. For example, Croatian Institute of Viticulture and Enology has started to develop a detailed Vineyard Register, which should provide a general statistical overview of all vineyard areas on a single production area as well as potential areas.

The only issues here are what methodology should be used in the process and what funds and human resources are required. These issues are addressed in this paper. The methodology of carrying out the land capability evaluation while considering an array of limiting factors of production for strategic types of perennial plantations is presented on the example of Osijek-Baranja County (Jurišić and Plaščak 2009).

2. Work methodology

GIS has been in use in Croatia for the purpose of planning at the regional level for some ten years. The methodology used in this example and used for the purpose of planning in the field of management of resource use is specific in the part that parameters for land evaluation are clearly and precisely defined – geomorphological, pedological and actual condition of land cover. The methodology of parameterization of relief is used for calculation of geomorphological parameters

(Hengl et al. 2003), and pedometric mapping methods are used for calculation of pedological variables (Hengl 2003). Inventory of the actual condition of land cover is made by using sketches and plans obtained during field data gathering. These sketches are then geo-referenced and overlapped with LANDSAT satellite images to determine the actual situation.

Methodology of raster GIS modelling was used throughout the study, which means that the basic decision making unit was pixel or cell grid square (see Fig. 1). The methodology of preparing thematic layers is presented in the following sub-chapter.

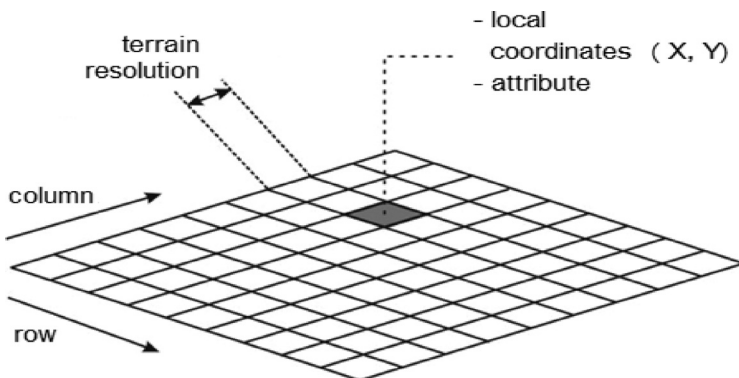


Fig. 1. *Raster-based GIS: each thematic layer consists of the smallest unit of pixel or grid square which is determined by the field resolution.*

2.1. Field data collection

To evaluate (locate) the current situation in the field in the best possible way, the field was recorded during the visit to the main economic operators.

Shorter surveys can be carried out in the process with economic operators (technologists). In addition to obtaining important technical data, this also provides an insight into the main issues in production. Also, each organization is required to submit a map showing the current situation and the location. These mostly include sketches or old plans that were either copied by hand or photocopied and diminished from the original cadastral maps.

Maps very often include a legend on the plot boundaries showing the sorts grown, and each plot has its own identification number.

2.2. Preparation of the thematic GIS layers

In the process of preparing GIS layers several raster resolutions should be used: (a) basic resolution for calculation of suitability – 100 m; (b) LANDSAT image at 30 and 15 m resolution; (c) a detailed topographic map 1:100K, also at 15 m resolution.

The total area is 97×83 km. Panchromatic image is at 15 m resolution (5508×6501 pixels).

According to this methodology the following thematic layers are made:

Topographic map 1:100K (topo100K) – Sheets of 1:100K topographic map, scanned and geo-referenced to the coordinate system, are used as GIS foundation. In our example the total of 19 sheets of topographic map of the Republic of Croatia were geo-referenced and joined together.

Scanned sketches (tables) – They present the current condition of perennial plantations (Fig. 2). In our example sketches and maps of four economic operators were gathered for the purpose of this study. After geo-referencing all scanned sketches were transferred into the vector format (Fig. 3).



Fig. 2. and 3. *Importing and assessment of old sketches and maps into GIS. Left: An example of an old plan; Right: The map of plots can be represented in a satellite image after geo-referencing.*

Digital relief model and relief parameters (DMR, slope, light) – digital relief model (DMR) is produced based on the combination of SRTM DMR (NASA 2005a) and DMR which was developed based on digitalized contour lines from 1:100K topographic maps (Fig. 4).

In this case the DMR based on topographic maps has greater absolute accuracy, while SRTM DMR shows greater local detail (changes in the mezzo relief). SRTM DMR was not used in areas with rich vegetation, because SRTM DMR usually shows also the surface of such objects, and not the real elevation of the terrain. Two geo-morphological factors were calculated based on DMR: slope (%) and the total annual amount of incident light (NASA 2005b).

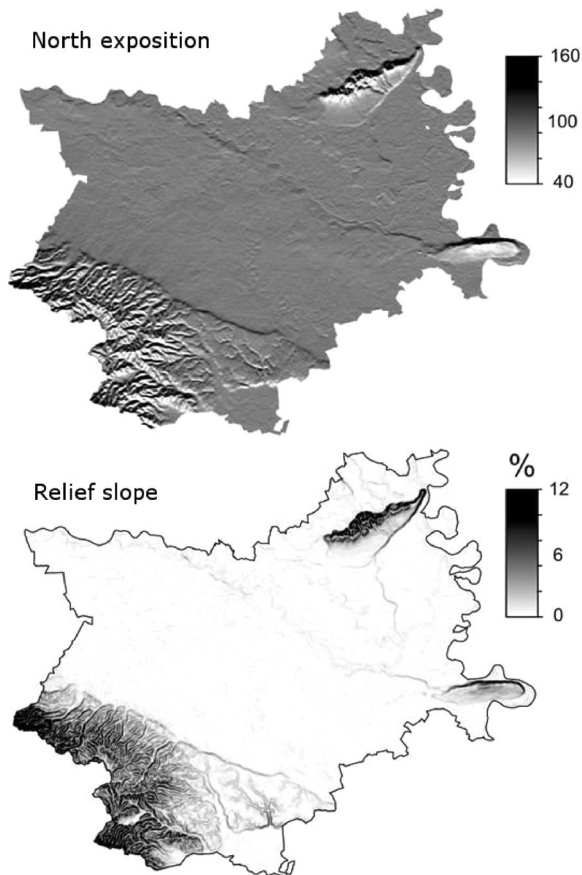


Fig. 4. *Geomorphological parameters calculated on the basis of digital model of the relief of the County.*

The slope was calculated by means of ILWIS GIS software, and incident light (KWh/m^2) by SaGa GIS software (<http://geosun1.uni-geog.gwdg.de/saga/>). Even these two parameters (slope and exposition) are sufficiently important for finding the best locations for some production (viticulture).

Planned purpose of the land (Purpose) – The planned purpose of the land was taken over based on the spatial plan developed by the Institute for Spatial Planning of Osijek-Baranja County (Institute for Spatial Planning of Osijek-Baranja County 2002). This is a 1:100K scale map which was scanned, geo-referenced in ILWIS and then digitized and polygonized (Fig. 5). The total area statistics was calculated after that, with special emphasis on agricultural land in the County.

The map of the planned purpose of the land is important to limit selection of the best locations for fruit/vine growing on the locations where valuable and especially valuable soils are found.



Fig. 5. *An example of Ikonos image, 1 m resolution, that can be used to make fast inventory of plots (Erdut vineyards).*

Pedological parameters (soil_type, soil_pH, soil_carb) – In addition to soil type (deep, fertile, gravel or dry), when selecting the soil in the process of vineyard planting it is of utmost importance to know the content of lime in the land envisaged for planting, for the depths 0–30 cm and 30–60 cm. Maps of soil acidity and carbonate content were made by interpolation of a limited number of pedological profiles.

The database of soil types in Croatia was used (Martinović and Vranković 1997); the total of 124 profiles from this database can be found in the County area.

The data were interpolated so that a map of soil types was made in the beginning (Alluvial, Chernozems, District Brown Soil, Eutric Brown Soil, Colluvial Soil, Loess Soil, Meadow Soil, Wetland Gley Soil, Pseudo-gleyed Soil, Rendzina, Wetland Black Soil, Semi-gley) by classifying geomorphological parameters, and then the mean value of pedological parameter was calculated for each soil type (pH, carbonates).

Satellite image (Panchromatic) – LANDSAT panchromatic satellite image was used at 15 m resolution. The image was made in September 1999, but it is still relevant for development of the basic studies. LANDSAT images (185 × 185 km scene) can be ordered and downloaded on-line via NASA server (NASA 2005a and NASA 2005b). Such an image is especially suitable for this kind of projects because it can be compared to the photo mosaic, which would be more expensive (Van Zyl 2001). Boundaries between the plots of agricultural land are clearly visible in the image as well as larger furrows within vineyards. To provide easier recognizing of orchards and vineyards, aero or Ikonos images should be used in future (Jurišić and Plaščak 2009).

Map importing, geo-referencing and integration were carried out by using the unique methodology as described below:

- Maps are scanned at 150 DPI resolution and more;
- Scanned maps are imported into a GIS software ILWIS and geo-referenced to the local coordinate system, 1:100K scale;
- Parts of maps are joined and modified according to the desired basic resolution and detail level;
- Different thematic layers are used for simple (for example, slope maps) and more complex calculations (for example, annual amount of direct solar radiation);
- Ultimately calculated thematic maps are used for decision making by using the so-called spatial queries; these queries are carried out in ILWIS directly via command line (Fig. 6).



Fig. 6. *Integration of GIS layers after importing for the purpose of group representations by using transparency in ILWIS: Erdut Hill as an example – vineyards owned by the wine-making company Erdutski vinogradi.*

2.3. Selection of best locations

Selection of the best location for a particular type of perennial plantation can be carried out by using logical and spatial queries. Locations for vineyards will be defined as overlapping areas between locations:

- Locations where, according to the spatial plan, either valuable or especially valuable soils and other arable land can be found, and
- Southern exposition of the relief with the total annual amount of light incidence $>1208 \text{ KWh/m}^2$, and
- Locations where the slope is not higher than 12% and lower than 2%, and
- Where elevation above the sea level is not lower than 110 m and soil acidity does not exceed 5.6 pH units.

This means that locations will be found that satisfy several important criteria in the same area (good exposition and good slope, and good elevation...). Such spatial enquiry can be expressed by means of the following ILWIS commands (so-called ILWIS *syntax*):

SUITABLE_VINEYARDS {dom=Bool} = iff(((purpose="ESPECIALLY VALUABLE SOIL ") or (purpose="VALUABLE SOIL ") or (purpose="OTHER ARABLE SOILS ")) and (light>1220) and (slope<12) and (DMR>110) and (soil_pH>5.6), 1, 0).

Table 1. *List of GIS layers used in the development of the study.*

GIS layer	Unit	Description and characteristics	Application
topo100K		Scanned and geo-referenced topographic map 1:100K. Raster map in real colours. Map size – 5508 × 6501 pixel.	Basic foundation for preparation of all other GIS layers.
table		Scanned, geo-referenced and vectorized plot boundaries. Vector map; total around 200 tables/plots.	Showing the current situation and locations of perennial plantations (PP) in the County area.
DMR	M	Digital relief model is a raster map showing the field elevation for each point in the space. Map size – 827 × 976 pixels.	It can be used for calculation of geomorphological and hydrological parameters, but also for 3D representations.
slope	%	Raster map developed on the basis of DMR, showing field inclination. Also in this case 100 m grid was used.	A very important agro-environmental parameter because it is related to agricultural production (>12% is not suitable for mechanization application).
light	KWh/m ²	Raster map calculated on DMR basis and knowledge of the solar radiation model.	It can be used to locate the areas suitable for vineyards. Southern exposition shows the highest values.
purpose	class	Polygon map showing land purpose classes according to the spatial plan.	Spatial planning of agricultural production should be limited to the locations where agricultural land is found.
soil_type	class	Raster map showing soil types from alluvial to chernozem and renzina soils in mountains.	Based on the soil type, a conclusion on other soil characteristics can easily be made.
soil_pH	0–15	Raster map produced by interpolation of observed values. In this case average was made according to soil type map.	Acidity is usually the key limiting factor for agricultural production.
tlo_karb	%	Raster map produced by interpolation of observed values. In this case average was made according to soil type map.	Vineyards require more carbonate soils. Acid soils may result in under-performance.
Panchrom.	0–256	Raster image. The smallest detail 15 m. Map size – 5508 × 6501 pixels.	Useful for recognizing the boundaries between agricultural land plots.

This is the so-called "Boolean" operation, because the result of the query will be a simple map showing areas which are either suitable for viticulture (1) or not suitable for viticulture (0). If the user wishes to increase the selection criteria, he/she

can simply change any of the parameters directly in ILWIS command (for example, slope <10% instead of <12%). Of course, the more strict criteria will result in smaller area of suitable locations (Miklos 1989).

Alternative to this Boolean procedure would be the use of limitations scores. In that case every parameter, limiting agro-environmental effect, is translated into a limitation score according to a mathematical or empirical formula. Use of limitation (negative) scores in this case is considerably more complex, because relations among the negative scores and limiting parameters are unknown. In addition, the number of agro-environmental factors can be pretty large, which means considerably larger calculations in GIS (Jurišić and Plaščak 2009).

3. Results and discussion

A map of the best locations for vineyards was developed based on a formula. This map is the ultimate result of work (Fig. 3). According to an estimate, around 17,782 ha in the County are suitable for viticulture (Državni zavod za statistiku 2005). If this is compared to data on actual situation (1,612 ha), it can be observed that the current utilization rate of resources in viticulture is around 10%.

Locations in Baranja that are unsuitable for vineyards are all locations situated on the sea level below 120 m, on the localities oriented toward north, north-eastern and eastern sites, unprotected against penetration of cold air; in Erdutsko brdo area), all locations where water is stagnant and frost can occur (depressions, furrows, micro-coves). Areas unsuitable for vine grape growing can also be found in Đakovo and Našice region – all locations where slopes exceed 12% and soil is acid or very acid ($\text{pH} < 5.0$). In terms of slope and suitability for use of mechanization, only the area around have issues due to the above described micro-relief.

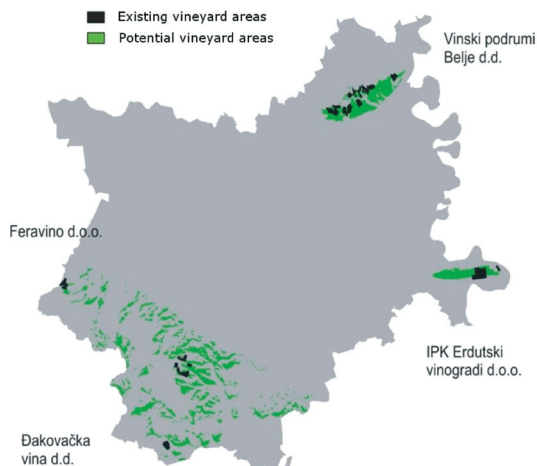


Fig. 7. The existing and potential areas under vineyards in 2004. Vineyards are currently planted on 1.612 ha out of the potential area of 17.782 ha.

These scales can be used to find the best locations for planting new vineyards. However, the areas that are not coloured green in the Fig. 7 show areas which could not be recommended as suitable for viticulture, i.e. loans or incentives for them should not be provided by the County or Government.

Analysis and processing of climate and edaphic parameters points to a very favourable climate and land conditions for vineyards as well as existence of great resources and the possibility for intensifying as well as rationalization of future production (Marijanović 2002). A conclusion can be made as the end result of this research that utilization rate of natural resources in viticulture is around 10% and that the most suitable locations for planting vineyards is the area of Erdutsko brdo and numerous locations between Đakovo and Našice (Fig. 8).

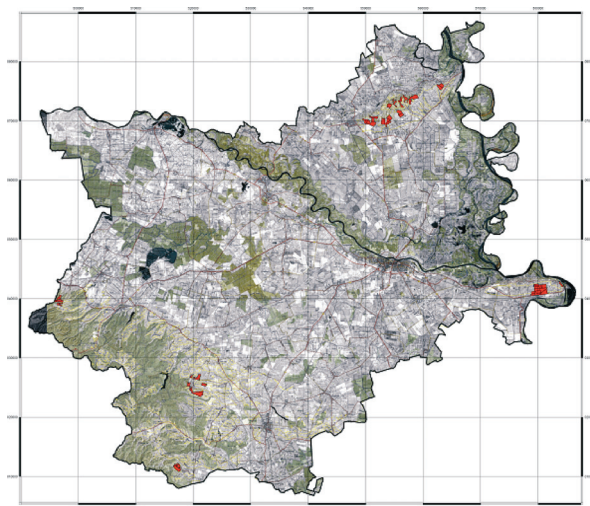


Fig. 8. *Best purpose map for viticulture (the current situation – red and possibilities – the green colour) in Osijek-Baranja County.*

4. Conclusion

This scientific research is mostly of methodological character, i.e. the goal is to bring the methodology of detailed spatial planning in GIS closer to the employees of the County Department for Agriculture and Forestry and other stakeholders.

Unlike the methodology used by the Croatian Institute for Viticulture and Enology, this research was conducted in the geo-information system. Relief data and satellite images were also used to verify the situation. Integration and combination of orto-photo images and Wine register with relief and satellite images would provide even better results than the results presented in this paper. If aero images are too expensive solution for development of the County GIS, use of Ikonos images should also be considered.

Nowadays there is a large number of potential users and applications which are based on updated geo-information, i.e. digital purpose maps. Decisions about the

land use and its change are still not made based on objective queries and criteria. Unfortunately, in our country there are no updated and detailed maps of areas which would show the actual situation in land use, the real potential of natural resources (soil, water, relief). All of the basic foundations of geodesy as the cadastre, aero photos and topographic maps also have not been transformed into digital form and made available to these services. Tools for relatively urgent and objective monitoring of changes in land use (satellite images), changes of the boundaries between agricultural units (aero-photos), positioning (GPS) and general condition of natural and human resources are not used.

Problems with the cadastre, land restitution, allocation and undefined ownership structure of land in the state ownership are a limiting factor in the process of determining the status and future purpose of these areas. Raising new perennial plantations and stimulation of potential producers (legal and physical entities) requires an extremely fast engagement at both national and county level in an extremely short period of time (a few years – EU accession).

In this example of development of a thematic map showing land suitability for growth of grape vine, the main microclimate factors limiting successfulness of production in the entire County area are: (a) local frost areas; (b) slope, over 15%; (c) insufficient carbonate content in the soil, i.e. excessive soil acidity. Ideal soil for grape vine production is mildly sloped (2–12%), of southern, south-western and western exposition, calcareous or mildly calcareous, with humus content around 3%, and of light texture (powdery/sandy loam).

Further steps shall include development of the full multidisciplinary GIZIS (Geographic and Cadastral Information System) of regions with agricultural production, and education of all key users, primarily employees of the County Development Department on how to use these tools.

References

- Državni zavod za statistiku (2005): Popis poljoprivrede 2003, on-line: www.hzs.hr.
- Hengl, T. (2003): Pedometric mapping: bridging the gaps between conventional and pedometric approaches, PhD thesis, University of Wageningen, Enschede, 214.
- Hengl, T., Gruber, S., Shrestha, D. P. (2003): Digital Terrain Analysis in ILWIS, Lecture notes and users' guide, International Institute for Geo-Information Science & Earth Observation (ITC), Enschede, Netherlands, 45.
- Husnjak, S., Bogunović, M. (2002a): Application of GIS technology in land management in Croatia, Proceedings of paper on CD-ROM of 17th World Congress of Soil Science, 14–21 August, Bangkok, Thailand, Papers on CD, No 340/1–10.
- Husnjak, S., Bogunović, M. (2002b): Komparativna istraživanja karte pogodnosti tla za obradu i karte rizika od erozije tla vodom u Republici Hrvatskoj, Hrvatske vode, godina 10, br. 40, 311–320.
- Institute for Spatial Planning of Osijek-Baranja County (2002): Prostorni plan županije: korištenje i namjena prostora, Županijski glasnik br.1/2002.
- Jurišić, M., Plaščak, I. (2009): Geoinformacijski sustavi GIS u poljoprivredi i zaštiti okoliša, Udžbenik, Poljoprivredni fakultet Osijek, 145–176.
- Jurišić, M., Hengl, T., Duvnjak, V., Martinić, I. (1999): Agro-ecological and land information system, *Strojarstvo*, 41 (5–6), 223–231.

- Jurišić, M., Hengl, T., Stanisavljević, S. (2005): Prostorno planiranje poljoprivredne proizvodnje – Vinogradarstvo: metodološki vodič i GIS za odabir novih lokacija za sadnju vinograda, Studija za potrebe Osječko baranjske županije, Osijek.
- Marijanović, I. (2002): Veliki Atlas Hrvatske, Mozaik knjiga, Zagreb, 480.
- Martinović, J., Vranković, A. (1997): Baza tala Republike Hrvatske, I-III., Ministarstvo zaštite okoliša i prostornog planiranja, Zagreb, 365.
- Miklos, F. (1989): Physiology of temperate zone fruit trees, John Wiley & Sons, 338.
- NASA (2005a): Moderate Resolution Imaging Spectroradiometer (MODIS) imagery, on-line: <http://edcimswww.cr.usgs.gov/pub/imswelcome/>.
- NASA (2005b): Shuttle Radar Topography Mission (SRTM), on-line by FTP server: <ftp://edcsgs9.cr.usgs.gov/pub/data/>.
- Van Zyl, J. J. (2001): The Shuttle Radar Topography Mission (SRTM): a breakthrough in remote sensing of topography, Acta Astronautica, 48 (5–12), 559–565.

Metodologija razvoja karata namjene zemljišta u GIS okruženju – upravljanje resursima

SAŽETAK. Svrha ovog istraživanja bila je utvrditi metodologiju bonitiranja poljoprivrednog zemljišta s obzirom na niz objektivnih ograničavajućih čimbenika koji se povećavaju, na primjer, kod višegodišnjih kultura. Metodologija parametrizacije reljefa rabljena je za izračun geomorfoloških parametara, a pedometrijske metode kartiranja za izračun pedoloških varijabli. Stvarno stanje pokrova zemljišta inventarizirano je na temelju skica i planova koji su prikupljeni tijekom terenskog istraživanja. Te skice su zatim georeferencirane i preklapljene s LANDSAT satelitskim snimkama kako bi se odredilo stvarno stanje. Optimalne lokacije za pojedini tip trajnog nasada odabrane su primjenom logičkih prostornih upita. One su (u ovom primjeru za vinograde) identificirane kao područja preklapanja (lokacije gdje se prema prostornom planu nalaze ili vrijedna, osobito vrijedna tla ili ostala obradiva tla i južne ekspoziције reljefa s količinom ukupne godišnje upadne svjetlosti $>1208 \text{ KWh/m}^2$ i lokacije gdje nagib reljefa nije veći od 12% i manji od 2%, odnosno gdje nadmorska visina nije manja od 110 m i gdje tla nisu kiselija od 5.6 pH). Kao rezultat upita dobivena je jednostavna karta koja pokazuje područja koja su pogodna (1) ili nisu pogodna za vinogradarstvo (0). Sličan pristup može se koristiti i na tematskim kartama različite surhe, na primjer, urbanističkim planovima, kartama izvora vode, plina, termalnih bunara i drugih resursa od posebnog značaja za državu. Prema dobivenim rezultatima u našem primjeru, za vinogradarstvo je pogodno ukupno 17.782 ha na području Županije. Optimalni način izrade prostornih planova za pojedine kulture bio bi izraditi karte negativnih bodova za sve kulture, a zatim standardizirati te vrijednosti kako bi za svaku lokaciju pronašli najbolju moguću kulturu. Tematski GIS slojevi mogu se rabiti kao osnova kreditiranja, savjeta o izboru kulture, donošenja odluka o preraspodjeli i korištenju, rekonstrukciji odnosno prenamjeni korištenja zemljišta.

*Ključne riječi: geoinformacijski sustavi (GIS), metodologija, tematske karte, upravljanje resursima, prostorni plan, karta namjene zemljišta, pretpri-
stupni fondovi EU.*

Primljeno: 2012-10-12

Prihvaćeno: 2013-01-15